Understanding Earth's Polar Challenges:

International Polar Year 2007–2008

SUMMARY BY THE IPY JOINT COMMITTEE

World Meteorological Organization
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Editors:
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Executive Summary

The International Polar Year (IPY) 2007–2008 co-sponsored by ICSU and WMO became the largest coordinated research program in the Earth's polar regions, following in the footsteps of its predecessor, the International Geophysical Year 1957–1958. An estimated 50,000 researchers, local observers, educators, students, and support personnel from more than 60 nations were involved in the 228 international IPY projects (170 in science, 1 in data management, and 57 in education and outreach) and related national efforts. IPY generated intensive research and observations in the Arctic and Antarctica over a two-year period, 1 March 2007–1 March 2009, with many activities continuing beyond that date.

IPY 2007–2008 involved a large range of disciplines, from geophysics to ecology, human health, social sciences, and the humanities. All IPY projects included partners from several nations and/or from indigenous communities and polar residents' organizations.

IPY 2007–2008 included education, outreach, and communication of science results to the public, and training the next generation of polar researchers among its primary missions. It broadened the ranks of its participants and the diversity of their products and activities to an extent never realized or even envisioned in the earlier IPYs. It reached out to many new constituencies, including polar residents, Arctic indigenous nations, and millions of people on the planet with no direct connection to the high latitudes.

IPY 2007–2008 generated a much anticipated 'pulse' (momentum) in the form of substantial new funding for polar research and monitoring programs, new observational and analysis technologies, integrated system-level approaches, and a broadened circle of stakeholders. It introduced new research and organizational paradigms that will have a lasting legacy of their own. It showed the power of integrative vision, and consolidated a new transdisciplinary approach that now includes biology, human health, social sciences, and the humanities, in addition to meteorology, glaciology, oceanography, geophysics, geology, and other traditional polar research fields. It sent a powerful message about the societal value of advanced research into rapid environmental change across the polar regions.

The IPY 2007–2008 science program was developed via four-year bottom-up planning (2003–2006) as an inter-disciplinary framework driven by six overarching themes: *Status, Change, Global Linkages, New Frontiers, Vantage Points* and *Human Dimension.*

The ICSU-WMO Joint Committee for IPY produced this preliminary summary of the IPY activities in which the Committee, its direct predecessors, the IPY International Programme Office, and associated teams were directly involved. The volume of 38 chapters in five parts (*Planning, Research, Observations, Outreach*, and *Legacies*), covers the development of IPY 2007–2008 for almost a decade, from 2001 till summer 2010. It has engaged almost 300 contributing authors and reviewers from more than 30 nations. This broad overview of IPY 2007–2008 demonstrates the extensive and essential contribution made by participating nations and organizations, and provides a prospective blueprint for the next IPY.

IPY 2007–2008 contributed to the theoretical and organizational strengthening of polar research, and advanced our understanding of polar processes and of their global linkages. Large-scale baseline data sets were established in many fields, against which future change can be assessed. Novel and enhanced observing systems were launched that will eventually produce long-term benefits to many stakeholders. Last but not least, IPY 2007–2008 trained a new generation of scientists who are determined to carry its legacy into the future.

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Preface

This summary volume is an attempt to capture the context, motivations, initiation, planning, implementation and the outcomes of the International Polar Year (IPY) 2007–2008, as well as the lessons derived from this key undertaking. IPY invigorated polar science, led to an unprecedented level of action, and attracted global attention to the polar regions at a critical moment in the changing relation between humanity and the environment.

Under the auspices of the IPY, co-sponsored by the International Council for Science (ICSU)[1] and the World Meteorological Organization (WMO)[2], thousands of scientists and educators contributed to implement a large number of internationally coordinated projects that made major discoveries in Earth's polar regions and reinforced the basis for monitoring changes and predicting the resulting regional and global impacts of those changes. The IPY was an international endeavour that involved more than 60 nations. It was also highly multidisciplinary, with strong engagement from biological and social disciplines to complement the geophysical sciences. Furthermore, IPY was multigenerational, since it drew together participants from the International Geophysical Year (IGY) 1957–1958 as well as a fresh cadre of the early career scientists who will increasingly lead polar science over the (polar) years to come. Finally, IPY was an educational endeavour that engaged an international network of teachers, developed key educational resources and captured broad public attention through a vigorous and creative outreach campaign.

On behalf of the international ICSU and WMO communities, we thank the many thousands of IPY participants, in particular the hundreds of project leaders, the numerous funding bodies that fuelled IPY, the logistics providers that enabled it, the committees that coordinated national efforts, the IPY International Programme Office that facilitated international coordination and nurtured networks of teachers and early career scientists, the ICSU Planning Group that developed the conceptual framework for IPY, the WMO Intercommission Task Group on IPY that promoted IPY ideas among WMO Members, and the ICSU-WMO Joint Committee and its Subcommittees that oversaw and steered IPY preparations and implementation. It is from the Joint Committee that the idea of this summary arose, and we further thank the committee members for their leadership in shaping the document. Nearly 300 contributors generously provided material for and edited sections of this volume and we especially wish to thank Drs Igor Krupnik and David Hik for tirelessly steering the overall writing project to its completion.

The example of IPY illustrates how ICSU and WMO work with the international scientific community to shape, launch and support international scientific programs of global significance. As described in the first part of this overview, there were many initial strands of discussion within the polar science community on the IPY concept. The ideas came from groups affiliated with ICSU and WMO, and from independent sources, and they ultimately coalesced into the IPY plan, which was given international legitimacy through the approval of WMO and ICSU's respective governing bodies. Our organizations jointly procured a venue and a director for the IPY International Programme Office and funded the meetings of the IPY Joint Committee, a modest investment that was amplified by several orders of magnitude through the generous contributions of numerous countries and donors. The key result of this collaborative approach was an impressive scientific and educational programme that has yielded new discoveries, developed new capabilities, and forged new partnerships that now lead us strongly into the legacy phase of IPY, as described in the summary report.

We are confident that you will enjoy the story of the IPY, and we urge you to take note of the work still ahead, since the study of the polar regions reveals their global significance and their influence on the rest of our planet. We hope that the overview of IPY will catalyse further enrichment of the IPY story and that it will serve as a valuable guide to planners of the future international and interdisciplinary scientific endeavours that will undoubtedly be needed in order to meet societies' diverse and mounting global environmental challenges.

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President of ICSU

Michel Jarraud
Secretary-General of WMO

[1] www.icsu.org
[2] www.wmo.int

Acknowledgements

IPY 2007–2008 was the first international polar program ever to be organized on such a broad multi-disciplinary basis, with strong engagement of biological, social, and human sciences that complemented the core geophysical sciences of the earlier IPY/IGY. Even more notable was a new level of collaboration of polar residents, including Indigenous people, with the IPY scientific teams, in the design, conduct and communication of many IPY projects and their results.

The Co-Chairs of the Joint Committee for International Polar Year 2007–2008 would like to express their deep appreciation and sincere thanks to:

- The many individuals who advocated for IPY during its formative years and during the implementation and observation phase.
- ICSU and WMO, the two main sponsors of IPY 2007–2008 international effort, who recognized and supported the IPY initiative from planning to completion (and also supported the activities of the IPY Joint Committee and its bodies).
- Many international organizations who threw their weight behind the development and implementation of IPY over those long years (2002–2010), including the International Arctic Science Committee, Scientific Committee on Antarctic Research, Arctic Council, Antarctic Treaty Consultative Meeting, Intergovernmental Oceanographic Commission of UNESCO, World Climate Research Programme, Council of Managers of National Antarctic Programs, Forum of Arctic Research Operators, European Polar Board, Arctic Ocean Sciences Board, International Arctic Social Science Association, International Permafrost Association, and many others, as well as national funding agencies, and national academies.
- National and international Space Agencies for the generous in-kind support in making available free of charge important satellite observational data and products specially tailored for the polar regions.
- Those national organizations and agencies that generously provided financial support to the Joint Committee, the International Programme Office, the JC subcommittees, the Association of Polar Early Career Scientists, and the activities they initiated.
- The governments of Canada, China, Finland, Germany, the Netherlands, Norway, Poland, Republic of Korea, Russian Federation, Spain, Sweden, Switzerland, U.K. and the U.S.A. that provided financial contributions to the IPY Trust Fund, and a secondment to support the International Programme Office's day-to-day activities, including the coordination of IPY operational data, and hosting the IPY meetings and workshops.
- Many dedicated IPY leaders who served as members of the ICSU Planning Group (2003–2004); the Joint Committee (2005–2010) and its subcommittees on Data Policy, Observations, Education, Outreach and Communication; Space Task Group; the Association of Polar Early Career Scientists, Eurasian International Programme Sub-Office; and many *ad hoc* groups established to advance IPY 2007–2008.
- The Staff of the International Programme Office (IPO), including David Carlson,

Director; Cynan Ellis-Evans, Senior Adviser; Odd Rogne, Senior Advisor; Nicola Munro, Administrator; Rhian Salmon, Education, Outreach, and Communication Coordinator; Camilla Hansen, Events Coordinator; Melissa Deets, Karen Edwards, and several other people who supported IPO activities in various forms throughout these years.

- The Heads of the Arctic and Antarctic IPY Secretariats who promoted International Polar Year in the countries involved, helped coordinate each countries' contribution to the IPY process and interactions with the national funding agencies.
- The staff of ICSU and WMO Secretariats who supported our meetings, outreach and public events, exhibitions and publications.
- The national committees and national polar programmes, which generated resources and support for IPY 2007–2008, both in their respective nations and internationally.
- Coordinators of 228 endorsed international IPY projects who played a key role in organizing the IPY science program and communicating its results to millions of people interested in the polar regions.
- Host countries, secretariats, and steering committees for the two major IPY Conferences in Russia (2008) and Norway (2010), and to Canada and the Canadian organizations in charge of the third IPY Conference, 'From Knowledge to Action' to take place in April 2012.
- National, provincial, and local governments of the countries in which IPY activities took place, including local communities that welcomed many IPY researchers and supported their operations with in-kind funding, services, advice, and hospitality.
- AND, MOST IMPORTANTLY, to the many thousands of participants in IPY 2007–2008, recognizing that IPY science and observations also depended on pilots, ship crews, drivers, indigenous and local partners in the host communities, technicians, student assistants, medical and support personnel, rescue crews, and many more people who worked so hard over many years to make IPY 2007 –2008 a major success and an enduring example of international collaboration.

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JC Co-Chair	*JC Co-Chair*	*JC Co-Chair*
2004–2009		*2009 –2010*

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INTRODUCTION

"Summarizing IPY": Perspective from February 2011

Igor Krupnik and David Hik

The Task

At its eighth meeting (JC-8) in February 2009, the Joint Committee (JC) for IPY 2007–2008 decided to produce a 'substantial summary report' on IPY 2007–2008 operations and to make it available to the IPY community by June 2010 at the first post-IPY Science Conference in Oslo, Norway. Immediately after that conference, the Committee's tenure was to end and the 'summary' report would serve as the final overview of the JC activities in the organization and implementation of IPY, to be delivered to the sponsor organizations, national committees, funding agencies and thousands of IPY participants. This document is the outcome of a collective leadership effort of the JC team as it completes its five and a half-year service to the IPY community.

Viewed from a historical perspective, particularly in comparison with the preceding International Polar Years, the bar has never been raised so high, both in terms of the time and scope of the work involved in producing such a summary. At the equivalent date, a year after the official completion of the first International Polar Year (IPY-1) 1882–1883, the world had just lived through the shock and the triumph of the rescue of the last IPY-1 field party of Adolphus Greely, with the tragic loss of 19 of its 25 members. Major reports on the results of IPY-1 were in the making but still a few years away. A year after the completion of the second International Polar Year of 1932–1933 (IPY-2) there had been no substantial overview of its results and the Organizing Committee estimated that it would take five years to produce a full summary. It did not happen until 25 years later. In 1960, a year after the completion of International Geophysical Year (IGY) 1957–1958, the publications related to IGY were streaming in and the first ten volumes in the IGY series, *Annals of the International Geophysical Year* were already printed. Nonetheless, no comprehensive summary of the IGY operations by its international committee followed. Clearly, *summarizing* an IPY was a tall order and was usually accomplished a long time after the year's completion or not at all.

Challenges

The challenges to producing a single document to summarize the operations of IPY 2007–2008 were many. This 'fourth' polar year was one of the most ambitious science initiatives ever attempted; it eventually evolved into the largest internationally coordinated research program in the Earth's polar regions in the past 50 years. It was a truly international endeavour that engaged an estimated 50,000 researchers, local observers, educators, students and support personnel from over 60 countries participating in more than 230 international projects and innumerable national and local efforts. It included intensive research and observations in both the Arctic and the Antarctic over a two-year period, from 1 March 2007 till 1 March 2009, but recognized that many activities would continue beyond that date. IPY 2007–2008 explored the links between both polar regions and the rest of the globe and ushered in a new era in polar science collaboration, as it involved the largest ever range of scientific disciplines, from geophysics and ecology to social science, humanities and economics. Also, unlike previous IPYs, it made Education, Outreach and Communication of science results to the public one of its primary missions. Because of that, it reached out to many new constituencies, including polar residents, arctic Indigenous nations and millions of people on this planet with no direct connection to the high latitudes. Altogether, IPY 2007–2008 broadened the ranks of its participants and the diversity of their products and activities to an extent never realized or even envisioned in the earlier IPYs.

IPY 2007–2008 was co-sponsored by the International Council for Science (ICSU) and the World Meteorological Organization (WMO); it was also supported—financially, logistically, intellectually, politically and publicly—by a great number of international organizations, science bodies, national agencies, independent and non-governmental groups, organizations of polar residents and indigenous people, national and local governments (see *Acknowledgments*). According to the estimates of the IPY International Programme Office, IPY 2007–2008 stimulated approximately US$ 400 M in new polar science research funding and approximately US$ 1200 M in total funding, not counting many national polar infrastructure investments.

Following in the footsteps of its celebrated predecessors, particularly IGY, IPY 2007–2008 was launched to create a legacy of enhanced observational systems, new research facilities and infrastructure. The observational networks envisioned as major outcomes of this IPY included integrated ocean observing systems in both the Arctic and Southern oceans, coordinated acquisition of satellite data products from multiple space agencies, and observational systems for meteorology and atmospheric chemistry, terrestrial and marine ecosystems, permafrost, sea ice and glaciers, human health and the well-being of polar communities. Many observing systems developed for IPY were intended to eventually become parts of the growing framework of existing global observing systems to serve the polar regions and the planet.

The goals and the vision of IPY 2007–2008 have been disseminated widely, since at least 2004, in several major outline documents (Rapley et al., 2004; NAS, 2004), at numerous international meetings, in hundreds of publications in major world languages, and on scores of websites. Since the very start of IPY planning, it was announced that the fundamental concept of the new IPY was of an intensive burst of internationally coordinated, interdisciplinary scientific research and observations focused on the Earth's polar regions. The aim of IPY was to exploit the intellectual resources and science assets of nations worldwide to make major advances in polar knowledge and understanding. The main geographic focus was the Earth's high latitudes, both the Arctic and Antarctica, but studies in any region relevant to the understanding of polar processes or phenomena were also encouraged. In addition, IPY 2007–2008 aspired to leave a legacy of new observational systems as the basis for observing and forecasting change, in order to improve understanding of the poles as key components of the global environment.

The initiators and planners of IPY 2007–2008 put a strong rationale for such a massive research, observation and public outreach program 50 years after the International Geophysical Year 1957–1958. They argued that the polar regions are especially important for a common understanding of planetary processes for the following reasons (Allison et al., 2007):

- Polar environments are changing faster than any other regions on Earth, with regional and global implications for societies, economies and ecosystems. These changes are particularly evident in widespread shrinking of snow and ice.
- Processes in polar regions have a profound influence on the global environment and, in particular, on the weather and climate system and sea level. At the same time, the polar environment is affected by processes at lower latitudes. Examples include the formation of the ozone "holes" and the accumulation of pollutants in the Arctic environment.
- The polar regions, particularly the Arctic, are home to more than four million people, and these communities face changes in their natural environment and in their natural resources and food systems that are, for the most part, faster and larger than any in recent experience or traditional knowledge.
- Within the polar regions lie important scientific challenges yet to be investigated and unique vantage points for science. The regions beneath the polar ice sheets and under the ice-covered oceans remain largely unknown. Many of the new scientific frontiers in the polar regions are at the intersection of traditional scientific disciplines.

There was also a strong *societal message* behind the urgency to launch a major new research and observational program in the polar regions at the beginning of the new millennium.

As the polar regions are integral components of the Earth system, they couple to global climate, sea level change, ocean circulation, biogeochemical cycles, ecosystems and human activities. At a time when the world's population is exerting an increasing influence on this planet and its environment, and the human condition is rapidly affected by global changes, the polar regions are critical to any vision of the Humanity's overall prospects on the 'ever-stressed' Earth. With the new technological capabilities now available (such as satellite remote sensing, autonomous platforms, global communications systems, high powered numerical Earth System Simulators and others) the time appeared ripe to achieve significant scientific advances during IPY. By stimulating and guiding an intense international burst of effort, IPY 2007–2008 aimed to accelerate progress in our common knowledge and to fulfill the needs in key information on polar processes and their global linkages for policy makers. At this critical time, it became clearer that the polar regions provide a litmus test and the insight to help the society recognize the planetary limits of our behavior (Allison et al., 2007).

The Scope

IPY 2007–2008 occupies a special place even when compared to the monumental and most comprehensive assessment programs of the past decade, such as the *Arctic Climate Impact Assessment* (ACIA, 2005), the *Antarctic Climate Change and the Environment* review (Turner et al., 2009), the *Arctic Human Development Report* (AHDR, 2004) and the *IPCC Fourth Assessment Report* (IPCC, 2007; Solomon et al., 2007). These and similar ventures were usually commissioned by high-level intergovernmental organizations or major international bodies, with a clear task, terms of reference and the message coming 'from the top.' IPY 2007–2008, to the contrary, started as an open grass-roots initiative aimed at *new research*. It maintained its 'bottom-up' character during its lifespan and it capitalized upon energy, ideas and activities assembled through free submissions by researchers, educators, data experts and media specialists from more than 60 nations.

The overall IPY program was built as a wide-ranging 'universe' of 228 international projects endorsed by the JC in 2005–2006 and supplemented by thousands of local actions undertaken by national institutions, school and environmental groups, and polar communities over the next five years. By February 2010, the electronic publication database for IPY 2007–2008 listed 2957 entries related to IPY activities (http://nes.biblioline.com/scripts/login.dll). As of June 2010, that number, was close to 4000, as several IPY-related books and reports were planned to be unveiled by or at the Oslo IPY Conference in June 2010. The overall scope of IPY 2007–2008 is hard to overestimate and its total 'footprint'—in science and observational activities, data collected, papers and books, students trained, web-based products, and innumerable public events—may not be fully known for many years.

For these and other reasons, any effort to 'summarize' IPY 2007–2008 at this time could only be addressed with certain boundaries in mind. First, any overview of IPY activities could only be a time-framed 'snapshot', a ***preliminary*** Summary based on information available to a certain point in time – in this case, summer-fall 2010. Second, an overview of such a massive program would be naturally focused on what had already taken place, in that case, on the planning, organization and the operations of IPY during 2005–2009, with but a fraction of its data processed and science results known by spring 2010. For that reason, this volume is framed primarily as an ***operational*** Summary of IPY rather than a 'synthesis' document on its science achievements. For the latter, the time will come in due course (we note that it took many years for syntheses of various scientific results to emerge from the IGY).

Third, it is widely assumed that major fields, disciplines, national IPY committees and individual IPY projects would eventually produce strings of products of their own. This is already happening. The Joint Committee, thus, can be accountable solely for the activities it initiated, endorsed and in which it participated to a certain extent. There are, in fact, 'many IPYs' familiar under various manifestations and in different languages to many people and groups, both national and international. This Summary represents the ***JC-framed overview*** of the planning and implementation of IPY over 10 years, from 2001 till mid 2010, during which the JC or its direct predecessors were directly involved. By this definition, it cannot be judged as a "down-to-the-last-detail" narrative that lists everything and everyone in the IPY field over those years, even though we tried to be as comprehensive as was practical. We hope the time will come for many groups that participated in IPY to produce their accounts of IPY history. This will enrich and expand the more specific 'JC' story. Nevertheless, we are convinced that the JC vision in this summary is worth sharing with the community not only to justify the common effort and the expenditures from many sources, but also as a prospective blueprint to follow for the next IPY.

Lastly, any summary of a multifaceted and diverse initiative, like IPY, cannot be but ***multi-vocal*** in its use of professional languages, visions, and styles. That breadth of 'many IPY voices' had to be preserved, so that space and Earth scientists, climatologists, oceanographers and cryosphere specialists, marine biologists, anthropologists, polar historians, indigenous researchers, educators and other IPY participants feel comfortable under one book cover – just as they enjoyed being together in 'one IPY'. That task was hardly on the mind of the earlier IPY/IGY organizers, who structured their summaries by major disciplines ('aurora', 'solar radiation', 'meteorology', 'earth currents', etc.) or under the national IPY report format. The JC team agreed from the beginning on the variety of styles, so that each constituent field in IPY 2007–2008 and each writing group could tell about its activities in a language familiar to its audience. That diversity of styles and goals is what really made IPY 2007–2008 so special; we did our best to retain it in this Summary. We assume that each group or discipline will eventually have the opportunity to present its own story in the format of its choice.

The Structure

The JC first discussed the idea to produce an in-depth IPY 'overview' document at the JC-7 meeting in July 2008 and more thoroughly at the JC-8 meeting in February 2009, following the release of the 12-page summary of IPY activities, *The State of the Polar Research* (Allison et al., 2009 – *Chapter 1.5*). The JC members approved the prospective title for the Summary (*Understanding Earth' Polar Challenges*), the draft outline for a document of five major parts (see below) and appointed a small Editorial Team to lead the effort, with a release of the final Summary scheduled for early 2011. It was envisioned to become the key reference source on the broad range of IPY activities, including origination, planning and implementation of IPY, with a succinct overview of its major results for participating researchers, science and agency planners, students, media specialists, and science historians.

In July 2009, an Editorial Team led by Igor Krupnik and David Hik, and assisted by Paul Cutler, Volker Rachold, Eduard Sarukhanian and Colin Summerhayes developed a detailed outline for the Summary of 30-some chapters organized in five Parts: *Planning and Implementing IPY 2007–2008* (Part 1); *IPY Science Program* (Part 2); *IPY Observing Systems, Their Legacy, and Data Management* (Part 3); *IPY Public Programs; Archiving and Publishing IPY* (Part 4); and *The Legacy of IPY and the Future of Polar Research* (Part 5). Eventually, each of these large sections comprising several Chapters received its 'coordinating editors – Paul Cutler and Igor Krupnik (Part 1); Ian Allison and Jerónimo López-Martínez (Part 2); Eduard Sarukhanian and Colin Summerhayes (Part 3); David Hik (Part 4); and Igor Krupnik and Volker Rachold (Part 5). Those eight 'coordinating editors' constituted the Editorial Board, together with Robin Bell, and under the overall leadership of Krupnik and Hik. The writing of individual chapters started in October-November 2009; the editing, reviewing, and revision of its many constituent parts continued through summer 2010. Some chapters were not completed until fall 2010.

All 21 JC members and observers, members of the Subcommittees on Observations, Data Management, and Education Outreach and Communication, as well as the staff of the International Programme Office (IPO) were invited to participate as contributors – writers, reviewers, editors, liaisons, etc. Most of them volunteered to serve. It was also agreed from the beginning that the JC team would reach out to many IPY scientists and invite them to join as lead and contributing authors, according to their respective fields of expertise. Almost 90% of people we invited off the JC-IPO network enthusiastically agreed to participate, often on very short notice. Over 50 scientists were also approached as external reviewers; most of them also agreed to serve. That outpouring of support greatly expanded the vision and the capabilities of the original JC team. Broadening the team also helped elevate the status of this volume from a 'technical overview' of IPY 2007–2008 to the high-quality scholarly summary of its many constituent fields and cover preliminary results from many of the IPY projects, which was not foreseen under the original plan.

All chapters written for the IPY Summary underwent several levels of peer-review, both internal and external. As of the last count (February 2011) the full Report team includes more than 240 lead and contributing authors and 50 reviewers from almost 30 nations and in all disciplines that participated in IPY. The Volume size and diversity conveys the energy of the large IPY community and we expect more people to assist us as reviewers and commentators in the months to come.

The draft Summary was submitted by the JC at the Oslo Conference in June 2010 as the main outcome of its work and in completion of its service in the implementation of IPY 2007–2008. As the JC completed its term at the Oslo IPY Conference, a small editorial group was tasked to undertake revisions and edits collected from the IPY community at the Oslo Conference and beyond. The completed Summary is now being disseminated to a wider audience as an electronic file and a printed book.

There was yet another factor that helped lift the enthusiasm of the JC team. None of the previous IPY/IGYs ever produced a full summary by its leading body as a large stand-alone document. So, the effort undertaken by the team assembled by the JC, in less than two years after the completion of IPY 2007–2008 observational period in March 2009 stands as a remarkable achievement. But neither did any previous IPY/IGY team face a community forum of the magnitude of the Oslo Science Conference, with its more than 2300 participants, as a concluding event for an IPY. This is once-in-a-lifetime opportunity for the JC to fulfill its mandate to the large community that worked tirelessly to make IPY the most exciting event in polar research in fifty years.

The Team

A Summary like this one is only as good as the team of volunteers who shared the JC commitment and vision. We believe this volume offers an ample reflection of the enthusiasm generated by IPY 2007–2008 that inspired so many people and organizations over 10 years, including the JC team and its collaborators.

We wish to acknowledge and thank all of the Coordinating Editors, who did most of the organizational groundwork for their respective sections. The Editorial board and the full JC team produced a shared vision for this summary overview of IPY that has driven our work over the past 15 months. Our warmest thanks go to the 'extended team', the many colleagues in IPY, who served as writers, chapter contributors, advisors and reviewers. This extended team wrote, rewrote, reviewed and provided so much inspiration, often on a very short notice. Working in a big team, rather than within a small group of the JC members, gave us strength and assured that this Summary is a *collective* and *collegial* perspective on why IPY was launched and what it has achieved. Without your input, we would never be able to produce such an extensive and in-depth coverage of many fields of IPY science and observational activities, history of its planning, and the assessment of its legacy. We are grateful for your energy, shared knowledge and your unyielding support to this last of the JC initiatives.

Nicola Munro, former Administrator of the International Programme Office deserves special appreciation for her help with the many Appendices and illustrations.

The production team in Edmonton included several members of the former Canadian IPY Secretariat. With deadlines pressing, Stacey Strilesky and Kristi Skebo made superhuman efforts to manage the flow of materials and to copy edit the text and supporting material from each of the chapters. Sandy Riel completed the layout and design, and her previous work on the ICARP II report, the SAON Initiating Group report and other IPY reports including the Polar Resource Book made this a very easy relationship. Additional copy-editing support was provided by Cara Seitchek in Washington, D.C.

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PART ONE

Planning and Implementing IPY 2007–2008

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Introduction

Igor Krupnik and Paul Cutler

The purpose of this opening section is to explore "what it takes" to launch an IPY. Its seven constituent chapters illuminate how the International Polar Year (IPY) 2007–2008 was built on the history of three earlier IPYs, how it has been conceptualized and developed by its champions, and how it was successfully implemented over the course of ten years from 2001 to 2010. Launched first in 1882–1883 and then every 50 years (or 25 years in the case of the International Geophysical Year 1957–1958), each of these four 'international polar years' has been a major milestone in the history of science. Each has served as a springboard for advances in scientific knowledge and in science methodology, technology, planning, international collaboration, and capacity building to its constituent disciplines. In addition, every 'polar year' has initiated an intensive public campaign to advance polar research and to inspire people's imagination about the Earth's polar regions. Such monumental enterprises usually required several years in planning and the efforts of many people and organizations in implementation.

It is, therefore, no accident that each successive initiative after the first International Polar Year (IPY-1)—the second International Polar Year 1932–1933 (IPY-2), the International Geophysical Year 1957–1958 (IGY, which was originally developed as IPY-3, but later became a global program with very strong polar component), and the recent International Polar Year 2007–2008—had advanced by invoking the memory of their predecessors. The IGY organizers, in particular, helped solidify that practice by producing extended historical overviews of both IPY-1 and IPY-2 (Heathcote and Armitage, 1959; Laursen, 1959) published in the first volume of their publication series, *Annals of the International Geophysical Year.* In a similar way, the drive for new IPY 2007–2008 started as the preparation for the "50th anniversary of IGY 1957–1958" or "IPY +50" (*Chapter 1.2*). It is also no accident that many champions of IPY 2007–2008 referred to their early memories or to the stories they heard from their mentors about the IGY era. Several major IPY 2007–2008 websites featured historical summaries of IPY-1, IPY-2, and IGY, often accompanied by early photographs and excerpts from old articles and books that, otherwise, are hardly cited in today's science publications (Fig. 1).[1]

Science history and legacy played such an important role in the development of IPY 2007–2008 because it helped generate grass-roots enthusiasm and marshal disciplinary and institutional resources. It also illuminated the specifics of modern science organization and planning. Several comparative overviews of three or even four International Polar Years were published as a result of IPY 2007–2008 (Andreev et al., 2007; Barr and Lüdecke, 2010; Behr et al., 2007; Elzinga 2009; Fleming and Seitchek 2009; Lüdecke, 2007b; Rae, 2003; Sörlin, 2007; Summerhayes, 2008). All shared valuable insights into the preparation of the earlier IPYs and explored how history can offer a successful playbook to today's science planners (Berkman, 2003; Korsmo, 2004, 2009; Korsmo and Sfraga, 2003; Lüdecke, 2004; Rae, 2003). That long-term historical view was on the minds of many champions and organizers of IPY 2007–2008 (*Chapter 1.2*) and it guided the approach to this opening section of the JC overview of IPY.

This first section starts with a synopsis of major steps in the origination and organization of three previous IPY initiatives: IPY-1, IPY-2, and IGY (*Chapter 1.1*). Since lengthy accounts of all earlier IPYs are available in many books and historical papers, the purpose of this chapter is rather practical, as it aims to introduce IPY 2007–2008 scientists and educators to certain approaches and strategies that emerged repeatedly over the past 125 years in the organization of all previous IPYs. Many of the same or similar strategies, like the active promotion of the proposal for a new IPY across professional fields and science organizations; seeking endorsement and support of the most respected international science bodies of the time; establishment of an effective international steering committee; focus on coordinated efforts, international dissemination of results, and publication, etc., were sought and successfully applied by early champions of this IPY. The planners of IPY 2007–2008 were also very effective in advocating certain basic principles such as multidisciplinarity, international cooperation, open communication, volunteer service, nurturing the next generation of scholars and students, and collegiality (that were also invoked by their predecessors), upon which modern science community functions and advances.

This comparative overview of the earlier IPY initiatives in *Chapter 1.1* leads to subsequent chapters that explore how the new IPY 2007–2008 originated in the late 1990s and early 2000s (*Chapter 1.2*) and gave rise to an organized planning process spearheaded by the IPY 'Planning Group' established by ICSU in 2003 (*Chapter 1.3*). The years 2003–2004 were a period of intensive communication, with many polar organizations contributing to the collaborative and grass-roots character of the new IPY initiative (*Chapter 1.4*). The main phase in the IPY 2007–2008 organization and implementation took place in 2005–2009 with leadership from the ICSU-WMO Joint Committee (*Chapter 1.5*), its subcommittees, and the International Programme Office (*Chapter 1.6*). These groups aimed, through a "light-touch" approach, to frame and add value to the work carried out by many national IPY committees (*Chapter 1.7*), funding agencies, and, most importantly, the individual teams that actually conducted IPY projects. While the narrative of this complex development of IPY 2007–2008 over almost a full decade (2001–2010) is still unfolding and remains to be thoroughly documented by our successors and future historians, this IPY Summary aims to seed this broader effort by capturing the main elements of the story.

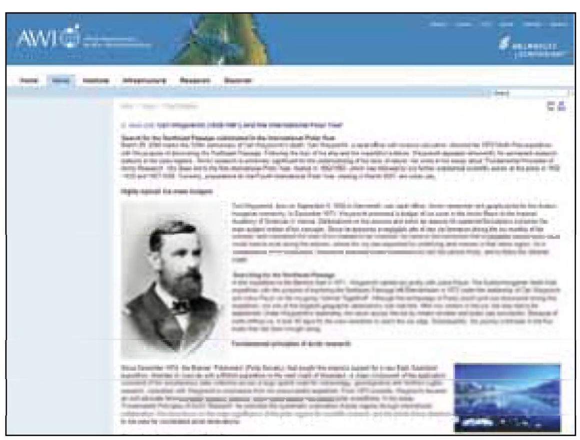

Fig.1. Examples of websites featuring information about previous International Polar Years.

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Note

1 See www.arctic.noaa.gov/aro/ipy-1/

www.ipy.org/about-ipy/ipy-history

www.ipycanada.ca/web/guest/history/unfinished_history

www.awi.de/en/news/press_releases/detail/item/carl_weyprecht_1838_1881_and_the_international_polar_year/?cHash=acae34ba6d

1.1 From IPY-1 to IGY: Early Lessons in Making Global Science

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This chapter is as a historical introduction to the main story of IPY 2007–2008; it provides short overviews of the origination and implementation of the three preceding International Polar Years in 1882–1883, 1932–1933 and 1957–1958. Such broad historical backdrop is essential to understand *why* the international science community was mobilized three times for large trans-disciplinary initiatives in the Earth's polar regions prior to IPY 2007–2008 and, specifically, to elucidate the factors that were critical in their successful planning and implementation.

Each of the previous IPY initiatives generated massive historiography.[1] Nevertheless, for the first time, research in the history of polar science was included as a *bona fide* component in IPY 2007–2008. It generated four international scholarly projects (IPY nos. 10, 27, 100, 135), two large conferences, five polar history workshops organized by the SCAR Action Group on the History of Antarctic Research (www.scar.org/about/history),[2] numerous overview papers and several summary volumes (Andreev et al., 2007; Barr, 2008; Barr and Lüdecke, 2010; Headland, 2009; Launius et al., 2010). New studies unraveled many critical aspects of the early IPYs, including its driving forces, personal motives of individual players, scholarly achievements, geopolitical and diplomatic factors affecting national participation. They also revealed how the previous IPYs were the products of the science and global politics of the day.

The present chapter addresses the step-by-step logistics of the origination, endorsement, planning and implementation of three earlier IPYs. Despite many differences, a remarkably consistent set of practical actions was needed to move each successive IPY from its first discussions to the drawing board to international endorsements to governmental-funded operations and, finally, to the processing of the data collected, and the publication of its results. These early lessons in 'making global science' thus contribute a crucial prologue to our understanding of how the fourth IPY 2007–2008 was born and what it has achieved.

First IPY: 1882 –1883

The canonical story of the origination of the First IPY (IPY-1) dates it to 1875 and ties it to a charismatic officer of the Austro-Hungarian Navy – Lieutenant Carl (Karl)[3] Weyprecht (1838–1881). But, the first person to propose the idea that the scientific exploration of polar regions should be based on international cooperation was Commander Matthew Fontaine Maury of the U.S. Navy (1806–1873), the director of the U.S. Naval Observatory in Washington, D.C. Maury had been the instigator and coordinator of a scientific network for the collection of wind and current data from ships, and the subsequent publication and interpretation of data that was adopted internationally in 1853 (Baker, 1982b; Rothenberg, 2009). A key element of his plan, prepared in 1860–1861 and later published in three languages (Maury, 1862), was that the data for Antarctica would be collected through such cooperative work and then studied at meteorological centers in Britain, France and the Netherlands (Baker, 1982b; Bulkeley, 2010).[4]

Maury's idea of internationally coordinated polar research had been re-launched 15 years later by a new champion, Carl Weyprecht, this time focused primarily on the Arctic. In January 1875, Weyprecht unveiled his proposal for a coordinated international program of polar research and observations, a remarkable departure from the then-typical unilateral efforts of individual nations to explore polar regions (Weyprecht, 1875a, 1875b; Fig. 1.1-1; Box 1).[5] In an era without telephone and airmail, Weyprecht advanced his idea with a remarkable speed. He published seven papers in 1875 and, with the help of his friends and his financial supporter Count Johann Wilczek, began disseminating offprints in German, French, English and Italian to scientific institutions and scholars around the world (Tammiksaar et al., 2009).

Although Weyprecht's role in the origin of IPY-1 has acquired almost mythological standing (cf. Berger et al., 2008), no individual could have single-handedly launched an international venture of such magnitude. Nor was Weyprecht's host country of Austria-Hungary well suited to lead the effort. Weyprecht's plan was eventually promoted by other better-positioned

Fig. 1.1-1 Carl Weyprecht (1838–1881), the early champion of International Polar Year 1882–1883 (www.awi.de/fileadmin/user_upload/News/Press_Releases/2006/1._Quarter/carl2_p.jpg)

Box 1 Fundamental Principles of Scientific Arctic Investigation

Excerpts from the Address delivered by Lieutenant Carl Weyprecht of the I.R. Austrian Navy before the 48th Meeting of German Naturalists and Physicians at Graz, 18 September 1875 (Weyprecht 1875b – English translation - www.scar.org/ipy/).

"[…] In view of the ever increasing interest in Arctic research and of the readiness with which governments and private individuals are continually furnishing the means for new expeditions, it is desirable to establish the principles on which they should be sent out, so that their utility to science may be in proportion to the great sacrifices made, and they be relieved of that adventurous character which does indeed charm the great public, but can only be prejudicial to science.

The following points meet the requirements set forth above:

I. *Arctic research is of the highest importance to the knowledge of Nature's laws.*

II. *Geographical discovery in those regions has a higher value in so far only, as it opens the field to scientific research in the narrower sense of the term.*

III. *Arctic topography in detail is but of secondary importance.*

IV. *The geographic Pole has for science no greater significance than any other point in the higher latitudes.*

V. *Stations of observation are – without regard to their latitude – the more favourable in proportion to the comparative intensity of the phenomena under investigation.*

VI. *Independent series of observations have but secondary value.*

These requirements may be met without spending those enormous sums, which almost all Polar expeditions hitherto have cost, and which have made it impossible for the less wealthy nations to take part in Arctic discovery. It is not necessary to extend our sphere of observations into the very highest latitudes in order to secure scientific results of the greatest importance.

For instance, stations at Nowja-Zemlya (76°), Spitzbergen (80°), East- or West-Greenland (76°-78°), North America East of Berings Strait (70°), Siberia at the mouth of the Lena (70°) would give us a zone of observation quite around the Arctic regions. Greatly to be desired are stations near the centres of magnetic intensity. The observations there would be connected with our own through the stations already established near the Polar circle, which only need to be strengthened. The means expended on any one of the more recent attempts to reach the highest latitude would be amply sufficient to sustain all these stations for a year.

The object of these expeditions would be: With instruments precisely alike, governed by precisely the same instructions, and for a period of one year at least, to record a series of the utmost possible synchronous observations.

Attention should be directed above all to the various branches of Physics and Meteorology as being of the highest degree of importance, then to Botany, Zoology and Geology, and lastly to geographical details as being of secondary interest.

Should it be possible to establish in connection with these Arctic stations of synchronous observations one or more in the Antarctic regions, we might expect results of inestimable value.

The expenses of these limited expeditions might, through the accessibility of the stations, be kept within such reasonable bounds as to be easily borne, if divided among several nations."

scientists, like Georg Neumayer (1826–1909), director of the *Deutsche Seewarte*/German Maritime Observatory in Hamburg; Christophorus Buys Ballot (1817–1890), director of the Dutch Meteorological Institute in Utrecht; and Heinrich von Wild (1833–1902), director of the Central Physical Observatory in St. Petersburg, Russia. They moved it through a respected professional body, the International Meteorological Congress and its permanent committee chaired by Buys Ballot, on which Wild and Neumayer also served (Cannegieter 1963). The Committee approved the idea in principle in April 1876 (Lüdecke 2004) and referred it to the 2nd International Meteorological Congress scheduled for September 1877, at which Weyprecht was invited to present his proposal in person (Weyprecht and Wilczek, 1877).

Weyprecht's plan laid out in 1875 argued for coordinated polar expeditions to set off in the (boreal) autumn of 1877. Wild advised Weyprecht to move its implementation to 1878, so that it could secure international endorsement at the 2nd Meteorological Congress; but then the Congress was postponed for two years, due to the Russian-Turkish (Balkan) War of 1877–1878. Finally, in April 1879, the Congress adopted Weyprecht's proposal (Lüdecke, 2004). It also instituted the International Meteorological Committee, the executive body for international collaboration in meteorology that became the precursor of the International Meteorological Organization and the actual sponsor of IPY-1 (and, later, of IPY-2).

The Committee was entrusted to convene a special International Polar Conference for further planning of the polar year (Cannegieter, 1963). That nine-member conference, mostly of the directors of respective national observatories and high-level representatives of national academies (plus Weyprecht) took place in Hamburg in October 1879.[6] It constituted an International Polar Commission (IPC), first chaired by Neumayer and later by Wild, that became the official planning and governing body of IPY-1. Weyprecht was left to propagate his project as a private individual (Tammiksaar et al., 2010). On 29 March 1881, he died of tuberculosis, three months prior to the departure of the first IPY expedition to the field.

Altogether, the International Polar Commission held five 'conferences' following its first meeting in Hamburg in October 1879: IPC-2 in Bern in August 1880, of nine delegates; IPC-3 in St. Petersburg in August 1881, of 10 delegates; IPC-4 in Vienna in April 1884, of 20 members (see photo with names in: Heathcote and Armitage 1959) to honor Weyprecht's contribution; and IPC-5 in Munich in September 1891.

The observation period for IPY-1 originally established at IPC-1 in Hamburg in 1879 was to have been one year starting in boreal fall 1881; but it was postponed for one year at IPC-2. New dates, from 1 August 1882 until 31 August 1883, were formally approved at IPC-3 in 1881 (Sukhova and Tammiksaar, 2008), when two American IPY expeditions were already in the field. Most of the expeditions left in May-July 1882 and returned home in September-November 1883 (Baker, 1982a; Barr, 1985/2008; Barr et al., 2010; Corby, 1982; Heathcote and Armitage, 1959). The span of IPY-1 observations was ultimately almost three years, from (boreal) summer 1881 to summer 1884, when the last expedition, led by Adolphus W. Greely, was rescued.[7] It is estimated that more than 700 people (all men?) took part in the work of twelve IPY-1 stations in the Arctic (Fig. 1.1-2) and two expeditions to the Southern Ocean (Fig. 1.1-3). The total at all locations, including several 'auxiliary' missions and over 40 participating observatories at lower latitudes was, probably, close to 1,000.[8]

The International Polar Commission was dissolved in 1891, eight years after the completion of IPY fieldwork. It produced seven *Bulletins* between 1882 and 1891 containing proceedings, minutes and short reports from the expeditions.[9] Altogether, it comprised 112 numbered communications in German, French and English, a total of 363 pages. The *Bulletins* were published by the Russian Academy of Sciences in St. Petersburg and edited by Wild, the Commission's chair (Wild, 1882). Extensive guidelines on the publication of data and reports were drawn up at IPC-4 in Vienna in 1884, but no uniform template was established and no centralized IPY-1 publication series was envisioned. Instead, each nation published its observations independently to a vaguely standardized pattern of the 'expedition volume.' These volumes were printed in several languages, primarily English, French and German, but also in Dutch and Russian, often with a parallel text. Altogether, 22 IPY-1 expedition volumes appeared between 1885 and 1910 (Cronenwett, 2010; Fig. 1.1-5).[10]

Box 2 Programme of Work of an International Polar Expedition

By Le Comte Wilczek and Carl Weyprecht, 1877, Printed by W. Stein, Vienna, 8 pages.

*[This programme was written in May 1877 for discussion by the International Meteorological Congress due to meet in Rome in September that year, and which political events caused to be adjourned to the following year.]**

"The enterprise that we propose to achieve has for its goal to undertake scientific exploration and, contrary to what most expeditions have done before, to make geographic discovery a secondary goal; this will therefore be the first step towards a systematic study of the regions of the terrestrial poles and towards the detailed observation of the phenomena particular to these regions, phenomena of which serious investigation is of the highest importance from the perspective of a large number of problems concerning the physics of the globe.

The goal of the expedition is to make, in the Arctic and Antarctic, or around those regions, and at as many stations as it may be possible to establish, synchronous observations following a programme decided upon in concert, so as, on the one hand, on proceeding through comparison, to deduce from observations collected at different points, independent of the particularities that characterise the different years of observation, the general laws governing the phenomena under study, and on the other hand, to calculate what chance there may be of penetrating further into the interior of these unknown regions.

To that end, each of the States participating in the work is obliged to equip at its own expense and to send an expedition to one of the places designated at the end of this programme. It will be up to each of the interested parties to decide in what measure they wish to prolong their expedition, as well as to determine the questions to address aside from those that will be fixed.

The investigations made in concert will only address the phenomena of meteorology, terrestrial magnetism, the aurora borealis, and the realm of ice. At each station, observations must be continued throughout a whole year, commencing 1 September 18xx and finishing 31 August 18yy.

The meteorological observations must be made in conformity with the resolutions of the permanent International Committee, and will apply to atmospheric pressure, the temperature and humidity of the air, the direction and force of winds, the state of the sky and its degree of cloud cover, and to condensation.

[…] It is presumed that all the stations will be established close to a coast. As one of the main goals of the expedition is to study the connection between the displacement of ice and the principal motors of that displacement, the winds and currents, it will be necessary to observe regularly the state and movement of the ice. There is reason to believe that the study of the distribution of ice in relation to the predominant winds and to periods of storms, if made at a large number of points as close as possible to the poles, will allow establishment of a theory of the movement of ice in Arctic regions, and thus enable us to find out more about the best ways of penetrating further poleward.

[…] The most favourable places for these various observations are listed below:

In the northern hemisphere:

Spitzbergen, on the north coast;
Nova Zemlya, on the north coast;
Finmark, around North Cape;
Siberia, on the north coast near the mouth of the Lena;
New Siberia;
Point Barrow, northeast of Bering Strait (occupied by Maguire, 1852-54);
Greenland's west coast, occupied by Denmark;
Greenland's east coast around 75N latitude.

In the southern hemisphere:

Around Cape Horn;
Kerguelen or the Macdonald Islands;
One of the groups south of the Auckland Islands.

Each of the interested countries is asked to establish a station at its own costs for at least a year at one of the points suggested above, and to conform strictly to the proposed programme […]."

Vienna, 30 September 1877.

[Translated from the French version by Colin Summerhayes, October 2007. See full translation at www.scar.org/ipy. The German original was published in Weyprecht and Wilczek 1877]

* *Translators note: This is a verbatim translation of the note on the front page of the article; in fact the meeting was eventually held in Rome in April 1879. It is not entirely clear why, but at its end the manuscript is dated 30 September 1877; perhaps this reflects the fact that it was written in May for presentation at a September meeting.]*

Fig. 1.1-2 (left) IPY-1 observation stations in the Arctic, 1881–1884. (from Neumayer 1901, courtesy Cornelia Lüdecke)

Fig. 1.1-3 (right) IPY-1 observation stations in the Southern Hemisphere, 1882–1884. (from Neumayer 1901, courtesy Cornelia Lüdecke)

The IPY-1 expeditions were also featured in numerous scientific papers and journal articles published across the participating nations, but no overall IPY-1 bibliography was produced. The IPC had directed that 12 to 16 copies of all IPY publications and copies of the related observation records and manuscripts should be archived in a designated IPY depository at the Central Physical Observatory in St. Petersburg, Russia (Baker, 1982b; Sukhova and Tammiksaar, 2008). Unfortunately, that depository was cut off from most of the outside world during World War I and after the Russian revolution of 1917. As a result, the IPY-1 archive stayed closed to the international science community until the 1990s. The IPY expeditions were also reported in newspapers, lectures, popular books and other media aimed at general public; but there is no record that the IPC ever considered what we call today an 'outreach strategy.'

The heart of IPY-1 envisioned by Weyprecht was the coordinated program of year-long observations, on the basis of which fundamental issues in polar and global meteorology and geophysics could be addressed. The British Meteorological Office and the *Deutsche Seewarte* (German Maritime Observatory) used IPY-1 data for the production of daily synoptic charts (Baker, 1982a; Corby, 1982) and at least one German dissertation by Sebald Berhard Ehrhart was based upon IPY meteorological records (Lüdecke, 2004; 2009 – Fig. 1.1-4). Sidney Chapman, the leading figure in IGY 1957–1958 acknowledged that IPY-1 "… made excellent contributions to the descriptive and statistical study of the aurora and to its connection with magnetic disturbance" (Chapman, 1959a); in another publication he made several references to their use (Chapman, 1959b). K.R. Birkeland, member of the Norwegian Aurora Polaris Expedition in 1902-1903, referred to his regular use of the observations made by 15 IPY-1 stations. But in general the data so painstakingly acquired by 14 expeditions and associated teams from 10 nations[11] (Baker, 1982b; Barr, 1985/2008; Heathcote and Armitage, 1959) were not fully utilized. Indeed, many of the IPY-1 data were not analyzed until the 1920s or even until recently (Baker, 1982a; Lüdecke, 2004; Wood and Overland, 2006; www.arctic.noaa.gov/aro/ipy-1).

The IPC dissolved itself in 1891, without producing a summary assessment of the IPY-1 program and its achievements. One such assessment was given some 40 years later by Henryk Arctowski[12] who observed: "It may be that if the publication, and above all the discussion of the observations had been left to a central office, possibly international, the scientific level of the work accomplished would have been better appreciated" (Arctowski, 1931). Due to the lack of such post-IPY-1 common body, financial constraints, or because powerful national institutions were not yet ready for long-term coordination, much of the potential scientific benefit from the synchronized observation program was missed. What remained was a collection of impressive but merely concomitant

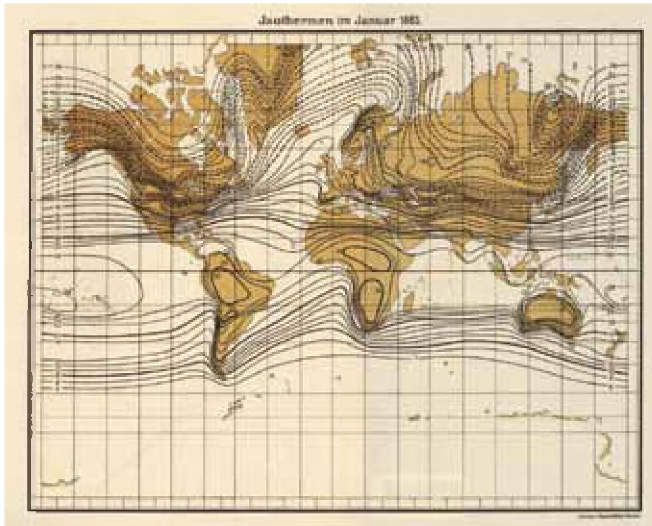

Fig. 1.1-4 Global map of the January 1883 isotherms based upon processed data of IPY-1 meteorological observations. (from Ehrhart 1902, courtesy Cornelia Lüdecke)

regional datasets. The IPY-1 input has been, perhaps, more lasting in its otherwise marginal fields, such as anthropology (Baker, 1982b; Barr, 1985/2008; Burch, 2009; Krupnik et al., 2005; Murdoch, 1892/1988; Turner, 1894), natural history (Dunbar, 1983; Loring and Spiess, 2007) or the study of carbon dioxide concentration (Baker, 1982a; 2009). Several IPY expeditions also brought substantial botanical, zoological and ethnological collections to their respective national museums. In any case, IPY-1 left behind a crucial institutional memory across various disciplines and enough momentum to launch a string of subsequent polar expeditions in 1895–1918, several international conferences on polar explorations, the second Polar Commission of 1913, and eventually, the second IPY in 1932–1933 (Elzinga, 2010a; Lüdecke, 2010; Lüdecke and Lajus, 2010; Roberts, 1949; Summerhayes, 2008).

Second IPY: 1932–1933

Unlike its predecessor, IPY 1932–1933 (IPY-2) did not have an early charismatic champion. Even the date of its conception has been disputed. It was assumed for years that the proposal for the 'second polar year' originated with German meteorologist Johannes Georgi who introduced it at a meeting at the *Deutsche Seewarte* (German Maritime Observatory) in Hamburg in November 1927 (Laursen, 1951; 1959; 1982). Recently, the original date was pushed backward by a full year and the idea was attributed to Leonid Breitfuss (Breitfuß), an émigré German-Russian scientist. Breitfuss, reportedly, spoke about the new 'polar year' at the first conference of the International Society for the Exploration of the Arctic by Means of Aircraft (AEROARCTIC), at which Georgi was also present (Lüdecke, 1995, 2003; Lajus, 2008; Lüdecke and Lajus, 2010). The original idea was then promoted by better-positioned Vice Admiral Hugo Dominik, director of the *Deutsche Seewarte*, who in December 1927 presented the proposal for a new polar program to the International Meteorological Committee (IMC), the executive body of IMO.[13]

Dominik and Dan la Cour, director of the Danish Meteorological Institute in Copenhagen lobbied for the new polar year via the International Meteorological Organization (IMO), the parent body of IPY-1 (Elzinga, 2009; Laursen, 1982; Lüdecke, 2008; Lüdecke and Lajus, 2010). A small meeting of IMO high-level officials in June 1928 appointed a subcommittee of five members[14] to prepare a formal proposal for the IMO Conference of Directors in Copenhagen in September 1929 (Laursen, 1959). The subcommittee met twice in 1929 and introduced its outline for IPY-2 at the Copenhagen conference attended by representatives from 34 countries. The conference endorsed a new program for collaborative observations to be made across both polar regions in 1932–1933, thus marking the 50th anniversary of IPY-1. It also appointed the *Commission for the Polar Year 1932–33* (CPY), originally composed of seven members, under the chairmanship

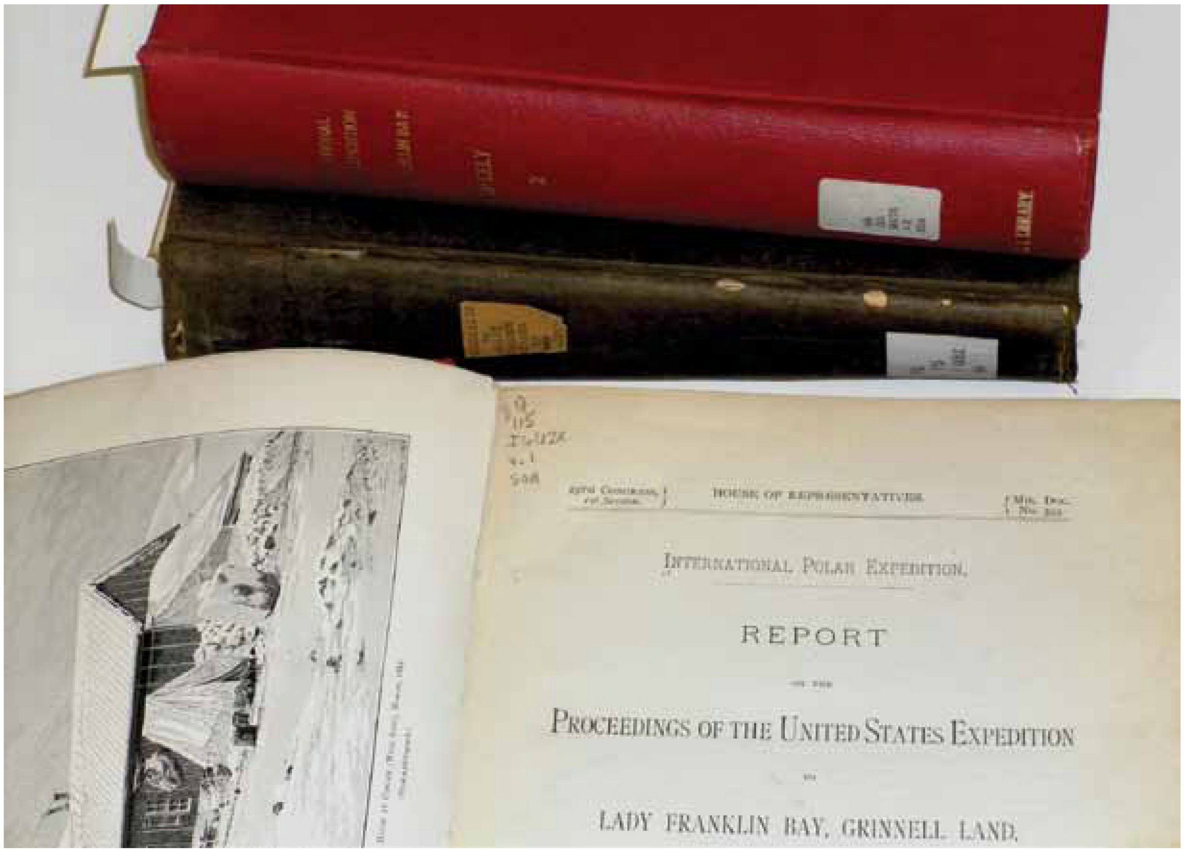

Fig. 1.1-5 Materials collected during IPY-1 were published in large-size 'Expedition report' volumes, like those for the U.S. IPY expeditions to Point Barrow, Alaska and Lady Franklin Bay, Elsmere Island, Canada. (Photo: Igor Krupnik)

of la Cour; it was later expanded to 15 members.[15]

IPY-2 was formally announced in December 1929 and national committees were set up by several countries to organize national IPY efforts (Patton, 1933). Germany and, particularly, Russia (then Soviet Union) developed the most ambitious IPY programs.[16] Also, an important step was the IMO's invitation to the International Union of Geodesy and Geophysics (IUGG) and other outside bodies to join forces in the IPY-2 planning. The IUGG General Assembly endorsed the plan for IPY-2 and set up a small committee in August 1930 to manage that cooperation.[17] This brought financial resources of IUGG to the IPY-2 process. It also opened a new page in IPY history, as the same model of partnership among several organizations representing international scientific unions and governmental meteorological agencies would be later invoked in the preparation for IGY and IPY 2007–2008. Eventually, the International Scientific Radio Union (URSI), International Council for the Exploration of the Sea and three commissions of the IMO (Commission for the Study of Clouds, Commission for Solar Radiation and the Commission for the Investigation of the Upper Air) joined the planning effort and promoted IPY-2 observations in their respective fields (Laursen, 1951, 1959).

By comparison with IPY-1, IPY-2 had a broader science program beyond meteorology, atmospheric electricity and aurora and geomagnetic observations, particularly in planetary geophysics. New fields included aerology, cosmic rays, radiation and radioelectricity, Earth currents, and ozone studies. More research was done from ships, particularly in the Russian Arctic, also on polar ice sheets and mountain glaciers in the temperate regions. At the same time, IPY-2 steered away from the IPY-1 'natural history' template that included botany, zoology, anthropology and museum collecting (Baker, 1982a). IPY-2 had little of that (Laursen, 1951) and whatever research beyond geophysics was conducted as individual team or even scientist's initiatives.

The CPY held three meetings: CPY-1 in August

1930 in Leningrad (St. Petersburg – Fig. 1.1-6), CPY-2 in September 1931 in Innsbruck and CPY-3 in Copenhagen in May 1933. At CPY-2 in 1931, it became clear that, owing to the world economic crisis, several nations would be unable to provide funds for their IPY efforts. The CPY considered postponing the start of IPY until a better time, but eventually resolved to proceed (Laursen, 1959).

IPY-2 officially lasted 13 months (same time-span as IPY-1): from 1 August 1932 until 1 September 1933. The operational dates for proposed Antarctic stations were set from January 1933 to February 1934 (Elzinga, 2009). Forty-four nations took part, four times the number of the IPY-1 participants, including several countries from the Southern hemisphere, such as Argentina, Australia, Chile, New Zealand and South Africa (Box 3).[18] Sixteen countries formed their national IPY committees and 22 organized expeditions or established observational stations beyond their national borders (Laursen, 1951). Also, the IPY-2 worldwide observational network introduced many nations and then colonial states to global science efforts, including those located far away from the Poles, making it a true international program. More than 30 stations operated in the Arctic, including nine that had been active in IPY-1 (Barrow, Bossekop, Cape Thordsen, Dikson, Fort Rae, Godhavn, Jan Mayen, Matochkin Shar and Sodankylä).[19] Despite much effort, no stations were established on the Antarctic continent; only three stations operated on sub-Antarctic islands and at the southernmost tip of South America.

Great attention was paid to the publication and management of the IPY-2 data. A special subcommittee for publications was established at CPY-1 in 1930. It prepared detailed instructions for future publication of data in meteorology, terrestrial magnetism, atmospheric electricity, aurora and aerology. Proceedings of three CPY meetings were published in French, English and German as subsequent issues of the *Secretariat de l'Organisation Météorologique Internationale.*[20] Other reports, observational instructions and resolutions related to IPY-2 appeared in IMO publications between 1929 and 1938. The full set of documents pertaining to the preparation, implementation and results of IPY-2 was compiled after World War II by the former CPY secretary Bruun de Neergaard in a manuscript preserved at the Danish Meteorological Institute (Laursen, 1951)[21]; it was never published.

The most important international contribution of IPY-2 was the almost complete set of daily synoptic

Fig. 1.1-6 First meeting of the Commission for the Polar Year 1932–1933 (CPY-1), 26–30 August 1930, Leningrad Russia. Most of the Russian and foreign dignitaries are sitting in the front row. Hugo Dominik is the third person and Dan la Cour is the last person on the right (see Lajus 2008 for the full list of names).

Photo courtesy: Julia Lajus, with the permission from the Russian Academy of Sciences Archives, St. Petersburg, Russia.

charts for northern hemisphere for 1932–1933 produced by the *Deutsche Seewarte*[22] (Fig. 1.1-7) and the magnetic data published by the Royal Meteorological Institute on behalf of the participating nations. In July 1934, la Cour delivered an interim overview of the goals and preliminary results of IPY-2 in his address to the 2nd General Assembly of the International Council of Scientific Unions (ICSU) in Brussels, nine months after the completion of the IPY-2 observation period (la Cour, 1935; Laursen, 1959). No international event or conferences were held in the aftermath, and the history, organization and the outcomes of IPY-2 were not reviewed again until after World War II (Laursen, 1951, 1959).

At CPY-3 in 1933, it was agreed that the Commission should continue in existence after the end of IPY-2 observation period, to ensure that all data would be organized and made available to the science community. A central Bureau (depository) for IPY-2 materials, including copies of magnetic and earth current registrations, was established at the Danish Meteorological Institute under la Cour's supervision. The CPY and the central Bureau were expected to receive copies of all publications generated by IPY-2 (Laursen, 1959). The Commission kept working with the same membership and leadership until September 1939, when World War II broke out and the international scientific collaboration was suspended. La Cour died in 1942 and parts of the IPY-2 archive in Copenhagen were reportedly lost during World War II (Laursen, 1951).

The CPY was not formally terminated until 1946. Since the tasks of CPY had not been completed and some of its funds were still available, the IMO established a 'Temporary Commission on the Liquidation of the Polar Year 1932–1933' of six members, three of whom served on the original CPY (Fleming and Laursen, 1946). The 'Temporary Commission' had its office

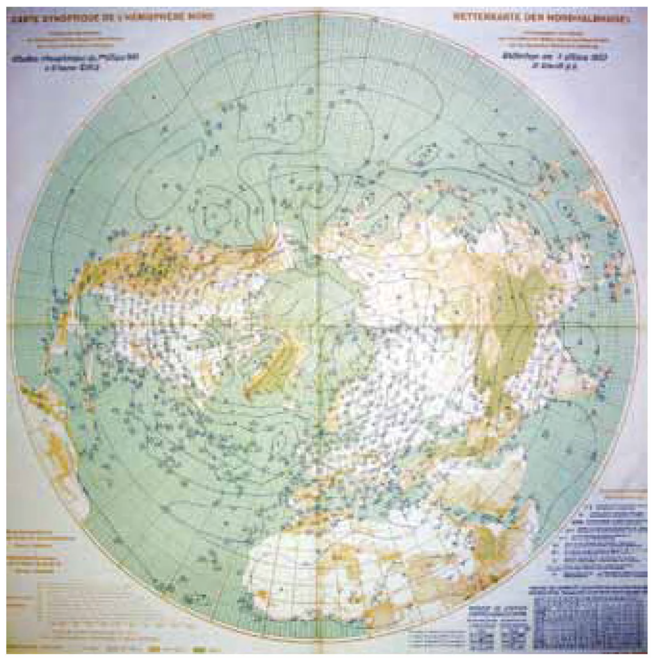

Fig. 1.1-7 Surface temperature map for Northern Hemisphere, 1 March 1933, based upon IPY-2 meteorological observations. Deutsche Seewarte, Hamburg. (Courtesy: Cornelia Lüdecke)

Box 3 List of Nations Participating in the Second International Polar Year 1932 –1933

Algiers
Argentina
Australia
Austria
Belgium
Brazil
Bulgaria
Canada
Chile
China
Colombia
Czechoslovakia
Denmark
Egypt
Finland
France
Germany
Great Britain
Haiti
Hungary
Iceland
India
Indonesia
Italy
Japan
Latvia
Madagascar
Mexico
Morocco
Netherlands
New Zealand
Norway
Peru
Philippines
Poland
Portugal
South Africa
Spain
Sweden
Switzerland
Syria
Tunis
Turkey
U.S.A
U.S.S.R.
Yugoslavia

at the same Danish Meteorological Institute. It completed its service on 31 December 1950, 17 years after the end of IPY-2, by producing a Bibliography of some 2,000 IPY-2 publications, and brief overview of its organization and implementation (Laursen, 1951).

Despite the efforts of the CPY, neither a special series nor a uniform template for the IPY-2 publication was established and each participating nation presented the results of its program at will in English, German and/or in French, but also in Russian, Polish, Norwegian, Danish, Italian, Spanish, Finnish and Portuguese (Laursen, 1951; Elzinga, 2009, 2010b). Overall, IPY-2 is a story of great perseverance in the time of world economic depression and political uncertainty. It was completed thanks in large part to the generosity of a few outside donors, such as the International Association of Meteorology, International Association of Terrestrial Magnetism and Electricity, Carnegie Institution and the Rockefeller Foundation (Elzinga, 2009; Laursen, 1982), despite global economic crisis and the resulting lack of much-needed funding in many nations like Canada, U.K. and the U.S.A.

For whatever reasons, the post-1933 process suffered from repeated delays in the processing and publication of the data collected. La Cour once estimated that it would take five years to ensure the legacy of IPY-2 (Elzinga, 2009). But six years went by without any international meeting or major presentation, until World War II broke out in 1939 and buried any further hopes. By the time the Liquidation Commission was established in 1946 to complete the unfinished tasks of IPY-2, it was too late to re-energize the polar science community. Perhaps, that feeling of unfinished mission contributed to a new drive for the 'third' IPY and to cutting the time between the two initiatives from 50 to 25 years. It also explained why the IGY planners were so keen in promoting the results of IPY-2 in publications related to their venture 25 years later (Bartels, 1959; Beynon, 1959; Brooks, 1959; Paton, 1959; Vestine and Nagata, 1959).

International Geophysical Year/IGY: 1957–1958

Of all IPY initiatives, the third IPY, which eventually became the International Geophysical Year 1957–1958, due to its global geographic scope, has the best-documented chronology and the least controversial origination story. The idea of holding a new polar year in response to recent progress in polar science and technology was put forward on 5 April 1950 by Lloyd Berkner (1905–1967), ionospheric physicist and then executive secretary of the U.S. Research and Development Board.[23] He did so at a small dinner party that honored visiting British geophysicist Sydney Chapman (1888–1970) at James van Allen's private house near Washington, D.C. (Chapman, 1953; Good, 2010; Jones, 1959; Korsmo, 2007, 2009). In that first deliberation, Chapman observed that the years 1957–1958 would correspond with the maximum of solar activity; so, a date was chosen to mark a 25-year interval since IPY-2.

People who proposed the idea for a new polar year were well positioned in the science hierarchy[24]; many of them also shared personal memories of the IPY-2 era. Several other veterans of IPY-2 became soon active in the planning and implementation of IGY.[25] The proposal for the 'third polar year' was advanced with a remarkable speed. A month later, in May 1950, the scientific aspects of the new initiative were discussed at a meeting at the Naval Rocket Station at Inyokern, China Lake, in California (Nicolet, 1982; Korsmo, 2007) and in July 1950 it was endorsed by the international conference on the Physics of the Ionosphere held at the Pennsylvania State College (Penn State), also in the U.S. In September 1950, Berkner and Chapman formally brought their proposal for the new polar year to the Mixed Commission on the Ionosphere of ICSU, a body comprising representatives from the International Union for Scientific Radio (URSI), International Astronomical Union (IAU) and the International Union for Geodesy and Geophysics (IUGG). The Commission endorsed the idea and forwarded it to the respective Unions; all approved it.[26] The proposal was then considered by the Bureau (officers) of ICSU in May 1951 and was referred to the ICSU Executive Board. A small 'preparatory committee' was charged to supervise the process. A large segment of the international science community was thus quickly made aware of the plans for a new polar year (Chapman, 1953).

Over the next two years, an organizational structure based on the ICSU Unions was put in place. Also, during the boreal summer of 1951, ICSU invited the World Meteorological Organization (WMO), the successor of IMO, to join the new initiative. WMO responded positively and urged that the observational program should be expanded to tropical and temperate regions, thus encompassing the whole planet. The shift to a new global vision was triggered by Danish meteorologist Johannes Egedal, who in his talk at the Assembly of the International Association of Terrestrial Magnetism and Electricity in Brussels (23 August 1951) argued vigorously that "observations . . . should be taken all over the earth", and especially at the tropical and southern non-polar regions. It was Egedal who suggested to Chapman that the global character of the program could best be shown by changing its name. Chapman, always a savvy planner, duly agreed. In October 1952, the ICSU General Assembly formally endorsed the new initiative under the name 'International Geophysical Year (IGY/AGI)/Année Géophysique Internationale' (Chapman, 1953; Jones, 1959). It became a joint initiative of ICSU and WMO, with a larger role played by ICSU.

On 30 June 1953, four years prior to the official starting date of IGY, the short-term 'preparatory committee' was transformed into a full-size *Comité Special de l'Année Géophysique Internationale* (CSAGI) of 13 members, with Chapman as President, Berkner as Vice-President and Marcel Nicolet (1912–1996) as Secretary General.[27] It met that same day in Brussels for its first session. The composition of CSAGI reflected the new structure of IGY. Unlike the planning bodies for IPY-1 and IPY-2, whose members were national delegates, CSAGI comprised representatives of five international scientific unions of ICSU,[28] *ex officio* members from ICSU and WMO, and its three executive officers, Chapman, Berkner and Nicolet. CSAGI also designated its member scientists as 'world

Box 4 List of Countries Participating in the International Geophysical Year (67 countries)

Argentina	German Democratic Republic	Panama
Australia	German Federal Republic	Peru
Austria	Ghana	Philippines
Belgium	Greece	Poland
Bolivia	Guatemala	Portugal
Brazil	Hungary	Rhodesia, Southern
Bulgaria	Iceland	Rumania
Burma	India	Spain
Canada	Indonesia	Sweden
Ceylon	Iran	Switzerland
Chile	Ireland	Thailand
China (Taipei)	Israel	Tunisia
Colombia	Italy	Union of South Africa
Cuba	Japan	U.S.S.R.
Czechoslovakia	Korea, Democratic Republic	United Kingdom
Denmark	Malaya	United States of America
Dominican Republic	Mexico	Uruguay
East Africa	Mongolian Peoples Republic	Venezuela
Ecuador	Morocco	Viet Nam, Democratic Republic
Egypt	Netherlands	Viet Nam, Republic
Ethiopia	New Zealand	Yugoslavia
Finland	Norway	
France	Pakistan	

Source: www7.nationalacademies.org/archives/igy_countries.html rapporteurs' for each discipline and made their respective unions responsible for specific components of the IGY science program. That decision doubled the size of the Committee.

The organization of IGY was a template for methodical planning and management (Chapman 1961). Nonetheless, it had its own 'bumps' and delays, particularly during 1952 and 1953. Also, the participation of the Russian (Soviet) scientists in IGY was not formally secured until 1954 (Bulkeley, 2008). That finally opened the door to the true international nature of IGY, in which scientists from 67 nations officially participated (Box 4). All major nations of both Northern and Southern Hemispheres (except the People's Republic of China) joined forces in IGY, as also did a large swath of countries from the tropical area, like the newly independent Ghana, Malaya, Morocco, Tunisia, and both North and South Vietnam.

The IGY program was designed in 1954 and was more or less determined by 1955, two years prior to its official launch date (Berkner, 1954; Kaplan, 1954). IGY was built on new partnerships between meteorology and a group of younger disciplines focused on solar-terrestrial interactions, such as geomagnetism and investigations of the ionosphere and cosmic rays. Specialists in the latter fields provided the bulk of the CSAGI members, including all of its officers. IGY science was initially organized in nine designated areas: meteorology, latitude and longitude determinations, geomagnetism, the ionosphere, aurora and airglow, solar activity, cosmic rays, glaciology and oceanography. Eventually, five more 'areas' were added: rockets and satellites, seismology, gravimetry, world days and nuclear radiation[29] (Nicolet, 1982). As in IPY-2, IGY steered away from non-geophysical research, though some zoological, medical and psychological studies were carried out, particularly in Antarctica; the latter were focused exclusively on the personnel of IGY polar stations (Aronova et al., 2010). No research on social issues or polar indigenous people was conducted during IGY.

IGY was managed for more than six years (1953–1959) by the CSAGI 'Bureau' of five members (Chapman, Berkner, Nicolet, Coulomb and Russian geologist Vladimir Beloussov, who was added in 1955). It was run on a day-to-day basis by the 10-member secretariat in Brussels (Nicolet, 1982). However, besides the overall agreements on the timing and scope of synchronous observations, global IGY activities were carefully orchestrated so to not infringe on the national sovereignty. Each participating nation was encouraged to plan and implement its own program, according to its resources and interests. Collaboration was promoted but not required. There was neither central IGY pro-

Fig. 1.1-8 U.S. Navy and construction personnel unload cargo on the Antarctic shore-fast ice during the U.S. "Deep-Freeze I" mission, 1955–1956, in preparation for IGY 1957–1957.
(Photo: Rocky Milano)

Fig. 1.1-9 The male-only, military-style pattern of many IGY operations is clearly seen in this photo featuring Adm. Richard Byrd (1888–1957, in the middle), and the members of the U.S. 'Deep-Freeze' Mission in Antarctica.
(Photo: Fritz Goro, 1956, courtesy Tom Goreau)

gram management nor complex finances besides the national program budgets, and political sensitivities of the Cold War era were always on IGY organizers' mind (Good 2010; Olson Belanger 2010).

CSAGI held six general meetings or 'Assemblies' during the IGY planning and implementation phase: CSAGI-1 in July 1953 (Brussels), CSAGI-2 in October 1954 (Rome), CSAGI-3 in September 1955 (Brussels), CSAGI-4 in September 1956 (Barcelona), CSAGI-5 in July-August 1958 (Moscow) and CSAGI-6 in May 1959 (Paris). Except for the first and the last meeting, all Assemblies were organized as large conferences with parallel sessions and plenaries. CSAGI also organized four medium-size conferences on Antarctic research in 1955, 1956 and 1957; one Arctic conference in 1956; five regional conferences for Western Hemisphere, Eastern Europe, Eurasia, Africa and Western Pacific; and meetings of four CSAGI Working Groups: on Oceanography (1957), Nuclear Radiation (1957), World Data Centers (1957) and Rockets and Satellites (1957–Nicolet, 1959).

Also, at CSAGI-2 in 1954, the delegates established a special body, the Advisory Council of IGY, composed of one delegate, not a CSAGI member, from each national IGY committee. The purpose of the Council, chaired by German geophysicist Julius Bartels, was to discuss and express views on general IGY matters besides the scientific program and to facilitate bilateral arrangements for mutual assistance (Chapman, 1960).

IGY officially lasted for 18 months, from 1 July 1957 to 31 December 1958. An estimated 60,000 people, of whom 10,000 were scientists, took part in its various activities (Elzinga, 2009).[30] Major preparatory and logistical steps were undertaken at least two years prior to the launch date, such as the construction of new science bases and airstrips across the polar regions (Fig.1.1-8). Most of the IGY field activities were all-men operations with a heavy portion of navy and air force personnel (Fig.1.1-9). Military and geopolitical factors of the Cold War era bore larger weight in IGY than in the previous IPY ventures and played decisive role in its funding and implementation, from the space satellite program to research on human physiology in extreme cold environment.

The 18-month IGY observation period was later extended by a full year (January-December 1959) under the title 'International Geophysical

Cooperation.' The decision to extend IGY for another year under a different name was taken by ICSU, which also established a successor body to CSAGI, the Special Committee for Inter-Union Cooperation in Geophysics (SCG), with essentially the same membership. The last meeting of CSAGI (CSAGI-6) and the first meeting of SCG were held concurrently in May 1959. At that joint meeting it was proposed to establish a representative successor group, *Comité Internationale de Géophysique* (CIG), to supervise the processing and publication of IGY-IGC data. Most of the CSAGI members were then transferred to CIG.[31] The CIG of 27 members (under the leadership of W.J.G. Beynon) and its Secretariat operated for eight more years, until December 1967. Its tasks, primarily the publication of the IGY-IGC results, were then entrusted to a small CIG *Terminating Group* that worked until 1970, twelve years after the official completion of IGY in 1958.

CSAGI-5 Assembly in Moscow in 1958 attended by more than 400 delegates, 800 guests and 200 journalists from 67 nations (Bulkeley, 2008) was the largest gathering conveyed to represent the IGY science. Later meetings were much smaller in size, like the Antarctic scientific symposium in Buenos Aires in

Fig. 1.1-10 One of six large-size IGY posters (Earth, Ocean, Space, Poles, Sun and Earth, Weather and Climate) produced by the U.S. IGY Committee for the IGY outreach program and published in its 44-page educational booklet, Planet Earth. (The Mystery with 100,000 Clues (1958) www7.nationalacademies.org/archives/ IGYPlanetEarthPosters.html)

1959 (Genest 2009) or the 1963 symposium 'Results of the IGY-IGC' in Los Angeles (Beynon, 1970). No major IGY summary conference was organized.

Wary of the failure of the IPY-2 team to publish the results of their venture, IGY planners designed an impressive publication program. The plans for a special IGY series, a full IGY bibliography and a final 'Coordinated Report' by CSAGI were first discussed at CSAGI-1 in 1953 and had been systematically reviewed at later meetings (Nicolet, 1958). The IGY publication series, the *Annals of the International Geophysical Year,* was started in 1957 under supervision by the IGY Editorial Committee of 19 members, with D.C. Martin as Chairman.[32] Altogether, 48 volumes of the *Annals* were printed between 1957 and 1970, many in several parts or issues that brought the total number of volumes to more than 70. The *Annals* also published extensive minutes of the CSAGI meetings and regional conferences (Nicolet, 1958, 1959), as well as reports from the national committees. The plans for a final summary report on IGY envisioned in 1953 never materialized, though several individual and national overviews and popular accounts of IGY were produced (Berkner, 1959; Chapman, 1959; Fraser, 1957; Odinshaw, 1958,1959; Silkin et al., 1962; Sullivan, 1961; Wilson, 1961). The full Bibliography of IGY publications eventually grew to more than 6,000 entries; it was published as the concluding volume of the *Annals* series with a 'cut-off' date of 1963 (Beynon 1970).[33]

Daily information on the IGY activities was disseminated via the *IUGG Newsletter, WMO Bulletin,* the internal *IGY News Letter* (published from 1956 to 1959 for the CSAGI members and national committees, and via monthly *IGY Bulletin* produced by the U.S. National Committee for IGY.[34] Updates on IGY were regularly printed in major scientific journals and the first popular overview of IGY for lay audience was released already in 1957, the year the IGY was started (Fraser, 1957). Unlike in IPY-1 and IPY-2, the IGY organizers developed a special outreach and educational program that included popular articles, booklets, posters (Fig. 1.1-10), films, classroom and other instructional materials (Korsmo, 2004, 2009). Also, a special IGY logo, with an explicit link to the most advanced technology of the era, the Earth-orbiting satellite (Fig. 1.1-11) was designed and adopted in 1955 for the use in all IGY publications, instruments and public materials (Odinshaw, 1956).

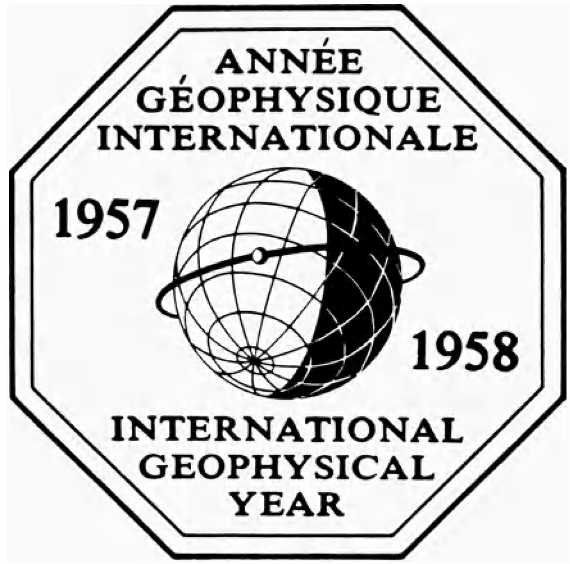

Fig. 1.1-11 IGY 1957–1958 logo. (Courtesy: National Air and Space Museum, Smithsonian Institution).

Perhaps the most lasting innovation of IGY was the system of the World Data Centers. Over the course of the IGY planning, it became obvious that no single depository for all IGY materials would be feasible. At CSAGI-4 in 1956, it was decided to establish three 'World Data Centers' to host the originals or copies of the IGY records, observations and tabulations. The Centers were geographically and politically dispersed: one in the U.S.A., one in the Soviet Union and one subdivided between Europe and the Western Pacific. By 1964, 64 Centers were active at 33 locations; many were still in operation when IPY 2007–2008 began (Korsmo, 2010).

Extended documentary collections related to IGY have been preserved at several archives, the richest collections being held at the U.S. National Academies in Washington, D.C. (U.S. National IGY Committee) and University of Alaska Fairbanks (Sydney Chapman's personal collection).[35] Others are scattered around the world in the archives of the participating nations, scientific and international organizations, and research institutions.

Overall, IGY 1957–1958 was a remarkable success in globally coordinated research planning, implementation, data processing and publication. IGY clearly marked a new era: it encompassed more disciplines, nations and research sites than any of its predecessors. Its activities spanned two full decades (1950–1970). It received the most sustained backing from its participant nations, international organizations and scientific bodies, including UNESCO. It also attracted an estimated USD 2 billion in overall funding (Bullis, 1973), equivalent to USD 14.3 billion in 2006 dollars.[37] IGY funding requests were eagerly matched by national governments, so that a substantial balance was carried forward for post-IGY programs and data-management.

The achievements of IGY, in science, new research techniques, international collaboration, public policy and outreach are hard to overestimate (Berguño and Elzinga, 2010; Bulkeley, 2008; Collis and Dodds, 2008; Dodds et al., 2010; Elzinga, 2009; Korsmo, 2010; Summerhayes, 2008). IGY raised the international organization and the status of polar research to a new level. The role of science in Antarctica, in particular, was transformed. New international regime for governance and collaborative research in Antarctica (Antarctic Treaty of 1959) was established as the direct result of IGY (*Chapter 1.4*). Three new special ('scientific') committees were created by ICSU to continue the international cooperation advanced by IGY, the Scientific Committee on Antarctic Research (SCAR, in 1958), Scientific Committee on Ocean Research (SCOR, in 1957) and Committee on Outer Space Research (COSPAR, in 1958). Furthermore, IGY triggered several subsequent international research programs, including the *Upper Mantle Programme* (1962–1968) and its successors; the *International Year of the Quiet Sun* (1964–1965); the *Global Atmosphere Research Programme* (1968–1979), which was succeeded by the World Climate Research Programme; and the *International Biological Programme* (1964–1974), which was succeeded by the International Geosphere-Biosphere Programme (Aronova et al., 2010; Baker, 1982a). By every possible measure, IGY would be a hard act to follow.

Conclusion: What Did It Take to Launch an IPY?

It is obvious that none of the earlier IPY/IGYs had a smooth sailing and all of them, at one point or another, were plagued with delays, personal and national rivalries, and institutional competition. To launch a science program on the magnitude of an international polar year several factors have to be in place. This includes, above all, successful coalition building and politicking, strong and savvy leaders, and a good sense of historical momentum (Korsmo, 2009; Needell, 2000). The original idea could be proposed by individual champions, like Weyprecht, Breitfuss or Georgi, but to become a reality it has to be pushed forward by people well-established in the international scholarly hierarchy, like Neumayer and Wild in IPY-1; Dominik and la Cour in IPY-2; Berkner and Chapman in IGY. Also, the proposal to launch a new initiative has to be advanced via the most respected professional organizations of the time. Specifically, IMO/WMO and ICSU, or their constituent bodies, acted as such channels. Ever since IPY-1, the idea of a globally coordinated science initiative at the Poles ('international polar year') was solidly rooted in the polar community's memory; but in order to move forward, it had to be re-energized via consistent and dedicated effort. An approaching major anniversary commonly triggered such process. A cadre of veterans with personal memory of the previous event may contribute a decisive force in 25 years (Chapman, Berkner, Vestine, Paton, and others in IGY); of course less so after 50 years.

The timely establishment of a special international body (committee, planning group) charged with the preparation, networking and advertising for a new IPY has always been the key factor in its successful implementation. Each venture also required canny managers, as well as skilled science 'diplomats,' that is, people capable of defusing or at least managing institutional rivalries and international conflicts, like Wild, la Cour, Chapman and Nicolet, to name but a few. In general, good diplomacy was always a prerequisite to the success of IPY, both internally, among competing science institutions, and externally – in the time of a major European War (IPY-1), global economic crisis (IPY-2) and Cold War confrontation (IGY). Last but not least, ALL major nations active in polar research have to be involved in the process, though the original champions for a new IPY might not necessarily come from the wealthiest or the most established nations, as happened in IPY-1 (Austria-Hungary) and IPY-2 (Germany and Russia).

A remarkably consistent time span—seven years in case of IPY-1 and IGY, six years in IPY-2—takes to move the idea from the initial talks to the official launch date. In the science community as different as it had been in 1875, 1926 and 1950, planning for a science venture on the scale of IPY/IGY proceeded through the same general phases: origination (6-7 years prior to the launch); dissemination and endorsement (5-6 and 3-5 years, respectively); development of the program by a specially appointed team (2-3 years); marshaling resources and logistics (2-3 years)—with little if any variation (Table 1.1-1). Such consistency is startling, as the ways science operated and polar affairs mattered in national politics could not have been more different during IPY-1, IPY-2 and IGY.

In a similar way, a successful completion of a large and complex venture on the scale of IPY was conditioned on a fairly consistent set of factors. The presence of a dedicated and energetic core team and its continuity throughout the planning, implementation and completion phases (often lasting for several more years) were crucial to achieve success and secure the legacy. The team had to move swiftly to demonstrate tangible results and to establish a timetable for processing the data after the end of the observation period. A string of summary meetings or a final conference are the most common means to present the results of a successful long-term program, as happened in IGY and partly in IPY-1, though not in IPY-2. Finally, systematically organized publications featuring data collected by several nations, a well-planned bibliography, and a cadre of scientists and their students bonded by shared experience produce the most durable legacy. That happened in all three ventures, most prominently in IGY. Data collected via national and international efforts are to be shared, safely deposited and substantially analyzed. Only IGY offered a good template, whereas IPY-1 and IPY-2 mostly failed in this regard.

History does matter to science, and both IGY and IPY-2 organizers tried to *learn* from the experience of their predecessors by studying their work and publishing their results. National or regional IPY historiographies emerged as important venues in strengthening institutional memories between the IPY ventures to allow international science community to quickly mobilize itself for the next IPY. The next chapters demonstrate how the organizers of IPY 2007–2008 used the playbook of the earlier IPY initiatives and aspired to build their collaborative venture upon the lessons of 125 years of international partnership in polar research.

	IPY-1	IPY-2	IGY
1. First discussion (public presentation) of the idea	7 years (September 1875)	<6 years (November 1926)	7 years (April 1950)
2. Endorsement by the first disciplinary science body	6.5 years (April 1876)	4.5 years (December 1928)	<7 years (July 1950)
3. First detailed proposal for new venture	5 years (May/September 1877)	3 years (August 1929)	3.5 years (February 1954)
4. Endorsement by major sponsor/s	3.5 years (April 1879)	<3 years (September 1929)	<5 years (October 1952)
5. First meeting of a special team tasked with planning	<2.5 years (October 1879)	2 years (August 1930)	4 years (June 1953)
6. Number of the planning team meetings prior to launch	3	2	4
7. First detailed outline unveiled	2 years (August 1880)	2 years (August 1930)	3 years (August 1954)
8. Specific science focus/ observational instructions approved	<1 year (August 1881)	<2 years (Winter 1930)	2 years (1955)
9. Planning for resources and logistics	2.5 years (1880–1882)	2 years (1930–1932)	3 years (1954–1957)

Table 1-1. Comparative Timelines for the Preparation Phase of IPY-1, IPY-2, and IGY

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Notes

[1] The key historical sources on IPY-1 include: Baker, 1982a; 1982b; Barr, 1983/2008; Corby, 1982; Elzinga, 2009; Heath and Armitage, 1958; Levere, 1993; Lüdecke, 2004; Sukhova and Tammiksaar, 2007/2008; Tammiksaar et al., 2009, 2010; on IPY-2 – Laursen, 1951, 1952, 1982; Lüdecke and Lajus, 2010; Lajus, 2008; on IGY 1957–1958 – Berkner, 1954; Bulkeley, 2008; Bullis, 1973; Chapman, 1953, 1954, 1959; Cochrane, 1978; Collis and Dodds, 2008; Fraser, 1957; Kondrat'ev, 1960; Korsmo, 2007, 2009; Needell, 2000; Nicolet, 1982, 1984; Odinshaw and Rothenberg, 1958.

[2] The group was established in 2004 in preparation for IPY; the first two volumes of its proceedings are already published as contributions to IPY project no. 27 (Lüdecke, 2007a, 2009).

[3] Weyprecht's given name in the registry was Karl, but in several of his German papers he was listed as 'Carl Weyprecht.' Later sources use both forms.

[4] In 1860, Maury completed a revised version of his seminal work, *The Physical Geography of the Sea,* adding new chapters on the Southern Ocean and Antarctica. On 10 April 1861 he circulated his ideas on polar scientific cooperation to the Washington ambassadors of leading maritime countries (Maury, 1862). Unfortunately, with the start of the American Civil War in 1861, Maury resigned his commission. Even before copies of his circular began making their way to the foreign ministries of Europe, its return address was no longer valid.

[5] Weyprecht, first referred to the need for synchronous observations in the Arctic in his talk at the Royal Geographical Society in London on 10 November, 1874. Nevertheless, he did not suggest a *multi-national* program of synchronous observations, which became the core of his proposal for IPY.

[6] The delegates at IPC-1 represented eight nations: Austria-Hungary, Denmark, France, Germany, the Netherlands, Norway, Russia and Sweden.

[7] In addition, the Finnish IPY station in Sodankylä and the Russian expedition to Sagastyr (Lena River delta) continued their observations until summer 1884 (Heathcote and Armitage, 1959).

[8] Baker, 1982a; Barr, 1985/2008; Heathcote and Armitage, 1959. In addition, ships taking scientists to and from the IPY expeditions took regular observations. Merchant ships were also asked to make observations and some of these were later used in Germany and the U.K. for synoptic studies. This makes a total of more than 60 IPY-1 stations and, probably, more than 100 if ship-based observations are included.

[9] Three issues in 1882, one in 1883, two in 1884 and one in 1891.

[10] Most of these volumes were recently posted on the NOAA IPY Website as a result of the NOAA historical IPY documentation effort (www.arctic.noaa.gov/ipy-noaa.html).

[11] Austria-Hungary, Denmark, France, Germany, the Netherlands, Norway, Russia, Sweden, United Kingdom/Canada and the United States. Many sources list 11 nations participating in IPY-1, though Finland was then officially part of Russia, Canada was the British dominion, and Norway was still formally part of Sweden. Austria-Hungary was, though, a 'dual' nation.

[12] Henryk Arctowski (1871–1958), a Polish-born Antarctic explorer and oceanographer and member of the Belgian Antarctic Expedition (the *Belgica* Expedition) of 1897-1899.

[13] Dominik's letter was sent to the IMC President, Prof. E. van Everdingen (Laursen, 1959). IMC was responsible for the issues related to international relations and it acted on behalf of the supreme body of IMO, the Conference of Directors. Thus, it corresponds to the WMO Executive Council of the present day (Laursen, 1982).

[14] D. la Cour, E. Van Everdingen, H.U. Sverdrup, H. Hergessell, and P. Wherlé.

[15] See list of CPY members in Laursen, 1959. Two more members were added in 1933. The CPY's only female participant, M. Bruun de Neergaard, acted as secretary to la Cour during the preparatory work, until she became the Commission's secretary and, finally, its full member.

[16] The high-level support for IPY by the Russian (Soviet) Academy of Sciences was instrumental to the early preparation for IPY-2 and to la Cour's decision to have the first IPY planning meeting in Leningrad in August 1930 (Lajus, 2008).

[17] C. Störmer (chair), S. Chapman, D. la Cour, C. Maurain, and P. Wherlé (Laursen, 1959). La Cour and Maurain also served on the IMO Commission for IPY.

[18] IPY-2 bibliography lists 46 nations (Box 2) plus the Azores (part of Portugal) and 'British Colonies and Protectorates' (Laursen, 1951).

[19] See the map and list of IPY-2 stations in Fleming 1933. The original IPY-2 outline aimed at establishing 43 stations in the Arctic and at least 5 stations in Antarctica (Fleming, 1931). In addition, more than 100 Russian (Soviet) weather stations conducted observations under the IPY-2 program; many were located in Siberia and the southern mountain regions (Andreev et al.,, 2007).

[20] No.6, 1930; no. 10, 1932, no. 16, 1933.

[21] Another important collection of records pertaining to the terrestrial magnetism studies during IPY-2 is hosted at the Carnegie Institution in Washington, D.C. (Neumann, 2009).

[22] The records from the last 15 days of August 1933 were lost during World War II.

[23] Berkner's life and career and his proposal to launch the 'third' Polar Year are covered in Needell, 2000.

[24] Other people present at that dinner party were J. W. Joyce, future director of the National Science Foundation office for IGY, E. Vestine, the head of the Section on Theoretical Geophysics at the Carnegie Institution in Washington, and S.F. Singer, then young space physicist (Chapman, 1959; Korsmo, 1998, 2007).

[25] Jean Coulomb (1904–1999), Takeshi Nagata (1913–1991), James Paton (1903–1973), Nikolay Pushkov (1903–1981) and James Stagg (1900–1975), to name but a few.

[26] URSI and IAU in September 1950, and the IUGG, chaired by Chapman, in August 1951.

[27] Eventually, CSAGI's membership grew up to 24 people. In 1955–1958, Berkner also served as the President of ICSU, which offered him the opportunity to contribute ICSU resources in support of IGY.

[28] International Union for Astronomy, International Union for Geodesy and Geophysics, International Union for Scientific Radio, International Geographical Union and International Union of Pure and Applied Physics.

[29] The inclusion of *nuclear radiation* to the IGY program was propelled by a number of concerned scientists who used the opportunity of IGY to monitor radioactive fallout from atomic bomb tests. In this sense the Cold War and the opposition to its real and prospective dangers were translated into an important scientific program (Aant Elzinga, personal communication).

[30] Another estimate lists 20,000 to 30,000 scientists, engineers and technicians and almost 'as many volunteer observers' (Cochrane, 1978).

[31] The first meeting of the CIG took place in November 1959; shortly after, the CSAGI Secretariat was closed (December 1959) and replaced with the CIG Secretariat in Paris.

[32] First 11 volumes were published or prepared under the auspices of CSAGI, before its termination in 1959; after that the CIG/IGC took responsibility for the publication of the Annals.

[33] In addition, several national, disciplinary, or transitional bibliographies of the IGY contributions were published between 1957 and 1963 (Beynon, 1970), including special bibliographic sections, *IGY Bibliographic Notes*, in many issues of the *IGY Bulletin*.

[34] These were published as sections of the *Transactions of the American Geophysical Union* and in separate issues. The first issue appeared in July 1957, following the official opening of IGY and the last, no. 62, in August 1962.

[35] www7.nationalacademies.org/archives/igyseries8.html (U.S. IPY Committee); www.aip.org/history/ead/19990060_content.html (S. Chapman's collection).

[36] In addition to funds allocated to ICSU for the implementation of IGY, UNESCO made available $110,000 directly to CSAGI. It also produced an IGY exhibit that toured many countries, published a booklet on IGY, a special IGY issue of the *UNESCO Courier* in 1957, and made available fellowships to young scientists from developing countries to participate in IGY observations.

[37] ICSU alone granted over $700,000, and UNESCO subsidies covered almost half of the CSAGI budget ($275,000). U.S. Congress appropriated more than $43 million for the U.S. IGY operations, which in today's terms may be as high as $350 million (http://en.wikipedia.org/wiki/NASA_Budget).

1.2 How IPY 2007–2008 Was Born: 1997–2003

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Introduction

Unlike three previous International Polar (Geophysical) Years in 1882, 1932 and 1957, IPY 2007–2008 lacks an origination legend of its own. So far, it has not generated its iconic 'creation myths,' similar to the story of the dinner party at James Van Allen's house in April 1950 that gave rise to IGY or Carl Weyprecht's proposal of 1875 that opened the door to IPY-1 (*Chapter 1.1*). A few published historical accounts on the origination of IPY 2007–2008 are rather brief; they also commonly dwell on certain lines of its multifaceted history.[1] The emerging history of IPY 2007–2008 is, actually, very complex and, in contrast to its predecessors, this IPY had numerous early advocates and independent origination sources over the course of several years. It also had a few false starts. Compared to the previous IPYs, it was much more a 'bottom-up' development with a far broader interdisciplinary appeal, as it engaged larger swaths of polar science community, beyond meteorology, oceanography, atmospheric and space studies that were instrumental to IPY-1, IPY-2 and IGY.

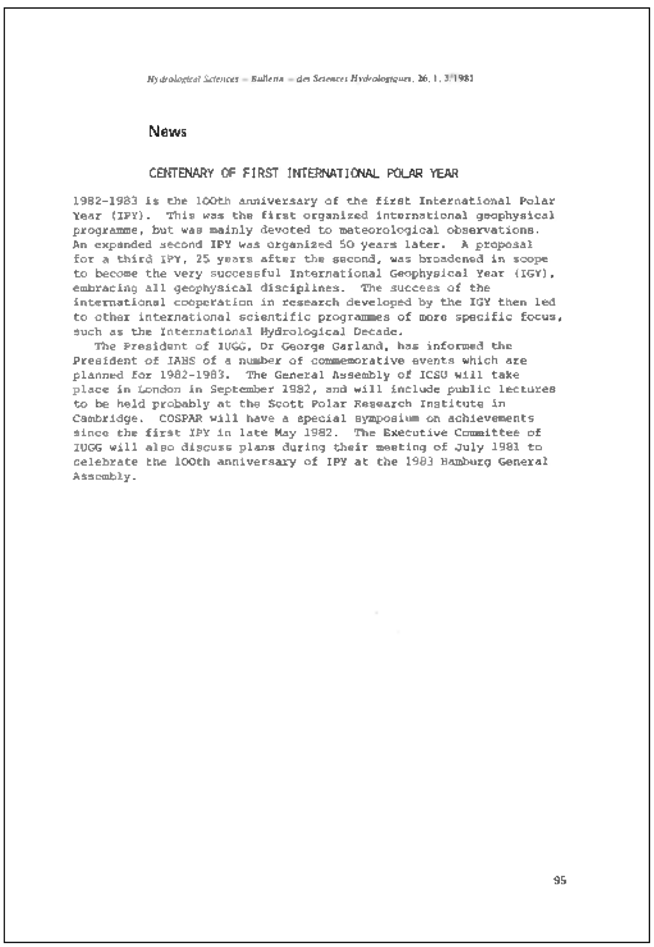
For over four years, from 2000 when the idea was put forward until spring 2004, many groups debated and advanced their proposals for a new IPY, until these independent, often competitive streams merged into a common planning process. Therefore, creating a shared origination narrative of IPY 2007–2008 remains a work in progress. It is also an urgent task while our memory is still fresh and most of the relevant sources are in hand. This chapter covers the period from the first discussions about launching the new IPY until summer 2003, when those efforts crystallized into a dedicated planning process spearheaded by the ICSU Planning Group (*Chapter 1.3*). It relies upon the emerging archives of various sources, including documents, papers, letters, website postings and recorded (taped) narratives of several early IPY champions (see *Acknowledgements*). A more detailed summary will be left for future historians to explore.

The IPY 2007–2008 Origination: Chronology and Narrative

1982 –1983: 'Aborted' 25th Anniversary

Evidently, the first time people started talking about the 'fourth' IPY was in the late 1970s, as the 25th anniversary of IGY was approaching. In 1978, ICSU established within its framework an *ad hoc* Group (later Committee) to study the desirability of ICSU commemorating in 1982-83 the anniversaries of all three earlier IPYs (F.W.G. Baker, pers. comm., 19 January, 2010). The Group was chaired by Marcel Nicolet, the former Secretary General of CSAGI (*Chapter 1.1*) and it was composed of several remaining IGY veterans, Vladimir Beloussov, W.J. Granville Beynon, Jean Coulomb, Viggo Laursen, Alan Shapley, with F.W.G. (Mike) Baker as Secretary. The idea of a new IPY was discussed during the meeting at the ICSU Secretariat in April 1981, but as no agreement was reached, no proposal for actions was put to ICSU. Nevertheless the Committee suggested to ICSU that two lectures should be organized at the forthcoming ICSU 19th General Assembly in Cambridge in 1982 as part of the commemoration of the three IPYs (Fig. 1.2-1); these addresses were given at the Scott Polar Research Institute in Cambridge by Canadian geophysicist George D. Garland and Russian geologist Vladimir V. Beloussov (Garland, 1982; Beloussov 1982). Several other anniversary addresses were delivered at major conferences and special symposia during 1982–1984 (e.g. Beynon, 1983) and a great number of historical overviews of IPY-1, IPY-2 and IGY were published (Baker, 1982; Barr, 1985; Nicolet, 1984), including a special issue of the *WMO Bulletin* (Corby, 1982; Laursen, 1982; Nicolet, 1982), but no new research or public projects were launched.

At a small event that Nicolet organized in Brussels in 1987 to commemorate the anniversaries of the three IPYs, the idea of when, why and the possibility of another "IPY" was discussed among the former members of the IGY Secretariat, Nicolet, F.W.G. (Mike) Baker and Phil Mange, but none of the participants took any action since they thought it was still a bit premature (F.W.G. Baker, pers. comm., January 2010). Thus the momentum to use the 25th anniversary of IGY and the 100th anniversary of IPY-1 to launch the 'fourth' IPY slipped away.



Hydrological Sciences – Bulletin – des Sciences Hydrologiques, 26, 1, 3/1981

News

CENTENARY OF FIRST INTERNATIONAL POLAR YEAR

1982-1983 is the 100th anniversary of the first International Polar Year (IPY). This was the first organized international geophysical programme, but was mainly devoted to meteorological observations. An expanded second IPY was organized 50 years later. A proposal for a third IPY, 25 years after the second, was broadened in scope to become the very successful International Geophysical Year (IGY), embracing all geophysical disciplines. The success of the international cooperation in research developed by the IGY then led to other international scientific programmes of more specific focus, such as the International Hydrological Decade.

The President of IUGG, Dr George Garland, has informed the President of IAHS of a number of commemorative events which are planned for 1982-1983. The General Assembly of ICSU will take place in London in September 1982, and will include public lectures to be held probably at the Scott Polar Research Institute in Cambridge. COSPAR will have a special symposium on achievements since the first IPY in late May 1982. The Executive Committee of IUGG will also discuss plans during their meeting of July 1981 to celebrate the 100th anniversary of IPY at the 1983 Hamburg General Assembly.

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Fig. 1.2-1. Report on the forthcoming activities associated with the 'Centenary of the First International Polar Year (March 1981.
(Courtesy Mike Baker)

1997–2000: IGY 50th Anniversary Is Approaching

The next calls for a new IPY came in the late 1990s when the 50th anniversary of IGY was on the horizon. In 1997 on the 40th anniversary of IGY, Chris Rapley, then Executive Director of the International Geosphere-Biosphere Programme (IGBP) in Stockholm, reportedly sent a letter to the ICSU Secretariat arguing for a major celebration event to be organized by the 50th anniversary of IGY in 2007. According to Rapley's account, he was informed that his idea was forwarded to several International Unions under ICSU but the proposal was considered a 'step too far.'[2] Everybody was suffering from 'initiative fatigue' and there was no enthusiasm for another major venture within the ICSU system (Chris Rapley, interview, 3 March, 2008). The latter may be due to the successful proliferation of many large international programs in the 1980s and 1990s, including IGBP itself, so that many science groups and researchers felt that they needed a breather.

Nonetheless, some unions were more open to the idea than others. At the 22nd General Assembly of the International Union of Geodesy and Geophysics (IUGG) 18–30 July, 1999, one of its constituent groups, the International Association of Geomagnetism and Aeronomy (IAGA) adopted a resolution recommending the preparation of 'collaborative programs [...] during the period 2003 to 2008 to mark the 50th anniversary of the IGY and to act as a springboard for future research' (IAGA 1999 – Fig. 1.2-2). Both IAGA and IUGG were active participants in IGY; evidently, their members had a strong feeling about its forthcoming 50th anniversary. The IAGA/IUGG nexus became a crucial link that eventually led to the International Heliophysical Year (IHY) planning a few years later (see below).

Another line of correspondence related to the 'next' IPY emerged in the late 1990s at the IASC Secretariat in Oslo (*Chapter 1.4*). Leonard

Johnson, formerly with the U.S. Office of Naval Research, was one of the key advocates. Again IASC, like ICSU, was suffering from 'initiative fatigue' of its own and was not very forthcoming to the new IPY idea.

Several other leading bodies and groups active in polar research, such as the Scientific Committee on Antarctic Research (SCAR), European Polar Board (EPB) and U.S. Polar Research Board (PRB) were apparently enduring a similar burden of core programs coupled with the lack of innovative 'big ideas' to enthuse their members. This was a reason given by some early IPY champions in the explanation why an idea of the new IPY suddenly became appealing to many people barely a few years later. Perhaps it happened thanks to the new cohort of leaders that came to many polar organizations at that very time.[3] Remarkably, in 2000–2001 at least four groups of scientists independently came forward with proposals for a new 'international polar year' to be launched in 2007. All based their arguments on the forthcoming anniversary of IGY and many also invoked the century-old legacy of the earlier Polar Years.

Antarctic Scientists Argue for the Celebration of IGY: 2000–2001

Antarctic scientists, predominately a physical science community with a deep memory of IGY, started talking about the approaching anniversary of IGY at least in 1999–2000. At that time, the talks were primarily about the need to prepare for a big '50-year celebration' event in 2007 (Bell, 2008; Summerhayes, 2008). Some of these debates were first reflected in the minutes of the SCAR XXVI annual meeting in Tokyo, 17–21 July 2000, at which the delegates were briefed about such discussion at the XII COMNAP (Council of Managers of National Antarctic Programmes) meeting a week prior. Among several issues addressed by COMNAP was the recommendation 'to prepare for recognition of the 50th Anniversary of the International Geophysical Year in 2007–2008' (*Chapter 1.4;* SCAR, 2001). A year later, at the SCAR Executive Committee Meeting in Amsterdam 22–24 August 2001, the approaching 50th Anniversary was once again addressed among 'other items.' No plan was adopted, except checking with ICSU about 'what plans ICSU may have' and no special ideas were put forward (SCAR, 2002).

Electronic Geophysical and International Heliophysical Years: 2000–2001

On 10 July 2000 the ICSU Secretariat received what may be justly called the first 'IGY+50' proposal from one of its constituent bodies, SCOSTEP (Scientific Committee on Solar-Terrestrial Physics). SCOSTEP was established by ICSU in 1972 out of several successor projects originating from IGY. In his letter Joe H. Allen, SCOSTEP's Scientific Secretary, asked for information about programs known to ICSU that were being planned around the 50th anniversary of IGY in 2007


http://www.iugg.org/IAGA/iaga_pages/pubs_prods/iaga_news_39/resolutions.htm

IAGA News No. 39, October 1999

The Proceedings of the IAGA Assembly during the 22nd IUGG General Assembly July 18-30 1999 Birmingham, UK, including the revised IAGA Statutes and By-Laws and the Division/Working Group Chairs and Co-chairs.

IAGA

INTERNATIONAL UNION OF GEODESY AND GEOPHYSICS

The International Association of Geomagnetism and Aeronomy

Resolutions

French Version

Appendix G: Adopted IAGA Resolutions

(Resolutions in French are on Page 20)

Resolution 1

IAGA,

considering the scientific success of the International Geophysical Year (IGY) 1957/8 and the long term benefits of the actions taken at that time, and

recognizing that these benefits resulted from international co-operation and co-ordination, and

noting that many current science programmes are directed towards studies of the physics and dynamics of the solar-terrestrial and solar-planetary systems,

recommends that national and international agencies support efforts and initiatives to develop collaborative programmes in these areas during the period 2003 to 2008 to mark the 50th anniversary of the IGY and to act as a springboard for future research.

1

Fig. 1.2-2. First resolution by the International Association for Geomagnetism and Aeronomy arguing for "collaborative programmes during the period 2003 to 2008 to mark the 50th anniversary of the IGY and to act as a springboard for future research" (July 1999) www.iugg.org/IAGA/iaga_pages/pubs_prods/iaga_news_39/resolutions.htm and referred to a proposal for 'IGY+50' by Dan Baker from the University of Colorado adopted by the SCOSTEP Bureau in 1999. The proposal put forward by SCOSTEP called to declare the period 2003 to 2008 'The IGY plus 50 years: new Perspectives for the Next Millennium,' with a worldwide program of research into the geophysics, geochemistry, biology and the dynamics of the solar-terrestrial and solar-planetary systems' (Allen, 2000). SCOSTEP appealed to several ICSU Unions to join forces in the preparation of a new program and pledged to take the lead in its Solar-Terrestrial Physics component.

The SCOSTEP proposal never referred specifically to the polar regions and had only passing references to the early 'international polar years.' It eventually evolved into what became the *electronic Geophysical Year* (eGY – www.egy.org/index.php), a parallel initiative that was implemented successfully and ended on 31 December, 2008.[4] Nonetheless, SCOSTEP's proposal almost certainly triggered a similar push for the 'International Heliophysical Year' (IHY) in 2007, also in commemoration of IGY. The IHY was launched by a group of astrophysicists at the Goddard Space Flight Center, U.S. National Aeronautics and Space Administration (NASA), Joseph Davila, Arthur Poland, Nat Gopalswamy and Barbara Thompson, who were aware of the SCOSTEP activities. The proposal for IHY was first unveiled in February 2001 (Davila et al., 2001 – Fig. 1.2-3); unlike the eGY, it was actively promoted as following in the footsteps of the IPY-1, IPY-2 and IGY. The first IHY website, under the title 'International Heliophysical Year' was launched in early 2002 at http://ihy.gsfc.nasa.gov.

International Heliophysical Year

A Program of Global Research Continuing the Tradition of Previous International Years

Joseph M. Davila, Arthur I. Poland
Goddard Space Flight Center

And

Richard Harrison
Rutherford Appleton Laboratory

February 12, 2001
Revised February 15, 2001

Overview

In 1957 a program of international research, inspired by the International Polar Years of 1882-83 and 1932-33, was organized as the International Geophysical Year (IGY) to study global phenomena of the Earth and geospace. The IGY involved about 60,000 scientists from 66 nations, working at thousands of stations, from pole to pole to obtain simultaneous, global observations on Earth and in space. There had never been anything like it before. The fiftieth anniversary of the International Geophysical Year will occur in 2007. We propose to organize an international program of scientific collaboration for this time period called the International Heliophysical Year (IHY). It will focus on the problem of solar variation effects on Earth.

1. Introduction

October 4, 1957, three months after the International Geophysical Year (IGY) began, Sputnik was launched. This was the beginning of the space age. Sputnik I and III and Explorer 1 along with numerous suborbital rocket flights contributed to the tremendous success of the IGY. Space science has made tremendous strides in the last 50 years. We now routinely monitor the Sun, the interplanetary medium, and the atmosphere of Earth from space. The IHY will provide a unique opportunity to coordinate observations from the current impressive fleet of international space missions, with data from solar ground based observatories, ground based auroral observatories, neutron monitor observations, magnetic field observatories, ionospheric, meteorological, and other atmospheric observatories. Unprecedented, simultaneous observations with broad coverage of all associated solar, heliospheric, geospace, and atmospheric phenomena will be obtained. The resulting data will allow global studies of the complete Sun-Earth system.

Figure 1 Sputnik I was launched three months after the IGY began. This marked the dawn of the age

1

Fig. 1.2-3.First online publication, the International Heliophysical Year. A Program of Global Research Continuing the Tradition of Previous International Years (Davila, Poland, and Harrison (http://ihy2007.org/resources/resources.shtml)

Neumayer Symposium, June 2001: New 'IPY-4' Is Proposed

Arctic scientists had their chance to discuss the approaching anniversary of IGY at the Arctic Science Summit Week (ASSW) in Iqaluit, Canada in April 2001 (*Chapter 1.4*) at the meetings of the European Polar Board (EPB) and the Forum of Arctic Research Operators (FARO). Jörn Thiede, Director of the Alfred Wegener Institute (AWI) in Bremen and the Chair of EPB was among those who raised the issue as he was already familiar with the IGY+50 discussion at the SCAR meeting of 2000. No decision was made, yet another important polar science constituency became aware of the calling for a new IPY.

A more inspirational concept for a new 'IGY'-like initiative was unveiled at the International Neumayer Symposium at Bad-Dürkheim, Germany 24-26 June 2001. The symposium held on the occasion of 175th anniversary of Georg von Neumayer, a native of southwestern Germany and a key figure in IPY-1 (*Chapter 1.1*), was organized jointly by AWI, the German Navigation and Hydrographic Service (BSH – Bundesanstalt für Seeschiffahrt und Hydrographie) in Hamburg and Rostock, the successor to the Deutsche Seewarte, of which Neumayer was once the Director, and *Pollichia,* the local Society for Natural Sciences. The life and career of Neumayer and the first IPY were featured prominently in the sessions. The symposium also awarded the Neumayer Medal to Leonard Johnson, former

Fig. 1.2-4. (left) The Neumayer Symposium at Bad-Dürkheim, Germany, June 2001: Leonard Johnson, author of the first outline for IPY 2007–2008. (Photo: Oliver Röller)

Fig. 1.2-5. (right) The Neumayer Symposium at Bad-Dürkheim, Germany, June 2001: Leonard Johnson (left) and Jörn Thiede. (Photo: Oliver Röller)

division head at the U.S. Office of Naval Research (Figs. 1.2-4, 1.2-5). In his address, Johnson proposed that a 'new International Polar Year' be launched in 2007, the 125th anniversary of IPY-1 (Johnson, 2001a, 2002a). The symposium adopted a 'Neumayer Declaration' arguing for a new major science initiative in the polar regions in 2006–2007, with its focus on climate variability and the dynamics of the Earth crust and sedimentary cover (Box 1; Kremb and Kremb, 2002). Johnson volunteered to promote a concept for a 'new IGY/IPY' among the U.S. scientists, whereas Thiede and Heinz Miller, also from AWI, agreed to move it through SCAR and EPB.

The Neumayer symposium, with its more than 300 scientists from Germany, Denmark, Norway, Russia, U.K. and U.S., started the process and by the end of 2001, Johnson published the first short article in a major science journal, *Eos* on the issue of the new 'polar year' (Johnson 2001a – Fig. 1.2-6).

Russian Bid for 'IPY-3': October 2001

In October 2001, Russian polar oceanographer and high-level politician Arthur Chilingarov made a public call for a 'Third International Polar Year' in 2007 at the Joint EU-Russia-Canada-U.S. Workshop on collaborative technological research for Arctic development in Brussels (25–27 October 2001[5]). The workshop was attended by more than 120 participants from several countries. Chilingarov's push for 'the third IPY' was not very specific as it was listed in passing among several other Russian proposals for collaborative projects in the Arctic, including energy, transportation, human and environmental safety, and new technologies.[6] On 20 December, 2001 Chilingarov reiterated his appeal for a package of such collaborative initiatives in the polar regions as a vehicle to the Russian-European partnership, including his reference to the 'Third International Polar Year' in a letter to the Director General Research office of the European Commission in Brussels.[7] Again, a new IPY was merely one idea of many; even the choice of a particular year was left 'open to international discussion'.

Chilingarov's proposal for a new IPY was evidently a part of a general push by Russian scientists to get back to the international arena with major new ideas in Arctic research and collaboration, after a decade of economic and financial stagnation. It quickly gained high-level governmental support (see below), but was not implemented until early 2003.

2002: IPY Proposals Gain Spotlight and Substance

During 2002, these independent and often competing nexuses in promoting IPY crystallized and aspired to develop more specific outlines for their programs. The emerging visions quickly diverged from the original concept of 'IGY+50' celebration and

Box 1 Neumayer Declaration

A 175th IGY Program:

Scientific Themes:

Using new technologies to determine:

1. Causes and effects of climatic variability (air-sea-ice interactions)
2. Lithospheric dynamics (evolution and history of crust and sedimentary cover)

Bad Dürkheim, 26.06.2001

instead, pushed firmly towards the 'fourth' IPY. New electronic communication and website technologies helped disseminate the message and increased the speed of exchange across the international science community (Berkman, 2003).[8] In addition, those nexuses often included many of the same people wearing different 'hats' in different settings, so that the idea was talked through and vetted repeatedly in meetings, papers and resolutions.

PRB/AOSB/EPB nexus. On 9 April 2002, Leonard Johnson gave a talk at the 84th meeting of the Polar Research Board (PRB) of the U.S. National Academies titled *Origins and Content of Proposal to Conduct International Polar Year,* which was the development of the plan drafted at the Neumayer symposium of 2001. His talk was followed by substantial discussion, at which several players in the future U.S. IPY planning were present, such as Robin Bell and Chris Elfring (PRB), Karl Erb (NSF), John Calder NOAA) and Pat Webber (IASC). The shared feeling was that the PRB should put 'some energy' into it. Chris Elfring, the PRB Executive Director, recalled that feeling: "There should be one! There should be one!" (C. Elfring, interview, 11 April 2008). The PRB agreed to run a special session on IPY at its next meeting in November 2002.

A much broader audience was briefed on the new IPY concept at the ASSW annual meeting in Gröningen, the Netherlands 21–26 April 2002. Johnson delivered his paper on IPY at the meeting of the Arctic Ocean Sciences Board (AOSB) and referred to positive reviews of the new IPY proposal by IASC and SCAR (Fig. 1.2-7). The AOSB response was measured and Johnson was encouraged 'to develop the IPY 2007 concept,' as further identification of costs and benefits for Arctic science was deemed necessary (AOSB, 2002:21). IPY was also discussed at the IASC Council meeting during ASSW (*Chapter 1.4*).

The IPY proposal received a more enthusiastic response at the 27th Meeting of SCAR Delegates in Shanghai, China 22–26 July 2002 (*Chapter 1.4*). The Delegates supported the motion for a new IPY program 'to celebrate the 50th anniversary of the IGY' and tasked a small group, chaired by Heinz Miller from AWI, to produce a report to the SCAR Executive Committee by its meeting in July 2003. It was also suggested that enquiries be made to ICSU and IUGG about their IPY plans. Chris Rapley, Vice-President of SCAR and Director of the British Antarctic Survey (BAS), agreed to act as a liaison to ICSU and IUGG.[9] Though the decision was short of formal endorsement, many people instrumental to the future IPY planning attended that meeting (Rapley, Thiede, Miller, López-Martínez, Orheim, Kotlyakov, Eflring, Allison and Erb). A smaller Antarctic meeting, the 9th West Antarctic Ice Sheet (WAIS) workshop in Sterling, Virginia 18–21 September 2002 also endorsed the plan for a new International Polar Year following the presentation by Robert Bindschadler from NASA.

By far the most substantial deliberation on the new IPY took place at a special session of the U.S. PRB in Washington, DC on 25 November 2002 (Fig. 1.2-8). The full-day meeting titled "How Might the Polar Science Community Commemorate the Upcoming Anniversary of the International Polar Year" attended by more than 40 scientists and agency representatives and chaired by Robin Bell, new PRB Chair, featured several invited talks[10] and five discussion panels. It advocated joining forces with the European Polar Board (EPB) to bring the idea of a new IPY into the public domain and to marshal support from scientists and funding agencies. One of the workshop recommendations was to organize a scholarly session and a 'town-hall' meeting on the new IPY at the joint meeting of the AGU/ESF/EGU in Nice, in early April 2003 to be prepared jointly by the PRB and EPB. A small *ad hoc* organizing group for that session was quickly formed made of Elfring, Bell, Johnson and Paul Egerton, the EPB Secretary (Elfring to Edgerton, 23 December 2002; Egerton to

Symposium Melds Past and Future Polar Research

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An international symposium, Perspectives of Modern Polar Research, was convened in Bad Durkeim, Germany, to celebrate the 175th anniversary of the birth of Georg von Neumayer, the noted polar explorer and facilitator of German and international polar science. Neumayer, who lived from 1826 to 1909, began his career as a seaman in the merchant marine. Through his skill in geophysics and meteorology, he rose to become the founder and director of the Flagstaff Observatory in Melbourne, Australia, hydrographer to the German Navy, and director of the Hamburg Oceanic Observatory. He was instrumental in organizing the first International Polar Year (IPY) in 1882–1883.

Symposium participants came from Denmark, Germany, Norway, Russia, the United Kingdom, and the United States. Presentations covered a wide range of topics, including Arctic biomass calculations, effects of ice scouring on benthic communities, tectonic issues, the life of the Norse settlers in southwestern Greenland and the enigma of their disappearance.

Georg von Neumayer, chief of the Deutsche Seewarte in Hamburg. Photo courtesy of Pollichia.

Eos, Vol. 82, No. 51, December 18, 2001

plus Arctic circulation and North Atlantic decadal variability.

Arising from the participant discussions was a strong consensus that a program should be formulated to commemorate the 125th anniversary of the initial IPY in 2007. After another IPY in 1932, the IPY evolved into the International Geophysical Year in 1957. Renewing the IPY concept would require applying to the International Council of Scientific Unions or some other appropriate body for sponsorship, participants noted.

The program envisioned for 2007 would investigate the role of air/sea/ice interactions in climatic variability. It would also probe lithosphere dynamics, defined as the evolution and history of crust and sedimentary cover. This would require modern interdisciplinary/international science using new technologies such as sea floor observatories and new platforms. The proposed European research ice breaker *Aurora Borealis*—with dual moon pools, dynamic positioning, and scientific drilling capability—is the prime example of such a platform. Participants made clear that science planning must start now and emphasize coordination with existing programs, such as Study of Arctic Environmental Change (SEARCH), as necessary components, with joint platforms where possible, and development of automatic equipment. According to the Neumayer Declaration adopted at the meeting, the geographic focus of the program would be the Polar regions.

The symposium was sponsored by Pollichia, a scientific organization founded in 1840 to promote the study of natural sciences in the Rheinland-Pfalz region of Germany. Currently, Pollichia has 3000 members and supports a multifaceted research program. Additional support was provided by the Bundesamt für Seeschiffahrt und Hydrographie and the Alfred Wegener Institute für Polar und Meeresforschung. Proceedings will be published as a special edition by Pollichia in the spring of 2002.

Perspectives of Modern Polar Research was held June 24–26, 2001.

Author

Leonard Johnson
University of Alaska, Fairbanks, USA

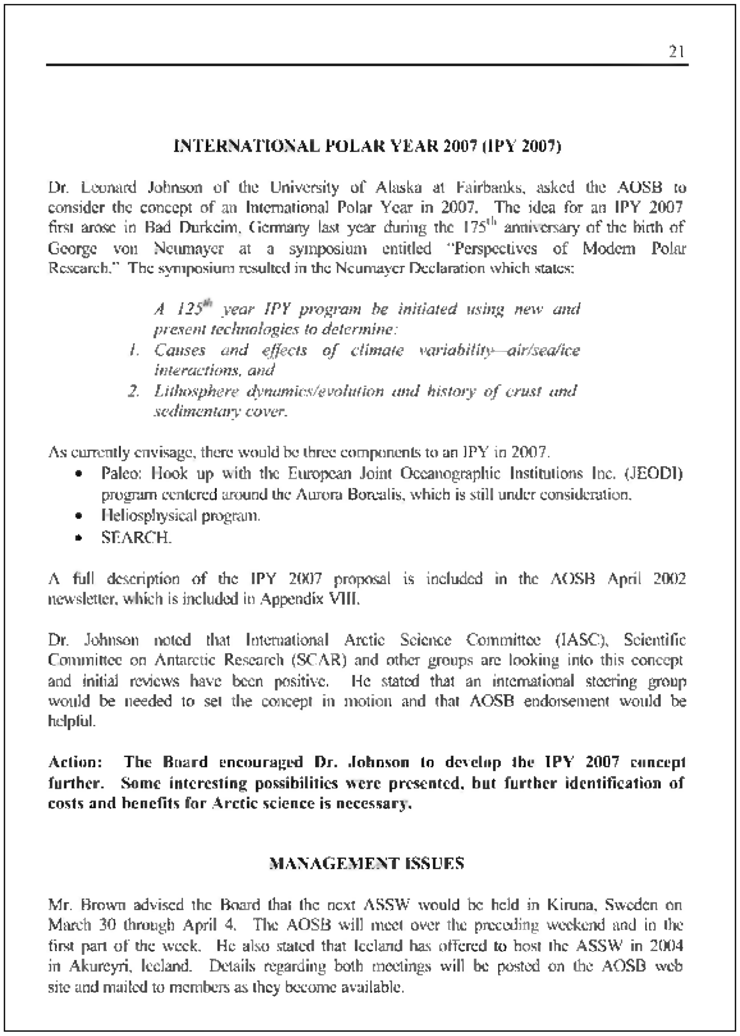
Fig. 1.2-6. First publication on new IPY and 'Neumayer Declaration' by Leonard Johnson (Eos Vol. 82, no.51, December 2001.

Thiede/Rapley/Jujie/Lopez/Orheim 7 January 2003).

WMO/WCRP nexus. One other strong push for a new IPY in 2002 came at the meeting of the World Climate Research Programme's (WCRP) joint Scientific Steering Group for the Arctic Climate System Study (ACSYS) and Climate and Cryosphere (CliC) Project in Beijing, China 21-25 October 2002 (*Chapter 1.4*).[11] The original discussion was centred on the proposal for a future 'polar decade', but the concept of an International Polar Year (IPY) to mark the 50th anniversary of the IGY in 2007–2008 was quickly introduced as "being discussed in many fora". The group agreed that the cryosphere and climate should be important elements of the future IPY, but it was more sympathetic to the concept of an 'International Polar Decade' to be launched in 2007–2008 rather than of a single 'year' (WCRP, 2002:18). The group established a small team to explore the issue and agreed that if the concept seemed worthy it should be "promoted through a letter to ICSU and WMO" (WCRP, 2002).[12] Several of the attendees of the 2002 meeting were later instrumental in IPY planning, including Mark Drinkwater, Barry Goodison, Jeff Key, Vladimir Ryabinin, Ian Allison, Vladimir Kotlyakov, Eberhard Fahrbach and Qin Dahe; the four latter eventually became members of the Joint Committee for IPY 2007–2008 (*Chapter 1.5*).

IHY 2007 Proposal. The IHY team had its major planning session organized by Davila, Poland and R. Harrison at the World Space Congress in Houston, Texas 17 October 2002 (Davila et al., 2002 – Fig. 1.2-9). Davila, Poland, Harrison, Thompson and Gopalswamy also had a poster presentation on IHY at the fall AGU meeting in San Francisco in December 2002. The group's main effort was put into organizing a special IHY session at the joint AGU/EGS/EGU meeting in Nice, France in April 2003 (see below), made of several invited talks and posters (Davila and Gopalswamy 2003). During 2001 and 2002, there were attempts to bridge plans for the IHY and IPY 2007 involving Davila, Bindschadler and Johnson (Johnson and Davila, 2002), but the proposed partnership never materialized and IHY eventually became a separate initiative (*Chapter 1.3*).

Russian IPY-3 Proposal. The European Commission's Director-General Research Office responded favourably to Chilingarov's letter about the '3rd IPY' of December 2001 and in April 2002, Yuri Sychev, Executive Director of the Russian Polar Foundation (*Poliarnyi Fond,* on which Chilingarov serves as the President) and



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INTERNATIONAL POLAR YEAR 2007 (IPY 2007)

Dr. Leonard Johnson of the University of Alaska at Fairbanks, asked the AOSB to consider the concept of an International Polar Year in 2007. The idea for an IPY 2007 first arose in Bad Durkeim, Germany last year during the 175th anniversary of the birth of George von Neumayer at a symposium entitled "Perspectives of Modern Polar Research." The symposium resulted in the Neumayer Declaration which states:

> *A 125th year IPY program be initiated using new and present technologies to determine:*
> 1. *Causes and effects of climate variability—air/sea/ice interactions, and*
> 2. *Lithosphere dynamics/evolution and history of crust and sedimentary cover.*

As currently envisage, there would be three components to an IPY in 2007.

- Paleo: Hook up with the European Joint Oceanographic Institutions Inc. (JEODI) program centered around the Aurora Borealis, which is still under consideration.
- Heliosphysical program.
- SEARCH.

A full description of the IPY 2007 proposal is included in the AOSB April 2002 newsletter, which is included in Appendix VIII.

Dr. Johnson noted that International Arctic Science Committee (IASC), Scientific Committee on Antarctic Research (SCAR) and other groups are looking into this concept and initial reviews have been positive. He stated that an international steering group would be needed to set the concept in motion and that AOSB endorsement would be helpful.

Action: The Board encouraged Dr. Johnson to develop the IPY 2007 concept further. Some interesting possibilities were presented, but further identification of costs and benefits for Arctic science is necessary.

MANAGEMENT ISSUES

Mr. Brown advised the Board that the next ASSW would be held in Kiruna, Sweden on March 30 through April 4. The AOSB will meet over the preceding weekend and in the first part of the week. He also stated that Iceland has offered to host the ASSW in 2004 in Akureyri, Iceland. Details regarding both meetings will be posted on the AOSB web site and mailed to members as they become available.

Fig. 1.2-7. Fragment from the minutes of the 21st AOSB meeting in Gröningen, April 2002, dedicated to the discussion on IPY (www.aosb.org/mtgs.html).

Vladimir Gruzinov visited the EC Joint Research Centre office in Brussels for discussions on the Russian IPY proposal. Russian scientists were also informed about the IHY activities at the World Space Congress in October 2002 (Electronic Bulletin, 2002) and about the IPY planning via their participation in the SCAR, AOSB and IASC sessions of 2002.

In November 2002, Nikolai Laverov, Vice President of the Russian Academy of Sciences, and Chilingarov sent a letter to the Government of the Russian Federation on behalf of the Russian Academy of Sciences and the State Duma with a request for Russia to put forward an initiative for 'International Polar Year' (Electronic Bulletin, 2003). A few weeks later, on 26 November 2002, the Council *(Sovet)* on the Issues of the Far North and the Arctic of the Russian Government charged the Russian Ministry of Foreign Affairs and the Russian Federal Service on Hydrometeorology *(Roshydromet)* 'to study the organizational issues, related to the participation of the Russian Federation in the preparation and implementation of International Polar Year 2007–2008' (*Spravka*, http://ipyrus.aari.ru). Evidently, the decision on the Russian IPY program was made at very high political level (reportedly, by the then Russian Prime-Minister Mikhail Kasyanov) and it put the Russian government firmly behind the Russian IPY proposal.

On 5 December 2002, Sychev sent a letter to several high-level officials at the European Commission's Director-General (DG) office titled "Russia-EU Co-operation for the International Polar Year (IPY)". He informed the European officials that Chilingarov's proposal "for the Russian Federation to take a leading role in the realization of the IPY has been approved by the relevant committees of the Russian Government" and invited the EC delegation to visit Moscow on 22 January, 2003 for informal preparatory discussions on IPY (Copy in Chris Rapley's files).

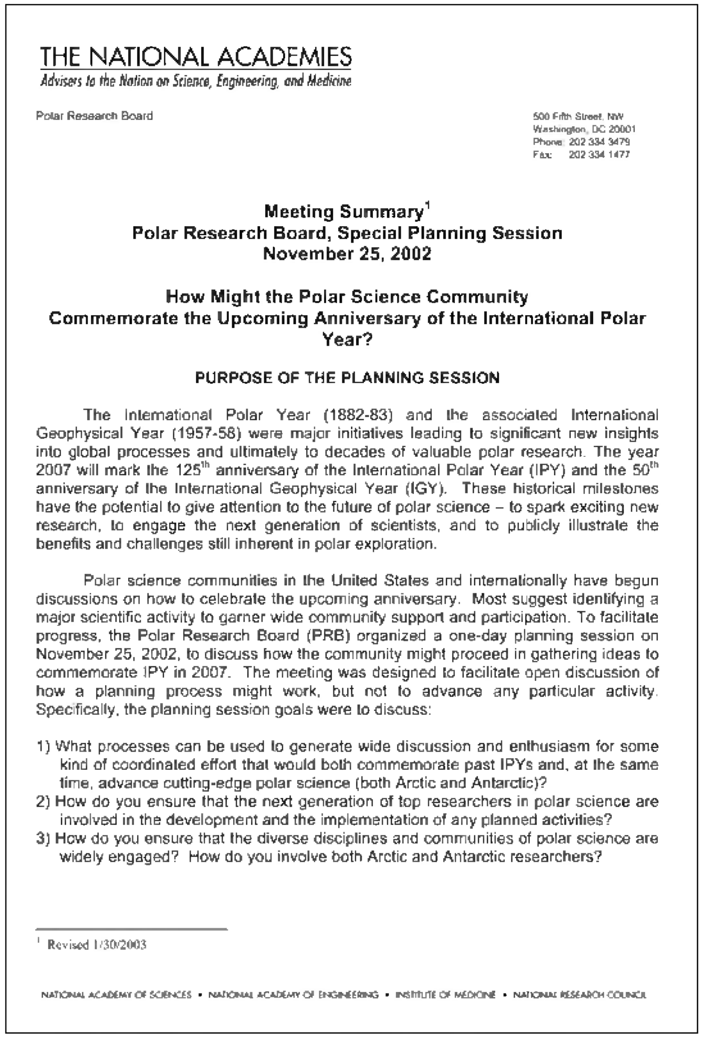
Russian Planning Goes Forward: January 2003

The next spike of activities associated with IPY took place in January 2003 and helped push its planning into high gear. On 22 January 2003, a small team of the EC Joint Research Centre (headed by Pieter van Nes) and EPB (Paul Egerton) visited Moscow where it had a joint meeting at the Polar Foundation *(Polyarnyi Fond)* with Chilingarov, Sychev and other Russian polar scientists and officials. Among the few outcomes of that meeting was the decision to establish a new 'international working group' on IPY that was scheduled to meet at the AGU/EGS/EGU meeting in Nice on 8 April 2003 (Electronic Bulletin, 2003). Evidently, the Russian Academy was already developing its own plan for IPY. The information on the Russian effort was passed quickly to the EPB and PRB planners and forced them to fast-forward their actions.

EPB-PRB Proposal Submitted to ICSU: February 2003

A small core group of the U.S. and European planners (Rapley, Bell, Elfring, Bindschadler, Johnson and Egerton) faced a target of their own, the proposal deadline (15 January 2003) for a special IPY session and town-hall meeting at the AGU/EGS/EGU in Nice. The session was to be chaired by Elfring and Egerton to represent the PRB and EPB support for a new IPY. By mid-January, Johnson had an outline with nine invited talks and 20 posters for a joint IPY/IHY session planned as an interdisciplinary forum, from space and solar physics to climate, polar history and education. The contours of new IPY and its cadres of advocates started to take shape, but it still lacked institutional backing and funding.

At the PRB, Bell and Elfring were anxiously trying to generate support for IPY via the U.S. National Academies, which was instrumental in the U.S. participation in IGY 1957–1958. On 10 January 2003, they sent a letter to the National Academies' members informing them on the new IPY initiative and asking for their feedback. The eventual outcome of that impromptu survey was a proposal from Elfring to the Academies' Presidents' Committee (on 13 February 2003) with a request for U.S. $200,000 in support for the U.S. planning for the IPY under PRB (that money was eventually granted several months later). The EPB in turn, met in January 2003 and nominated Chris Rapley as a point person in its planning for IPY.



THE NATIONAL ACADEMIES
Advisers to the Nation on Science, Engineering, and Medicine

Polar Research Board

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Meeting Summary[1]
Polar Research Board, Special Planning Session
November 25, 2002

How Might the Polar Science Community Commemorate the Upcoming Anniversary of the International Polar Year?

PURPOSE OF THE PLANNING SESSION

The International Polar Year (1882-83) and the associated International Geophysical Year (1957-58) were major initiatives leading to significant new insights into global processes and ultimately to decades of valuable polar research. The year 2007 will mark the 125th anniversary of the International Polar Year (IPY) and the 50th anniversary of the International Geophysical Year (IGY). These historical milestones have the potential to give attention to the future of polar science – to spark exciting new research, to engage the next generation of scientists, and to publicly illustrate the benefits and challenges still inherent in polar exploration.

Polar science communities in the United States and internationally have begun discussions on how to celebrate the upcoming anniversary. Most suggest identifying a major scientific activity to garner wide community support and participation. To facilitate progress, the Polar Research Board (PRB) organized a one-day planning session on November 25, 2002, to discuss how the community might proceed in gathering ideas to commemorate IPY in 2007. The meeting was designed to facilitate open discussion of how a planning process might work, but not to advance any particular activity. Specifically, the planning session goals were to discuss:

1) What processes can be used to generate wide discussion and enthusiasm for some kind of coordinated effort that would both commemorate past IPYs and, at the same time, advance cutting-edge polar science (both Arctic and Antarctic)?
2) How do you ensure that the next generation of top researchers in polar science are involved in the development and the implementation of any planned activities?
3) How do you ensure that the diverse disciplines and communities of polar science are widely engaged? How do you involve both Arctic and Antarctic researchers?

[1] Revised 1/30/2003

NATIONAL ACADEMY OF SCIENCES • NATIONAL ACADEMY OF ENGINEERING • INSTITUTE OF MEDICINE • NATIONAL RESEARCH COUNCIL

Fig. 1.2-8. Cover page of the meeting summary of the PRB special planning session on IPY, 25 November 2002. (Courtesy, Chris Elfring)

On 6 February 2003, Rapley and Bell submitted a two-page document ("Proposal to Establish an ICSU Planning Group for an International Polar Year 2007/8" – Box 2) to the 86th ICSU Executive Board meeting scheduled on 8-9 February 2003. The proposal argued for an international committee of ten members tasked to 'formulate a concept and plan for an IPY 2007/8 and to design the means of ICSU leading such a program' (Rapley and Bell, 2003). With strong support by Jane Lubchenko, ICSU President, and Thomas Rosswall, ICSU Executive Director, the ICSU Board endorsed the proposal and charged the new Planning Group to develop an outline for IPY by February 2004. That opened an intensive campaign of communication and lobbying, now firmly set under the ICSU umbrella and operated jointly by EPB and PRB.

ICSU Plan Collects Endorsements: March – April 2003

Following the approval of EPB-PRB proposal by ICSU, Rapley circulated a two-page letter called 'International Polar Year 2007–2008.' It was widely

Box 2 Proposal to Establish an ICSU Planning Group for an International Polar Year 2007/8

Background

The year 2007 will mark the 125th anniversary of the First International Polar Year (1882/3), the 75th anniversary of the Second Polar Year (1932/3) and the 50th anniversary of the International Geophysical Year (1957/8). The IPYs and IGY were major initiatives, which resulted in significant new insights into global processes, and laid the foundation for decades of invaluable polar research.

The Poles are one of the remaining unexplored frontiers on Earth, from unknown mountain ranges to remote and unique ecosystems. The Poles also continue to be considered major players in the global climate system whose role we do not understand well. An initiative in 2007 celebrating the historic events and recognizing the importance of polar science has the potential to act as a springboard for further major advances in polar science. A New International Polar Year has the potential to galvanize an intense program of new and exciting observations and research, to attract and develop the next generation of polar scientists, and to engage the public in perceiving and supporting the benefits and challenges inherent in polar exploration and Earth System science.

The Need for an ICSU IPY Planning Group

Polar science communities, organizations and institutes worldwide are alert to the opportunity and are already discussing how the anniversary might best be used to advance polar science. Ideas for major scientific activities are being formulated and support from the science community is being sought. The level of interest and activity is growing rapidly. Nevertheless, efforts are uncoordinated, with inevitable overlap and duplication, and even differing and divergent views on the fundamental objectives of an IPY.

Organizations such as the U.S. Polar Research Board and the European Polar Board have recognised the need to facilitate progress, to seek order, and to develop an internationally agreed strategy, framework and plan. The U.S.-PRB has already held one planning meeting and produced a valuable initial report.

Nevertheless, with powerful players such as national environmental research funding agencies, space agencies, major institutes and even government departments taking an active interest worldwide, the authority and influence of U.S.-PRB, EPB or even the international scientific bodies such as IASC and SCAR are unlikely to be sufficient to achieve the necessary degree of coordination and agreement.

Consequently, there is a strong case for ICSU to establish a Standing Committee for an IPY 2007/8.

The purpose would be to provide an authoritative means of developing, guiding and overseeing an agreed international program of science and related initiatives. The justification lies in ICSU's established role as the world's leading arbiter and coordinator of international scientific research, as well as its historic role in the development and coordination of the IGY.

The Proposed Way Forward

Since four-and-a-half years is already a rather short time to address such a challenge, it is proposed that ICSU establish an IPY Planning Group (IPY-PG) as a matter of urgency.

The role of the IPY-PG should be to formulate a concept for an IPY 2007/8 and to design the means of ICSU leading such a programme.

Suggested Terms of Reference are:

(i) To gather, summarize and make widely available information on existing ideas for an IPY serving as a clearinghouse for ideas,

(ii) To stimulate, encourage and organize debate amongst a wide range of interested parties on the objectives and possible content of an IPY,

(iii) To formulate a set of objectives for an IPY,

(iv) To develop an initial high level Science Plan for an IPY which engages younger scientists throughout the planning process.

(v) To develop a specific set of objects targeted at formal and informal education as well as the general public in the next IPY,

(vi) To develop a proposed mechanism for the design, development, guidance, and oversight of an IPY,

(vii) To propose to the ICSU 28th General Assembly in 2004 the formation of an IPY 2007/8 Standing Committee, with a view to carrying forward the detailed design, development, guidance, and oversight of an IPY in 2007/8.

Chris Rapley, European Polar Board

Robin E. Bell, Chair, U.S. National Academies Polar Research Board

6th February 2003

disseminated through many professional networks, also via SCAR and EPB channels. The letter with an attached questionnaire described the plans for a new International Polar Year 2007–2008 developed in the United States (by the National Academy of Sciences), Russia (through the vice-chairman of the [Russian] Duma, i.e. Chilingarov), Europe (via EPB) and internationally (via ICSU and SCAR). It made direct references to the early IPYs and IGY, and asked for ideas on objectives, organizational principles and expected outcomes of the new IPY. The responses were expected by mid-March 2003 for the forthcoming session on IPY 2007–2008 at the Arctic Science Summit Week (ASSW) in Kiruna, Sweden 31 March 2003 and at the joint AGU/EGS/EGU meeting in Nice 8 April 2003.

Another important action undertaken by Rapley was to commission a historical summary document on the IPY-1, IPY-2 and IGY prepared by Joanna Rae, an archivist with the British Antarctic Survey (Rae, 2003). It summarized major highlights of the three earlier 'polar years,' as well as their 'lessons learned' (i.e. challenges, successes, planning difficulties, funding, etc.) that were relevant to the new IPY.

On 12-14 March 2003, a small EPB team (Rapley and Egerton) visited Washington, DC for a series of meetings with the U.S. IPY advocates (Elfring, Bell, Bindschadler, Johnson, Jezek and Poland) and agency representatives. It also made preparations for the next major public test for IPY at the ASSW in Kiruna 29 March–4 April 2003. At that meeting, Rapley and Elfring delivered a joint plenary presentation (Fig. 1.2-10) on the concept for a new IPY that was widely discussed at many sessions (*Chapter 1.4*). Crucial endorsements came from IASC and the AOSB; the latter established its own exploratory group (Robert Dickson, Tom Pyle, Leif Anderson and Sergey Priamikov) to support planning for IPY (*Chapter 1.4*) and produced its 'white paper' published in the special 'IPY issue' of the AOSB Newsletter in July 2003 (Fig. 1.2-11; Dickson et al., 2003). Another achievement from Kiruna was a link to the Arctic Council via Helena Ödmark, Swedish Senior Arctic Official (SAO), who introduced the plan for the new IPY to her colleagues on the Arctic Council (*Chapter 1.4*).

Yet another planned 'show of support' for IPY, a joint IPY/IHY session and town-hall meeting at the AGU/EGS/EGU in Nice, France 8 April 2003, did not materialize. Though Rapley and Bell delivered their talks on IPY, the IPY/IHY poster session failed to generate the anticipated crowd and the town-hall meeting was cancelled. Nonetheless, on 9 May 2003 the ICSU team submitted a full proposal to ICSU signed by Rapley, Bell and Elfring, called "Proposed Approach and Workplan: ICSU Planning Group for a Fourth International Polar Year (IPY4) 2007/8". The 17-page document outlined the emerging vision for IPY planning, including some preliminary ideas on its science content, the list of several new proposals for IPY studies in response to an earlier questionnaire from March 2003 and specific recommendations for

Fig. 1.2-9. IHY poster prepared for the World Space Congress, October 2002.

the IPY Planning Group including a preliminary list of its 'core members' from several nations.[13]

Russian Proposal Advances Through WMO: April–June 2003

Meanwhile, the Russian plan for the 'third IPY' obtained its own traction within the Russian science community and relevant agencies. A special committee of the Russian Academy of Sciences and *Roshydromet* was put in place in March 2003 to develop a concept for a new IPY program (Kotlyakov to Rapley, March 2003). On 22 April 2003, a seven-page document "Concepts of Conducting the 3rd International Polar Year" was approved by the Academy's Scientific Council on Arctic and Antarctic Exploration. The main goals of the proposed '3rd IPY' were listed as the "determination of existing and (the) assessment of future climate and environmental conditions changes in the polar regions and determination of consequences of such changes for natural and socio-economic complexes."[14] The outline, though advocating a broad international program, was written with Russia's economic interests in mind and argued for certain 'practical outcomes' of IPY, particularly for "marine transport systems; development and exploration of oil-and-gas resources; development of bio-resources; environmental activities and ecological policy; and socio-economic problems." This was a very different concept from that developed by the ICSU/EPB/SCAR/IASC/AOSB nexus.

In two weeks, this proposal was approved by the Russian Academy; it was endorsed by the Russian Government and was taken to the 14th WMO World Meteorological Congress (supreme body of WMO) in Geneva 5–24 May 2003.[15] It was submitted on behalf of the Russian Federation by Alexander I. Bedritsky, the head of the *Roshydromet*, who was elected the WMO President at the same Congress. On 21 May, 2003, the Congress approved the Resolution 33 calling for 'launching a third IPY in 2007–2008 under the auspices of WMO' (Box 3) and requested that a special *ad hoc* working body would be established under WMO to prepare a plan of action for the third IPY and coordinate its implementation' (WMO, 2003). The Congress also charged the WMO Executive Council to examine the preparation process at its 56th session in May 2004 and put it under the responsibility of the WMO Secretary-General. This was a stunning achievement for the Russian IPY proposal; Eduard Sarukhanian, then Director of the World Weather Watch-Applications

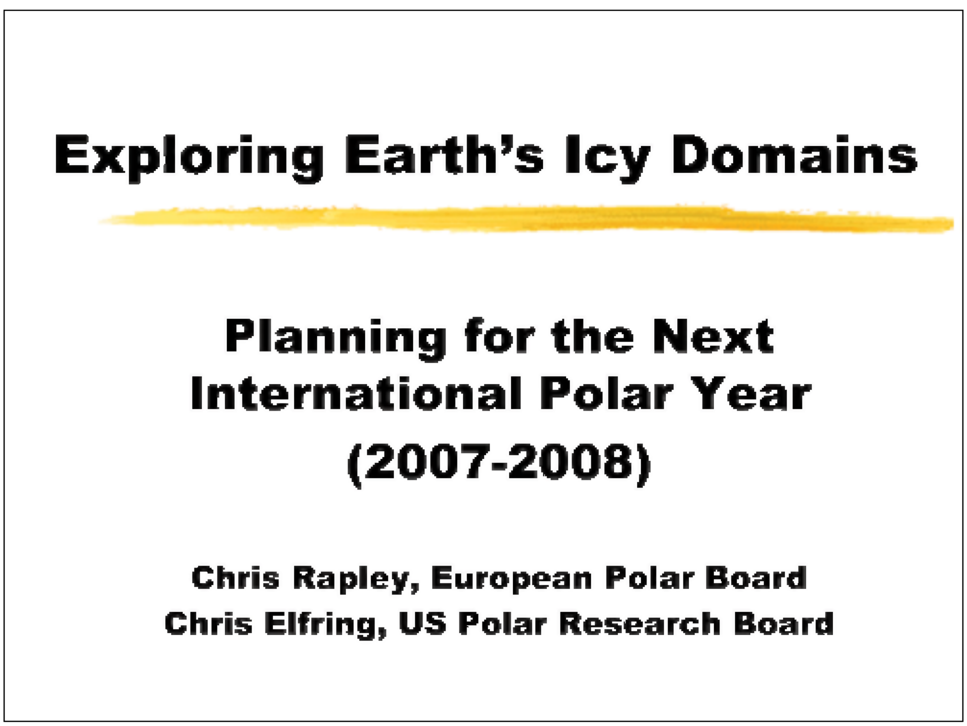

Fig. 1.2-10. Cover slide of the joint presentation by Chris Rapley and Chris Elfring (Exploring Earth's Icy Domains Planning for the Next International Polar Year, 2007– 2008) at the ASSW in Kiruna, Sweden, March 2003.

Department at the WMO Secretariat and Bedritsky's election as the WMO President were instrumental to its sailing through the WMO system.[16] In July 2003, the office of the WMO Secretary-General issued a call to WMO Member governments for information regarding the planning and implementation of the new Polar Year to be delivered by 30 September 2003.

Though the original Russian submission listed as prospective partners several international organizations, such as the Arctic Council, Antarctic Treaty Consultative Meeting, Council of the Barents/Euro-Arctic Region, ICSU, IASC, SCAR and IOC, there was no explicit reference to the ICSU planning for IPY in the WMO resolution. The scene was thus set for two separate preparation processes under ICSU and WMO.

Fig. 1.2-11. Cover page of the special 'IPY edition' of the AOSB Newsletter (July 2003) with an opening article by Chris Elfring and Chris Rapley.

ATCM and SCAR Move towards the ICSU Planning: June 2003

With their detailed outline document "Proposed Approach and Workplan for IPY" and a draft slate of Planning Group members, the ICSU planners were looking for an official endorsement of their IPY team from ICSU, particularly since the 14th WMO Congress had just approved the WMO planning for IPY. That much-needed step came at the meeting of the ICSU Officers 8–9 June 2003, which approved the establishment of the ICSU Planning Group for IPY of nine members[17] representing a broad spectrum of polar disciplines (climate and sea ice studies, space and Earth geophysics, oceanography, glaciology, geology, biology and social sciences), with a few more to be added later. It also requested that the Group coordinate its planning with the ICSU-member Unions, including IUGG and IUGS, and work in close consultation with WMO, SCAR and IASC. Thus the collaborative, interdisciplinary and 'bipolar' nature of the future IPY was ensured by ICSU in the very composition of its planning team.

The PG was tasked with the preparation of a progress report for the ICSU Executive Board in February 2004 and of the final plan for IPY for the presentation to the ICSU 28th General Assembly in October 2005. It was initially given U.S. $25,000 for its activities. It was agreed that the first meeting of the Group would be scheduled for July 2003 (*Chapter 1.3*), barely six months after ICSU approved the initial EPB-PRB proposal in February 2003.

An early collision of the two planning processes for IPY set up by ICSU and WMO took place at the 26th ATC Meeting in Madrid 9–20 June 2003. At that meeting, the Russian Delegates submitted their proposal for the 'Third International Polar Year Initiative' citing its recent endorsement by WMO (XXVI ATCM, IP-123), whereas SCAR in its report to ATCM referred to the newly established 'Planning Group' at ICSU (*Chapter 1.4*). In the ensuing discussion, delegates from the U.K., Canada, Chile, France, the U.S., Norway, New Zealand and the Netherlands sided with the SCAR position. The final ATCM Resolution (*Support of the ATCM for the International Polar Year 2007/8 – Chapter 1.4* Box 4), though noting 'the active commitment to an IPY of the World Meteorological Organization (and other international bodies),' recommended that SCAR and COMNAP 'work with ICSU to pursue actively the planning and implementation […] of an International Polar Year to address priority polar science issues of global relevance.' Yet another critical endorsement came a month later at the SCAR Executive Committee

Box 3 Extract from the Proceedings of the XIVth World Meteorological Congress, 2003

9.1 Cooperation with the United Nations and other organizations *(agenda item 9.1)*

Initiative for a Third International Polar Year

9.1.27 Congress noted with satisfaction the proposal of the Russian Federation that WMO propose an initiative to hold a Third International Polar Year (IPY) in 2007–2008. It stressed that the First and Second IPYs, held in 1882-1883 and 1932-1933, had made a fundamental contribution to developing an understanding of hydrometeorological processes in the polar regions, had contributed to the development of the hydrometeorological observing system and to the conduct of work in high latitude regions of the planet.

9.1.28 Congress also noted the importance of developing research into processes governing environmental changes in the polar regions, and also elaborating monitoring and forecasting systems, taking account of the sensitivity of high latitude regions on our planet to global, natural and human impacts.

9.1.29 Congress noted that global climate change in the twenty-first century might have significant manifestations in the natural environment of polar regions that would be significant for certain kinds of activity carried out in Arctic areas and affect the lifestyles of indigenous peoples in the Arctic and their economic livelihoods. Those changes might affect the interests of many countries taking part in Arctic and Antarctic activities.

9.1.30 Congress expressed the opinion that the main international cooperation efforts under a Third IPY should be aimed at determining current and evaluating future climate change and the state of the polar environment. The observational data and scientific results obtained would ensure further development of monitoring and forecasting systems for hydrometeorological processes in the polar regions and would also form a basis for developing recommendations to government agencies and interested organizations conducting activities in the Arctic and Antarctic.

9.1.31 Congress stressed that the conduct of activities under a Third IPY initiative must combine the interests of all WMO Programs aimed at studying present and future environmental changes in polar regions and also, where possible, taking account of the Arctic and Antarctic programs carried out under the auspices of other international organizations such as the Arctic Council, the Consultative Conference on the Antarctic Treaty, SCAR, IOC and IASC (see also items 3.1.8 and 3.3.3).

9.1.32 Congress adopted Resolution 9.1/3 (Cg-XIV) - Holding of a Third International Polar Year in 2007–2008.

Draft resolution

Res. 9.1/3 (Cg-XIV) — HOLDING OF A THIRD INTERNATIONAL POLAR YEAR IN 2007–2008

THE CONGRESS,

CONSIDERING the fundamental contribution of the First and Second IPYs, held in 1882-1883 and 1932-1933, to the understanding of hydrometeorological processes in the polar regions;

NOTING the sensitivity of high latitude regions of our planet to natural and human impacts at global and regional levels and the need in this connection to study processes governing environmental changes in polar areas;

FURTHER NOTING that the main efforts at international cooperation under a third IPY will be to determine present and evaluate future climate change and the state of the environment in the polar regions;

CONSIDERING FURTHER that the observational data and scientific research results obtained will form a basis for developing recommendations for national government agencies and bodies involved in activities in the Arctic and Antarctic;

APPROVES the idea of holding a third IPY in 2007–2008 under the auspices of WMO;

REQUESTS the Executive Council at its fifty-sixth session to examine the preparation and holding of a Third International Polar Year in 2007–2008 in collaboration with other international organizations such as the Arctic Council, the Consultative Conference on the Antarctic Treaty, SCAR, IOC and IASC and the establishment of an ad hoc working body to prepare a plan of action in preparation for a third IPY and to coordinate its implementation;

REQUESTS the Secretary-General to prepare the relevant program document for the above-mentioned Executive Council session.

meeting, in Brest 11-15 July 2003 (*Chapter 1.3*). By that time, the ICSU/PRB/EPB team was already preparing for its first meeting and was shaping its strategy for the IPY planning process based upon its "Workplan" document and a list of several new initiatives considered as prospective components for future IPY.

Summary: IPY status in Summer 2003

By mid-summer 2003, the 'origination' phase for IPY 2007–2008 was over. The idea was well-established across many sections of the polar science community (though not all of them) and it was vetted and supported at several high-profile meetings. It had moved from its original *celebratory* mode (IGY+50) into the *research-oriented* mode and was actively seeking ideas for new research programs. Two crucial powers, ICSU and WMO, both with the long history of supporting early IPY/IGY, had already endorsed it and created their planning bodies for the new IPY. Both made explicit recognition of the need for 'close consultations' with other agencies and several critical international players, like SCAR, IASC, AC, ATCM and AOSB, were already on board. National planning efforts had been started by at least two leading polar nations, the U.S. and Russia. The information about the new IPY was widely disseminated, both nationally and internationally, via new channels like websites, electronic newsletters, transferable PowerPoint and poster presentations, online journals and fora, and the like.

The advance of IPY 2007–2008, though initially splintered into several competing streams, was greatly facilitated by the shared interest and interrelations among major scientific bodies, polar programs and disciplines.[18] A small group of highly positioned scientists and agency executives (like Rapley, Thiede, Erb, Orheim, Miller, Kotlyakov, Priamikov, Elfring, Egerton and others) were attending many of the same meetings, often both for the Arctic and Antarctic, and they had numerous opportunities to test their ideas in different audiences. That was one of the most obvious strengths of the ICSU/SCAR/IASC/EPB/PRB/AOSB nexus that relied upon regular high-profile cross-disciplinary meetings, such as the annual ASSW and SCAR events and AGU/EGU sessions, which brought together many hundred polar researchers. For more isolated 'streams,' there were always some people who attended other meetings and acted as liaisons. Such cross-networking was also common in the earlier IPY and IGY ventures, but never before was there an opportunity to advance IPY proposals to so many scientists, scientific groups and in so many professional settings at once.

Nonetheless, the IPY planners faced a challenging task of sorting and bringing together those different nexuses, the separate planning processes started at ICSU, WMO and those for the IHY and eGY. IPY had yet to gain high ground over a myriad of ongoing

23 June 2003

DRAFT DECISIONS

MEETING OF OFFICERS

8-9 June 2003
ICSU Secretariat

EXTRACT

16. International Polar Year (IPY)

The EB at its last meeting discussed briefly a proposal to launch an International Polar Year in 2007/2008 and a comprehensive plan had subsequently been submitted to ICSU.

Discussions were ongoing with SCAR, IUGG and IUGS to ensure that the planned activities were complementary to the planned IGY+50 (IUGG) activities, as well as the planned International Year of Planet Earth (IUGS 2004).

Decisions taken:

to agree to the proposed membership of the *Ad hoc* Planning Group as follows: Chris Rapley (Chair, UK), Robin Bell (Vice-Chair, USA), Ian Allison (Australia), Robert Bindshadler (USA), Steve Chown (South Africa), Gerard Duhaime (Canada), Vladimir Kotlyakov (Russia), Olav Orheim (Norway), Zhanghai Zhan (China), an appropriate representative of India and of Latin America, nominees(one each) of IUGS and IUGG, and Science Programme Leaders as these are appointed (5-6 envisaged); attention needed to be paid to the balance between the Arctic and the Antarctic;

to request that the Group report on progress to the EB in February 2004;

to further request that the Planning Group coordinate its planning with IUGS and IUGG and that it work in close consultation with WMO, SCAR and IASC; and

to recommend to the EB at its meeting in September that it allocate 25,000 US$ for this Group.

Fig. 1.2-12. Extract from the minutes of the ICSU Officers meeting, 8-9 June 2003, outlining ICSU support for the IPY Planning Group.

Box 4

Resolution 2 (2003)

SUPPORT OF ATCM FOR THE INTERNATIONAL POLAR YEAR 2007/08

The representatives,

Aware that the polar regions are key components of the Earth System;

Considering the important role of the Polar Regions both in driving and responding to Global Climate Change;

Recognizing the opportunities afforded by new technological and logistical developments for polar research in the 21st century to develop an understanding of key global phenomena at the frontiers of discovery;

Acknowledging the important contribution to scientific knowledge resulting from international cooperation in scientific investigations in the Polar Regions;

Noting the opportunity offered by the 125th anniversary of the first International Polar Year (IPY), the 75th anniversary of the second IPY, and the 50th anniversary of the International Geophysical Year (IGY), to galvanize an intensive program of internationally coordinated research in the Polar Regions;

Noting the active commitment to an International Polar Year of the World Meteorological Organization (WMO) and the interest of other international bodies responsible for the coordination of research in the Arctic.

Noting the establishment by the International Council for Science (ICSU) of an overarching Planning Group to coordinate the planning for and the establishment of the IPY (2007/08) that will encompass a wide range of science issues of global interest;

Recommend that the parties:

- call upon SCAR and COMNAP to work with the International Council for Science (ICSU) to pursue actively the planning and implementation by all interested organizations of an International Polar Year (2007/09) to address priority polar science issues of global relevance;
- within the context of their national Antarctic research programs and capabilities to support science programs proposed for the IPY (2007/08) to achieve outcomes which would not otherwise be possible if undertaken by national programs along;
- make the support of the IPY (2007/08) a priority within their national research activities.

polar programs and initiatives, all with budgets and dedicated cadres of their own. Outside Russia, there was little governmental support of IPY across the national science agencies and offices. That came as little surprise. An outcome of a genuinely bottom-up process, the new IPY steered away from military, economic or strategic issues related to global politics, polar regions and outer space competition that were so dominant in IGY 1957–1958. It also envisioned a certain level of inclusion of biological and social sciences, in both ICSU and WMO proposals, and it appealed to the socio-economic issues relevant to polar residents, something that never occurred in the earlier IPYs. As a societal phenomenon, IPY 2007–2008 was indeed a product of the post-Cold War era and of modern science.[19]

Acknowledgement

This overview is based upon the collection of the early IPY 2007–2008 documentation stored at the IPO (Chris Rapley personal files), PRB, also accumulated by Amanda Graham and Igor Krupnik, and on the interviews with Chris Rapley (3 March, 2008), Peter Clarkson (6 March, 2007), Chris Elfring (11 April, 2008), Robert Bindschadler (19 May, 2008), Leonard Johnson (7 June, 2008), Jörn Thiede (23 September, 2008), Helena Ödmark (25 February, 2009), Eduard Sarukhanian (25 February, 2009) and Vladimir Kotlyakov (18 December, 2009) recorded by Igor Krupnik. Several early documents related to the IPY planning process were posted on the IPY interim website at http://classic.ipy.org/index.php, on the U.S. National Committee for International Polar Year at www.us-ipy.org/downloads.shtml or may be searched online. We are grateful to many colleagues who generously shared their memories of the early phases of IPY and to Aant Elzinga for his helpful comments. This narrative on the origin of IPY 2007–2008 remains a work in progress, with several gaps yet to be filled through future research.

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Notes

[1] Andreev et al., 2007; Bell, 2008; ICSU PG, 2004; IOC, 2004; Stirling, 2007; Summerhayes, 2008; Tsaturov et al., 2005.

[2] Unfortunately, no traces of that correspondence have yet been recovered.

[3] In their memoirs about 'early IPY years,' Robin Bell, Robert Bindschadler, Chris Elfring, Chris Rapley, Jörn Thiede independently alluded to the longing for a major innovative and unifying program in polar research that was common around 1998–2000.

[4] Several people instrumental to the eGY, such as Paul Berkman, Mark Parsons, Alan Roger, were also active in IPY 2007–2008.

[5] At that time, Chilingarov was the Deputy Chairman of the Russian State Duma (lower chamber of the Russian Parliament). Some Russian sources (Andreev et al., 2007:97; Khronika, 2007) erroneously cite 25 October 2002 as the date of Chilngarov's statement in Brussels.

[6] Report on the Brussels workshop was published online by Stanley Morris, Director of the IPSC (Institute of the Protection and Security of the Citizen) under the European Commission's Joint Research Centre in Ispra, Italy. It was posted on the website of the Arctic Council, Senior Arctic Officials (http://arctic-council.npolar.no/Meetings/SAO/2001%20Es/11_3sao.pdf). It also marked the first intervention of Stanley Morris and his Institute of the Protection and Security of the Citizen in the Russian IPY process. The IPSC has no stake in polar research, as its activities are focused primarily on external security, agriculture, maritime affairs and nuclear safeguards (http://ipsc.jrc.ec.europa.eu/activities.php?id=1).

[7] Chilingarov's letter was addressed to Barry McSweeney, Director-General, DG Joint Research Center; Guy Legras, Director-General, DG External Relations; Francois Lamoreux, Director-General, Transport and Energy; Jean-Froncois Verstrynge, DG Environment; and Achilleas Mitsos, Director-General, DG Research (copy in Russian, with English translation in Chris Rapley's files).

[8] The first IPY-related website was launched by the IHY group at http://ipy.gsfc.nasa.gov and http://ihy.gsfc.nasa.gov in early 2002 and by early 2003 several other IPY-focused websites were running, such as www.nationalacademies.org/prb/ipy, www.eoss.org/igy.htm, www.polarcom.gc.ca/polaryear.htm, and a Russian IPY site at www.polarf.ru.

[9] Later in 2002, Rapley was also tasked to be the liaison in the IPY planning for the European Polar Board (EPB) then chaired by Thiede. The idea was to have some key advocates representing several organizations participating in the same process, something that the IGY planners (e.g. Chapman, Berkner, and others) used very successfully in their early process.

[10] Fae Korsmo, Robert Bindschadler, Phil Smith and Stephanie Pfirman.

[11] The joint ACSYS-CliC Steering Group was established in 2000 "to formulate and guide the ACSYS observational and modeling programs for determining Arctic climate processes and realistic representation of the Arctic region in global climate models" – see http://acsys.npolar.no/introduction/impplan/tor.php#SSG.

[12] This was perhaps the earliest known reference to having two organizations, ICSU and WMO, as prospective supporters of the IPY. It came naturally from ACSYS/CliC, which is a joint venture launched by ICSU, WMO, and Intergovernmental Oceanographic Commission (IOC).

[13] The original is in the ICSU Archives. A shorter version of the proposal was posted in September 2003 on SCAR website – see: www.scar.org/ipy/approachworkplan.html.

[14] See English copy: www.ipy-api.ca/english/documents/e_int_russian_ipy_concept.pdf.

[15] In fact, the draft text for inclusion in the 14th WMO Congress agenda was submitted on 11 April 2003, that is two weeks prior to the official endorsement of the IPY proposal by the Russian Academy of Sciences.

[16] In the next few weeks, the information on the WMO approval of the Russian proposal was systematically disseminated out of the IPSC office in Ispra to the polar scientists and agency officials worldwide. Various copies of the WMO documents were later posted on various websites, e.g. www.ipy-api.ca/english/documents/e_int_declaration_from_un.pdf.

[17] Chris Rapley (Chair, U.K.), Robin Bell (Vice-Chair, U.S.A.), Ian Allison (Australia), Robert Bindshadler (U.S.A.), Steve Chown (South Africa), Gérard Duhaime (Canada), Vladimir Kotlyakov (Russia), Olav Orheim (Norway), Zhanghai Zhan (China), an appropriate representative of India and of Latin America, nominees (one each) of IUGS and IUGG, and Science Programme Leaders as these are appointed (5-6 envisaged).

[18] It should be noted that SCAR is an Interdisciplinary body of ICSU and IASC is ICSU's Associate member. IUGG and IGUS are Members as is the U.S. National Academies (in this case represented by the PRB).

[19] The idea of the truly 'modern' character of this IPY was raised in many early presentations (Berkman, 2003) and is specifically addressed in Elzinga (2009), Korsmo (2010), and Stirling (2007).

1.3 Early Planning for IPY: July 2003–December 2004

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The 'planning phase' for IPY 2007–2008 began in earnest in July–August 2003, in the midst of the boreal summer break and with many Arctic scientists gone to their field sites. That the IPY planners significantly advanced the fledging concept during that time is a tribute to their energy and dedication. Intense meetings and assignments completed in the wee hours of the night built momentum so that major events that required extensive preparation could be scheduled in a matter of weeks, not months. In 2003 and, again, in 2004, that strategy and effort paid off.

PG-1 Meeting: July 2003

The first meeting of the IPY Planning Group (PG-1) was held 31 July - 2 August, 2003 in Paris at the ICSU headquarters (see http://classic.ipy.org/international/documents/). The group was small (ten participants only).[1] Nonetheless, the PG leaders, Chris Rapley and Robin Bell decided that an actual meeting, even if small, was sufficient to make an effective start to the formal planning for IPY and would lend much-needed credibility. Holding the meeting at ICSU sent a message that IPY was intended as an international, science-focused effort. The convened members believed it essential to move as quickly as possible to demonstrate that a new planning body could provide leadership and vision, and bring many nations and participants together around the IPY idea (Box 1: PG Terms of Reference).

The aims of the meeting were to develop a shared vision of the goals of new IPY, develop selection criteria by which projects could be judged to see whether they were IPY relevant activities, identify and begin taking steps to ensure coordination with other relevant bodies and activities, and take steps to encourage nations to organize some group or point of contact to facilitate IPY planning at the national level. The PG team worked to articulate clear answers to some fundamental questions about the nature of IPY 2007–2008 – Why polar? Why international? Why a year? There was easy consensus, encouraged by ICSU, on some of the key elements that would come to define IPY: that it would involve both poles, that it would be multi-disciplinary and that it would be truly international.

From the outset, the planners were influenced by many elements viewed as legacy of the previous International Geophysical Year (IGY) 1957–1958 (*Chapter 1.1*). Three key themes were identified as a starting point to gather community input: Exploring new frontiers, Understanding change at the poles and Decoding polar processes. Even at this first meeting, the importance of education and outreach in the new IPY was stressed by calling it a "remarkable opportunity" to train the next generation of polar scientists and engage the public in the excitement of polar science. Plans were made to start on a draft science plan to ICSU that would be needed before the ICSU Executive Board meeting in February 2004.

The group noted that there were other incipient efforts to celebrate the 50th anniversary of IGY, each with a different emphasis. It deliberated on the importance of coordinating with other bodies and activities (e.g. UNESCO's International Year of Planet Earth). There was significant debate on how to work with the WMO on its IPY initiative and how to coordinate with the International Heliophysical Year (IHY) if it turned into a separate activity. It was agreed that this IPY should be open and inclusive (and the phrase "let a thousand flowers bloom" was eagerly invoked).

The Planning Group knew that for implementation to happen, individual scientists, science societies and nations needed to be engaged. Significant effort was devoted to outlining the contents of a letter designed to be distributed widely to arouse and engage potential participants and, especially, to encourage nations to set up national committees or some other mechanism to steer their national participation. Outlining the letter, in fact, helped the Planning Group articulate its vision concisely for the first time. The group also recognized the need for flexibility, given that different nations have different processes for decision making and funding.

The first PG meeting included the start of various discussions that would continue at its later sessions; about how IPY would be communicated and coordinated, on the future IPY logo, website, secretariat, data management, etc., and about creation of an IPY planning timeline. Planning Group members all committed to finding opportunities to talk about IPY in as many settings as possible, to build momentum and to confirm that IPY was real and going to happen. They made plans to hold a second meeting in December 2003.

In hindsight, the first meeting of the Planning Group was critical to IPY success (Fig. 1.3-1). It created a solid rationale for why IPY should occur, outlined enough detail about what it might accomplish to excite people with the vision and set a tone of openness so that a wide community could be engaged.

First Attempts at Coordination: Rosswall Visits WMO Secretariat, September 2003

Unbeknownst to the PG members, Thomas Roswall, Executive Director of ICSU, and Michel Jarraud, WMO Secretary-General, met at the first Earth Observing Summit in Washington, DC during the days of the PG meeting (31 July – 1 August 2003).[2] The two parties agreed to share information about their respective work on the 'third' (WMO) and 'fourth' (ICSU) polar year.

In early September 2003, Rosswall paid a visit to the WMO Secretariat in Geneva. Prior to that meeting, ICSU expanded the size of the IPY Planning Group and made its membership public[3] (Box 2). It also posted a 5-page overview document about the vision, general principles and some key characteristics of IPY

Box 1 Terms of Reference of the ICSU IPY 2007–2008 Planning Group

The role of the IPY-PG should be to formulate a concept for an IPY 2007-8 and to design the means of ICSU leading such a program.

Specifically the Group's tasks are:

(i) To gather, summarize and make widely available information on existing ideas for an IPY, serving as a clearinghouse for ideas,

(ii) To stimulate, encourage and organize debate amongst a wide range of interested parties on the objectives and possible content of an IPY,

(iii) To formulate a set of objectives for an IPY,

(iv) To develop an initial high level Science Plan for an IPY, which engages younger scientists throughout the planning process,

(v) To develop a specific set of objectives targeted at formal and informal education as well as the general public in the next IPY,

(vi) To develop a proposed mechanism for the design, development, guidance and oversight of an IPY,

(vii) To present a draft plan to the ICSU EB at their February 2004 meeting, and

(vii) To report to the ICSU 28th General Assembly in 2005 a plan for an IPY in 2007–2008 for final endorsement.

(Approved February 2003)

IPY Planning Timeline

Grey arrows indicate opportunities for ideas to come into the process. Small numbers indicate the approximate month that the PG meeting's activity should occur.

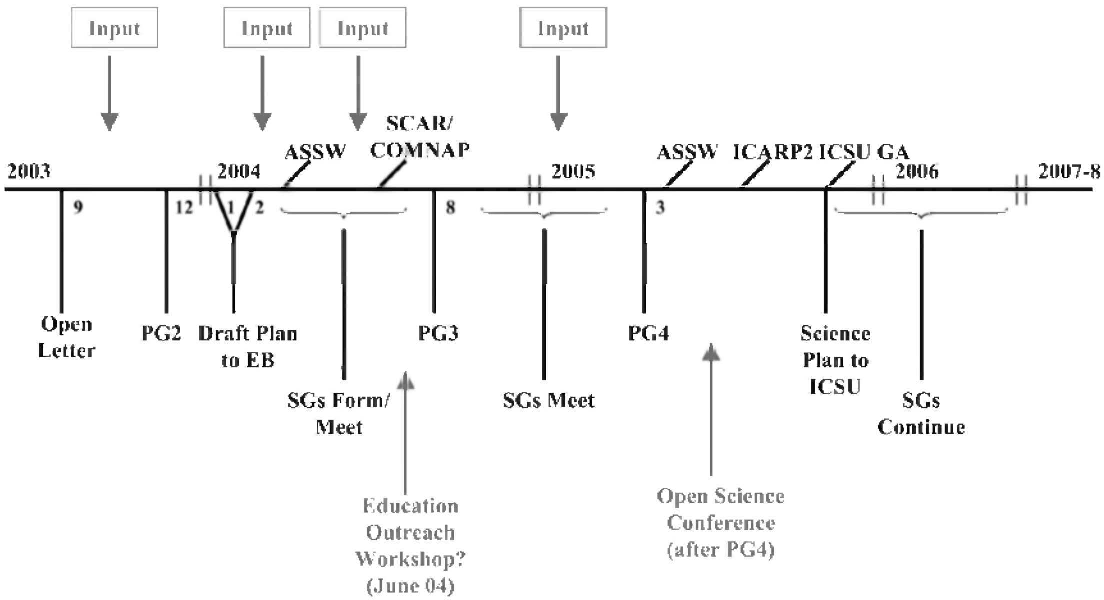


Fig. 1.3-1. Draft timeline established at PG-1, August 2003.

developed by PG-1 (3 September 2003). In addition, Rosswall sent a one-page memo on IPY to all ICSU National Members, Scientific Unions, Interdisciplinary Bodies, the European Polar Board and IASC (7 September 2003) making the ICSU support for IPY and the Rapley-Bell team known. A letter co-signed by Rapley and Bell was attached to Rosswall's memo describing the first Planning Group's meeting and requesting comments on the prospective IPY science themes and research activities to be submitted to PG by 15 December 2003 (ICSU PG, 2003b). This letter amounted to a second call to the scientific community inviting grass-roots input for the future IPY program; several more would follow in 2004–2006.

At the WMO Secretariat, Eduard Sarukhanian led the preparation of an extensive 'background' document, *Third International Polar Year (2007–2008),* summarizing the WMO position (WMO, 2003). Besides outlining several prospective fields, in which WMO could make significant contribution to IPY (such as meteorological, hydrological and marine observations; polar stratosphere ozone; environmental pollution; weather forecasting and climate projection; polar oceanography), the document proposed "to hold the International Polar Year in 2007/08 as a *WMO and ICSU joint initiative"*. The WMO also proposed to bring in the Intergovernmental Oceanographic Commission (IOC) of UNESCO as the third key partner in IPY (*Chapter 1.4*). If all three organizations were eager to join forces, the WMO recommended establishing a Joint Steering Body comprising representatives of WMO, ICSU and IOC to develop an IPY science program and implementation plan (WMO, 2003). Hence, the blueprint for a joint leadership in IPY and for building a unified team for its planning and implementation was put on the table in September 2003 by WMO.

At the first 'sharing' ICSU–WMO session, Rosswall briefed his WMO counterparts about the recent Planning Group meeting and its approach. He invited Sarukhanian to become a WMO 'liaison' to the ICSU Planning Group and to join it at its next gathering in Paris (PG-2).[4] To avoid any further misunderstanding with the numbering ('third' or 'fourth' IPY), the Executive Heads of ICSU and WMO agreed to call it officially 'IPY 2007–2008.' Rosswall also took the WMO proposal about joining forces in IPY to the ICSU planners, but practical steps in rapprochement from both sides did not take place until a few months later, in December 2003 or even in February 2004.

ICSU and WMO Processes Gain Steam: September–December 2003

During the short intermission between the ICSU-WMO meeting and the second gathering of the ICSU Planning Group in December 2003, both parties worked hard to build momentum for their respective planning processes. The Rapley-Bell letter of 3 September 2003 that was circulated by Rosswall generated a large number of responses: by December 2003, over 130 inputs had been received (ICSU PG, 2003c). Bell made a presentation on the new IPY at the 9th International Earth Sciences symposium in Potsdam, Germany (8-12 September 2003); she also spoke to a much larger constituency about the ICSU planning at the AGU meeting in San Francisco on 10 December 2003 (Bell et al., 2003). The AGU meeting featured two sessions on IPY with over a dozen invited papers[5], a massive poster session and an IPY 'town-hall' meeting (in lieu of the one that did not materialize eight months earlier at the AGU/EGU gathering in Nice, France). Papers were also given on the IHY (by Davila and his team) and on the eGY (by D.N. Baker and the eGY team), but the three planning processes were presented to different audiences in different disciplinary fields.

In September 2003, the U.S. IPY planning team of 20 members under the National Academies started its work on the IPY science overview document (NRC, 2004). Connected through Bell, Bindschadler and Elfring to the ICSU Planning Group, the U.S. team became a strong ally and a valuable testing ground to many ideas developed by the ICSU planners. During the final months of 2003, several nations – Canada, Denmark, Germany and the U.K. – moved to form their national IPY committees in addition to those already present in the U.S. and Russia. By February 2004, 14 countries had established their national IPY committees or points of contact (*Chapter 1.6*).

Several key endorsements were also secured. On 14 October 2003, the UNESCO General Assembly referred to the "desirability of joint action in relation to the International Polar Year (2007–2008)" (http://unesdoc.unesco.org/images/0013/001320/132068e.pdf, p. 52). On 23–24 October 2003, the Arctic Council's Senior Arctic Officials (SAO) meeting in Svartsengi, Iceland discussed the IPY planning and decided to invite ICSU planners to give a presentation at the next meeting in May 2004 (see below). The IASC Executive Committee held its own discussion about IPY in November 2003 (*Chapter 1.4*). Lastly, the Russian IPY team proposed in October 2003 to hold a meeting of the international group of 'experts' on IPY in January 2004. Leaders of the ICSU Planning Group (Rapley and Bell), as well as representatives of the WMO, Arctic Council, IASC, SCAR and other major polar agencies were invited to participate.

PG-2: December 2003

The second PG meeting took place on 17–19 December 2003, again, at the ICSU headquarters in Paris. It was the first gathering of the expanded Planning Group (with 17 people in attendance - see minutes at http://classic.ipy.org/international/documents/)[6] and also the first since the Call for IPY Ideas had been issued in September 2003. Altogether, 135 'research ideas' for IPY activities had been submitted in about three months from 22 countries by individual scientists, research institutions, national and international groups, a clear demonstration of huge enthusiasm for IPY among the polar science community. Hence, the meeting primary aims were to review the submitted ideas and to assign tasks to prepare a report to ICSU by January 2004, in maintaining an aggressive timetable of necessary actions.

Initially, the PG considered a presentation on the WMO position on IPY made by Vladimir Ryabinin from the World Climate Research Programme (WCRP – *Chapter 1.4*). Ryabinin outlined the WMO interest in a joint WMO/ICSU initiative for IPY and also in inviting IOC participation. WMO suggested a strong joint proposal for IPY, to be prepared in collaboration with the PG that would recommend establishment of a Joint Steering Committee, supported by program offices at each of the organizations. That Joint Committee would then develop the Science Program and Implementation Plan for IPY to be presented to the WMO, IOC and ICSU Executive Committees for approval by June 2004.

After considerable debate the PG agreed (without complete consensus) to recommend to ICSU and WMO that they jointly co-sponsor IPY 2007–2008 and that WMO have minority representation on the Planning Group. Overall, the PG members welcomed the WMO approach, but they made it clear that the full spectrum of disciplines, in both physical and social sciences, need to be included and that other organizations, beyond WMO, IOC and ICSU should be involved. It was recognized that the balance of governmental (WMO) and non-governmental (ICSU) organizations would be powerful and beneficial to the overall success of IPY, but it was felt that rules of procedure should be kept light and open. PG members pointed out that as a governmental organization, WMO would be able to contribute resources to support an IPY secretariat and that WMO co-sponsorship of IPY would assist active participation by nations such as China and most South American nations. In the end, the PG agreed to a modified version of the WMO proposal for cooperation and adopted a declaration that it was committed to develop relationships with organizations with defined interests in polar regions.

Updates were provided by representatives of two ICSU International Scientific Unions: the International Union of Geological Sciences (IUGS) regarding International Year of Planet Earth (IYPE) and the International Union of Geodesy and Geophysics (IUGG) on the Electronic Geophysical Year (eGY). The IYPE was to focus on capacity building and it was felt that IPY could build on the success of the IYPE by focusing on the role of the polar regions in the "planetary machinery". It was also recognized that there was scope to establish a Joint Observing Programme among the eGY, IHY and IPY and indeed both the e-GY and IHY eventually contributed to IPY 2007–2008 as cluster programs. In addition, it was felt that there were good grounds for closer links with SCAR and IASC as these ICSU-affiliated organizations could have specific roles in science steering groups or as science coordinators themselves. The need for IPY to leave a legacy of improved cooperation, data access and systems was highlighted, and the prospective IPY logo was discussed.

For the rest of the meeting, PG members divided into three groups to review some 135 'research ideas' submitted for future IPY projects from individual scientists, research institutions, national and international teams. It was agreed that the ideas be initially clustered using the overarching science themes (Change, Decode, Explore), the four geographic descriptors (Arctic, Antarctic, Bipolar, Global) and nine broad disciplinary classifications. The pool of over 130 'research ideas,' though with certain overlap, clearly indicated research priorities of the polar science community, as the two strongest clusters were the role of polar processes in global climate and weather, and biodiversity and change in terrestrial and marine ecosystems. There proved to be insufficient time to complete the analysis of all of the submitted ideas, so the group decided to work by e-mail over the next several weeks to develop the guiding principles, management strategy and research themes to be summarized into a draft plan for consideration by the ICSU Executive Board in February 2004. The poor response from social sciences was noted as a special concern. Gérard Duhaime, social scientist on the PG, felt this was due to communicating with the wrong partners, i.e. associations and ICSU Scientific Unions (which were dominated by non social science disciplines), the need to better inform social scientists about the "new" inclusive nature of IPY 2007–2008 (*Chapter 1.4*) and to demonstrate that this Polar Year was genuinely interested in social sciences, social issues and polar residents, including indigenous peoples.

It was proposed that submission of further ideas for IPY activities be encouraged with a deadline of 12 March 2004, so that they might be considered at the next PG meeting. It was further decided that a draft Science Outline be developed by March 2004 based on those ideas for future IPY projects. That draft Science Outline should be presented to the community for comment at the Arctic Science Summit Week (ASSW, April 2004), at the 5th International Congress of Arctic Social Sciences (ICASS-5) of the International Arctic Social Sciences Association (May 2004) and at the SCAR open science conference (July 2004).

ICSU and WMO Consider Closer Cooperation: January 2004

The key interaction between the ICSU, WMO and the Russian teams took place 22–23 January 2004 in St. Petersburg at the meeting titled "Cooperation for the International Polar Year 2007–2008"; it was hosted by *Roshydromet* and the Russian Academy of Sciences at the Russian Arctic and Antarctic Research Institute, AARI (ICSU PG, 2004b:23–25; *Electronnyi bulleten,* 2004). Over 40 scientists and polar agency representatives from ICSU, WMO, SCAR, IASC, Arctic Council and the European Commission (EC) participated, including Rapley and Bell for ICSU PG, Sarukhanian for WMO, Thiede for SCAR, Rogne for IASC, Egerton for EPB and Morison for the U.S. *SEARCH* program. The Russian IPY team was represented by Chilingarov, Tsaturov, Kotlyakov, Frolov, Danilov, Klepikov, Priamikov, Gruzinov, Sychev and other experts.

The meeting started very cautiously as all parties were testing the waters by arguing for the 'possibilities' and 'challenges' of the new IPY. Key presentations by Rapley and Sarukhanian, and informal interactions helped bring the participants closer. A 'Joint Statement' was adopted at the end of the meeting recommending to ICSU, WMO and other interested organizations to nominate IPY 2007–2008 as a program of high priority. The concluding paragraphs of that statement stressed the need for 'jointly-coordinated' efforts of WMO and ICSU and recommended that WMO and ICSU develop a plan for IPY "based on a wide range of inputs …and in close cooperation with IASC, SCAR and the EC." The Meeting also voiced support to a member-country or a group of countries addressing the UN General Assembly with a proposal to approve a UN Resolution on holding IPY 2007–2008. That proposal never materialized.

Upon returning from the St. Petersburg meeting, the ICSU PG issued a call (on 28 January 2004) for additional input from the national IPY committees, ICSU Scientific Unions and broad science community for research 'ideas' to be considered for the IPY science program. The deadline for new submissions was set to 15 March 2004, two weeks prior to the next Planning Group meeting.

PG Reports to ICSU and WMO: February 2004

Following on their previous arrangements, ICSU and WMO continued on the path towards merging their planning processes for IPY. On 11 February 2004, Rapley and Bell presented on behalf of the Planning Group a 25-page 'progress report' to the 88th Meeting of the ICSU Executive Board in Paris (ICSU PG, 2004a). A day prior (10 February) Rapley gave another IPY-focused presentation to the representatives of the ICSU Scientific Unions at the French Academy of Sciences. Besides providing a detailed summary of its activities since February 2003, the PG team dwelled extensively on the emerging ICSU-WMO relationship and stressed its wish "to avoid the possibility of the development of (two) separate initiatives". It also advocated its aim "to incorporate as far as possible the interests of all relevant scientific bodies, and those of developing initiatives, such as the proposed International Heliophysical Year (IHY)." It vowed to develop an outline for the IPY science plan by late April 2004, so that it would be open for community evaluation at several forthcoming meetings in April–July 2004 (see below). The PG Report recommended that the ICSU Executive Board make an official announcement of the ICSU support to IPY 2007–2008 and recommended that the Board consider joint sponsorship of IPY with other interested bodies, primarily the WMO.

The outcomes of the meeting could not have been more positive to the PG planners as the ICSU Board supported them on all counts. The team was commended on its successful efforts and was charged to present the finished report by 1 October 2004. The ICSU Board made an announcement "to establish an International Polar Year 2007–2008, subsequent to confirmation by the 28th ICSU General Assembly (in 2005) and recommended the establishment of the IPY secretariat (at least by 1 October 2004)". By far the most important decision was to propose to WMO that "the two organizations should jointly sponsor IPY 2007–2008 and appoint a Committee to plan and coordinate IPY activities." With that, the proposal for joint sponsorship of IPY was officially on the table. It was now the WMO's turn to respond and practical steps were indeed soon undertaken.

On 9 March 2004, Rapley was invited to WMO Secretariat in Geneva for yet another discussion on the joint ICSU-WMO efforts with Jarraud, Sarukhanian and Elena Manaenkova, Director of the Secretary-General's Office and External Relations. He also gave a presentation on the ICSU Planning Group activities to the group of Directors of WMO Departments. The response at WMO was cordial and enthusiastic. Shortly after, Sarukhanian started working on a set of IPY-related documents for the forthcoming WMO Executive Council meeting (scheduled for June 2004), including a resolution endorsing future 'Joint Organizing Committee' for IPY to be established by ICSU and WMO. In addition, WMO decided to create a special internal body (called 'Inter-commission Task Group on IPY') to coordinate the IPY activities among the WMO Technical Commissions for the fields in which WMO was supposed to take the lead, such as meteorological observations, weather forecasting, climate modeling, oceanographic studies and others.[7] The path for merging the ICSU and WMO planning processes was thus wide open.

IHY Team Branches Off

The PG report to ICSU in February 2004 referred to its continuous interactions with the International Heliophysical Year (IHY) as well as two other similar initiatives, the eGY and the International Year of Planet Earth, IYPE, under UNESCO. Nevertheless, with each passing month, the planning for IPY and IHY became more detached. Both initiatives continued to claim their origins to the same line of succession from IPY-1 to IPY-2 to IGY and they often used the same photos of Carl Weyprecht and IGY rockets in their respective documents (Fig. 1.3-2), but with less and less knowledge of each other's work, they were looking increasingly like distant kin. Their last joint action had been planning for the AGU/EGU session in April 2003. Since July 2003 onward, no member of the IHY planning group attended any important IPY meeting; similarly, the first issue of the *IHY Newsletter* (July 2003) contained no reference to IPY.

The separation became official in April 2004 as the IHY team gathered for its first planning meeting in April 2004 at the National Solar Observatory in Sac Peak, New Mexico, U.S.A. The meeting press release (*Scientists to plan International Heliophysical Year*) as well as several preparatory and subsequent documents (i.e. Davila, 2004; Davila et al., 2004) lacked any reference to the activities related to IPY 2007–2008. In 2005, IHY became a recognized initiative under the UN Office for Outer Space Affairs in Vienna with its own logo, Organizing Committee and Secretariat, a *Newsletter* and website (www.ihy2007.org/), and, finally, its own publications.[8] Eventually, all four initiatives—IHY, IPY, eGY and the International Year of Planet Earth—became fully independent programs that charted their separate courses.[9]

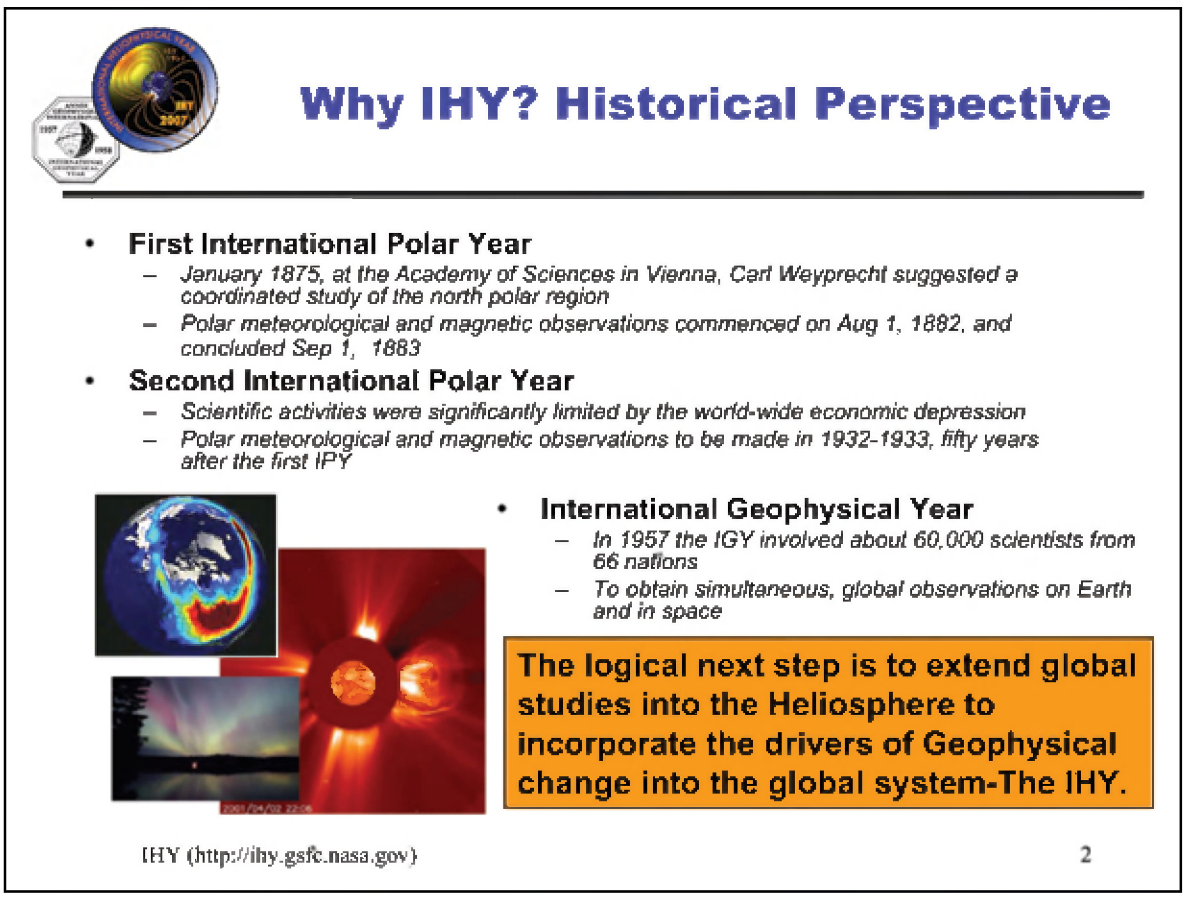


Fig. 1.3-2.'Shared genealogies,' separate tracks. Presentation on the plans for International Heliophysical Year 2007 by Joseph Davila (March 2, 2004), with no references to the planning for IPY 2007–2008.

PG-3, First Discussion Forum and New Endorsements: March-April 2004

The first IPY *Discussion Forum* was brought together at relatively short notice and held at Reid Hall[10] in Paris on 31 March 2004, immediately before the third PG meeting. It was attended by representatives of six IPY National Committees (Belgium, France, Germany, Italy, Japan and U.K.), the Spanish National Point of Contact and seven international organizations as well as an IHY representative.[11] The forum emphasized that the establishment of criteria for the overall program, content and research activities was important and that there should not be more than ten (ideally fewer) science themes identified. There was some concern about lack of certain nations on the membership of PG, but it was made clear that the PG membership was not based on national representation. Transparency, good communications and outreach were identified as critical for the IPY planning process to keep the community informed and involved. These views reflected the uncertainty still present in the community about how IPY would develop, with the ownership of the evolving program now firmly residing with the PG. The Discussion Forums (and later Open Consultative Forums) subsequently went from strength to strength and proved invaluable in bringing the PG (and later the Joint Committee – *Chapter 1.5*) together with the community, as forum participants saw their views reflected in the PG documents.

The third PG meeting (PG-3) was also held in Reid Hall, Paris immediately after the Discussion Forum (1–3 April 2004; http://classic.ipy.org/international/documents/).[12] The primary objectives of the meeting were to prepare a draft Outline Science Plan and develop further the IPY concept as well as reviewing the IPY ideas submitted to date (Fig. 1.3-3). The PG clarified a set of umbrella (later mandatory) criteria to identify acceptable IPY proposals and then proceeded to cluster the ideas for future IPY projects (now having grown from 130 to over 350) into what were initially seven major themes that would be further developed and refined after the meeting for inclusion in the IPY Science Plan. The group also discussed the exact dates for IPY 2007–2008. The PG decided that the official period of IPY would be from 1 March 2007 until 1 March 2009 to allow observations during all seasons, and the possibility of two summer field seasons, in each polar region. It was anticipated that the core activity would take place in 2007–2008.

Much of PG-3 was taken up with developing the basic structure and contents of the IPY 'Outline Science Plan' (Figs. 1.3-4 to 1.3-6). Riding the energy generated by the PG-3 discussion, the planning team aimed to complete the first draft of the Plan by 15 April 2004 so that it could be presented at several high-profile meetings during the following months. The 40-page document, *International Polar Year 2007–2008: Initial Outline Science Plan* (ICSU PG 2004b – Fig. 1.3-7), was eventually posted online on 20 April 2004. It unveiled for the first time the full list of the IPY science objectives and *five* major science themes proposed for the new IPY ("The Pulse of the Polar Regions," "Understanding Change," "Global Teleconnections," "Investigate the Unknowns" and "Unique Vantage Point of the Polar Regions"). It also included a 15-page Appendix introducing the more than 350 submitted 'science ideas' organized by themes and by nations or major science organizations. This was an impressive display of the enthusiastic response from the polar science community. Nonetheless, the stakes were high and the meetings soon to follow revealed rifts and tensions among certain key constituencies, particularly with regard to the role of social sciences and polar residents in the IPY 2007–2008 activities. The ensuing debates helped formulate substantial changes in the IPY overall design in the next few months.

The first of these tests to the IPY planners were at two back-to-back IPY 'forum' sessions at the Arctic Science Summit Week (ASSW) in Reykjavik, 25 April 2004 (chaired by Rapley – Fig. 1.3-8)[13] and at the European Geosciences Union (EGU) Assembly at Nice, France, 29 April 2004 (chaired by Sarukhanian).[14] Both demonstrated a lot of enthusiasm in the ranks and the overall support for the proposed IPY science outline, primarily among physical scientists. Things became more unsettled at the Arctic Council' Senior Arctic Officials meeting in Selfoss, Iceland, 4-5 May 2004, where Rapley gave a presentation similar to the one he delivered at ASSW ten days prior. This time, the response was quite different, particularly by the representatives of Arctic indigenous organizations. Participants confirmed strong interest in IPY from the Council, but they questioned a passing reference to the

Fig. 1.3-3. Eduard Sarukhanian presents the WMO position at PG-3 meeting in Paris, April 2004.
(Photo: Chris Rapley)

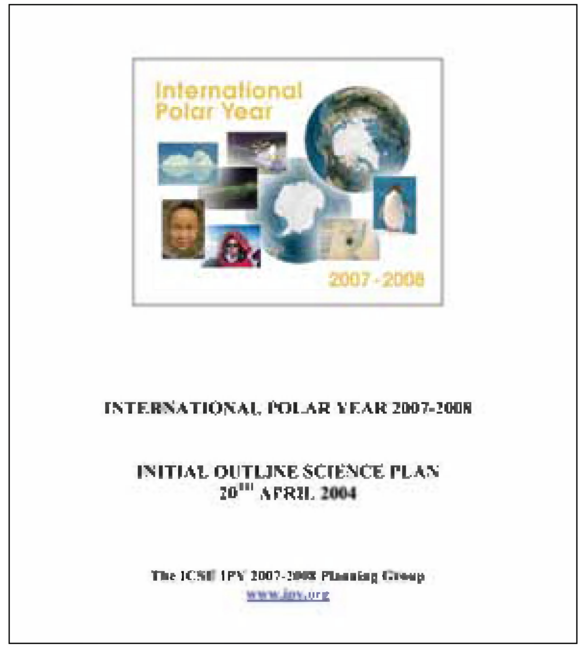
Fig. 1.3-4 (middle). Planning group members (left to right): Gino Casassa, Chris Elfring, Werner Janochek (International Union of Geological Sciences, IUGS, reporter on the International Year of Planet Earth), Ed Sarukhanian, Michael Kuhn (International Union of Geodesy and Geophysics, IUGG). Olav Orheim, Ian Allison, and Prem Pandey in the background. April 2004.
(Photo: Chris Rapley)

Fig. 1.3-5 (bottom left). Planning group members (left to right): Olav Orheim, Ian Allison and Prem Pandey, April 2004.
(Photo: Chris Rapley)

Fig. 1.3-6 (bottom right). Planning group members (front group, left to right): Hanne Petersen, Vladimir Kotlyakov, Robert Bindschadler, Gérard Duhaime and Robin Bell, April 2004.
(Photo: Chris Rapley)

Fig. 1.3-7 (right). Cover page of the 'Initial Outline Science Plan' for IPY prepared by the Planning Group (20 April 2004).

Fig. 1.3-8 (left). Cover slide of Chris Rapley's presentation on PG activities at the 'open science' plenary meeting in Reykjavik, 25 April 2004.



Box 2 Membership of the ICSU IPY 2007–2008 Planning Group (2003 –2004)

Chris Rapley, Chair
British Antarctic Survey
United Kingdom

Robin Bell, Vice-Chair
Lamont-Doherty Earth Observatory
Columbia University
U.S.A.

Ian Allison
Australian Antarctic Division &
ACE CRC
Australia

Robert Bindschadler
Oceans and Ice Branch
NASA Goddard Space Flight Center
U.S.A.

Gino Casassa
Centro de Estudios Científicos
Chile

Steve Chown
Department of Zoology
University of Stellenbosch
South Africa

Gérard Duhaime
Université Laval
Canada

Vladimir Kotlyakov
Glaciological Association
Institute of Geography,
Russia

Michael Kuhn
(*ex officio*, IUGG liaison)
Institute of Meteorology and Geophysics
Austria

Olav Orheim
Norsk Polarinstitutt
Norway

Prem Chand Pandey
National Centre for Antarctic & Ocean Research
Department of Ocean Development
India.

Hanne Kathrine Petersen
Danish Polar Center
Denmark

Henk Schalke
(*ex officio*, IUGS liaison)
IUGS-UNESCO Division of Earth Sciences Joint Programme Project
The Netherlands

Werner Janoschek
(*ex officio*, IUGS liaison)
Geologische Bundesanstalt
Austria

Eduard Sarukhanian
(WMO liaison)
World Meteorological Organization
Switzerland

Zhanhai Zhang
Polar Research Institute of China
China

'human dimension' in the science outline and called it inadequate. They stressed the need to generate substantive input by social and human sciences, engage indigenous and other local communities in IPY research, and to develop mechanisms for sharing IPY science results and other outcomes with polar residents (*Chapter 1.4*). As far as the Arctic Council members were concerned, the IPY planners still had homework to do.

An even more heated debate about the status of social science and polar residents in IPY took place two weeks later, at the 5th International Congress of Arctic Social Sciences (ICASS-5) in Fairbanks, U.S.A., 19–23 May 2004 (*Chapter 1.4*). At a special IPY panel and at the Congress plenary session, Arctic social researchers argued for more input from social scientists, Arctic indigenous organizations and polar communities regarding the objectives, themes and issues in IPY. They asked for more active engagement of those three constituencies in the IPY planning process and on equal terms with physical and natural scientists (IASSA, 2004a). Though they eventually offered their help and voted unanimously in support of IPY, it was obvious that the issues of polar residents' participation and of the social themes in broader sense (including social sciences, humanities, human health and community well-being) would require a radical revision of the existing IPY documents. A solution had to be found within a few months remaining until September 2004, the official end of the PG-led planning process.

June–September 2004: Planning for JC and the Social Science Theme

Boreal summer months (June-August) of 2004 witnessed several new developments crucial to the success of the early preparation phase for IPY. Firstly, the merger of the two planning processes for IPY started by ICSU and WMO in early 2003 became official. Following the ICSU Executive Board meeting in February 2004, Thomas Rosswall sent an official letter to WMO and later met with Michel Jarraud to discuss the co-sponsorship of IPY by the two organizations. The two sides agreed on all issues. On 1-2 June 2004, the ICSU Officers meeting formally approved the merger of the two processes and on 14 June 2004 the WMO Executive Council in Geneva similarly endorsed the joint co-sponsorship of IPY with ICSU and the establishment of the 'Joint Organizing Committee' (later renamed to *Joint Committee*) for further planning and coordination of IPY activities. The WMO Secretary-General was tasked to define Terms of Reference, composition and funding for the new joint team to replace the Planning Group in coordination with ICSU and other interested organizations, such as SCAR, IASC, IOC and others.

On 26 June 2006, Rapley gave a presentation on the preparation for IPY 2007–2008 at the 37th session of the Executing Council of Intergovernmental Oceanographic Commission (IOC). The Council agreed to contribute to IPY through several existing programs co-sponsored by IOC and expressed its interest in having IOC represented on the proposed IPY Joint Committee (*Chapter 1.4*).

Another critical milestone was the SCAR Open Science Conference in Bremen, Germany 25–31 July 2004 that was run parallel to the 16th meeting of COMNAP. The joint event attended by about 1,000 participants featured two IPY sessions, four keynote IPY presentations (by Bell, Rapley, Karsten Gohl and Terry Wilson) and two IPY 'discussion forums' led respectively by Ian Allison for SCAR and Anders Karlqvist for COMNAP (*Chapter 1.4*).[15] Outside of the meetings, Rapley, Sarukhanian and Leah Goldfarb (for ICSU) held intensive discussions about the composition of the future Joint Committee for IPY.

Thirdly, social scientists associated with IASSA (International Arctic Social Sciences Association – *Chapter 1.4*) had been working closely with Rapley and Bell to provide input to the IPY Outline Science Plan. In fact, they were revising and editing the Outline sections relevant to the social issues and polar residents.[16] By mid-August 2004, the IASSA team submitted its proposal to the PG arguing for *additional* sixth theme and a new observational initiative in the IPY Science Plan to cover social science research and to encourage the participation of polar Indigenous peoples and their organizations, with their specific research themes and agendas. This proposal was formally approved at the last PG meeting in September 2004 (see below).

On 5-6 August 2004, Rosswall visited the WMO Secretariat to discuss with Jarraud, Sarukhanian and Manaenkova the proposed Terms of Reference and the composition of the future IPY Joint Committee. It was agreed that the new 'Joint Committee' be established by 1 October 2004 of two Co-Chairs,[17] ten regular members to be appointed jointly by ICSU and WMO and five *ex officio* members from ICSU, WMO, IASC, SCAR and IOC, with preferably equal number of experts on the Arctic and Antarctic. On 16 August 2004, Rosswall issued a call for nominations for the members of the Joint Committee to run IPY for the next five years, 2005–2009. Regarding the scientific disciplines to be covered by the future JC members, the letter cited Social Sciences (two experts, including Economy), Meteorology, Climatology, Oceanography, Remote-sensing, Glaciology, Biology and Geosciences (in that order). Rosswall's letter was addressed to ICSU National Members, Scientific Unions, Interdisciplinary Bodies, and IPY National Committees and contact points. A few days later (20 August 2004), Jarraud sent a similar call on behalf of WMO to the WMO Executive Council members.

Amid these various events, the PG team worked frantically throughout July and August 2004 trying to complete the Outline Science Plan for the forthcoming PG meeting and the preceding deliberations at the IPY 'Discussion Forum', scheduled for September 2004.

PG-4, Second Discussion Forum and the Framework Document: September 2004

The second IPY 'Discussion Forum' was held, again, at Reid Hall in Paris on 13–14 September 2004. It was attended by over 60 people, including representatives of 13 National Committees, major funding agencies and 20 international organizations, as well as 15 members of the PG and staff of the ICSU secretariat. The meeting was used to introduce the revised Outline Science Plan in which the new sixth theme and the inclusion of social sciences, as well as interweaving of social issues with the other themes was outlined. The Discussion Forum gave a strong message of support for the inclusion of social sciences as the IPY "sixth theme." There were also extensive discussions on implementation issues, including appropriate mechanisms for the proposal submission process and defining the roles of the Joint Committee, the International Programme Office and the National Committees. The Forum participants were not supportive of the previously suggested concept of "core" and "associated" projects in IPY and they argued that the focus should instead be on identifying ideas. It became clear that the idea of the "IPY flagship projects" was not liked by most of IPY scientists though the funding agency representatives saw some merit.

Fig. 1.3-9. Planning group members at their final meeting in Paris, September 2004 (L to R) Front Row: Robin Bell, Chris Rapley; 2nd Row: Vladimir Kotlyakov, Tim Moffat, Gino Casassa, Hanne Petersen; 3rd Row: Michael Kuhn, Olav Orheim, Ian Allison, Zhang Zhanhai; 4th Row: Vladimir Ryabinin, Robert Bindschadler, Gérard Duhaime.

Two other main topics raised were how to involve young scientists and establish a legacy of the next generation of polar researchers, and whether there were opportunities to involve commercial organizations in IPY.

The fourth and final meeting of the IPY Planning Group (PG-4) was held at ICSU headquarters in Paris on 15–16 September 2004[18] (Fig. 1.3-9). Rapley reported on the search for the members of the ICSU/WMO Joint Committee (JC) and on defining the criteria for its membership (including the selection of the two Co-Chairs)[19]. Invitations for the hosting of an International Programme Office (IPO) in 2005–2009 had been distributed and three proposals were received from U.K., Finland and India, though only U.K. and Finland were eventually considered. It was agreed for ICSU and WMO to announce a new call for "Expressions of Intent" (EoI) for future IPY projects on 1 October 2004, using the text provided by the PG (*Chapter 1.5*). These were supposed to replace the largely informal submission of ideas for IPY activities that had occurred up till now with a standard pro-forma and a follow-up evaluation.

Data Management and Education and Outreach policies for IPY were discussed as a part of the overall organizational framework to move IPY forward to implementation. The inclusion of the AC and ATCM in the JC was considered and, while there were some concerns about "politicizing" IPY, the consensus was that both entities should be involved. It was also reported at the meeting that the UN Resolution on IPY was on track to be presented at the October 2004 meeting of the UN General Assembly, promoted by China, though eventually it did not happen.

In relation to the Expressions of Intent, it was agreed that neither the PG nor the future JC should be viewed as peer review 'vetting' bodies, and that the scientific quality of the IPY proposals should be assessed through already established evaluation procedures at each funding agency. Instead, the JC would match proposals against IPY-specific criteria. Specifically, the future JC would be expected to develop a standard template and a set of mandatory criteria that each IPY project must demonstrate (e.g. it should be international, occur during the Polar Year, have plans for project management and data management, etc.). It was agreed that as the PG would cease to exist by October 2004, the IPO would oversee the EoI submission process during the transitional period between PG and JC. A process and timetable was developed by which proposals should be submitted and selected for endorsement as part of IPY. Initial EoIs would be required by 14 January 2005.

The remainder of the PG meeting was devoted to working through the draft 'IPY Framework' document (the expanded version of the Outline Science Plan) that was substantially revised in two intensive days before PG-4 concluded. A number of issues were identified that could not be addressed by the PG and so were set aside for later consideration by the JC in 2005. These included management topics such as establishment of the IPY Subcommittees on Data, Observations, and Education and Outreach, issues such as the IPY logo (Box 3) and IPY commemorative stamps.

PG Completes Its Work: October 2004

The ICSU Planning Group completed its task in October 2004 by producing a major document summarizing its vision of the future Polar Year and the results of the planning process.[20] It was posted online by 1 November 2004 and soon became available as a slim volume of 38 pages published by ICSU (Rapley, et al., 2004). Entitled *"A Framework for the International Polar Year 2007–2008"* (Fig. 1.3-21), the document outlined the PG's Science and Implementation recommendations. It also included recommendations for addressing the important education, outreach and communication issues, and considered the critical issue of data management in IPY projects. The document, which had been developed in close consultation with the international polar science community, provided a definitive statement of how the IPY planning process had progressed and where it then stood. The document also outlined the PG's vision of how that process should proceed now that responsibility was being passed to the JC.

On 20 November 2004, the ICSU Executive Board at its meeting in Trieste, Italy approved the *IPY Framework* Document and expressed its deep appreciation to the members of the PG. Rapley gave the final overview of the PG activities to the ICSU Board (Fig. 1.3-22) that responded with a round of applause. The ICSU Board viewed the IPY planning process and the PG report as a benchmark of good practice.

With the Outline Science Plan for IPY now

Box 3 The development of an IPY 2007–2008 Logo

Robert Bindschadler

IPY-1 in 1882–1883 and IPY-2 in 1932–1933 had no logos or special letterheads of their own, but IGY 1957–1958 had its iconic logo of the planet with the orbiting satellite (Fig. 1.3-10) that was featured on its many publications, posters and public materials, and even instruments used during the IGY observational period (Odinshaw, 1956). So the need for IPY 2007–2008 to have a special logo was considered since the very early days of the planning process (Chapter 1.2).

The first concepts I recall were offered by Chris Elfring and were produced at the U.S. National Academy of Sciences (Fig. 1.3-11). The proposed graphics showed two hemispheres in a couple of different views and arrangements, but basically the same (Fig. 1.3-12). The reaction was "Nice," but no "wow, that's it!", rather "(pause) these are a good beginning". I commented that people (or a person) needed to be somehow incorporated into the logo, otherwise it could just as well be IPY of some other planet.

I think it was at that meeting when we were given ICSU commemorative mugs. As we struggled with the idea how to match the human component and the concept of both poles, Robin Bell grabbed the marker and sketched a rough human figure on her mug (Fig. 1.3-13) and coloured in the poles. It was after that sketch that Chris Rapley began to talk about the Vitruvian Man sketch by Da Vinci projected over the globe.

At that meeting, I was charged with developing ideas for the IPY logo and to take the task to the NASA graphic artists at the Goddard Space Center. Back at Goddard, I met with two artists, James O'Leary and Katy Gammage. I showed them the Academy's samples (Fig. 1.3-11) and said we wanted people included. Their initial concepts were varied, but fell into two primary categories: one that tried to show the field activities of polar research (people in parkas, snowmobiles, tents, etc. Fig. 1.3-14) in a single complex scene and another, using a collage of images of the Arctic (Fig. 1.3-15). A second suite of concepts was more polished and I shared these with the PG members, but the response was mute and hardly anything came back until the next PG meeting.

At PG-3 in April 2004, we discussed logos only quickly at the end of the meeting. The field scene versions had no support. The collage version was more popular, but I remember Rapley's comment that it was too complex to work as a simple graphic. He wanted a simpler design with fewer shades of gray so that it would work on the letterhead and could be "faxed well." Nonetheless, the 'collage' image was put on the cover of the IPY 'Outline Science Plan' produced later that month with the assistance of Ralph Percival, local graphic person at the British Antarctic Survey (Fig. 1.3-16) and also onto various IPY PowerPoint presentations later in 2004, though with white background. I also used it in my briefings about IPY since spring 2004 and I discovered that the face of the Inuit child in the logo usually elicited audience connection. The quality to hold attention and prompt questions about IPY was a remarkable and very compelling characteristic of this design.

After that, most of the iterations of the logo design revolved around the collage. Some new images were added and the pictures were rearranged; positioned in a wide strip for a banner or more square for a slide background (Fig. 1.3-16), but there was no more substantive discussion of the logo in the PG. The idea of a logo competition wherein entries would be received was popular, but we needed a logo right away and recognized that the time would not allow a competitive process.

Fig. 1.3-10. IGY 1957–1958 logo, the ultimate source of imagination for IPY 2007–2008 planners.

Fig. 1.3-11. Early version of the IPY 2007–2008 logo produced at the U.S. National Academy of Sciences (NAS, September–November 2003).

Fig. 1.3-12. NAS 'two hemisphere' design discussed at the PG-2 meeting (December 2003).

Fig. 1.3-13. Sketch of human figure over the globe backdrop produced by Robin Bell (December 2003).

Fig. 1.3-14. NASA draft logo based upon the 'field activities' concept (winter 2004).

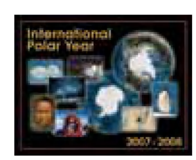


Fig. 1.3-15. 'Collage' version of the IPY imagery developed by the NASA graphic artists in winter 2004.

By the last PG meeting in September 2004, the collage logo was the closest we had come to, but it was not granted any official status yet. When Cynan Ellis-Evans set up the interim IPY Programme Office, he employed the collage logo in the design of the web page with a blue background. This worked very well (Fig. 1.3-16). In the meantime Odd Rogne suggested a logo (I first saw it at the IPY session at EGU in April 2004) that had as a central element a "stepped line" – flat, then steeply up, finishing with a gradually upward incline and an arrow-tip (Fig. 1.3-17) intended to signify the rapid increase in knowledge (and funding?) that we hoped would characterize IPY. It never made it past the sketch stage, but it certainly introduced the idea of a diagonal element with an arrow tip. The other design is what Chris Rapley had advocated since 2003: a symbolic human figure imposed over the globe. In a stretch of desperation and drawing on the example of the IGY logo, he added an arrow (the 'Swoosh') to replace the orbiting satellite track of IGY and to indicate the energy of IPY and its global scope, teleconnections, etc. (Fig. 1.3-18). It soon became the de-facto official logo, particularly after Chris used it in several of his high-level presentations on IPY towards the end of 2004.

The "happy" in the ending to this story came from Cynan. In October or November 2004, he made the best of any residual logo competition by merging the two logos in a variety of ways including a montage that even restored the twin polar hemispheres of the original NAS design and a very attractive header/footer strip (Fig. 1.3-19). Its strongest side was that it showed both polar regions (whereas the IGY logo only featured one). Eventually, we left the final selection up to the incoming Joint Committee; a number of individual projects and other IPY organizations took different versions (and portions) of the logo and manipulated it further, as they saw fit. Considering the mountain of other very important business through which the IPY planning in 2003–2004 had to plow, the somewhat rocky path to the IPY logo is an interesting lesson in group dynamics, namely, how we can accomplish big things while disagreeing over what seem like a minor detail.

At its first meeting in March 2005, the Joint Committee reviewed various versions of the logo and approved the globe with a human figure and a 'swoosh' version with a white font on black cover (Fig. 1.3-20) as the official logo of IPY 2007–2008. Various combinations of the original logo and banner design in colour, black-and-white and web format continued to be used throughout IPY by certain projects, organizations and national committees (see http://classic.ipy.org; www.us-ipy.org/, http://ipyrus.aari.ru/; www.international-polar-year.de/Startseite.4+M52087573ab0.0.html; http://international.usgs.gov/ipy/default.shtml).

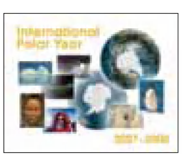


Fig. 1.3-16. The revised 'collage' version of the IPY images used for the 'Outline Science Plan,' the IPY Framework document, and various presentations in April-October 2004.

Fig. 1.3-17. Sketch with a diagonal arrow developed by Odd Rogne (April 2004).

Fig. 1.3-18. Combined version of IPY imagery used by Chris Rapley in his presentation to the ICSU Board (November 2004).

Fig. 1.3-19. Combination of the 'globe' logo and a blue banner strip develop by Cynan Ellis-Evans for the initial IPY website (http://classic.ipy.org).

Fig. 1.3-20. Final IPY 2007–2008 approved by the Joint Committee (March 2005).

published, the PG fulfilled its Terms of Reference and was terminated. It was replaced by the JC whose first planned meeting was in early 2005 (*Chapter 1.5*). The 19-member JC was to be led by two Co-Chairs, Ian Allison (Australia) and Michel Béland (Canada). A number of former PG members were appointed (Allison, Bell, Rapley, Kotlyakov, Sarukhanian and Goldfarb), but overall, this was a new group that needed to develop its own methods for continuing IPY planning. Cynan Ellis-Evans, the former secretary of the PG, agreed to serve as the Interim Director of the IPY Programme Office, to be hosted at the British Antarctic Survey in Cambridge, U.K. (where it eventually stayed for the rest of IPY 2007–2008). All these transitions became official and were advertised to the polar science community in November 2004 (http://classic.ipy.org/news/story.php?id=118), together with the new call for EoIs issued on 5 November 2004 by Rosswall and Jarraud in six languages (English, French, Spanish, Russian, Arabic and Chinese – Fig. 1.3-23) on behalf of two sponsoring organizations and addressed to ICSU International Scientific Unions and National Members, Permanent Representatives of WMO Members, IPY National Committees and Contact Points.

From PG to JC: October 2004–January 2005

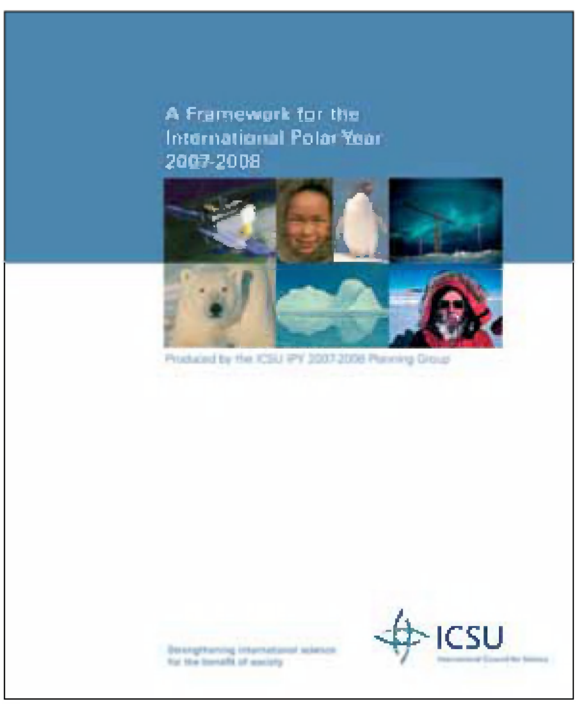


Fig. 1.3-21 (left). Cover page of the IPY 'Framework' Document (November 2004).

Fig. 1.3-22 (right). Cover slide of Rapley's final presentation to the ICSU Executive Board in Trieste (20 November 2004) featuring the new logo and graphics of IPY 2007 –2008.

With the Planning Group disbanded after PG-4 and the newly established Joint Committee not scheduled to meet until early 2005, the momentum of the IPY process was potentially threatened. Ellis-Evans (as the Interim Director of the IPY Programme Office) had taken a lead in coordinating the international calls for IPY ideas, establishing an accessible ideas database, and building and maintaining the first IPY website. Rapley and Ellis-Evans had also prepared the successful bids to ICSU/WMO for U.K. to host the IPO and to U.K. Natural Environment Research Council (NERC) for five years of funding to support the IPO at the British Antarctic Survey. The NERC funding was not available until January 2005; consequently, IPO activities were almost entirely provided from BAS resources until then. It is worth noting that during late 2004 there was still little secured financial support to IPY from national funding organizations (with the notable exception of the commitment in November 2004 of £5M by NERC), though within a few months several other nations subsequently announced their support.

The publication of the *Framework* document engendered widespread enthusiasm, but also raised a number of practical questions as the community began to develop potential activities for IPY within the broad structure proposed by the PG. Within the limitations of a skeleton IPO and in the absence of an authoritative body to represent the IPY science until the JC began its work, the major priorities for the "interregnum" phase were to keep the IPY community informed, maintain the international profile of IPY wherever possible through interactions with international and national organizations, and to coordinate the submission of the EoIs that would provide the foundations for the eventual IPY science and education/outreach program.

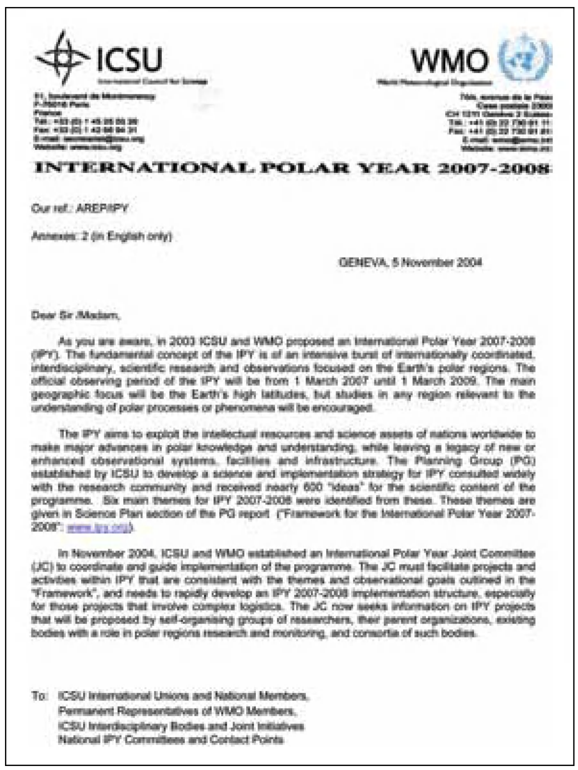
During this transitional period of late 2004, the Interim Director and, to a lesser extent, former PG members and the new JC Co-Chairs, were actively promoting IPY at international events. These events included the EGU and AGU meetings and, importantly, the Arctic Climate Impact Assessment (ACIA) Conference and Arctic Council Ministerial Meeting, both held in Iceland in November 2004. At those meetings, IPY was promoted in several presentations and panel discussions, against a background of publication of the ACIA report and the Reykjavik Declaration in which Arctic Ministers recognized IPY as a unique opportunity to stimulate Arctic activities and raise awareness and visibility of the Arctic region (*Chapter 1.4*).

Summary: Putting IPY 2007–2008 Structure in Place

By November 2004, the IPY structure, which would shape its operation for the next five years, had started to solidify. The new steering body—the Joint Committee of 19 members with two Co-Chairs—was established, an official call for 'Expressions of Intent' (pre-proposals) was issued with the deadline of 14 January 2005 and a new hub in the form of the International Programme Office (with an active IPY website) was up and running. Many IPY National Committees were also established and were coordinating with the International Programme Office as the emerging lynch pin in the international IPY network. Last but not least, IPY already had a dedicated constituency and a pool of more than 350 research 'ideas' submitted by scientists from many nations and covering all fields of prospective IPY research: from geosciences and space studies to life sciences, social sciences and the humanities. In the next few months, the number of such research proposals would increase to more than 800 (*Chapter 1.5*) demonstrating the strong support for IPY across broad swath of the polar research community.

By all accounts, the first planning phase for IPY was remarkably successful. In barely 15 months, between July 2003 and October 2004, competitive and sometimes contentious ground percolating with many conflicting ideas was transformed into a fairly orderly field, with common goals, a clearly articulated program and a dedicated mobilized constituency of many hundred if not a few thousand activists: scientists, agency people, science managers, educators and interested media specialists. Several strategic decisions had been made, including the smooth merger of the ICSU and WMO planning for IPY and the organization of the IPY program along trans-disciplinary science themes ('Status,' 'Change,' 'Global Linkages,' 'New Frontiers,' 'Vantage Points' and 'Human Connection') rather than filling a matrix of projects along the established 'disciplines'.

Another early achievement was the abandonment of the 'flagships' project concept which gave a clear advantage to large and established research programs often dependent upon multi-year governmental funding. The latter decision, in particular, helped democratize the IPY submission process and made it open to science ventures and teams of any size and from every nation. This was reflected in the submission of over a thousand Expressions of Intent for future IPY activities by January 2005 (*Chapter 1.5*). The early IPY planners also navigated successfully through the


ICSU
WMO

INTERNATIONAL POLAR YEAR 2007-2008

Our ref.: AREP/IPY

Annexes: 2 (in English only)

GENEVA, 5 November 2004

Dear Sir /Madam,

As you are aware, in 2003 ICSU and WMO proposed an International Polar Year 2007-2008 (IPY). The fundamental concept of the IPY is of an intensive burst of internationally coordinated, interdisciplinary, scientific research and observations focused on the Earth's polar regions. The official observing period of the IPY will be from 1 March 2007 until 1 March 2009. The main geographic focus will be the Earth's high latitudes, but studies in any region relevant to the understanding of polar processes or phenomena will be encouraged.

The IPY aims to exploit the intellectual resources and science assets of nations worldwide to make major advances in polar knowledge and understanding, while leaving a legacy of new or enhanced observational systems, facilities and infrastructure. The Planning Group (PG) established by ICSU to develop a science and implementation strategy for IPY consulted widely with the research community and received nearly 600 "ideas" for the scientific content of the programme. Six main themes for IPY 2007-2008 were identified from these. These themes are given in Science Plan section of the PG report ("Framework for the International Polar Year 2007-2008": www.ipy.org).

In November 2004, ICSU and WMO established an International Polar Year Joint Committee (JC) to coordinate and guide implementation of the programme. The JC must facilitate projects and activities within IPY that are consistent with the themes and observational goals outlined in the "Framework", and needs to rapidly develop an IPY 2007-2008 implementation structure, especially for those projects that involve complex logistics. The JC now seeks information on IPY projects that will be proposed by self-organising groups of researchers, their parent organizations, existing bodies with a role in polar regions research and monitoring, and consortia of such bodies.

To: ICSU International Unions and National Members,
Permanent Representatives of WMO Members,
ICSU Interdisciplinary Bodies and Joint Initiatives
National IPY Committees and Contact Points

Fig. 1.3-23. Call for IPY 'Expressions of Intent' by Thomas Rosswall and Michel Jarraud, 5 November 2004 (English version).

differences in the ICSU (non-governmental scientific bodies) and WMO (governmental organizations) management processes. They recognized that the balance of two approaches would be powerful and beneficial to the success of IPY, but they insisted that rules of procedure should be kept light and open to a broad community at its many professional meetings. They also argued that the full spectrum of disciplines, both in physical and social sciences, needed to be included and that many more organizations, beyond WMO, IOC and ICSU should be actively involved (*Chapter 1.4*). At the end, the PG and both of the sponsoring organizations, ICSU and WMO, succeeded in building a viable system that endured through the following years of the preparation and implementation of IPY (*Chapter 1.5*). Future IPY historians will definitely unravel a more complex narrative on how that has been achieved.

Last but not least, the PG team successfully negotiated the entry of social scientists and indigenous organizations into IPY by creating an explicit 'theme' to accommodate their highly specialized research. That latter development was particularly welcomed in the timely endorsement of IPY by the Arctic Council Meeting of Foreign Ministers in Reykjavik in October 2004 (*Chapter 1.4*), which became the first expression of support for the IPY made at the high political level.

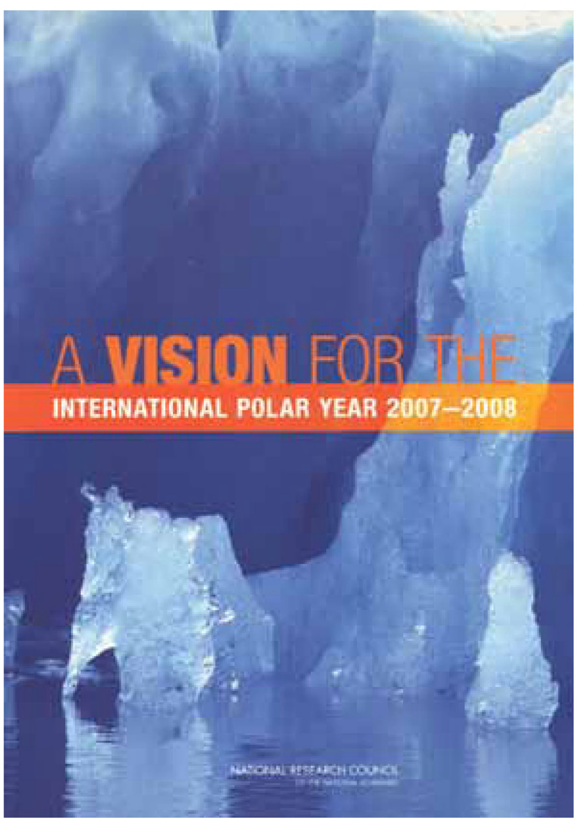


Fig. 1.3-24. "A Vision for the International Polar Year 2007–2008" Report by the U.S. National Committee (July 2004).

Nonetheless, certain shortcomings in the system created during the early planning of IPY 2007–2008 were also obvious, particularly in comparison to the similar structures in IGY and in earlier polar years (*Chapter 1.1*). Both the ICSU PG and its most active national partners, like the U.S. National Committee for IPY that released its own major document, *A Vision for the International Polar Year 2007–2008* in August 2004 (NRC, 2004 – Fig. 1.3-24), were teams with a limited lifespan and a strictly defined mission, namely to develop a scholarly justification and a preliminary outline for IPY. Both the ICSU PG and the original U.S. IPY Committee were discontinued in late 2004 and were replaced by successor groups, with but a limited overlap in membership and expertise with their predecessors. In each case, there was an obvious gap in the accumulated momentum that did not happen in earlier ventures, in which the same steering bodies, like CSAGI in IGY, the International Polar Commission in IPY-1, and the Commission for the Polar Year in IPY-2, served continuously for the duration of the planning and implementation process and even for years after its completion (*Chapter 1.1*). Also, with its limited lifespan, the PG was never expected to generate funding or to lobby the relevant international or national groups and agencies in support of IPY, which was, again, an important task performed by similar teams in the previous polar years and what CSAGI did so successfully on behalf of IGY (*Chapter 1.1*). As a result, the early planning phase under PG neither yielded any funds to be used for further IPY operations (as happened in IGY 1957–1958) nor created any working funding mechanism for its successor. The financial support for IPY and for many activities to be performed by the JC and several associated bodies thus remained one of the thorniest issues for ICSU and WMO throughout the IPY implementation phase of 2005–2009.

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WMO, 2003. Third International Polar Year (2007–2008). Background document, p11, fig 14.

Notes

[1] PG Chair and Vice Chair Chris Rapley and Robin Bell; members Bob Bindschadler, Vladimir Kotlyakov, Olav Orheim and Hanne Peterson; and organizational liaisons Michael Kuhn (IUGG), Henk Schalke (IUGS) and Carthage Smith (ICSU). Chris Elfring provided coordination support.

[2] The Earth Observation Summit (31 July–1 August 2003) was organized by the U.S. State Department and the National Oceanic and Atmospheric Administration (NOAA) to promote a new U.S.-led initiative in global environmental observation. The Summit endorsed the Declaration on Global Observations and established an intergovernmental Group on Earth Observations (GEO) to coordinate and prepare a 10-year implementation plan for what became known as the Global Earth Observation System of Systems (GEOSS) www.climatescience.gov/Library/observation-summit2003.htm.

[3] To the nine members nominated in June 2003 (Rapley, Bell, Allison, Bindshadler, Chown, Duhaime, Kotlyakov, Orheim, and Zhang), five more were added in September 2003: Gino Casassa, Prem Chand Pandey, Hanne K. Petersen, Michael Kuhn and Henk Schalke – Box 2. The two latter provided liaison to IUGG and IUGS, respectively.

[4] Following that meeting, Sarukhanian was appointed WMO Secretary-General 'special advisor' on IPY, in charge of the WMO planning. He held this key position for almost seven years ensuring continuity in WMO support to IPY.

[5] By Mary Albert, Karl Erb, Ghassam Asrat, John Calder, John Behrendt, Fae Krosmo, Kendrick Taylor, Miles McPhee, Paul Mayewski, Joseph Davila, James Morison, Bernard Coakley and others.

[6] Chris Rapley (PG Chair), Robin Bell (Vice-Chair), Ian Allison, Robert Bindschadler, Gino Casassa, Gérard Duhaime, Vladimir Kotlyakov, Olav Orheim, Hanne Petersen, Zhanhai Zhang, Michael Kuhn (IUGG), Vladimir Ryabinin (WCRP), Thomas Rosswall (ICSU), Leah Goldfarb (ICSU), Daniel Rodary (ICSU), Tim Moffat (Secretary) and Wolfgang Eder (UNESCO) standing in for Henk Schalke for IUGS item. Apologies: Steven Chown, Prem Pandey, Ed Sarukhanian (WMO) and Henk Schalke (IUGS).

[7] Qin Dahe, Director of the Chinese Meteorological Administration, was proposed to chair the group made of several disciplinary experts associated with WMO (Barry Goodison, Oystein Hov, Arni Snorrason, Stephen Pendlebury, Ivan Frolov, Geerd Hoffman, Alex Sterin and others).

[8] See Davila et al., 2006; 2009; Thompson et al., 2009. The full chronology of IHY, from 2002 till 2009, and the IHY Newsletter archive (2003–2009) are available at http://ihy2007.org/newsroom/newsroom.shtml. See most recent updates on the IHY at www.ihy2007.org/.

[9] In September 2005, the representatives of four 'international science years' scheduled to take place during the period 2007–2008—the IHY (J. Davila), IPY (D. Carlson), eGY (D. Baker) and IYPE (E. de Mulder)—signed a formal declaration pledging "vigorous and open communication, as well as joint activities in areas of common scientific interest, as well as in education, outreach and capacity building" *(Putting the "I" in IHY, 2006).*

[10] Reid Hall (4 Rue de Chevreuse, Paris, France) is a complex of academic facilities owned and operated by Columbia University (U.S.A.) that is located in the St. Germain des Prés district of Paris. It houses the Columbia University Institute for Scholars at Reid Hall in addition to various graduate and undergraduate divisions of over a dozen American universities. For over a century, Reid Hall has served as a link between the French and American academic communities.

[11] See minutes at http://classic.ipy.org/international/documents/.

[12] Participants: Chris Rapley, Robin Bell, Ian Allison, Robert Bindschadler, Gino Casassa, Gérard Duhaime, Chris Elfring, Vladimir Kotlyakov, Olav Orheim, Prem Pandey, Hanne Petersen, Michael Kuhn (IUGG), Werner Janoschek (IUGS), Ed Sarukhanian (WMO), Leah Goldfarb (ICSU), Elisabeth Merle (ICSU), Cynan Ellis-Evans (BAS) and Tim Moffat (BAS, Secretary).

[13] Presentations by Chris Rapley on the IPY Outline Science Plan; Vladimir Ryabinin (WCRP), Patrick Webber (IASC), Jerry Brown (IPA), Robert Dickson (ASOB), Mary Albert (U.S. IPY activities), and Jacek Jania (Polish preparations for IPY). Most of these presentations can be accessed at http://classic.ipy.org/international/presentations (as of February 25, 2010).

[14] Presentations by Robin Bell on the IPY Science Plan; Ed Sarukhanian on WMO and IPY; Odd Rogne on IASC and IPY; Roland Schlich on SCAR and IPY; Heinz Miller on IPY and Cryospheric studies, Stephanie Pfirman on Education and Outreach in IPY; Alan Rodger on eGY; and Andy Breen on IHY, see http://classic.ipy.org/international/presentations.

[15] The IPY presentations were delivered by Chris Rapley, Robin Bell, Ed Sarukhanian, Colin Summerhayes (on SCAR and IPY), Louwrens Hacquebord (IASC and IPY), Hanne Petersen (Education and Outreach in IPY) and Michael Kuhn (IGY+50), see http://classic.ipy.org/international/presentations.

[16] This effort to put social sciences on the IPY program was also strengthened by passionate calls from Louwrens Hacquebord and Aant Elzinga, from IASC and SCAR's Action Group on history of Antarctic research, respectively, at the SCAR meeting in Bremen, who argued that IPY 2007–2008 should be called the 'Year of the Human Dimension' (*Chapter 1.4*).

[17] Originally ICSU-WMO considered one person as the leader of the future IPY Joint Committee. Ian Allison was approached during the SCAR Open Science Conference (July 2004) and asked if he would be prepared to chair the JC. In the following discussion, the idea of two Co-Chairs, one appointed by WMO and one by ICSU was proposed. It was enthusiastically supported by both organizations.

[18] C. Rapley, R. Bell, I. Allison, R. Bindschadler, G. Casassa, V. Kotlyakov, O. Orheim, H. Petersen, V. Ryabanin, L. Goldfarb, P. Pandey, E. Sarukhanian, D. Rodary, T. Moffatt (Secretary), J-P. Cadet (representing IUGS), C. Ellis-Evans (BAS) and C. Elfring (NAS). Apologies from Chown, Kuhn, Zhang, Janoschek and Schalke (IUGS).

[19] The selection of the future JC members, in fact, was going quietly on the sidelines of the PG-4 meeting, by a small group made of Rosswall, Rapley, Bell, Goldfarb and Sarukhanian in charge of the process.

[20] The document was finalized by Cynan Ellis-Evans (on behalf of the PG) and by Leah Goldfarb (for ICSU) before submission for publication at the end of October 2004.

1.4. Planning for IPY: A Collaborative Venture

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The purpose of this section is to demonstrate and capture the broader scope of community involvement in the initiation and early planning for IPY 2007–2008 in the years prior to the beginning of the 'operational' phase of IPY and the establishment of the IPY Joint Committee in 2005 (*Chapter 1.5*). The short sections below provide a more granular look at the truly bottom-up development of IPY that can be captured in *Chapters 1.2* and *1.3*. It offers perspectives on the contribution of *ten* major international polar agencies and organizations to the IPY process, in addition to ICSU and WMO. The role of each organization in IPY initiation and planning is described up to late 2004–early 2005; the information relevant to the later period is presented in other sections. Also, we decided to concentrate only on the role of *international* organizations, since the stories of many national groups and agencies involved in IPY 2007–2008 are to be covered in the respective national IPY reports that are currently under preparation.

Ten sections below are placed according to a rough chronological order of each organization's entry in the IPY process, starting with eight science organizations and followed by two major inter-governmental bodies, the Arctic Council and the Antarctic Treaty Consultative Meeting. This account of the early IPY 2007–2008 history is far from being complete, as many more agencies and groups were instrumental in the preparation of IPY. We hope that the short summaries of the activities of the lead international champions of IPY presented here will encourage other organizations to develop the accounts of their respective contributions to IPY for subsequent publications.

International Arctic Science Committee (IASC)

Volker Rachold and Odd Rogne

The first informal e-mail correspondence about a possibility of the new 'International Polar Year' between Odd Rogne (then Executive Secretary of IASC) and a few individual early champions started in the late 1990s. A key correspondent was Leonard Johnson (former division head at the U.S. Office of Naval Research – *Chapter 1.2*). During those early exchanges, Rogne argued that any initiative for a new IPY had to be taken by international organizations and required a forward-looking science vision. The IASC Executive Committee was made aware of the correspondence, but did not decide to take any further actions.

The possibility of a new IPY was briefly discussed during the Arctic Science Summit Week (ASSW) in April 2001 by the European Polar Board (EPB) and by the Forum of Arctic Research Operators (FARO). The IASC Executive Committee did not decide on any actions related to IPY, but had agreed to test the idea within FARO. Overall, a new IPY was seen as a major logistical challenge that would require complex and, perhaps, painful re-allocation of funding. Nonetheless, IPY was also viewed as a tremendous opportunity, for which a compelling science vision had to be developed.

An important step towards IPY planning was taken at the Symposium, *Perspectives of Modern Polar Research* in Bad Dürkheim (Germany), 24-26 June, 2001 (*Chapter 1.2*), on which IASC was informed. In November 2001, the IASC Executive Committee discussed the development of ideas for IPY and noted that a major project in the Arctic Ocean as a prospective theme for IPY had been suggested (Johnson, 2001). Nonetheless, it was again agreed that a new IPY should be major multi-disciplinary initiative and that the push for a new venture should come from many fields; hence no actions were taken.

Throughout 2001–2002, major IASC activities were focused on the development of the *Arctic Climate Impact Assessment* report (ACIA, 2005) and on the planning for the second International Conference on Arctic Research Planning (ICARP II) scheduled for 2005. At that stage, it was unlikely that a new IPY would become a reality. The IPY concept was discussed by the IASC Executive Committee during ASSW in April 2002, but, again, IASC did not take any steps. Nonetheless, several developments in the ACIA and ICARP II process in 2001–2002, such as broadening the disciplinary scope of the two ventures and more active engagement of Arctic indigenous people and social scientists, were later instrumental to the IPY planning process.

At its February 2003 meeting, the IASC Executive Committee was informed that a special meeting of the U.S. Polar Research Board in October 2002 had been devoted to the concept of a new IPY 2007–2008 and that several other related activities were taking place (*Chapter 1.2*). The Executive Committee agreed that there was a need for inspiring ideas along the lines of "grand scientific challenges". IASC Council and Regional Board members were encouraged to put forward such ideas or proposals for IPY for further consideration by IASC.

In April 2003, Chris Rapley gave a presentation on the IPY planning by ICSU at the ASSW in Kiruna, Sweden. This time, the attitude turned 180 degrees and the debate revealed rising enthusiasm among the IASC members and strong support from the IASC Council. The IASC Executive Committee was tasked to consider the role that IASC could play in further development of IPY and certain seed funding was set aside to stimulate IPY planning. It was noted that the ICARP II multi-disciplinary approach in developing long-term science plans would be beneficial to IPY. Consequently, some elements of ICARP II Science Plans were directly translated into IPY Projects. Chris Elfring, Director of the U.S. Polar Research Board, was nominated to serve as the IASC point of contact for ICSU and its IPY Planning Group.

As SCAR had succeeded in promoting IPY to the Antarctic Treaty Consultative Meeting in June 2003 (*Chapter 1.2* and below), it was logical for IASC to approach the Arctic Council for the similar high-level governmental support. The proposal sent to the ATCM was slightly changed for the Arctic by adding "people living in the Arctic" and "next generation of polar scientists". At its meeting in September 2003, the Arctic Council Senior Arctic Officials had agreed to support IPY (see below). The IASC Executive Committee had a considerable discussion about IPY at its November 2003 meeting and agreed that a clear supportive statement should be sent to the ICSU Planning Group, together with information about actions taken by IASC. The Committee also summarized some of IASC's concerns related to IPY, namely that the Planning Group had to clarify its coordinating role in the process and that some of the ideas for IPY currently in circulation were merely upgrades of ongoing research. According to the Committee, the emerging vision for IPY was somewhat restricted to traditional science thinking. *"Create history – not repeat it"* should be the slogan for IPY 2007–2008 planning, very much in line with the previous IPYs that were propelled by innovative thinking (IASC, 2003). Odd Rogne and Patrick Webber (then President of IASC) were mandated to take actions to expand the IASC role in IPY.

By early 2004, IPY became one of the key issues on IASC's agenda. The IASC Council, at its meeting during the ASSW 2004 in Reykjavik in April 2004 reviewed the initial Outline Science Plan for IPY prepared by the ICSU Planning Group (*Chapter 1.3*). It noted that the 'Human Dimension' component of the proposed science plan needed considerable improvement. Themes adopted for ICARP II were recommended as possible input. Also, the Council argued for a better balance in IPY between the two polar regions, since the composition of the Planning Group was tilted towards Antarctica. Political support for IPY was growing at both international (AC, ATCM) and national level, thus it was important to expand this political base for IPY 2007–2008. *Opening the Arctic for Science* was a prospective vision for the IPY mission advanced by the IASC Council. Lastly, as national IPY Committees had been established by that time in several countries, the role of IASC and other similar international organizations in IPY implementation should eventually increase (IASC, 2004).

At the IASC Executive Committee Meeting in

November 2004, it was agreed that the standing IASC Executive Secretary should represent IASC on the IPY Joint Committee. Subsequently, IASC representatives took active part in all meetings of the Joint Committee and in the implementation of IPY during 2005–2010.

Scientific Committee on Antarctic Research (SCAR)

Colin Summerhayes

The Scientific Committee on Antarctic Research (SCAR) was formed by ICSU in 1958 to continue the work on coordinating Antarctic research that had begun during the International Geophysical Year of 1957–1958. SCAR's mission is *"to be the leading independent organization for facilitating and coordinating Antarctic research, and for identifying issues emerging from greater scientific understanding of the region that should be brought to the attention of policy makers".* The membership of SCAR comprises the National Committees or research councils of 36 nations that are active in Antarctic research, and nine ICSU Scientific Unions.

The earliest record of SCAR involvement with IPY 2007–2008 is from the report of the SCAR meeting in Tokyo, 17-21 July, 2000, where Karl Erb (U.S.A.) told Delegates that the COMNAP XII Meeting held during the previous week had agreed "to prepare for recognition of the 50th Anniversary of the International Geophysical Year in 2007–2008". The following year (22 August, 2001), at the joint meeting of the SCAR and COMNAP Executive Committees in Amsterdam, there was a discussion on the prospective activities to celebrate the 50th Anniversary of the International Geophysical Year in 2007–2008 (*Chapter 1.2*).

At the 27th SCAR meeting, in Shanghai, on 22-26 July, 2002 (Fig.1.4-1), delegates were reminded that the year 2007–2008 would be the 50th Anniversary of IGY, and so was also an important anniversary for SCAR, which had been formed in 1958. Delegates were asked to consider what plans SCAR had to celebrate or commemorate this anniversary. Heinz Miller (AWI) gave a presentation on a proposal to investigate the Ice Divide of Eastern Antarctica (IDEA), which would involve a surface traverse of Eastern Antarctica over a four-year period (2007–2011), with a series of glaciological, geological, geophysical and climatological

Fig. 1.4-1. A group of the participants of the XXVII SCAR meeting (Shanghai, 22-26 July 2002) including several people who were later instrumental in the IPY development: first row - Chris Rapley (PG Chair, JC member and SCAR Vice President 2000-2004, later President, 2006-2008, fourth from left), Roland Schlich (SCAR Vice President 2000-2004, fifth from left), Bob Rutford (outgoing SCAR President, eighth from left); second row - Jerónimo López-Martínez (JC Co-Chair and SCAR Vice President 2002-2006, second from left), Prem Pandey (PG Member, sixth from left), Jörn Thiede (SCAR President 2002-2006 and EPB Chair, seventh from left), Olav Orheim (PG Member and organizer of the 2010 Oslo IPY Conference, eighth from left), Chris Elfring (Director, U.S. Polar Research Board, ninth from left); third row - Michael Stoddart (Leader of the CAML IPY Project, third from left); fourth row - Vladimir Kotlyakov (PG and JC Member, fifth from left), Ian Allison (PG Member and JC Co-Chair, seventh from left), Chuck Kennicutt (JC Member, and SCAR President 2008 onwards, eleventh from left), Heinz Miller (one of the first proposers of an IPY science project, fifteenth from left). Many other key members of the SCAR and IPY communities are also in the photograph.

(Photo: SCAR archives, courtesy Colin Summerhayes) studies. There was general support for the proposal and a small group was established (under the leadership of Heinz Miller) to consider how the plans could be best elaborated and advanced, and to prepare a report to the SCAR Executive Committee at its meeting in July 2003. Delegates supported the proposal for an IPY program to celebrate the 50th anniversary of IGY and it was suggested that enquiries should be made to ICSU and IUGG. Chris Rapley agreed to follow up this proposal.

Following SCAR's well-received presentation at the ATCM meeting in June 2003, the SCAR Executive Committee met in Brest, France on 11-15 July, 2003 (Fig.1.4-2). By that time, the ICSU Planning Group was already established, with Rapley as a Chair (*Chapter 1.3*). The Executive Committee welcomed this news, but noted that the lead time was short for such a major initiative and that much work needed to be done. The Committee recognized that IPY would also coincide with the 50th Anniversary of SCAR and agreed that the proposed role of SCAR in IPY should be emphasized. As part of SCAR participation in IPY, it was recommended that SCAR inform the ICSU PG and National Antarctic Committees that it recommends that research on subglacial environment should be a major component of the 'scientific frontiers' theme in IPY 2007–2008. Also, on 11 July, 2003 the SCAR and COMNAP Executive Committees met in Brest and discussed the current state of preparation for IPY.

At the SCAR meeting in Bremerhaven, Germany (21 January, 2004), following an update presentation by C. Rapley, the SCAR Executive Committee (EXCOM) strongly endorsed the active involvement of SCAR in the IPY planning process. By that time, there were ten members on the ICSU IPY Planning Group (PG), who were active in SCAR – C. Rapley, R. Bell, I. Allison, R. Bindschadler, G. Cassassa, S. Chown, V. Kotlyakov, O. Orheim, P. Pandey and Z. Zhang (in June 2004, Allison agreed to be the official SCAR representative on the PG). EXCOM tasked the new SCAR Executive Director (Colin Summerhayes) with representing SCAR interests in the IPY planning to maximize SCAR's role in implementing Antarctic components of IPY. As a first step, an IPY web page was created on the SCAR web site (Fig. 1.4-3); this was eventually linked to the main IPY website. Summerhayes attended the IPY Open Forum in Paris on 31 March, 2004 and made a presentation that explored the role that SCAR and its programs might play in making IPY a success. SCAR saw itself as a vehicle for enhancing achievement of the goals of IPY through providing ready access to Antarctic Treaty Parties and to the extensive network

Fig. 1.4-2. SCAR Executive Committee meeting in Brest, France, 11-15 July 2003. EX COM members (left to right): Bob Rutford, Roland Schlich, Chris Rapley, Peter Clarkson (SCAR Executive Director), Jörn Thiede, SCAR President, (Howard-Williams is not visible and Jerónimo López-Martínez is taking the photograph) with the heads of SCAR subsidiary bodies, Chuck Kennicutt, Alessandro Capra, and John Turner. (Photo, Jerónimo López-Martínez)

Fig. 1.4-3. SCAR IPY web page - www.scar.org/ipy/news/

of SCAR scientists, and through encouraging its program scientists to make their projects IPY activities. A presentation on the prospective role of SCAR in IPY was made at the EGU meeting in Nice, France in April 2004 by SCAR Vice President Roland Schlich.

Leaders of the five main SCAR science programs were asked in May 2004 to adapt the texts of their final program plans to indicate the extent to which these would make contributions to IPY. In May and June 2004, the SCAR Secretariat was engaged in planning IPY sessions for the forthcoming SCAR Open Science Conference (Bremen, 26-28 July, 2004). At that conference, C. Rapley gave a keynote address on "A New phase of exploration and understanding: planning for the IPY 2007/2008"; two more IPY-related keynotes followed (by K. Gohl and T. Wilson – *Chapter 1.2.*). A four-hour IPY Open Forum was held on 28 July, with talks from C. Rapley, R. Bell, E. Sarukhanian, C. Summerhayes, L. Haquebord, M. Kuhn, W. Janoschek and H. Petersen. There were also two open discussion sessions on the IPY, one chaired by SCAR (Allison) and one by COMNAP (Karlqvist).

In June 2004, in response to a paper drafted by Summerhayes, "Ideas for SCAR Involvement in the IPY," the EXCOM decided to form an *ad hoc* SCAR Advisory Committee on IPY, chaired by the Executive Director, with the tasks to monitor the IPY process as it unfolds and to advise SCAR how its contributions to IPY should develop; to work with COMNAP to realize IPY objectives for the Southern Hemisphere; and to ensure that IPY is represented in the SCAR Scientific Research Programs. The group met on 30 July, 2004 in Bremen and reviewed the draft IPY Implementation Plan. EXCOM tasked the Executive Director to prepare a paper on SCAR and IPY for the October 2004 Delegates meeting, and to represent SCAR at the IPY Open Meeting in Paris on 13-14 September, 2004. In parallel with SCAR's formation of an internal IPY group, in June 2004 COMNAP formed its own Coordinating Group for IPY preparations (the IPY CG), chaired by Karlqvist.

On 25 August 2004, SCAR presented two documents for consideration by the IPY Planning Group at its PG-4 meeting in September in Paris, "SCAR Comments on the IPY 2007–2008" and "Recommendations on data management for the International Polar Year 2007–2008" (prepared by the Joint SCAR-COMNAP Committee on Antarctic Data Management, JCADM). The JCADM paper advised ICSU to establish an IPY Data Advisory Group (IPY-DAG) to organize and oversee IPY data management. The SCAR Executive Director represented SCAR at the next Open Forum in Paris on 13–14 September, 2004, and made presentations on both the SCAR and JCADM proposals. The SCAR paper to the IPY Planning Group was subsequently modified into recommendations on SCAR's involvement in IPY, for consideration by the XXVIII SCAR Delegates meeting in Bremerhaven on 4-8 October, 2004 (SCAR XXVIII Working Paper 41). That report, which was approved by the Delegates, included several specific recommendations, such as, to focus attention on the subglacial highlands of the Gamburtsev Mountains (*Chapter 2.8*) and subglacial Antarctic lake environments (*Chapter 2.6*); develop an integrated Southern Ocean Observing System (SOOS) to understand the role of Antarctica in the Global Climate System (*Chapter 3.4*); make SCAR's Circum-Antarctic Census of Marine Life (CAML) a component to IPY (*Chapter 2.3*); support the Cryosphere Theme being developed by SCAR and WCRP to improve coordination and coverage of cryospheric observations (*Chapter 3.7*); and make a comprehensive data and information management strategy an integral and essential part of the IPY legacy (*Chapter 3.11*).

When the call for expressions of intent in IPY activities was distributed by ICSU and WMO in November 2004, SCAR ensured that all of its science groups considered submitting proposals for IPY activities. Independently, SCAR directly stimulated the development of two IPY programs – CASO (Climate of Antarctic and the Southern Ocean) and SASSI (Synoptic Antarctic Shelf-Slope Interactions Study). In addition, SCAR developed a design plan for a SOOS. SCAR also encouraged the cryosphere science community and WCRP to submit an expression of interest focused on the bipolar Cryosphere plan being developed jointly by SCAR, CliC and WCRP. This duly emerged as another IPY program.

Following ICSU invitation (8 August, 2004) to nominate an *ex officio* representative to the IPY Joint Committee, SCAR Executive Director (C. Summerhayes) attended all of the Joint Committee and Open Forum meetings during 2005–2010. SCAR's representation also provided an avenue through which COMNAP could communicate its ideas to the JC.

European Polar Board (EPB)

Jerónimo López-Martínez, Paul Egerton, Gérard Jugie, Chris Rapley and Jörn Thiede

The European Polar Board (EPB) was established in 1995 as the European Science Foundation's (ESF) expert committee on the polar research. The organization has expanded to the point that current EPB member countries manage and operate 25 Antarctic research stations, 22 Arctic research stations, 31 research vessels and 26 aircraft engaged in supporting science in both polar regions. More than two dozen European nations took part in IPY 2007–2008, between them investing around € 200 million in most of IPY 228 endorsed international projects (Egerton and Allen, 2007).

The EPB played an important catalytic role in the early stages of planning for IPY 2007–2008, first in conjunction with the approaching 50th anniversary of IGY 1957–1958. A series of EPB meetings in the early 2000s was instrumental to the development of IPY and its scientific program. A proposal to ICSU arguing for the launch of IPY in 2007 was sent on 6 February, 2003 on behalf of the EPB and the U.S. Polar Research Board in a letter signed by Chris Rapley (then EPB vice Chair) and Robin Bell (then U.S. Polar Research Board Chair).

The EPB promotion of IPY 2007–2008 in those early years was facilitated by the involvement of several key people, who were active among its membership and especially in the EPB executive committee. Those early champions of IPY had a vision and an influential position to promote IPY through the leading European polar research institutions, national and international polar organizations (e.g. G. Jugie, A. Karlqvist, O. Orheim, C. Rapley, C.A. Ricci and J. Thiede, among others).

The forthcoming celebration of the IGY anniversary was first included as a "long-term issue" in the minutes of the EPB Executive Committee meeting held in Paris on 15-16 December, 2000. It was decided to review the issue at the next EPB plenary meeting and to report on the plans for automatic measurements, Antarctic grand traverse, and other key challenging scientific ideas. The planning for the anniversary of IGY was also on the agenda of the EPB Plenary meeting held in Iqaluit, Nunavut, Canada on 25 April, 2001.

In April 2002, some general ideas about IPY were discussed once again at the EPB plenary meeting during the Arctic Science Summit Week (ASSW) in Groningen, The Netherlands. In late 2002, the U.S. Polar Research Board (PRB) agreed to join forces with the EPB in preparation for IPY. In January 2003, both organizations made plans for a joint IPY session and a town-hall meeting at the April 2003 EGU meeting in Nice (*Chapter 1.2*). Also, on 30 January, 2003, at the EPB Executive Committee meeting in Meudon Bellevue, Paris, Chris Rapley was asked to act as the EPB 'lead' on IPY and to collaborate with ICSU towards its realization. In March 2003, Rapley and Paul Egerton (EPB Executive Director) visited Washington, D.C. on a mission to discuss IPY organization with the U.S. partners (Chris Elfring and Robin Bell at PRB, Karl Erb at NSF, Ghassem Asrar at NASA, Lou Brown and Sara Bowden at AOSB, and others).

During late 2002 and early 2003, Paul Egerton intensified connections through the European Union (EU) offices with Russian polar scientists about prospective IPY collaboration. He attended a dedicated mission to Moscow in January 2003, with several EU officials, including S. Morris from the JRC and A. Ghazi, Director General Head of Unit Environment, to meet with Arthur Chilingarov and other Russian IPY planners (*Chapter 1.2*).

The EPB meeting during the ASSW in Kiruna, Sweden in April 2003 featured extensive discussion about IPY following the presentation by C. Rapley and C. Elfring at the ASSW Integrated Project Session on 31 March, 2003. The EPB members also contributed to the dissemination of information about the preparation for IPY via other polar organizations, such as the Council of Managers of National Antarctic Programs (COMNAP) and SCAR (e.g. at the COMNAP and SCAR-EXCOM meetings in Brest in July 2003).

EPB viewed IPY 2007–2008 as an important opportunity to reinforce the European participation in polar research. In early 2004, it produced a special roadmap document outlining the prospective 'European component' of IPY, including its logistical, coordinating and funding scenarios (Jugie and Egerton, 2004). The

Fig. 1.4-4. EPB members discuss IPY during the SCAR Open science meeting in Bremen, Germany (26-28 July 2004). Left to right: Jan Stel, Hanne Petersen, Anders Karlqvist, Olav Orheim, Chris Rapley, Jörn Thiede, Gérard Jugie.
(Photo: Jerónimo López-Martínez)

Fig. 1.4-5. EPB Executive Committee meeting in Stockholm at the Swedish Academy of Sciences, 14 April 2004. Left to right: Jan Stel, Gérard Jugie, Anders Karlqvist, Jörn Thiede, Jerónimo López-Martínez, and Chris Rapley.
(Photo: Paul Egerton)

news from the AOSB

Contribution by the Arctic Ocean Sciences Board (AOSB) to the planning of an International Polar Year in 2007-08

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Summary: The Arctic Ocean Sciences Board warmly and strongly endorses the plans for a fourth International Polar Year in 2007-08, and commends three special studies as part of that initiative:

- A multi-platform Intensive Observing Period to focus on the Arctic Ocean itself, its physics, biogeochemistry, variability and the climatic drivers of that variability.
- An integrative circum-arctic assessment of the physical, biogeochemical, ecological and socio-economic importance of the Arctic shelves
- A study of the role of the High-latitude Oceans in the Global Water Cycle.

These studies are of very different scale, ranging from the regional scale required for the intensive system study of the Arctic Ocean, increasing to include much of the Arctic–subarctic seas in the integrative study of Arctic shelves in order to cover the exchanges of water to and from these shelves including associated fluxes of chemical constituents, and finally increasing to the global scale on which the Earth's Water and Carbon Cycles operate.

Rationale: the case for a new IPY is commended by the following facts:

(i) The Arctic Ocean is likely to be very different in 2007-8 from that revealed in our past observational record. There seems little doubt that the Earth is warming. Including 2002, all ten of the warmest years since records began in 1861 have occurred since 1990 (Jones and Moberg, 2003), the 4 warmest years of all being grouped in the last six (1998, 2002, 2001 and 1997 in descending order). Because of these recent extremes, the pace at which average global temperatures have been rising, which amounted to ~+0.6 °C over the past century (IPCC, 2001), accelerated in the past two decades to a rate of ~0.2 °C per decade. To quote the Third Assessment Report of the IPCC (IPCC TAR, *Impacts, Adaptation and Vulnerability*, Section 5.7 p.59) "*Climate change in the polar region is expected to be among the greatest of any region on Earth. Twentieth century data for the Arctic show a warming trend of as much as 5 °C over extensive land areas.*" and on p60, "*The Arctic is extremely vulnerable to climate change and major physical, ecological and economic impacts are expected to appear rapidly*". Preliminary reports from the Arctic Climate Impact Assessment (ACIA; reported in Arctic Bull., March 2003, p10) "*...suggest that mean annual temperatures could continue to increase by 2 to 5 °C and that UV-B radiation ...could increase by 20-90% in April in much of the Arctic by 2010-2020*". These facts in themselves commend the further intensive study of the Arctic system in IPY-4. This is reinforced by the fact that the recent amplification of the NAO—the dominant recurrent atmospheric forcing mode in the Arctic sector—may be unique in 600 years (Jones 2003).

(ii) Change in the Arctic is likely to have global climatic impacts. Two main changes of global scale and importance are expected. First, it has long been recognized that the Atlantic Meridional Overturning Circulation (MOC) is potentially sensitive to greenhouse gas- and other climate forcing, and that changes in the MOC have the potential to cause abrupt climate change. Most (but not all) projections of greenhouse gas induced climate change anticipate a

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Fig. 1.4-6. Front page of the AOSB science proposal for IPY 2007–2008 (*AOSB Newsletter*, 2003, July, pp. 3-11)

preparation of IPY was also taken into account in the EPB process of developing a European Polar Consortium through the use of the FP6 ERA NET (6th European Framework Program), with the aim of coordinating and funding a network for European Polar activities during the IPY era and beyond.

EPB participated in the IPY Open Forum in Paris on 31 March, 2004, represented by Gérard Jugie, Chair, and Paul Egerton, Executive Director. All EPB Chairs and vice-Chairs during the early planning period for IPY were actively engaged in the IPY process either as members of the ICSU Planning Group (Chris Rapley, Olav Orheim, Hanne Petersen), ICSU-WMO Joint Committee (Chris Rapley and Jerónimo López-Martínez) or via their respective national IPY committees (Jörn Thiede, Gérard Jugie, Anders Karlqvist, Carlo Alberto Ricci, Jan Stel and Olav Orheim, among others – Fig. 1.4-5).

EPB members reviewed the progress in the preparation of IPY science program at the plenary meeting in Reykjavik, Iceland during the 2004 ASSW (23 April, 2004) and at the SCAR Open science meeting in Bremen, Germany (26–28 July, 2004). The EPB continued promoting the coordination of the European participation in IPY and in polar research, in general, after the establishment of the IPY Joint Committee and the IPO in 2004.

Arctic Ocean Studies Board (AOSB)

Sara Bowden

The Arctic Ocean Sciences Board, during its April 2002 meeting in Groningen, The Netherlands, received a report from Leonard Johnson of the University of Alaska Fairbanks with the concept of an 'International Polar Year' beginning in 2007 (*Chapter 1.2*). The Board expressed its great interest to the new IPY proposal, which was acknowledged in the AOSB 2002 meeting report along with an article that appeared in the 2002 AOSB *Newsletter* (Johnson, 2002).

Between the 2002 and 2003 meetings of the AOSB, the IPY concept began to take hold, with several member countries considering possible IPY projects. Prior to the 2003 AOSB meeting in March 2003, Chris Rapley and Paul Egerton from the European Polar Board visited the AOSB secretariat at the U.S. National Science Foundation in Washington, D.C. to discuss the scope, timing and organization of IPY 2007–2008 and the role of Arctic Ocean studies in IPY. At the same time, the International Arctic Science Committee (IASC) asked the AOSB to participate in the Second International Conference on Arctic Research Planning (ICARP II) process, so that at the March 2003 AOSB meeting in Kiruna, Sweden, both the ICARP II and IPY proposals were on the table for discussion.

At the 2003 meeting, Rapley informed the AOSB on the establishment of IPY Planning Group by ICSU and that a deadline for a first detailed proposal for IPY was due to ICSU by 12 May, 2003. This time, the idea of an IPY was enthusiastically supported by the AOSB members, resulting in a full Board endorsement of the IPY process. The minutes of the Board's discussion reveal that the members believed that the role of the Arctic Ocean in the climate system should be one of the central themes in the new IPY. The Board selected an *ad hoc* drafting group (made of Robert Dickson, Leif Anderson, Sergei Priamikov and Thomas Pyle) to develop a white paper with specific suggestions from member countries and to provide those suggestions to the IPY planners by 1 June, 2003.

From March until early June 2003, the drafting group developed three major AOSB initiatives for IPY. The

July 2003 AOSB *Newsletter* details the three initiatives: (1) multi-platform Intensive Observing Period to focus on the Arctic Ocean, its physics, biogeochemistry, variability and the climatic drivers of that variability; (2) integrative circum-arctic assessment of the physical, biogeochemical, ecological and socio-economic importance of the Arctic shelves; and (3) study of the role of the High-latitude Oceans in the Global Water Cycle. The rationale for the three suggested proposals was based upon the fact that the Arctic Ocean was likely to be very different in 2007–2008 from that revealed in the past observational records and that the forthcoming change in the Arctic would likely have global impacts. The full text of the white paper was published in a special 'IPY issue' of the AOSB Newsletter (July 2003 – Fig.1.4-6) that opened up with a short overview of IPY by Chris Elfring and Chris Rapley (AOSB, 2003).

By the time of the next AOSB meeting in April 2004 in Reykjavik, Iceland, the ICSU process had developed into a full-fledged planning group. Naja Mikkelsen of the AOSB attended the IPY Open Forum in Paris in March 2004, from which the five main science themes for IPY 2007–2008 were developed. During the following AOSB meeting, it was agreed that the three AOSB proposals developed in 2003 tracked nicely with the proposed IPY themes. Knowing that the ICSU Planning Group would meet again in September 2004, the Board appointed Robert Dickson to produce an initial draft of a feasibility study, which would serve to integrate all three AOSB proposals. It was agreed that time did not permit the full integration of all ideas related to the Arctic Ocean studies submitted to the IPY Planning Group, but rather to focus on the three developed by the AOSB (integration of most of the physical oceanographic IPY proposals was completed at a later date). Dickson visited key players in the AOSB planning and developed an overarching AOSB draft proposal that was vetted by the drafting group in Copenhagen in June 2004. The integrated plan, which was renamed the 'integrated Arctic Ocean Observing System' (iAOOS), was endorsed as an AOSB observing plan for the Arctic Ocean and submitted to the IPY PG in September 2004. It was eventually approved by the IPY Joint Committee as a 'core project' in 2005; the Science Plan for iAOOS, approved by both the AOSB and CliC Boards, was fully developed and published in 2006 (Dickson, 2006; *Chapter 3.3*).

The World Climate Research Programme (WCRP)

Barry Goodison and Vladimir Ryabinin

The World Climate Research Programme (WCRP) was founded in 1980 by WMO and ICSU. In 1993 the Intergovernmental Oceanographic Commission (IOC) of UNESCO became the third sponsor of WCRP. WCRP plays a key role in stimulating, coordinating and facilitating climate research and has made major contributions to IPCC and Ozone Assessments as well as to the development of climate prediction. The WCRP research over the past decade was clearly indicating the likelihood of massive changes in the Polar Regions and their high importance for the rest of the globe. This awareness helped set the stage for the climate component of IPY 2007–2008 and served as an essential justification for a new IPY.

In 2000, WCRP initiated the core project "Climate and Cryosphere" (CliC), a global initiative, which would continue beyond the end of the Arctic Climate System Study (ACSYS). In October 2002, the ACSYS/CliC Scientific Steering Group discussed the idea of a new IPY in detail for the first time within WCRP. Chad Dick, Director of the ACSYS/CliC IPO (IACPO), who had been involved in early discussions with other groups, presented the concept of an International Polar Year (IPY) in 2007–2008 to mark the 50th anniversary of the International Geophysical Year (IGY). The SSG had a positive discussion on the status of the concept and possible projects that CliC and WCRP might like to consider supporting under the IPY framework (*Chapter 1.2*).

To move the discussion forward, Ian Allison, Roger Barry, Chad Dick, Vladimir Kotlyakov and Jay Zwally formed an *ad hoc* committee, which agreed that cryosphere and climate should be an important element of the IPY program and that synchronous observations of snow cover, sea-ice, permafrost, mountain glaciers and ice sheets should be made in both hemispheres. They also recommended that a concept paper should be developed to justify the initiation of an International Polar Decade (IPD) in 2007–2008 rather than just a "Polar Year," which was deemed to be too short for climate studies (*Chapter 1.2*).

This discussion continued at the next session of the Joint Scientific Committee (JSC) for the WCRP in March 2003 and resulted in JSC supporting the involvement of WCRP in the activities associated with a proposed

International Polar Year, *if* it would focus on global change. It asked CliC to organize preparations within WCRP, taking into account the interests of all relevant projects and working groups, and represent WCRP in corresponding discussions. WCRP- and CliC-affiliated specialists took an active role in the discussions of the IPY concept and agenda, both at national and international arenas, and within ICSU and WMO circles. A discussion paper on WCRP's contribution to IPY was prepared and submitted to the ICSU IPY Planning Group and two scientists associated with WCRP, Ian Allison and Vladimir Kotlyakov were invited to serve on the IPY Planning Group in 2003–2004.

In 2004, WCRP projects and working groups were asked by the JSC to consider how their activities might benefit from WCRP participation in IPY 2007–2008. The 25th Session of the WCRP JSC (Moscow, March 2004) noted the leading role played by the CliC project, on behalf of WCRP, in the development of plans for IPY and requested CliC to continue playing this role for WCRP, keeping all other relevant parts of WCRP informed.

The main ideas expressed by WCRP/CliC representatives at the time were focused on creating a dataset of multidisciplinary and multi-scale observations in the polar atmosphere, ocean, cryosphere and land that would be instrumental for diagnostics of the state of the polar climate system and would enable its comprehensive modeling and prediction. The abilities to scale observations up and down and provide a coherent description of the climate system were deemed important. The WCRP/GEWEX CEOP (Coordinated Enhanced Observing Period) project was seen at that time as a model for such combined observing and modeling activity. In the early WCRP statements on IPY 2007–2008, a strong requirement was also expressed on the need to have a comprehensive data management system. The ACSYS Data and Information Service (ADIS), which at the time was being reviewed with an intention to propose a Data and Information Service for CliC (DISC) was offered as a prototype. The input from the WCRP community, such as ideas expressed at several Open IPY Forums, was taken into account in the IPY *Framework* document (Rapley et al., 2004) produced by the IPY Planning Group, including its data management part. Four scientists associated with WCRP, Ian Allison, Eberhard Fahrbach, Vladimir Kotlyakov and Qin Dahe, were invited to serve on the IPY Joint Committee (JC), and Ian Allison became one of its Co-Chairs.

Responding to the IPY JC call for the proposals for IPY 2007–2008 ('Expressions of Intent' – EoI) in November 2004, WCRP issued its internal call for ideas for IPY projects. Approximately 100 ideas associated with WCRP activities were put forward, and among them approximately twenty major "pre-proposals" were submitted to the IPY JC. In May 2005, the Integrated Global Observing Strategy (IGOS) Partnership endorsed the IGOS Cryosphere Theme Report prepared by WCRP and SCAR, which proposed a community-consensus based approach to the development of cryospheric observations. The work on this report resulted in the proposal of the Global Interagency IPY Polar Snapshot Year (GIIPSY) proposal, which subsequently led to the establishment of the IPY Space Task Group.

WCRP and its projects became a leading international agency of 23 major IPY 2007–2008 projects. Twelve other projects were related to WCRP or one of its projects. Almost all of the WCRP- and project-related proposals were endorsed by the IPY JC. It is clear that climate research strongly shaped the IPY science agenda.

International Arctic Social Science Association (IASSA)

Igor Krupnik and Yvon Csonka

IASSA (established in 1990) was among the last major professional polar organizations to endorse IPY 2007–2008 and to join its planning process in spring-summer 2004. The 300-to-400-strong association of scientists in the fields of arctic human and social sciences (anthropology, history, sociology, economy, archaeology, linguistics) was not a member of the ICSU-WMO network, though it had established relations with IASC and the Arctic Council, in its capacity as permanent observer and via its collaboration in *Arctic Human Development Report* (2002-2004), ICARP-2 and other cross-disciplinary polar programs. IASSA's entry was, nonetheless, a significant event, as it finally shaped the broad integrative nature of the new IPY, and its openness to the human and socio-cultural themes.

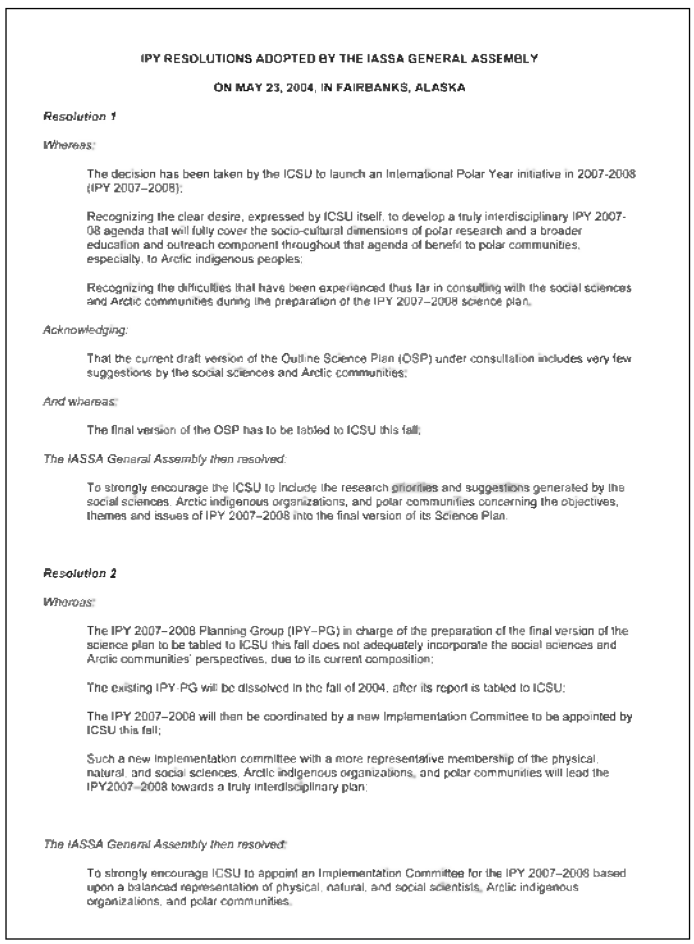
Several early IPY planning documents generated by both ICSU and WMO in 2003 referred to the need to include 'human dimensions' in IPY 2007–2008 (*Chapter 2.10*) and many early IPY champions considered expanding the new IPY program into the social/human field (*Chapter 1.2*). To ensure its contribution, in July 2003, two IASSA members, Gérard Duhaime, past President (1998–2001), and Igor Krupnik, were invited to join the ICSU Planning Group (PG) and the U.S. National IPY Committee, respectively.[1] Later, other social scientists were placed on national IPY committees in 11 other countries.[2] Two national IPY programs, in Canada and Greenland, advocated a strong focus on societal issues and Arctic residents since their inception in early 2004. Also, since 2003, IASSA regularly published information on the IPY planning in its semi-annual newsletter *'Northern Notes'* (Krupnik, 2003).

Nonetheless, five main science themes proposed for new IPY by the ICSU Planning Group ('frontiers,' 'change,' ''snapshots,' 'teleconnections' and 'vantage points' – *Chapter 1.3*) were not very conducive to socio-cultural and human research. The share of proposals for social/human studies in IPY 2007–2008 submitted by early 2004 was minuscule, the fact acknowledged by the IPY planners (ICSU PG, 2004b) and at the Arctic Council's meetings in April and October 2003, and May 2004 (*Chapter 1.3*).

At the special session dedicated to IPY at the 5th IASSA Congress in May 2004 (*International Polar Year 2007–2008: Opportunities for Northern Communities and Social Sciences* – see Krupnik, 2004; www.icass.gl; www.iassa.gl/icass5/program.htm) G. Duhaime advocated for the increased role of IASSA and the more active presence of Arctic residents in IPY. Two resolutions related to IPY and drafted by Duhaime and Krupnik were adopted by IASSA's General Assembly on 23 May, 2004 (IASSA, 2004; Fig. 1.4-7). Another critical step was the establishment of a special IASSA 'IPY task-group' of scientists from 10 nations, (www.iassa.gl/ipy/alaska/ipy_taskgroup.htm), including IASSA current and all past Presidents. It was charged to 'facilitate cooperation between IASSA and ICSU PG' (Peter Schweitzer to C. Rapley, 15 June, 2004).

Following Duhaime's suggestion, the IASSA-IPY team offered its expertise to PG to expand the sections of the 'Framework' document (Rapley et al., 2004) focused on social issues and polar residents. The proposal developed by the IASSA team[3] in summer 2004 eventually became the sixth science theme and additional 'observation initiative' in the ICSU PG 'Framework' plan (Rapley et al., 2004; *Chapter 1.3*). Two scientists nominated by IASSA, Grete Hovelsrud (Norway) and Igor Krupnik (U.S.A.), were invited to serve on the ICSU-WMO Joint Committee (JC) and to represent the field of social/human studies (*Chapter 1.5*).

In late 2004, IASSA launched its 'IPY Facilitation Initiative' to encourage researchers in social sciences and the humanities to become involved with the IPY science program. IASSA offered a pool of social science



IPY RESOLUTIONS ADOPTED BY THE IASSA GENERAL ASSEMBLY

ON MAY 23, 2004, IN FAIRBANKS, ALASKA

Resolution 1

Whereas:

The decision has been taken by the ICSU to launch an International Polar Year initiative in 2007-2008 (IPY 2007–2008);

Recognizing the clear desire, expressed by ICSU itself, to develop a truly interdisciplinary IPY 2007-08 agenda that will fully cover the socio-cultural dimensions of polar research and a broader education and outreach component throughout that agenda of benefit to polar communities, especially, to Arctic indigenous peoples;

Recognizing the difficulties that have been experienced thus far in consulting with the social sciences and Arctic communities during the preparation of the IPY 2007–2008 science plan.

Acknowledging:

That the current draft version of the Outline Science Plan (OSP) under consultation includes very few suggestions by the social sciences and Arctic communities;

And whereas:

The final version of the OSP has to be tabled to ICSU this fall;

The IASSA General Assembly then resolved:

To strongly encourage the ICSU to include the research priorities and suggestions generated by the social sciences, Arctic indigenous organizations, and polar communities concerning the objectives, themes and issues of IPY 2007–2008 into the final version of its Science Plan.

Resolution 2

Whereas:

The IPY 2007–2008 Planning Group (IPY–PG) in charge of the preparation of the final version of the science plan to be tabled to ICSU this fall does not adequately incorporate the social sciences and Arctic communities' perspectives, due to its current composition;

The existing IPY-PG will be dissolved in the fall of 2004, after its report is tabled to ICSU;

The IPY 2007–2008 will then be coordinated by a new Implementation Committee to be appointed by ICSU this fall;

Such a new Implementation committee with a more representative membership of the physical, natural, and social sciences, Arctic indigenous organizations, and polar communities will lead the IPY2007–2008 towards a truly interdisciplinary plan;

The IASSA General Assembly then resolved:

To strongly encourage ICSU to appoint an Implementation Committee for the IPY 2007–2008 based upon a balanced representation of physical, natural, and social scientists, Arctic indigenous organizations, and polar communities.

Fig. 1.4-7. Two resolutions in support of IPY adopted by the IASSA General Assembly, 23 May 2004.

experts who attended numerous IPY-related events, advocated on behalf of the social/human themes, and joined a number of IPY-associated committees, including the JC subcommittees on observation, data management and education (Birger Poppel, Joan Nymand Larsen, Lene Kielsen Holm, Lawrence Hamilton). IASSA's actions and the creation of a special socio-cultural theme resulted in an increased flow of proposals in social and human studies (*Chapters 2.10, 2.11*). IASSA's active participation in IPY 2007–2008 proved very beneficial to the association's status in polar science, as it helped strengthen IASSA's relations with IASC, the Arctic Council, and other international organizations.

International Permafrost Association (IPA)

Jerry Brown

The International Permafrost Association (IPA), governed by a 26-member Council, was founded in 1983 with its initial objectives to convene international conferences and facilitate the international exchange of scientific information among permafrost scientists and engineers. In 1989, the IPA became an Affiliated Organization of the International Union of Geological Sciences (IUGS). Joint Commissions, working groups and agreements were developed with SCAR, the International Geographical Union, the International Union of Soil Sciences, the WCRP Climate and Cryosphere (CLiC) project, among other international organizations.

The formal IPA participation in the IPY planning started with the IPA Council recommendation in July 2003 at its meeting in Zurich, Switzerland. By November 2003 a multi-authored draft plan was prepared and circulated for comment ("The Thermal State of Permafrost: A Contribution to the International Polar Year"). The IPA-IPY plans were further developed in several meetings in 2004, including the Arctic Science Summit Week in Reykjavik (April 2004), the SCAR Open Science conference in Bremen (July 2004), the Russian permafrost conference in Tyumen, Siberia and the IPA Antarctic workshop in Madison, Wisconsin (Brown, 2010).

The concept of a carbon-permafrost project for IPY 2007–2008 ("Carbon Pools in Permafrost" – CAPP, IPY no. 373) was first proposed at the CLiC meeting, 20–25 October, 2004 in Hobart, Australia as a joint CLiC, IPA and Global Carbon Project. By the end of 2004, the plans for proposed IPA-IPY "Thermal State of Permafrost" (TSP, IPY no. 90) study were well formulated (Brown, 2004; *Chapter 2.7*), with a planning and implementation proposal submitted to the International Union of Geological Sciences (IUGS). Planning of these IPY activities was largely accomplished under the coordination of the IPA and its working groups and with initial financial support from the IUGS. This grant enabled a later comprehensive planning session in November 2005 in Copenhagen following the ICARP II conference. The Copenhagen workshop, organized by the IPA Secretariat, was attended by some 60 participants representing four permafrost projects advanced in IPY (*Chapter 2.7*).

Intergovernmental Oceanographic Commission (IOC)

Keith Alverson

Established in 1960, the Intergovernmental Oceanographic Commission of UNESCO promotes international cooperation and coordinates programs in marine research, services, observation systems, hazard mitigation and capacity development in order to learn more about and better manage the nature and resources of the ocean and coastal areas. Through the application of this knowledge the commission aims to improve management practices and the decision-making process of its 136 Member States, foster sustainable development and protect the marine environment.

The Member States of the IOC first considered participation in IPY 2007–2008 at their 37th Executive Council in June 2004. Following a presentation by Chris Rapley, Chair of ICSU-IPY Planning Group, the Executive Council agreed that the IOC should contribute to IPY through: (1) filling polar gaps in the Global Ocean Observing System (GOOS) by enhancing surface-buoy and neutrally buoyant float deployments, installing and upgrading tide gauges, and carrying out coordinated hydrographic surveys, including carbon and biological measurements; (2) promoting research in the framework of the IOC-WMO-ICSU co-sponsored World Climate Research Program; (3) developing mechanisms within its International Ocean Data and Information Exchange (IODE) to recover and provide access to past and present polar ocean data; (4) generating comprehensive and integrated ocean data sets for polar regions; and (5) participating in IPY research experiments. In light of these agreed potential contributions, the Executive Council resolved (Resolution EC-XXXVII-3), to inform ICSU and WMO of IOC's interest in joining the proposed ICSU–WMO Joint Committee and to develop a plan for IOC's participation in the science initiatives of IPY.

Following these decisions, the IOC began its engagement in the IPY planning and implementation process by hosting the IPY 'Open Forum' at IOC/UNESCO headquarters in Paris in September 2004 (*Chapter 1.3*). Keith Alverson, the secretariat's head of section for ocean observations and services, was nominated to serve on the Joint Committee as an *ex officio* member to ensure the IOC participation in the IPY implementation throughout 2005–2010.

Arctic Council (AC)

Helena Ödmark

The Arctic Council (AC) was established in 1996 as an intergovernmental forum for regional cooperation among the eight Arctic States (Canada, Denmark/Greenland/Faroe Islands, Iceland, Norway, Russian Federation, Sweden and United States) and six organizations of indigenous peoples: Aleut International Association, Arctic Athabaskan Council, Gwich'in Council International, Inuit Circumpolar Conference, Russian Association of Indigenous Peoples of the North, Siberia and the Far East (RAIPON) and Saami Council. The AC deals with environmental protection and sustainable development, and concentrates on northern circumpolar issues of common interest and concern. Between the bi-annual AC Meetings of Foreign Ministers, work is conducted in six working groups and is managed by the Senior Arctic Officials (SAOs).

The first recorded actions by the AC related to IPY 2007–2008, took place in March–April 2003, following the Arctic Science Summit Week (ASSW) in Kiruna, Sweden. Having attended a presentation by C. Elfring and C. Rapley on the initial planning for IPY 2007–2008 (*Chapter 1.2*), Helena Ödmark, Swedish Senior Arctic Official, informed the Icelandic SAO Chair, Gunnar Palssòn, and her colleagues at the SAO meeting in Reykjavik in April 2003, that a new "International Polar Year" was being planned. There was great interest for IPY among the AC members. One of the priorities for the AC under the Icelandic chairmanship (2002–2004) was to strengthen cooperation in Arctic research. At this time, the Council was also supporting the preparation of the *Arctic Climate Impact Assessment* report (ACIA 2004) and of the *Arctic Human Development Report* (AHDR, 2004); the latter would rely on data from social and human sciences. Both were subsequently published in late 2004. It was hard to envision a successful IPY 2007–2008 without an active participation of the AC, when the scientific community was making plans for an "International Polar Year", not an "International Polar *Research* Year."

The SAO meeting in Svartsengi, Iceland in October 2003 decided to invite the IPY planners to its subsequent meeting in Selfoss in May 2004 (*Chapter 1.3*). The 2003 SAO meeting also launched a public diplomacy effort to emphasize the importance of including the "human dimension" in IPY. Chris Rapley presented the emerging outline for the IPY science program in Selfoss in May 2004. The reaction confirmed the strong interest from the AC member states, permanent participants and observers in the IPY planning process. In particular, the meeting stressed the necessity to translate the originally brief reference to "human dimension" into substantive input by social and human sciences, as well as to give full attention to the needs and interests of the Arctic residents. The IPY planners were encouraged to involve indigenous and other local communities in IPY research activities, to appreciate the value of traditional knowledge, and to share the results of their work with Arctic residents. The meeting also adopted a special statement to express AC commitment to IPY 2007–2008.

The SAO Chair attended the IPY Discussion Forum in Paris in March 2004 and, again, in September 2004 in Paris to provide the AC input to the planning process and to emphasize, in particular, the importance of including the human dimension theme in IPY. The AC also stressed the importance of studying the ongoing polar climate change in the context of IPY.

The Declaration adopted at the fourth AC Meeting of Foreign Ministers in Reykjavik in October 2004, welcomed "the continuing contribution of indigenous and traditional knowledge to research in the Arctic" and recognized IPY 2007–2008 as a unique opportunity to stimulate cooperation and coordination on Arctic research. It underlined the role of the AC as a high-level intergovernmental forum in providing political support for IPY in the Arctic region. That was notable, as it was the first expression of support for IPY 2007–2008 made at high political level.

In the Reykjavik Declaration of October 2004, the Foreign Ministers also decided that the AC would support the development of research proposals to the IPY Joint Committee. That decision was further elaborated in the accompanying "Report from SAOs to Ministers at the Fourth AC Ministerial Meeting" where SAOs recommend to Ministers to "endorse the development of proposals based on the work of the AC, as core projects of the IPY." It also welcomed in that context an offer from Sweden to host an organizing session on monitoring and an offer from the United States to host an organizing session on the Arctic Human Health study. Subsequently, the proposals for the "Arctic Human Health Initiative" (AHHI, IPY no. 167) and for "Coordination of Observation and Monitoring in Arctic Research" (COMAAR, IPY no. 305) were endorsed by the IPY JC and became the core projects of IPY.

The SAO report to the Reykjavik Ministerial Meeting also recommended to seek AC membership on the IPY Joint Committee established by ICSU and WMO. That eventually resulted in the AC, as well as the ATCM representatives being offered seats as observers on the JC. The AC representative first attended the JC-2 meeting in November 2005; it instituted the AC formal presence in IPY implementation throughout 2005–2010 (*Part 5*).

Antarctic Treaty Consultative Meeting (ATCM)

Manfred Reinke and Johannes Huber

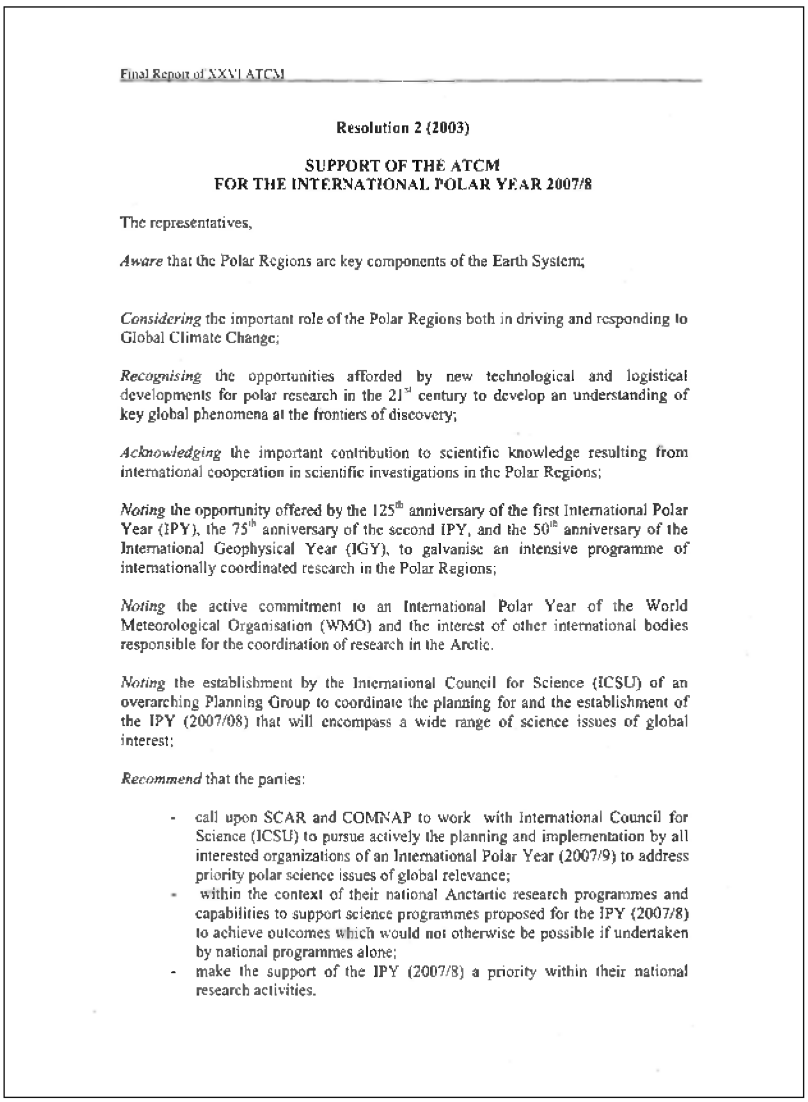
Antarctic Treaty Consultative Meetings bring together the Parties to the Antarctic Treaty of 1959. The meetings are held annually and rotate between the Consultative Parties in English alphabetical order. There are at present 48 Parties to the Antarctic Treaty, 28 Consultative and 20 Non-Consultative Parties. The original Signatories to the Treaty are the 12 countries that were active in Antarctica during International Geophysical Year of 1957–1958 and then accepted the invitation of the U.S. Government to participate in the diplomatic conference at which the Treaty was negotiated and adopted. Since 1959, 36 other countries have acceeded to the Treaty. According to Art. IX.2, they are entitled to participate in the ATCMs during such times as they demonstrate their interest in Antarctica by *"conducting substantial research activity there."*

The Antarctic Treaty is forever linked to the International Polar Years through the words of its Article II: *"Freedom of scientific investigation in Antarctica and cooperation toward that end, as applied during the International Geophysical Year, shall continue, subject to the provisions of the present Treaty."* Consequently, the preparation for IPY 2007–2008 was an important matter of discussion at the ATCM annual meetings since 2003.

The first discussion about the upcoming IPY 2007–2008 took place at the ATCM XXVI in Madrid on 9–20 June, 2003. At that meeting, SCAR (supported by Information Paper IP-120) informed the participants that ICSU had established a planning group for its "International Polar Year 2007–2008" initiative. The Russian Federation's representative referred to a similar initiative adopted by the XIV WMO Congress that approved the idea of holding the 'third IPY in 2007–2008", under the auspices of the World Meteorological Organization (WMO) (ATCM, 2003a; *Chapter 1.2*). The proposal for IPY 2007–2008 attracted significant support from the ATCM. Ten countries and COMNAP intervened to provide verbal support, and the U.K. and SCAR provided a draft for the plenary, which was approved unanimously as Resolution 2 (2003) *"Support of the ATCM for the International Polar Year 2007/08"* (Fig. 1.4-8) calling on SCAR and COMNAP to work with ICSU to pursue actively the planning and implementation by all interested organizations of an International Polar Year to address priority polar science issues of global relevance. The Resolution called additionally upon the Treaty Parties to make the support of the IPY a priority within their national research activities (ATCM, 2003b).

The ATCM XXVII met in Cape Town on 24 May–4 June, 2004 and had extensive discussion on the preparation for IPY (ATCM, 2004). On behalf of its parent body ICSU, SCAR presented an Information Paper (IP-74) outlining the current state of program planning for IPY. The paper was prepared by the IPY Planning Group. Interventions on IPY from the floor were made by Germany, Norway, Chile, Finland, Bulgaria, Sweden, Russia, China, Australia, Argentina, U.K., Korea, SCAR and COMNAP. SCAR noted that data management would be a key element of the new IPY proposals and reminded Parties of the established network of Antarctic data centers coordinated through SCAR and COMNAP pointed to the relevance of the development of multinational partnerships to support logistics underlying major IPY research projects. In addition, the Meeting noted that there was an increasing focus on bipolar research and that the topics of education and outreach for the legacy of IPY would be key elements of the new IPY proposals. The Meeting endorsed the approach of SCAR and asserted that it would continue to give support for the IPY initiative (ATCM, 2004).

The ATCM continued its support for, and overview of the IPY planning and implementation process at each of its subsequent annual meetings during 2005–2009 (ATCM XXVIII, 6-17 June, 2005, Stockholm; ATCM XXIX, 12–23 June, 2006, Edinburgh; ATCM XXX, 30 April–11 May, 2007, New Delhi; ATCM XXXI, 2–13 June, 2008, Kyiv; ATCM XXXI, 6–17 April 2009, Baltimore – *Chapter 1.5; Part 5*). The ATCM representative was invited to serve on the IPY Joint Committee as an observer since 2006.



Final Report of XXVI ATCM

Resolution 2 (2003)

**SUPPORT OF THE ATCM
FOR THE INTERNATIONAL POLAR YEAR 2007/8**

The representatives,

Aware that the Polar Regions are key components of the Earth System;

Considering the important role of the Polar Regions both in driving and responding to Global Climate Change;

Recognising the opportunities afforded by new technological and logistical developments for polar research in the 21st century to develop an understanding of key global phenomena at the frontiers of discovery;

Acknowledging the important contribution to scientific knowledge resulting from international cooperation in scientific investigations in the Polar Regions;

Noting the opportunity offered by the 125th anniversary of the first International Polar Year (IPY), the 75th anniversary of the second IPY, and the 50th anniversary of the International Geophysical Year (IGY), to galvanise an intensive programme of internationally coordinated research in the Polar Regions;

Noting the active commitment to an International Polar Year of the World Meteorological Organisation (WMO) and the interest of other international bodies responsible for the coordination of research in the Arctic.

Noting the establishment by the International Council for Science (ICSU) of an overarching Planning Group to coordinate the planning for and the establishment of the IPY (2007/08) that will encompass a wide range of science issues of global interest;

Recommend that the parties:

- call upon SCAR and COMNAP to work with International Council for Science (ICSU) to pursue actively the planning and implementation by all interested organizations of an International Polar Year (2007/9) to address priority polar science issues of global relevance;
- within the context of their national Anctartic research programmes and capabilities to support science programmes proposed for the IPY (2007/8) to achieve outcomes which would not otherwise be possible if undertaken by national programmes alone;
- make the support of the IPY (2007/8) a priority within their national research activities.

1.4-8. XXVI ATCM resolution in support of International Polar Year 2007–2008 (June 2003).

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Notes

[1] The only social scientist with a substantial intellectual input during the early planning stage for IPY (2001–2003) was Fae Korsmo (Korsmo 2001; 2004; Korsmo and Sfraga 2003). Three social scientists, Korsmo, Carole Seyfrit and archaeologist Glenn Sheehan, participated in the IPY 'planning session' of the U.S. Polar Research Board in November 2002 (*Chapter 1.2*).

[2] Bulgaria, Canada, Germany, Denmark, Greenland, Iceland, Norway, the Netherlands, Russia, Sweden, U.K. and the U.S.A.

[3] The group included Michael Bravo (U.K.), Yvon Csonka (Greenland), Igor Krupnik (U.S.A., Chair), Ludger Müller-Wille (Canada), Peter Schweitzer (U.S.A.), Frank Sejersen (Denmark), and Sverker Sörlin (Sweden).

1.5 Organization and Implementation of IPY: 2005–2009

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By early 2005, following the publication of the *Framework* document (Rapley et al., 2004) and the call for the 'Expressions of Intent' (EoI) for IPY projects (*Chapter 1.3*), a significant transition was apparent in the IPY process. An identifiable IPY community was emerging and becoming active in the evolving IPY network. At the same time, national committees and international organizations began to interact with the emerging IPY structure to ensure their role in the planning process.

Though the core elements of IPY 2007–2008 were nominally in place since October-November 2004 — the Joint Committee, the International Programme Office, the Subcommittees of Data Management and Education, and the network of science teams behind emerging IPY projects — few were yet functioning. Many members of the newly appointed Joint Committee did not know each other and their regular communication with each other and with the Programme Office only started in January-February 2005. Their first face-to-face meeting did not take place until March 2005. During that 'interregnum' phase, the embryonic Programme Office, with Cynan Ellis-Evans serving as Interim Director, was inundated with enquiries from the science community, indicative of the early interest and enthusiasm associated with IPY.

As IPY 2007–2008 unfolded, the elements of this emerging structure started functioning. The Joint Committee (JC) with its three Subcommittees on Observations, Data Management, and Education, Outreach and Communication; the International Programme Office (IPO); the national IPY Committees and their umbrella body called Heads of the Arctic and Antarctic Secretariats (HAIS – *Chapter 1.7*); numerous organizations and national funding agencies that advanced the IPY; and 230+ endorsed international projects augmented by dozens of "national" IPY initiatives – all of these eventually became active. Some have already produced reports on their activities during the IPY era, like the IPO (*Chapter 1.6*), the Subcommittee on Data Management (Parsons et al., 2010 – *Chapter 3.11*), the Subcommittee on Observations (Mohr et al., 2010 – *Part 3, Introduction*), the Subcommittee on Education and Outreach (Kaiser, 2010; *Chapter 4.1*).

This chapter presents the story of IPY 2007–2008 from the perspective of the Joint Committee. It addresses the role of JC in the planning, implementation and completion of IPY, primarily covering the JC meetings and other major activities during 2005–2009.

Composition and role of the Joint Committee

In selecting the membership for the JC, originally of 14 scientists and five *ex officio* members (*Appendix 1*),[1] ICSU and WMO planners consciously deviated from the pattern that was typical for similar supervisory bodies in IPY-1, IPY-2 and IGY (*Chapter 1.1*). Few JC members held senior administrative positions (Rapley, Kotlyakov, Béland, Qin) and there were no official representatives of the Scientific Unions, unlike in IGY 1957–1958, which was organized by a mixture of senior science managers and scientific unions. Though balance in national representation of scientists on the JC was sought (Australia, Brazil, Canada, China, Germany, Japan, Norway, Russia, Spain, Sweden, U.K., and U.S.A), no member of the JC was officially considered his/her nation's spokesperson. Rather, the sponsors, ICSU and WMO, selected the JC membership from a large list of candidates nominated by the national committees and scientific organizations to bring the best expertise from a spread of science fields.

The disciplinary balance among scientists on the Joint Committee (including the *ex officio* members) embraced Glaciology (Allison, Fujii, Kotlyakov, Qin), Oceanography (Alverson, Fahrbach, Summerhayes), Meteorology (Béland, Sarukhanian, Yamanouchi), Geology (López-Martínez), Geochemistry (Rachold), Geophysics (Bell), Remote sensing (Rapley, Mohr), Biology/ecology (Danell, Fanta), Environmental Science (Goldfarb) and Social Sciences (Hovelsrud, Krupnik), reflecting the new integrated environmental and societal priorities of modern polar science. The JC included four women—Bell, Fanta, Hovelsrud and Goldfarb (ICSU representative in 2005–2007)—which spoke much about the changing face of polar research. Many JC members were involved directly in IPY field research and spent months on ships, in camps and at stations and villages around the Poles; a few were leaders or national coordinators of major international projects during IPY.[2]

The 19 men and women on the Joint Committee (Fig.1.5-1, Box 1), whose numbers eventually grew to 21,[3] were required to navigate the organization and implementation of IPY 2007–2008 in close cooperation with other partners: the IPO, Subcommittees, IPY co-sponsors and other supporting organizations, over 30 national IPY committees and a myriad of individual science teams. Some of those links worked better than others; a more detailed assessment of this collaboration is presented in the final section of this volume.

Fig. 1.5-1. JC-1 attendees on the staircase at the ICSU Secretariat (Hotel de Noailles). *Back row:* Kjell Danell, Cynan Ellis-Evans (IPO), Tim Moffat (BAS), Yoshiiyuki Fujii; *Second row:* Jerónimo López-Martínez, Grete Hovelsrud, Colin Summerhayes, Vladimir Kotlyakov, Keith Alverson, Tillmann Mohr, Odd Rogne; *Third row:* Chen Zhenlin (guest), Edith Fanta, Eduard Sarukhanian, Leah Goldfarb; *Front row:* Robin Bell, Michel Béland, Ian Allison, Qin Dahe, Chris Rapley, Igor Krupnik.
(Photo: ICSU Secretariat)

Box 1 Tribute to Edith Fanta (1944 –2008)

It was with great sadness that we learned about the untimely death of one of the JC members, Dr. Edith (Edith Susana Elisabeth) Fanta on 7 May 2008 (Fig. 1.5-2). We knew that Edith's health had been deteriorating for some years and had forced her to skip some of the JC meetings in 2007, but it did not prevent her from being very active in various functions, among others as Chair of the Scientific Committee of the Commission on Conservation of Antarctic Marine Living Resources (CCAMLR). Edith was the principal organizer of the 9th SCAR International Biology Symposium in 2005 on her home turf at the Universidade Federal do Paraná in Curitiba, Brazil, the first in South America. She was also a member of the Brazilian team on the SCAR Standing Scientific Group on Life Sciences and a member of the IPY project on Evolution and Biodiversity in the Antarctic (EBA, IPY no. 137) providing Brazilian input to this IPY venture.

Fig .1.5-2. Edith Fanta at the JC-4 meeting in Svalbard, September 2006. (Photo: Cynan Ellis-Evans)

Edith was strongly involved in the protection of the Antarctic environment, in research on international treaties for environmental protection and in building research capacity in the region, particularly by and for scientists from the South American nations. She stimulated many colleagues to devote time to Antarctica as she did for over 25 years. Edith deeply cared about science education and about bringing younger scholars, particularly women, to polar research.

Edith was a delightful person – always friendly and good-humored, always trying to solve disputes in a harmonious way, but never allowing herself to be pushed aside in a discussion. She leaves behind an empty space, not least because of the enthusiasm with which she undertook her scientific and management activities. She will not be easily replaced.

Edith was more than just a colleague: she was our friend. She was also a mighty presence at the JC meetings – hard-working, focused and with a strong sense of responsibility for the region and the field of science she represented. Edith was the only member of the JC who did not live to see IPY 2007–2008 completed, but her place in its history is solidly secured.

More on Edith Fanta

Edith Fanta. Obituary. *Polar Record* 2009 45(234):288
www.ats.aq/devPH/noticia_completa.aspx?IdNews=13&lang=e
http://classic.ipy.org/international/joint-committee/fanta.pdf
www.ipy.org/news-a-announcements/item/1615-edith-fanta

Setting the IPY Program: Evaluating 'Expressions of Intent': January-March 2005

The rising IPY momentum in early 2005 saw a flood of online (and offline) submissions of 'Expressions of Intent' (EoI) for IPY projects. Unlike the two previous calls for IPY "ideas" in September 2003 and March 2004 (*Chapter 1.3*), EoI submissions were requested against a standard template. It was also made clear that EoIs were only the first stage in the IPY endorsement process and that successful applicants would need to submit a full proposal by June 2005. Between 5 November 2004 and 14 January 2005, almost 900 EoI proposals were submitted to the IPY Programme Office in Cambridge. Of those, 869 were eventually evaluated by the JC members and their assessment was finalized in March 2005 (see below).

At the IPO, the Interim Director Cynan Ellis-Evans undertook to compile all the EoIs onto a searchable online database (http://classic.ipy.org/development/eoi/index.htm) to provide the research community, national IPY committees and funding agencies with a full range of IPY proposals. This accessible and transparent approach encouraged more submissions.

The EoI database was to stay open throughout the IPY period and eventually grew to include more than 1,100 submissions (http://classic.ipy.org/development/eoi/), though later proposals were not reviewed by the JC.

In late January 2005, the IPO sorted the EoIs into seven thematic groups; in early February, the grouped submissions were forwarded to the members of the JC, according to their disciplinary expertise.[4] A template of 10 evaluation criteria, from the *Framework*, was assembled by the IPO[5] (*Appendix 4*) and, during February 2005, seven small teams of JC members each reviewed over 120 EoIs against them. This open process was not undertaken in the earlier IPY/IGYs and it again illustrated the bottom-up nature of the IPY 2007–2008. The assessment was completed by 1 March 2005, demonstrating that the JC and the IPO had built the capacity to lead the community in developing IPY 2007–2008.

Selection of a Director for the IPY International Programme Office

A well-staffed, centralised project office to coordinate IPY had been seen as essential by the ICSU Planning Group. In response to an international call from ICSU and WMO (*Chapter 1.3*), the U.K. Natural and Environmental Research Council (NERC) generously offered €1.8 M over 5-6 years, plus in-kind facilities at the British Antarctic Survey in Cambridge to support the International Programme Office (IPO) for IPY 2007–2008. That provided funding for three full-time core positions: a Director, an Office Administrator and a Project Officer (*Chapter 1.6*).

Selecting the right person as Director was paramount to ensuring the success of the IPO and hence of IPY itself. An announcement for this position was made jointly by WMO and ICSU on 17 November 2004. A total of 20 applications were received and were evaluated by a five-person selection panel[6]. The top four applicants were interviewed at BAS in Cambridge on 4 March 2005. The panel's recommendation was subsequently approved by the Executive Director of ICSU (Thomas Rosswall) and the Secretary-General of WMO (Michel Jarraud) and the position of IPO Director was offered to David Carlson, who took the job on 9 May 2005 (*Chapter 1.6*).[7]

JC-1 Meeting and First Open Consultative Forum: March 2005

The first meeting of the JC was held on 7-9 March 2005 at the ICSU Secretariat in Paris, and was attended by all but one of the 19 members (*Appendix 3*, Fig. 1.5-1). Thomas Rosswall (Executive Director, ICSU) and Hong Yan (Deputy Secretary-General, WMO, representing Michel Jarraud) were present at the opening and both welcomed, on behalf of sponsors, the creation of the JC and outlined the significance of IPY. Following a review of its Terms of Reference provided by ICSU and WMO (Box 2) the committee determined its main tasks over the next few years would be to define the projects comprising IPY; to encourage maximum participation, particularly from non-polar nations; to promote data management and education/outreach/communication as important components; to advocate funding for the IPY activities; and to provide guidance and direction to the IPO.

JC members had reviewed and assessed 869 submitted Expressions of Intent online before the meeting. Those assessments were formally approved at JC-1. Many EoIs contained overlapping ideas and a substantial number constituted small national proposals or ideas advanced by individual scientists. It was essential for IPY implementation to try and consolidate many of these into a smaller number of international projects. At JC-1, the members grouped EoIs by science objectives and discipline, also identifying the cross-cutting themes and legacy projects. Almost 50 large science topics were identified from among the EoIs and these were related back to the six IPY themes in the *Framework* document (Rapley et al., 2004). The JC also noted a number of critical gaps in EoI submissions, like the involvement of space agencies.

IPY data management was discussed and a decision was made to form a sub-group of JC members to define an IPY data policy, which would closely follow ICSU and WMO policies, and to establish a separate *ad hoc* task group to define an IPY data management strategy. Another *ad hoc* task group was recommended to develop an education and communication plan, prior to setting up a full IPY Subcommittee on Education and Outreach. It was also agreed that it would be valuable to have an Observing Systems Subcommittee. The third *ad hoc* group was established and

Box 2 International Polar Year Joint Committee (IPY JC)
Terms of Reference (TOR)

(Approved by ICSU and WMO, 20 November 2004)

The International Polar Year Joint Committee is appointed by the International Council for Science (ICSU) and the World Meteorological Organization (WMO) for a period until the end of 2009. The IPY JC consists of two Co-Chairs and no more than 12 additional members appointed by ICSU and WMO. In addition, SCAR, IASC and IOC have been invited to nominate *ex officio* representatives. The Executive Heads of ICSU and WMO each appointed an *ex officio* member of the Committee. The Co-Chairs can invite additional persons to attend sessions for specific agenda items as necessary.

The Joint Committee shall be responsible for scientific planning, coordination, guidance and oversight of the IPY. In performing its functions, it will be supported by an International Programme Office. It should work closely with all relevant organizations and National IPY Committees/contact persons. The IPY JC shall meet at least twice a year.

The specific tasks of the IPY JC are:

1) To define Core Projects based on the IPY Science Plan and submissions received.

2) To develop and keep under continuous review an implementation plan for the IPY in close consultation with National Polar Programs and other appropriate bodies and to ensure that the plan develops in such a way as to make optimal use of available resources.

3) To establish a mechanism for the design, guidance, development and oversight of the IPY projects, including for example, Project Steering Committees for Core Projects and Subcommittees for Data Policy and Management, and for Education, Outreach and Communication.

4) To provide leadership in developing IPY data policy and data management protocols.

5) To promote the IPY goal and objectives, its deliberations and achievements through development of education and outreach programs in order to attract new generation of polar scientists and technologists, and to capture the interest of the general public and decision-makers in polar regions.

6) To encourage the active participation of other relevant organizations in the IPY.

7) To convene sessions of an IPY Open Consultative Forum to which all stakeholders will be invited. The Forum will serve as a consultative process for expressions of views on the IPY development, as a platform for dialogue among the various stakeholders and as a venue for exchange of information on IPY development. The Forum should be convened at least once per year.

8) To raise additional funds for the planning and coordination activities, including activities of subcommittees that the IPY JC may wish to set up and to assist in convincing national and international funding bodies to fully support the Core Project of the IPY.

9) To provide oversight and guidance to the activities of the IPY International Programme Office.

10) To report to ICSU and WMO Executive Bodies on the IPY organization and implementation after each meeting of the IPY JC.

http://classic.ipy.org/international/joint-committee/terms.htm

tasked to formulate the Terms of Reference for that subcommittee and report back to the JC.

The JC agreed that engaging the political and governmental communities, including the Antarctic Treaty Parties and Arctic Council (AC) was important, but concerns were raised about politicizing a science-driven committee. Following the JC-1 meeting (on 24 March 2005), Vitaly Churkin, then Chairman of Senior Arctic Officials (SAO) of the Arctic Council, wrote to Thomas Rosswall (ICSU) and Michel Jarraud (WMO), requesting AC representation on the JC. In May 2005, the ICSU Executive Board, having weighed the JC views and the request from the AC, decided to invite the AC and the Antarctic Treaty Parties to appoint one Observer each to the JC, pending WMO approval, which was subsequently given. The AC nominated the Chair of SAO, Vitaly Churkin, as its representative. The Antarctic Treaty Parties appointed the Head of the Antarctic Treaty Secretariat, Johannes Huber, as their representative.[8]

Also considered was a proposal for a "Eurasian IPY Project Office" based in St. Petersburg with financial support from Norway, Sweden and the U.S.A. The concept of regional IPY project offices to enable access to certain polar areas and to address logistical and infrastructure issues was supported in principle by the JC, but a decision on the Eurasian Regional Office was deferred until the next JC meeting pending additional information, including its proposed relationship with the IPO.

After reviewing a number of different designs, the JC approved an IPY logo developed by its predecessor, the IPY Planning Group (*Chapter 1.3*). A new IPY website was launched shortly afterwards bearing this logo (www.ipy.org/ipy-v2).[9]

At the end of the JC-1 meeting, the overall scope of IPY was taking a clear shape. The likely large-scale and internationally-based core scientific activities had been defined from the EoIs and efforts had commenced to integrate the many EoIs into these core projects.[10]

On 10 March, immediately after JC-1, the first IPY 2007–2008 Open Consultative Forum (OCF) was held at the UNESCO Headquarters in Paris (Fig. 1.5-3). More than 60 participants attended, including 15 members of the JC and representatives of 18 National IPY committees.[11] Participants were given a brief overview of the IPY planning process, an explanation of how EoIs were assessed, information on the process for full proposal submission and a report on the outcomes from JC-1. One major issue for stakeholders was that 30 June 2005 should not be the only deadline for submission of full proposals, but that there also be subsequent submission opportunities. The JC also undertook to arrange a meeting between IPY representatives and funding agencies and to compile a list of potential IPY logistic requirements for the Council of Managers of National Antarctic Programs (COMNAP) and the Forum of Arctic Research Operators (FARO). Representatives of a number of National Committees, international polar organisations and programs gave presentations on their IPY preparations. Overall, the support from stakeholders for the evolving IPY process was high, with appreciation that the program was developing with appropriate community consultation.

Building the IPY Science Program: March 2005–February 2006

Following the assessment of EoIs, letters co-signed by JC Co-Chairs Ian Allison and Michel Béland were sent to all EoI proposers in late March 2005.[12] Three submission deadlines were eventually established to give IPY participants time to develop international links: 30 June 2005, 30 September 2005 and 31 January 2006.

Altogether 422 ‘full proposals’ were eventually

Fig. 1.5-3. First Open Consultative Forum, 10 March 2005. Ian Allison, Michel Béland, Tillmann Mohr, and Edith Fanta represented the Joint Committee and chaired the session.
(Photo: Jerónimo López-Martínez)

received, with 337 being scientific or data management proposals and 85 being for education and outreach activities. The number of proposals received in each round was 109, 92 and 209 respectively, and 12 later submissions were also accepted. Each was independently reviewed by three to four JC members and assessed against 15 IPY criteria.[13] (After the second round, education and outreach submissions were reviewed by the EOC Subcommittee rather than the JC.) Proposals that were assessed as meeting the criteria became 'endorsed IPY projects' and were added to the emerging IPY 2007–2008 project chart developed by the IPO Director, David Carlson (Fig. 1.5-4). This eventually became known as the IPY 'honeycomb chart' (*Appendix 6*). All submitted 'full proposals' were made openly accessible on the IPO website (http://classic.ipy.org/development/eoi/proposals.php). Both the EoI and the 'full proposal' databases remained accessible throughout and beyond IPY 2007–2008, showing both the openness of the IPY processes and the breadth of its science.

By the time IPY 2007–2008 formally commenced in March 2007, a total of 228 'full proposals' had been endorsed[14] – 170 in scientific research; 57 in Education, Outreach and Science dissemination; and one in Data Management. Although not all were eventually funded,[15] that network of endorsed international projects (often known by their acronyms and 'IPY number') became the core of IPY 2007–2008 program. The build-up of IPY through an open and cross-national process overseen by the JC strengthened its image as inclusive and grass-roots initiative (Stirling, 2007). No similar process existed in the previous IPY/IGYs, in which activities, though internationally coordinated, were always planned and implemented by nations under their own national IPY plans. Most of the funding for the international IPY 2007–2008 projects was, nonetheless, allocated by national funding agencies. Some nations like Canada, China, Russia, Sweden and U.S.A. also funded a large number of 'national' IPY initiatives not necessarily related to the JC-endorsed proposals.[16]

JC-2 Meeting and Second Open Consultative Forum: November 2005

The second JC meeting (JC-2) was held on 15-17 November 2005 at the headquarters of WMO in Geneva, Switzerland (*Appendix 3*). It came on the heels of the official declaration of IPY 2007–2008 by the 28th ICSU General Assembly (Box 3) that was attended by Ian Allison, David Carlson and Colin Summerhayes of the JC. The JC-2 meeting also had a powerful 'prelude' in the form of a series of meetings attached to the International Conference on Arctic Research Planning (ICARP-2, 10-12 November 2005) in Copenhagen, Denmark, including a meeting of funding and mission

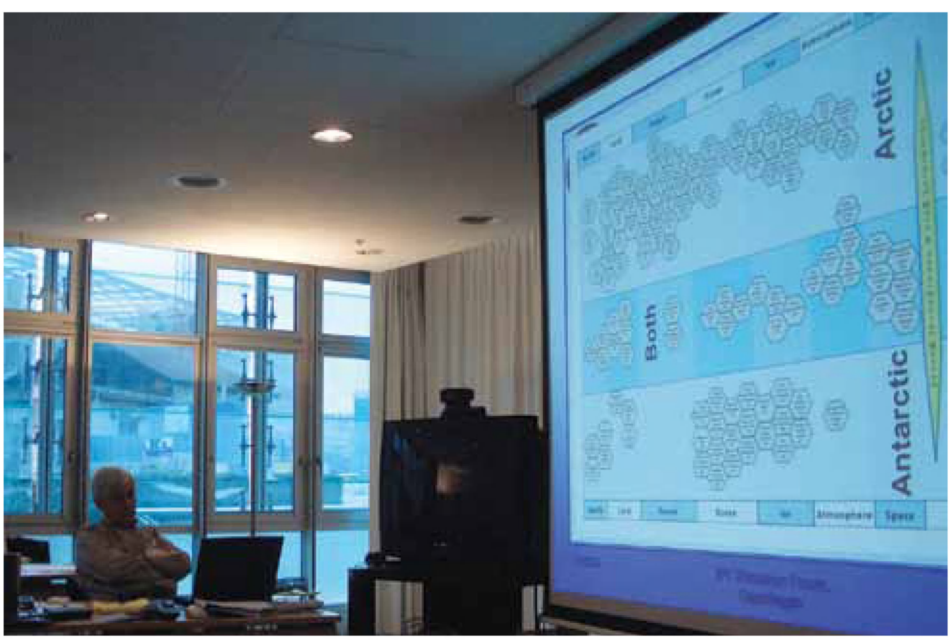

Fig. 1.5-4. Early version of the IPY project chart presented at JC-2.
(Photo: Chris Rapley)

Box 3 Formal establishment of IPY 2007–2008 by the 28th ICSU General Assembly

The 28th ICSU General Assembly was held from October 18-21 2005 in Suzhou, China and was attended by more than 200 scientists. They represented 111 national ICSU Members, 42 International Scientific Unions and 15 ICSU Interdisciplinary Bodies and Scientific Associates.

The main business item of the Assembly, which meets every three years, was to adopt a new ICSU Strategic Plan for 2006-2011. This plan—ICSU's first—had been developed through extensive review, planning and consultation during the previous three years, and the IPY 2007–2008 was to be one of the major activities. Although the ICSU Executive Board had approved establishment of the IPY in February 2004, it had to be ratified by the full Assembly.

Ian Allison and Dave Carlson attended the Assembly on behalf of IPY and Allison presented IPY program to delegates on 19 October. The delegates subsequently accepted by acclamation the resolution "to establish the International Polar Year 2007–2008….". Many delegates commented that IPY was the sort of project that ICSU needed to raise its profile.

An ICSU press conference was held on October 21 and attended by nearly 40 representatives of the international science press as well as Chinese national television, newspapers and journals. Many of the questions at this conference related to an ICSU press release (19 October) on the establishment of IPY.

agencies organized by the European Polar Board and focused on the implementation of IPY, and the second IPY Open Consultative Forum (13 November; Fig. 1.5-5). These events gave IPY a boost in visibility across the broad spectrum of scientists, policy makers, and organizations. The ICARP-2 had over 450 participants and the 'Forum' was attended by 150 people.

Participants at JC-2 were informed of the activities of the WMO Inter-commission Task group on IPY, which, in collaboration with WMO technical commissions, had developed a number of constructive actions towards IPY implementation. These were focused primarily on further development and extension of observing networks in polar regions, standardization of the observations and instrument traceability, and access to data to be obtained during IPY. The JC also considered the progress of the nascent IPY Subcommittees on Observations; Data Policy and Management; and Education, Outreach and Communication. Terms of Reference were developed for these subcommittees. Reports were given on behalf of bodies interested in the support and promotion of IPY, including the Arctic Council, the Antarctic Treaty Consultative Meeting (ATCM), World Climate Research Programme (WCRP), SCAR and IASC.

Three breakout groups discussed and reported back on the key issues of building the IPY science program through the ongoing assessment of full proposals, links with logistical organizations and IPY fund-raising. (Figs. 1.5-6) The proposal to establish a special Eurasian IPY 'sub-office' in St. Petersburg, Russia to facilitate IPY activities in the Russian Arctic, which had been deferred from JC-1, was endorsed.

JC-3 Meeting: April 2006

The JC-3 meeting took place on 20-22 April 2006 at British Antarctic Survey headquarters in Cambridge, U.K. (*Appendix 3*, Fig. 1.5-7). By this time, all elements of the IPY structure were firmly in place. The JC reviewed the activities of the IPO and reports from the three Subcommittees on Education, Outreach and Communication; Observations; and Data Policy and Management. A proposed IPY 'Data Policy' was formally introduced for the first time. Another 'first' was the introduction of the IPY 'Youth Steering Committee' (by David Carlson), a new group that would take prominence during the later phases of the IPY. The JC was briefed on the status of IPY funding by several participating nations.

The JC-3 also finalized the review of 'full proposals' submitted as IPY projects. The IPY 'honeycomb' project chart was revised and would keep its same general shape for the duration of IPY with minor modifications (*Appendix 6*).

A special session, chaired by Robin Bell, was devoted to the integration of individual project clusters within the emerging science program and across IPY themes. A Task Group (led by Ian Allison) was established to develop an integrated 'IPY Science Plan' by the next JC meeting; this eventually resulted in the document *Scope of Science for IPY 2007–2008* (Allison,

Fig. 1.5-5. Second Open Consultative Forum, Copenhagen November 2005. Left to right: Ian Allison, Michel Béland, David Carlson, Cynan Ellis-Evans and Mark Parsons.
(Photo: Chris Rapley)

Fig. 1.5-6. JC-2 session in Geneva. Left to right: Michel Béland, David Carlson, Leah Goldfarb, Tillmann Mohr and Jerónimo López-Martínez.
(Photo: Chris Rapley)

Fig. 1.5-7. JC Co-Chairs, Michel Béland and Ian Allison, outside the IPO at the British Antarctic Survey, Cambridge, U.K. during JC-3, April 2006.
(Photo: David Carlson)

et al., 2007) (Box 6).

A notable development for a meeting a year *prior* to the opening of IPY was its focus on the impact of the IPY after its completion in March 2009. For the first time, the JC addressed what later became known as 'IPY legacies'. JC members identified a list of successes that they hoped would emerge from IPY 2007–2008: (1) a new regime for research access to the Arctic; (2) integration of local communities and social sciences; (3) new observing systems in the Polar Regions; (4) changing the data management and data centre culture; and (5) new understanding of the operation of polar climate (*Part 5, Introduction*).

The JC also discussed the issue of Ethical Principles for IPY projects and expressed its reservation regarding any commercial partnerships within IPY activities. It reviewed the preparations for IPY 'launch activities', scheduled for early 2007, and agreed to explore the options for an 'IPY Summary Conference' to take place in either 2009 or 2010. A "statement of requirements" for such meetings was to be drafted for the next JC session in September 2006.

Actions from JC-3 and IPY implementation were subsequently discussed at various meetings, including the 3rd IPY Open Forum during the SCAR Open Science Conference in Hobart, Australia in July 2006 (Box 4). Over the course of IPY, the JC Members and the staff of International Programme Office gave numerous presentations on IPY to many scientific and public audiences worldwide (Box 5, *Chapter 1.6*).

JC-4 Meeting: September 2006

The JC-4 meeting was held on 26-28 September 2006 at the University Center of Svalbard (UNIS) in Longyearbyen (78°N) on the Arctic island of Svalbard (*Appendix 3*, Fig. 1.5-9). As part of its regular agenda, the JC reviewed reports on the activities of the IPO, the three Subcommittees (on Data Management; Observations; Education, Outreach and Communication), the Youth Steering Committee and on the status of IPY funding. The JC agreed on the establishment of the IPY Space Task Group as a sub-group of the Subcommittee on Observations in order to help meet the requirements on satellite data of individual IPY projects by the space agencies. The JC also welcomed a new group of heads of the national IPY secretariats (HAIS) that was preparing for its first meeting in Washington, D.C. in October 2006 (*Chapter 1.7*).

At JC-4, members broke into small teams to advance completion of the "science plan" in time for the IPY opening in March 2007 (Box 6, Fig. 1.5-10).

The JC reviewed planning for the main 'IPY launch event' on 1 March 2007 (Box 7) and of the several related national launch events. Two national IPY committees submitted reports on their activities for the JC evaluation; that practice was repeated at several further JC meetings.[17] The JC also held a short joint session with the hosting Norwegian IPY committee.

The JC approved a 'mid-program' IPY science meeting in Russia in 2008 and a full IPY 'science conference' in 2010. The SCAR open science conference, scheduled for July 2008 in St. Petersburg, Russia (and for the first time to be organized as a joint event with IASC) was suggested as a suitable high-profile bipolar forum for the first IPY conference. In response to a solicitation by the IPO (August 2006), the Norwegian and Canadian national IPY committees expressed their interest in hosting the 2010 IPY conference. At JC-4, the Norwegian IPY Committee presented a formal proposal for an IPY Science Conference to be held in Oslo in 2010, with a prospective attendance of between 2000 and 3000 scientists. Thus the trajectory of IPY activities was advanced to 2010, more than a year after completion of the observational period in March 2009.

Box 4 Third Open Consultative Forum: Hobart, July 2006

This OCF was held in Hobart, Australia on 8 July 2006 in conjunction with the XXIX biennial SCAR meeting and the second SCAR Open Science Conference. This collection of Antarctic meetings (8-19 July) had about 900 participants from 32 countries and provided an excellent opportunity to disseminate IPY information. It also allowed participants in many SCAR-led IPY projects to discuss and coordinate their activities.

The OCF was attended by over 70 people including nine representatives from the JC and the IPO. It included an update on IPY implementation (Rapley and Allison), a report of IPO activities (Carlson) and a presentation about Antarctic research within IPY and the role of SCAR (Summerhayes). There was broad discussion from the floor on issues of data management, IPY observations, young researchers and EO&C. The state of national funding for IPY projects was a concern for many.

IPY was well promoted at the opening of the SCAR Open Science Conference. Dave Carlson gave a Plenary Keynote on IPY and the other eight keynote presentations also referred to the IPY. An Information Paper (IP 17) reporting IPY developments and SCAR participation on IPY projects was tabled at the XXIX SCAR Delegates Meeting on 18 July.

Box 5 Eco Polar Ushuaia 2006: an initiative to promote IPY in South America

From 26 to 28 May 2006, a series of activities to disseminate information about IPY were held in Ushuaia, the southernmost city of the world and the capital of Tierra del Fuego Province, Argentina. Named *Eco Polar Ushuaia 2006,* this event attracted primarily participants from South American countries, with the great majority coming from Argentina (Fig. 1.5-8).

The residents of Tierra del Fuego and its authorities have strong polar interests. Ushuaia is less than 1,000 km from the Antarctic Peninsula and a key access point to Antarctica. *Eco Polar Ushuaia 2006* was hence supported by many national and local organizations. Among the key objectives of *Eco Polar Ushuaia* were bringing IPY objectives to local people and spreading the message of the importance of polar regions to issues like climate change, especially to the southernmost regions of South America. The activities also included a focus on IPY education, outreach and communication to the many tourists using this gateway to Antarctica.

Over 1,200 participants attended lectures, workshops and exhibitions during the event. They included the main Argentinean Antarctic representatives and the Executive Secretary of the Antarctic Treaty Secretariat in Buenos Aires (Jan Huber, an observer on JC). David Carlson, Rhian Salmon and Jerónimo López-Martínez were invited to share the objectives and scope of IPY 2007–2008 from the perspectives of JC and IPO. They gave public lectures, met with several groups of teachers and joined other activities open to the public. The three were named *Honor Guests of Tierra del Fuego* and received a certificate from the Governor.

Fig. 1.5-8. Logo of the Usuhuaia meeting.

Fig. 1.5-9. Fahrbach, Sarukhanian, Béland and Carlson against a polar backdrop at JC-4, Longyearbyen.
(Photo: Ian Allison)

JC-5 Meeting and the Launch of IPY: February – March 2007

The JC-5 meeting (*Appendix 3*) was held at the ICSU Secretariat in Paris, in conjunction with the formal launch of IPY on 1 March 2007 (Box 7). The JC members also attended the 'IPY Launch event' at Palais de la Découverte and the Opening French IPY ceremony at the building of the French Senate, Palais de Luxembourg (Figs. 1.5-12, 13, 14 and 15).

The 79-page *Scope of IPY Science* (Allison et al., 2007) had been released online and copies had been printed by WMO for distribution at the time of the launch and immediately afterwards. In addition, many endorsed IPY projects were moving towards implementation. With IPY entering the field phase, the role of the JC was changing from one of planning to one of maintaining the momentum and visibility of IPY activities and forging interdisciplinary links between constituent projects. These issues were discussed in two "brainstorming" sessions during JC-5.

The JC again considered the issue of 'legacy' that would result from IPY 2007–2008. This was broadly categorized as the legacy from new scientific data and knowledge, from expanded observational networks and techniques and from improved ways of collaboration. HAIS assisted in stimulating IPY legacies beyond the project level (*Chapter 1.7*). The JC also agreed to work with SCAR and IASC to identify and capture the IPY legacy.

JC-5 confirmed that the first dedicated IPY science conference would be the joint SCAR/IASC meeting in St Petersburg in July 2008 and also accepted the offer from Norway to host the second in Oslo in 2010.

Activities of the Subcommittees on Data Policy and Management, Observations (including its sub-group, the Space Task Group), and Education, Outreach and Communication were reviewed. The offer of appointment of a data coordinator for IPY operational data by the Norwegian Meteorological Institute, with support from Canada and Germany, was welcomed. The JC also reviewed reports from several national IPY committees on their ongoing activities.

Because of delays in funding of a number of national IPY programs, requests had been received for IPY to be extended for an additional 6 to 12 months. The JC resolved that the formal IPY period remain 1 March 2007 to 1 March 2009, but that any requirement to extend IPY projects should be reviewed as part of ongoing assessment of the overall program.

JC-6 Meeting: October 2007

The sixth meeting of the IPY Joint Committee (JC-6) was held in Quebec City, Canada on 25-26 October

Box 6 'The Scope of Science for IPY 2007–2008' (2007)

The *Framework* document produced in 2004 (Rapley et al., 2004 – *Chapter 1.3*) was a 'Preliminary Plan' for IPY. It defined the concept and rationale for IPY, its organizational structure and the scientific themes the program would address. But it was not a 'science plan' in the sense that it did not provide detail of the scientific objectives and design of many component projects that would become a large, multi-disciplinary international program.

Following the bottom-up development process established for IPY 2007–2008, its Science Plan could be assembled from the ideas and proposals submitted from scientists around the world. By January 2006, more than 400 proposals had been submitted and, after rigorous assessment, the JC had endorsed 228 of them. At the JC-3 meeting (April 2006), JC Task Group (Allison, Béland, Bell, Krupnik, Danell, Fanta and Sarukhanian) commenced drafting a 'science plan' to define the overall scope of IPY research and to explore how those projects would integrate to address the six IPY science themes. A major objective of this exercise was to produce a clear statement of what IPY would be from the perspective of its research agenda and to enhance the public understanding of the goals of IPY.

Also, in early 2006, Carlson and Bell compiled a short internal document that defined the breadth of IPY science. Using it as a basis, the Task Group went through all of the endorsed projects to determine which themes they addressed, how they contributed to these and how the individual projects fitted together. A number of obvious 'project clusters' emerged that identified big science questions that IPY would address and which eventually provided a structure for the IPY science plan. A skeleton of the plan was developed from this preliminary analysis and was distributed to JC members prior to JC-4 in September 2006.

At three sessions during JC-4, the JC members broke into small expert groups (Fig. 1.5-10) that prepared outline drafts against each of about 20 major topics within the six IPY 'science' themes. Following JC-4, Ian Allison summarized these initial contributions into a full draft of the science plan that later became known as *'The Scope of Science for the IPY 2007–2008'* document (Fig. 1.5-11). Over the next few months, the JC members worked by email, contributing text, editing and corrections. The IPO, and particularly Cynan Ellis-Evans, provided the major support for the publication (layout, illustrations, etc.).

The 79-page document was finalized and posted on the IPY website (www.ipy.org) on 12 February 2007, just prior to the launch of IPY in March 2007. WMO had 3000 copies printed, some of which were distributed during the launch and the rest mailed to IPY stakeholders in the following months. The document provided an overview of the wide scope of IPY science based on the research plans and objectives of the 228 endorsed projects. It described the broad-scale science objectives rather than individual projects, although a list of all endorsed projects was appended. It also very much focused on the science, although brief overviews of the IPY structure and organization, data management, observational networks, and education and outreach were also included (see www.ipy.org/about-ipy; www.icsu.org/Gestion/img/ICSU_DOC_DOWNLOAD/1155_DD_FILE_IPY_Science_Plan.pdf)

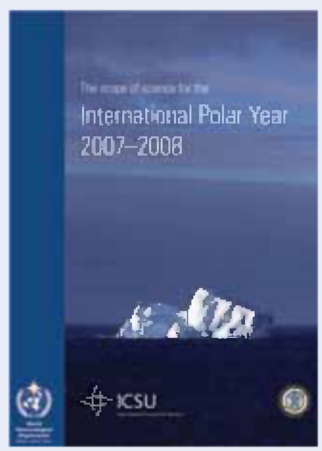

Fig.1.5-11. Cover page of the 'The Scope of Science for the International Polar Year 2007 –2008" (2007).

Fig. 1.5-10. JC 'biology' team of Edith Fanta, Cynan Ellis-Evans, and Kjell Danell works on its section for the Scope of Science Document at JC-4 in Svalbard. (Photo: Jerónimo López-Martínez)

Box 7 Global launch of IPY 2007–2008: March 2007

ICSU and WMO officially launched IPY 2007–2008 on 1 March 2007 in a morning ceremony at the Palais de la découverte in Paris, France that was webcast around the world. The ceremony aimed to reflect and appreciate the broad set of people and organizations that had contributed to the initiation and planning of IPY and conveyed the excitement of the 220 IPY projects and the sheer scale of the IPY program.

Marie-Lise Chanin of the French Academy of Sciences chaired the opening session (Fig. 1.5-12), which included speeches from T. Rosswall, M. Jarraud, D. Carlson, I. Allison, M. Béland and Jack Guichard from the Palais.

Fig. 1.5-12. Opening of IPY 2007–2008 at the Palais de Découverte, 1 March 2007. Left to right: Marie-Lise Chanin (the French Academy of Sciences), David Carlson (IPO), Thomas Rosswall (ICSU), Michel Jarraud (WMO), Ian Allison (JC) and Michel Béland (JC).
(Photo: Jerónimo López-Martínez)

Fig. 1.5-13. V. Kotlyakov (JC member and IGY veteran) and Adrienne Smith, (graduate student at Lamont Doherty Earth Observatory of Columbia University) cutting the "iceberg" cake for the IPY Opening.
(Photo: Igor Krupnik)

This session was crowned with a joint symbolic cake-cutting by early career scientist Adrienne Smith, graduate student at Lamont Doherty Earth Observatory of Columbia University[1] and Vladimir Kotlyakov, the most senior JC member and a participant in IGY 1957–1958 fifty years ago (Fig. 1.5-13). HSH Prince Albert II of Monaco gave an opening address to the audience of IPY activists, journalists, educators and representatives of science organizations (Fig. 1.5-14).

Rhian Salmon from the IPO then moderated a press conference. Following this, the ~200 attendees, including more than 70 members of the Press, browsed small exhibits featuring individual IPY projects from various fields, such as Plates and Gates (no. 77), Polar Snapshot from Space (GIIPSY, no. 91), Antarctic Ice Accumulation and Discharge (ASAID, no. 88), Arctic Modelling and Observing (DAMOCLES, no. 40), Marine Mammal Explorations (MEOP, no. 153), and Reindeer Herding and Climate Change (EALAT, no. 399). The participants had a chance to discuss IPY in personal interactions with the team leaders, JC members, JC subcommittee chairs and representatives from IPY education, art, youth and early career polar scientists.

Prince Albert II marked the official start of IPY by launching a global network of science centres and conducting a live, video-linked demonstration of a loaded wire pressure melting its way through a block of ice.

Fig. 1.5-14. HSH Prince Albert II of Monaco addressing the IPY Opening Ceremony, 1 March 2007.
(Photo: Igor Krupnik)

[1] As part of her IPY work, Adrienne Smith traveled to both the Greenland ice sheet and Antarctica with the AGAP project. She is working on the study of subglacial lakes in Antarctica and on the grounding line of the Jacobhaven Fjord in Greenland.

Fig. 1.5-15. JC Members at the JC-5 meeting on the stairs of the ICSU Secretariat in Paris, March 2007. Left to right: Igor Krupnik, Chen Zhenlin (guest), Cynan Ellis-Evans (IPO), Tom Gross (IOC, for Keith Alverson), Volker Rachold, Kjell Danell, Michel Béland, Jan Huber, Grete Hovelsrud, David Carlson (IPO), Robin Bell, Ian Allison, Qin Dahe, Eduard Sarukhanian, Chris Rapley, Odd Rogne (IPO), Tillmann Mohr, Eberhard Fahrbach, Colin Summerhayes, Carthage Smith (ICSU). Missing: Edith Fanta, Jerónimo López-Martínez, Nicola Munro (IPO). (Photo: ICSU)

2007 (*Appendix 3*). It was the only North American meeting of the Joint Committee. The meeting included a joint session with the Canadian National IPY Committee and JC members participated in the Canadian IPY event *Meet the Press: Canadian IPY Celebration* organized by the Université Laval.

With IPY field activities already in their eighth month and on the eve of the first IPY Antarctic field season, there was a lot of new information on the project efforts, funding and status. Reports from ten national IPY committees were tabled and short overviews from major supporting organizations were also presented.[18]

The JC noted with concern that, according to the survey by its Subcommittee on Data Policy and Management, 40% of substantially funded 'full proposals' had not provided information regarding their data management plans (based upon responses from 80 projects). A small JC breakout group addressed this and subsequently advised JC-6 that the data plan should aim to identify all IPY metadata by June 2009, ensure all data were available by March 2010 and have all data in secure archives by March 2012 (*Chapter 3.11*).

The Education, Outreach and Communication Subcommittee reported on the first IPY 'Polar Day', held on 21 September 2007 and focused on sea ice. This was the first of seven planned major outreach and educational events (*Chapter 4.1*). Also in September 2007, the former IPY 'Youth Steering Committee' became the Association of Polar Early Career Scientists (APECS)—an important and active new body emerging out of the IPY (*Chapter 4.3*).

The JC-6 meeting again addressed the issue of IPY legacies (*Part 5: Introduction*) on the basis of a discussion paper written by David Carlson and an external review on IPY 2007–2008 planning prepared for the OECD Global Science Forum (Stirling, 2007). Carlson's paper highlighted *four* prospective IPY legacies: observations, data, future researchers and infrastructure. Another emerging legacy was the strengthening of bipolar (Arctic-Antarctic) science planning and coordination, and the growing partnership between two major international polar science organizations—IASC and SCAR (*Chapter 5.5*). At JC-6, these two organizations agreed to extend the IPY momentum by establishing a joint Bipolar Action Group to define a strategy for post-IPY collaboration. Another development in the post-IPY process was the offer from the Canadian IPY Committee to host a major post-IPY science and policy conference in 2012. This offer was accepted. For the first time, the JC also considered the role of its members after the end of the JC term in 2009, as well as the fate of the JC-IPO records, website postings and publications.

JC-6 established crucial milestones in planning for the completion of IPY and for securing its legacy. Following JC-6, negotiations commenced to find a secure repository for the IPY archival files, including the voluminous IPO electronic and online records. Eventually, Scott Polar Research Institute in Cambridge, U.K. agreed to host the IPY 2007–2008 archives and memorabilia through an agreement with the IPO (*Chapter 4.2*). The Arctic Portal (IPY no. 388) took responsibility for maintaining IPY electronic records. In spring 2008, Igor Krupnik began recording narratives of the early IPY champions on the origination and planning for IPY in 2000–2003 for future IPY historical records (*Chapters 1.2 and 1.3*).

JC-7 Meeting and Fourth Open Consultative Forum: July 2008

With IPY field activities now past their mid-point, and with limited remaining financial support available from the sponsors, it was decided to hold only one JC meeting in 2008 (JC-7) and to hold a final meeting of the committee (JC-8) in conjunction with the official IPY 'closing' ceremony in March 2009.

JC-7 was held in St. Petersburg, Russia, 4-5 July 2008 at the Arctic and Antarctic Research Institute (*Appendix 3,* Fig. 1.5-16) prior to the joint SCAR/IASC IPY Open Science Conference[19] (*Chapter 5.5*; Klepikov, 2008). The conference was the first major meeting for presentation of results from IPY 2007–2008. The IPY observational phase had now been running for more than one year and many endorsed scientific projects were well underway. This JC meeting was, again, concerned largely with the issues related to the legacy of IPY. Ensuring appropriate identification and access to all IPY data and their long-term preservation, continued to be a major challenge. National data coordinators, or data "points of contact", were to be sought to help with meta-data registration, but for certain data, particularly from the social sciences and some life sciences, there were no guaranteed long-term archives.

The JC prepared an outline of a statement on IPY activities and ongoing polar challenges to be released near the end of the IPY observational period in early 2009, and prior to the 50th anniversary of the Antarctic Treaty (*Chapter 5.5*). Preliminary arrangements for the

Fig.1.5-16. JC-8 Meeting in St. Petersburg, July 2008. Left to right: Rhian Salmon (IPO), Odd Rogne (IPO), Nicola Munro (IPO), Olav Orheim (Norwegian IPY Secretariat, standing), Ian Allison, Keith Alverson, Vladimir Kotlyakov. (Photo: Jerónimo López-Martínez)

IPY science conferences in June 2010 (Oslo, Norway) and in 2012 (Montréal, Canada) were confirmed. Nevertheless, the JC itself was to be disbanded at the end of 2009 and the IPO was funded only until September 2009. The JC hence agreed to seek an extension of its own term and to seek supplementary funding for the IPO so that both could be continued until the Oslo meeting in order to ensure a smooth transition from the IPY 2007–2008 to IPY legacy phase.

JC-7 also addressed a paper prepared by David Carlson on legacy - *IPY IPO Planning Document – 2008 and Beyond.* This gave a thorough analysis of various impacts to be left by IPY 2007–2008 and the necessary strategies to secure their life after IPY 2007–2008. A possibility of an *IPY Legacy* publication series of several volumes was introduced. In addition, it was agreed that a small task group of the JC should prepare a short outline for a synthesis paper that would document the planning and implementation of IPY 2007–2008. This would be discussed further at the JC-8.

The 4th IPY Open Consultative Forum (OCF) was held at the Pribaltyiskaya Hotel, St. Petersburg, on 7 July 2008, after JC-7. The OCF followed an APECS workshop and many of the attendees were early career scientists. With IPY now fully underway, this forum served largely as an information session and reports were given on the status of IPY activities (Carlson) and data issues (Mark Parsons). Discussion from the floor included the role of IPY in encouraging interest in polar science in non-polar countries, with IPY activities in Portugal given as an example. The issue of an historical analysis of this IPY was also raised, with a plea for preservation of materials documenting IPY planning and implementation.

JC-8 Meeting: February 2009

JC-8 was held at the headquarters of WMO in Geneva, on 23-24 February 2009 (*Appendix 3*, Fig. 1.5-18) in conjunction with the 'IPY ceremony' organized jointly by WMO, ICSU and the IPO to celebrate the completion of the IPY observation period on 1 March 2009 and the release of the JC Statement "The State of Polar Research" (Allison et al., 2009). The meeting focused on an orderly transfer of tasks from the fixed-term international support structures that were put in place in 2005–2006 to implement IPY.

Reports on plans for 2009-2010 activities were tabled by the IPO and JC subcommittees, as well as from many partner bodies focused on their future efforts to promote the IPY legacy. WMO, ICSU and the Arctic Council presented their respective roadmaps to ensure sustainability of several IPY activities beyond IPY, such as WMO's concept for an International Polar Decade (*Chapter 5.6*), the Snow, Water, Ice and Permafrost in the Arctic (SWIPA) project of the Arctic Council (*Chapter 5.2*), and the Sustaining Arctic Observing Network (SAON) initiative (*Chapter 3.8*). In addition, the JC acknowledged an Arctic Council initiative to independently assess the IPY legacy in a message that was subsequently sent to the Arctic Council and the Antarctic Treaty Consultative Meeting:

> *"The Joint Committee for the International Polar Year would welcome the support of the Arctic Council and Antarctic Treaty System in promoting and facilitating the legacy of IPY 2007–2008, particularly in maintaining collaborative research and observations between nations".*

The JC also adopted "The State of Polar Research" document (Box 8), as a preliminary account of the results from the IPY 2007–2008 and the future challenges in polar science.

Furthermore, it approved the format of the 'Certificate of Appreciation' to be sent to IPY participants including prominent researchers, project coordinators, chairs of IPY national committees and members of IPY international bodies. Altogether, 920 IPY participants were awarded Certificates signed by Thomas Rosswall for ICSU and Michel Jarraud for WMO.

Much of the JC discussion was on activities in 2009–2010 and beyond. Olav Orheim, head of the Norwegian Secretariat for the Oslo Science Conference (OSC) in June 2010, presented the organizers' vision for making the OSC the largest-ever gathering of polar scientists, with 3000 participants expected (www.ipy-osc.com/). Patrick Borbey, Assistant Deputy Minister, Canadian Ministry of Indian and Northern Affairs, briefed the JC on the Canadian preparations for the IPY conference 'From Knowledge to Action' to be held in April 2012 in Montréal. The organizers were also expecting up to 3000 participants, with a strong presence of Northern residents and a focus on human aspects of polar research (*Chapter 5.6*).

Box 8 "The State of Polar Research" (2009)

By the time of JC-6 (Quebec City, October 2007) the IPY field phase was barely 6-months old, but the JC already turned its attention to assessment of the effectiveness of the overall program. In this, the JC aimed for a very preliminary and brief assessment of whether IPY had achieved a level of research, which would not have existed without such an internationally collaborative effort. Other criteria to be included in the assessment were whether IPY addressed the key research issues identified in the *Framework* document (Rapley et al., 2004); whether international collaboration had been enhanced; whether IPY had significantly increased funding available for polar research; and how IPY had progressed against its Education, Outreach and Communication "legacy" objectives. Allison, Béland and Carlson were tasked with drafting a paper on this for comment and feedback from JC members by the end of 2007.

This brief "assessment" was eventually submitted as a paper and published as a mid-term review of IPY (Allison et al., 2008). It was realised, however, that it was too early for a complete and impartial assessment of IPY activities and that the JC should aim for another report on the status of IPY. The IPY sponsors (ICSU and WMO) advocated for a modest-size overview that could be presented at the conclusion of the IPY field program in spring 2009 and which would highlight IPY cooperation, major advances and the most important issues for the polar regions.

At JC-7 (St Petersburg, July 2008), Allison presented a draft outline of such a status report and JC members reviewed examples of major broad-scale advances in polar science from the new results presented at the SCAR/IASC Open Science Conference. The status report (called "*The State of Polar Research*"), which evolved with the considerable input from David Carlson and IPO, included these scientific highlights and the new observational networks advanced by IPY cooperation. The report stressed the continuing urgency for polar research and recommended enhanced and ongoing support and funding for polar research, sustained multidisciplinary observational systems, and a system for long-term IPY data preservation.

The "State of Polar Research" (Allison et al., 2009 – Fig. 1.5-17) was released online for the IPY Ceremony on 25 February 2009 and printed copies were distributed by WMO in English, French, Spanish and Russian. This brief (16-page) document highlighted main IPY achievements by early 2009, but it was broadly acknowledged that it would be over-shadowed by the scientific advances that would eventually come from the program in the next few years.

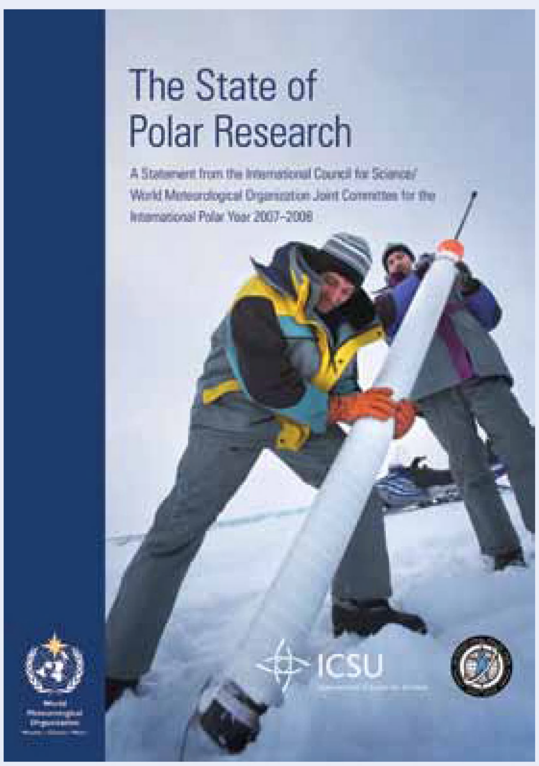

Fig. 1.5.17. Cover page of the 'State of Polar Research' document (Allison et al., 2009).

Box 9 Celebration of the International Polar Year 2007-2008: February 2009

Celebration of IPY was organized by WMO, ICSU and IPO 25 February, 2009, to mark the formal completion of the IPY observation period (1 March, 2009) and to present to the scientific community, public, and media a statement *"The State of Polar Research"* prepared by the IPY Joint Committee.

The main event took place on 25 February at the WMO headquarters in Geneva. Three hundred participants, including 150 IPY researchers, representatives of diplomatic missions in Geneva, and journalists attended the Ceremony. They were welcomed by M. Jarraud, C. Brechignac, President of ICSU, and D. Hasse, President of APECS. The message from H.R.H. Crown Princess Victoria of Sweden was presented by H.E. Mr. H. Dahlgren, Permanent Representative of Sweden to the United Nation Office and other international organizations in Geneva. Three presentations made by David Carlson, Ian Allison and Michel Béland on behalf of the JC team outlined the main IPY achievements. In recognition of the successful work carried out during the IPY years, the Certificates of Appreciation were presented by C. Brechignac and M. Jarraud to Prof. Vladimir Kotlyakov, former participant of IGY and the JC member, and Mélanie Raymond, one of the youngest participants of IPY (Fig. 1.5-18) Altogether, 918 IPY participants from 60 nations received their award Certificates after the ceremony or later via mail.

The Ceremony was accompanied by musical interlude of traditional and modern Canadian Inuit dancing and singing performance by a group of students enrolled in Nunavut Sivuniksavut College, Ottawa, Canada.

On the previous day, 24 February 2009, the JC members and more than 100 guests gathered for the IPY 'celebration' attended a reception at the Palais des Nations (Geneva) for the opening of *"Our Polar Heritage"* photo exhibit by French photographer Christian Morel. The exhibit created a unique photographic testimony of scientists of all disciplines working in the Arctic during the IPY years. Participants were welcomed by Mrs. S. Ordzhonikidze, Director-General of the UN Office in Geneva, M. Jarraud, WMO Secretary-General, and H.E. M. Grinius, Permanent Representative of Canada to the UN Office and other international organizations in Geneva who supported the exhibition.

Fig. 1.5-18. At the 'IPY Ceremony' in Geneva, Vladimir Kotlyakov, the most senior JC Member and former participant of IGY 1957–1958, and Mélanie Raymond, one of the youngest participants of IPY receive the Certificate of Appreciation by Catherine Bréchignac and Michel Jarraud on behalf of ICSU and WMO, 25 February, 2009.
(Photo: WMO)

A somewhat contentious issue, debated over the two days, was the production of a report summarizing IPY planning and activities from the perspective of the JC and stakeholders. Several alternative visions of this document were discussed, including a major summary volume, a shorter technical report and an IPY science overview paper for major scholarly journals. Eventually the JC agreed upon working on two final products: an 'IPY overview' (this volume) and a short synthesis paper on the key IPY science achievements for a journal, such as *Science*. The overview volume would be accomplished by the entire JC under the leadership of a five-member Editorial Board of Allison, Béland, Bell, Carlson and Krupnik. The structure of the IPY 'summary' and a schedule to produce a full draft for the Oslo Conference, with final release in early 2011, were approved. The short synthesis paper on the key IPY science achievements and impacts was tasked to a team of Allison, Béland and Carlson.

The last day of the JC-8 was uplifted by an 'IPY Celebration' organized at the WMO Headquarters and an international press conference and photographic exhibition at the UN Palais de Nations (Box 9). It was agreed that JC communication would be maintained by e-mail and that the members would use the Oslo conference in 2010 to publicize the outcomes of IPY to the broad polar community and beyond.

JC activities in 2009

In June 2009, ICSU and WMO had agreed to extend the JC term by six months beyond the end of 2009, the original term in the JC ToR. The Committee would work primarily by correspondence up to June 2010. It was also agreed that a last one-day meeting (JC-9) would be held during the IPY Science Conference in Oslo in June 2010. In the intervening period, the JC worked with its various bodies and other groups to ensure the consolidation of the progress that had been made in international polar cooperation and the advancement of polar science. This included preparation for the Oslo Science Conference (OSC) in 2010. Five members of the JC (Cutler, López-Martínez, Rachold, Sarukhanian and Summerhayes) served on the OSC Steering Committee, together with the IPO Director (Carlson) and a member of the EOC Subcommittee (Pauls). Other JC Members also served on several science subcommittees for the Oslo Conference (Allison, Béland, Bell, Fahrbach, Hovelsrud, Kennicutt, Krupnik).

JC members were active at numerous meetings during 2009 promoting the IPY legacy and, together with the IPO staff and members of Subcommittees, contributed to several reports on IPY activities (Jezek and Drinkwater, 2010; Kotlyakov et al., 2010).

In May 2009, Ian Allison stepped down as a Co-Chair of the JC, but remained on the committee. ICSU and WMO appointed Jerónimo López-Martínez to replace him as Co-Chair, working with Michel Béland for the remainder of the JC term.

In late 2009 and early 2010, most JC members participated (as authors, reviewers and liaisons to external contributors) in the production of the IPY 'JC Summary' (this volume). Igor Krupnik and David Hik, former head of the Canadian IPY Secretariat, were nominated by the JC Co-Chairs to lead this process, supported by a seven-member JC editorial board of Allison, Bell, Cutler, López-Martínez, Rachold, Sarukhanian and Summerhayes.

JC-9 Meeting: June 2010

The ninth and final JC meeting was held at the Research Council of Norway in Oslo, Norway on 7 June 2010 (*Appendix 3*; Fig. 1.5-19). It took place one day prior to the opening of the IPY Oslo Science Conference (Box 10). The JC-9 meeting, although brief, was crucial to the orderly completion of the JC work and to setting the agenda for the follow-up activities after the termination of the JC past the Oslo Conference.

The meeting started with a brainstorming session led by Robin Bell to identify major achievements of IPY in the fields of scientific organization, general science knowledge about the polar regions and advancement along the six IPY scientific themes (Status, Change, Global Connections, Frontiers, Vantage Points, and Human Dimensions). Responses from JC members were summarized to frame a common vision of the results of IPY (*Chapter 5.1*). At this preliminary stage, the JC identified the following major advances of IPY 2007–2008:

(1) Global-polar linkages – biological, physical (oceans/atmosphere), other;
(2) Development of new observing systems to provide data for forecasts, interdisciplinary studies, global

connections;

(3) Ice sheets – large-scale change, dynamics, subglacial hydrology;

(4) New integrative power – integration at various scales, multiple perspectives (disciplinary, local, and indigenous knowledge), societal needs for integrative approaches;

(5) Change in the polar regions – multiple evidence of rapid change from various fields and disciplines;

(6) New vision of biodiversity in the polar regions, both marine and terrestrial.

The main business of JC-9 was the assessment of the status and of further steps needed to complete the JC 'summary', *Understanding Earth' Polar Challenge.* The Report co-editors, Igor Krupnik and David Hik, presented a 7-page update. As of 7 June 2010, the Report already comprised 38 chapters in five parts, with 7 appendices and over 200 illustrations. Copies of the preliminary Report were distributed and endorsed by the JC. The JC expressed its sincere appreciation for the amount of work and dedication by the editorial team in bringing the report this far. The JC agreed to commit all needed support from its members so that the project would be completed according to the schedule, i.e., by early 2011. Recognizing that the JC would have ceased to exist by this time, this support would be provided on a voluntary basis, under the leadership of the present editorial team (Igor Krupnik, David Hik, Ian Allison, Robin Bell, Paul Cutler, Jerónimo López-Martínez, Volker Rachold, Eduard Sarukhanian and Colin Summerhayes) and the four Report sponsors – ICSU, WMO, SCAR and IASC. Upon completion, the IPY summary, submitted on behalf of the JC to the sponsor organizations should be published as a printed volume and also made available as a downloadable PDF file.

Olav Orheim, the Chair of the Oslo IPY Conference steering committee reviewed the upcoming conference events and the final closing ceremony of IPY 2007–2008 scheduled for 12 June, 2010. Kathleen Fischer, Executive Director of the Canadian Federal IPY Program Office, shared the plans of the Canadian organizers for the next post-IPY conference, *From Knowledge to Action*, scheduled for 22–27 April 2012 in Montreal, Canada. The conference is expected to attract a large group of science, policy and political delegates from around the world and to serve as the wrap-up event for IPY 2007–2008. This meeting will consider the policy implications of the IPY contribution to polar research, education, public status of science, and international collaboration in the polar regions (*Chapter 5.6*; www.ainc-inac.gc.ca/ai/mr/nr/s-d2009/23301-eng.asp; www.ipy2012montreal.ca/index.html).

On behalf of WMO, Eduard Sarukhanian introduced

Fig.1.5-19 JC-9 Meeting at the Research Council of Norway, Oslo, Norway. Left to right: Manfred Reinke, Tillmann Mohr, Olav Orheim, Michel Béland, Jerónimo López-Martínez, Robin Bell, Odd Rogne, Ian Allison, Eduard Sarukhanian, Takashi Yamanouchi, Helena Ödmark, Grete Hovelsrud, David Carlson, Deliang Chen (ICSU Executive Director), Paul Cutler, Vladimir Kotlyakov, and Chuck Kennicutt.
(Photo: Igor Krupnik)

another major polar initiative under consideration called *The International Polar Decade* (IPD). The concept of IPD has been already reviewed at the meeting of the WMO Executive Council Panel of Experts on Polar Observations, Research, and Services (13-15 October, 2009) and it was also considered by several organizations, including IASC, Arctic Council, UNESCO and others (*Chapter 5.6*; ftp://ftp.wmo.int/Documents/SESSIONS/EC-PORS-1/Doc.7.4(1).pdf). The main goal of IPD is to launch a process of coordinated research and observations in the polar regions to meet the requirements of the long-term climate change studies and prediction to benefit societal needs. The IPD is viewed by many of its champions as a natural outcome of IPY 2007–2008. The meeting agreed to consider IPD as a part of IPY legacy that addresses

Box 10 Oslo Science Conference and Closing of IPY 2007–2008

The five-day IPY Science Conference, *Polar Science – Global Impact* (8-12 June, 2010) held at the Lillestrøm Conference Center outside Oslo became the concluding event for IPY 2007–2008. The Oslo conference, in planning since 2006, emerged as the largest ever gathering of polar researchers, educators, science managers and public officials (*Chapter 5.6*). It engaged more than 2300 participants from 49 nations and featured more than 2000 presentations (1050 oral talks and over 1000 posters - http://ipy-osc.no/section/news). Each conference day included plenary talks and concurrent sessions organized along six themes: (1) Linkages between Polar Regions and global systems; (2) Past, Present and Future Changes; (3) Polar Ecosystems and Biodiversity; (4) Health, Society and Resources; (5) New Frontiers, Data Practices and Directions; and (6) Polar Science Education, Outreach and Communication. It also featured daily poster sessions, discussions and roundtables, exhibits, screening of the documentaries and movies related to the polar regions, and numerous public events (http://ipy-osc.no/osc_programme).

Fig.1.5-20 Jerónimo López-Martínez. JC Co-Chair delivers his plenary address on behalf of the Joint Committee at the IPY closing ceremony on 12 June 2010. Gerlis Fugmann, APECS President, is on the right.
(Photo: Igor Krupnik)

IPY 2007–2008 was officially closed on the last day of the Oslo Conference at its plenary morning session (http://ipy-osc.no/article/2010/1276298669.27) chaired by Gerlis Fugmann, President of the Association of Polar Early Career Scientists (APECS). It began with an opening address by Jerónimo López-Martínez, the JC Co-Chair. In his presentation on behalf of the IPY Joint Committee, López-Martínez reviewed major steps in the preparation and implementation of IPY 2007–2008 and declared the overall success of the IPY program, including its science, education and outreach efforts. He also briefed the broad IPY community about the JC work on the preparation of the IPY summary report (Fig.1.5-20). In conclusion, he thanked the IPY sponsors, ICSU and WMO, many other international organizations, national agencies and IPY committees, members of the IPY subcommittees, secretariats and projects, the staff of the International Programme Office, and many thousands of IPY participants for their contribution to IPY 2007–2008.

López-Martínez's address was followed by short presentations from David Carlson, Director of IPO; Volker Rachold, Executive Secretary of IASC; Michael Sparrow, Executive Director of SCAR, and Jenny Baeseman, Director of APECS (Fig. 1.5-22). Concluding remarks were delivered by Deliang Chen, ICSU Executive Director, and Elena Manaenkova, WMO Assistant Secretary General. They both praised the thousands of IPY participants for their energy and dedication during the more than seven years that took the international community to plan and implement this coordinated polar program, the largest ever undertaken.

On behalf of ICSU and WMO, Elena Manaenkova declared the fourth IPY officially closed. As a symbol of transition, Dr. López-Martínez handed over the IPY 2007–2008 flag to Gerlis Fugmann (Fig.1.5-21). This act indicated that the next generation of polar researchers would continue the momentum generated by IPY and would now be in charge of preserving its legacy.

issues critical to improving long-term international cooperation in polar research and observation. Nevertheless, it stressed the need to formulate the goals and timeframe of the initiative more clearly. The JC urged WMO to continue working with potential stakeholders and to run a series of pilot workshops to identify scientific objectives of IPD and design its framework that would be appealing to the science community and funding agencies.

The JC members reviewed short concluding reports from the Subcommittees on Observations; Data Policy and Management; Education, Outreach and Communication and also from major partners in the IPY implementation process (IASC, SCAR, Antarctic Treaty Conference, Arctic Council). Unfinished business of the JC at the completion of its tenure and the closing of IPY 2007–2008 was addressed, following a short presentation by Igor Krupnik. Some of those unfinished tasks include: archiving the JC and IPO documentation; making the minutes of the JC meetings available to interested researchers; supporting national IPY committees working on their national IPY reports; assisting in IPY overview publications and bibliography; and others. The JC members agreed to include the list of such 'unfinished IPY tasks' in the JC Summary (see *Epilogue*).

The meeting concluded with the final statements by JC Co-Chairs Michel Béland and Jerónimo López-Martínez (who also invited comments from Ian Allison as former JC Co-Chair), David Carlson (on behalf of IPO), Dr. Deliang Chen, Executive Director of ICSU (on behalf of ICSU), and Eduard Sarukhanian (on behalf of WMO). The speakers thanked the JC members for their service to the IPY process, from November 2004 till June 2010, and expressed their hope that new partnerships built during IPY would be instrumental to its legacy in the years ahead.

The ICSU/WMO Joint Committee for IPY 2007–2008 was officially terminated on 30 June 2010.

Conclusions: The Functions and Legacies of the Joint Committee for IPY 2007–2008

It is obvious from this account that the JC played various roles and had different levels of activity during its term (January 2005–June 2010). That term may be divided into three phases: 1) *planning* for IPY, from 2005 to March 2007; 2) the IPY *observational* (research) period, from March 2007 to February 2009[20]; and 3) assessing and securing the *legacy* of IPY, March 2009 to June 2010. The JC leadership role during the *planning* phase in 2005–2007 was epitomized in the 79-page document, *The Scope of Science for the International Polar Year 2007–2008* (Allison et al., 2007). During the *observational* period, IPY implementation was advanced mainly through the efforts of individual project teams, of the funding agencies and of the IPO through its many outreach venues, while the JC increasingly turned its attention to resource mobilization, in particular for support of operational data management activity and for securing the IPY legacies. The invigorated role of the JC during that latter phase culminated in this current volume prepared by almost 300 contributors.

The JC held nine meetings between March 2005 and June 2010, which is more than that for the equivalent steering bodies in earlier IPYs (five meetings for IPY-1, three for IPY-2, and six for IGY – *Chapter 1.1*). These 2-3-day semi-annual sessions provided thorough updates and overviews of IPY activities. The JC was the *most disciplinarily balanced* body within the IPY structure and hence best able to represent the diversity of the IPY 2007–2008 and to provide equal voice and role to each of the constituent science fields ("Earth", "Land", "Ocean", "People", "Ice", "Atmosphere" and "Space").

The role of the JC as the recognized leadership body and the ultimate authority in IPY was firmly backed by the IPY sponsors, ICSU and WMO. The primary role of the JC was to encourage and build multidisciplinary international polar research under the IPY umbrella and to assess submitted proposals against the IPY criteria. Additionally, the JC approved and authorized the membership and Terms of Reference for its subcommittees; the establishment of the Eurasian sub-Office in St. Petersburg, Russia; the Ethical Principles for the IPY (www.ipy.org/about-ipy, *Appendix 8*); and the selection of venues for major IPY conferences. The JC considered many contentious issues, often in heated debates and with disagreement among members,[21] however, decisions were always eventually reached by consensus. Fortunately, the JC was spared any serious political issues that plagued its predecessor, CSAGI, in IGY 1957–1958, during an era of political rivalries and confrontation (Bulkeley, 2008; 2009).

The JC also served as a forum for new ideas for change in the IPY process. Every JC meeting had agenda items for discussion of such 'new ideas.' Some, like the idea of the 'IPY Publication series' introduced at JC-7, were only implemented to a limited extent, if at all. Others, like the establishment of the IPY archives (JC-6) or the endorsement of the Association of the Early Career Scientists (APECS–*Chapter 4.3*), were eventually picked up by more appropriate players. The role of the JC as the key IPY 'vetting body' was recognized widely by independent observers (Stirling, 2007).

The JC will most certainly be remembered for its three major achievements: 1) definition of the core IPY science based on 228 international projects reviewed and endorsed by the JC in 2005 and 2006; 2) initiation of a series of three consecutive major IPY conferences in 2008, 2010 and 2012 with their specific messages; and 3) being the main advocate of the IPY 2007–2008 legacy based on JC recommendations for a way forward (*Part 5*). While the analogous bodies for the IPY-1, IPY-2 and IGY also aspired to similar achievements, none succeeded in completing all three.

In fulfilling its role in IPY as defined by ICSU and WMO in 2004, the JC never acted alone. Many other players helped steer the large IPY flagship to its destination: the IPO, national committees, lead IPY sponsors, and numerous supporting agencies and organizations. The activities of the IPY subcommittees were particularly noteworthy in: identifying and filling observational gaps within IPY observing components (*Part 3*) that eventually led to the creation of the IPY Space Task Group; developing IPY data management strategy (*Chapter 3.11*); and enhancing public and media interest and participation in IPY (*Part 4*).

Assessing the IPY implementation in 2007–2009, the 61st session of WMO Executive Council (June, 2009) ". . . noted with satisfaction the remarkable progress in the implementation of IPY and highly appreciated the work of the WMO/ICSU Joint Committee (JC) for IPY, its Subcommittees, IPY International Programme Office, and over 50,000 participants of the IPY projects from more than 60 countries. The Council was pleased to note that during the IPY period the researchers made fundamental scientific discoveries, developed new methods and tools, advanced interdisciplinary and international links in polar science and, most importantly, gained new understanding of the role of the Polar Regions in the total Earth system. The Council recognized that the success of IPY had inspired many

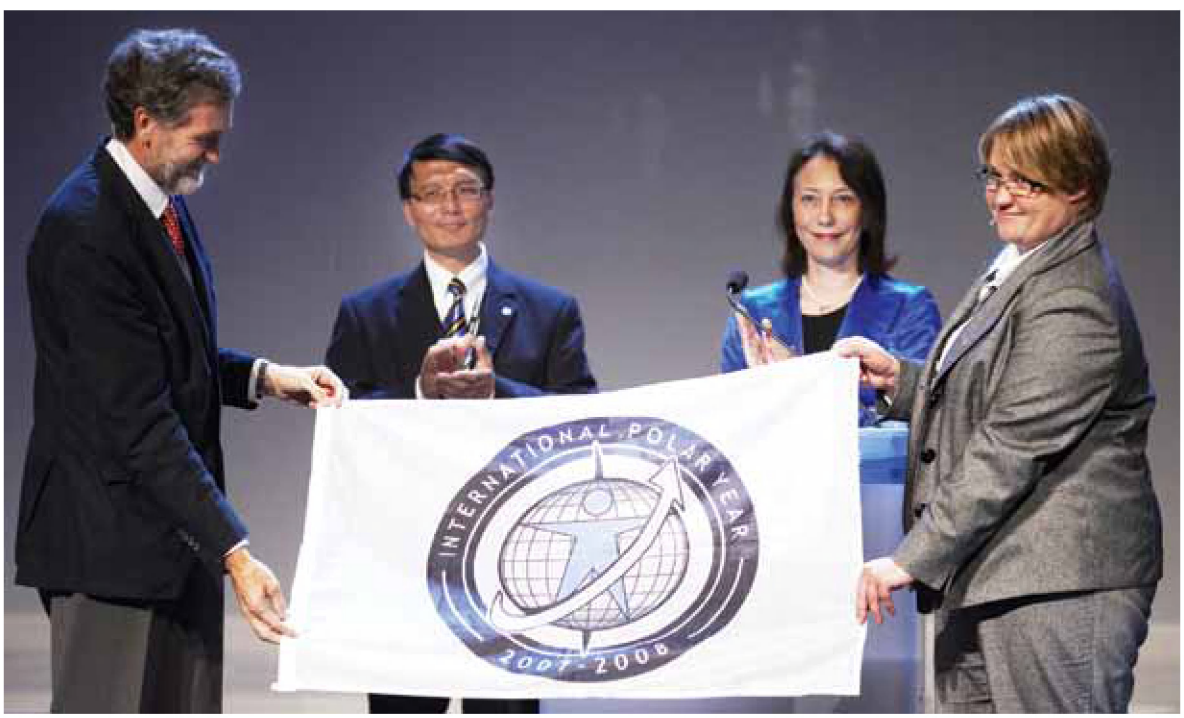

Fig.1.5-21 IPY 2007–2008 was officially closed on 12 June 2010, with the symbolic passing of the IPY flag from Jerónimo López-Martinéz, JC Co-Chair, to Gerlis Fugmann, APECS President, as Deliang Chen, ICSU Executive Director, and Elena Manaenkova, WMO Assistant Secretary General, applaud. (Photo: Jon-Petter Reinertsen)

Fig.1.5-22 Closing of IPY 2007–2008 at the conclusion of the Oslo Science Conference, 12 June 2010. Left to right: Elena Manaenkova (Assistant Secretary General, WMO), Michael Sparrow (SCAR), Jenny Baeseman (APECS), Volker Rachold (IASC), David Carlson (IPO), Jerónimo López-Martínez (JC), Deliang Chen (Executive Director, ICSU, standing at the podium). (Photo: Igor Krupnik)

nations to continue IPY projects beyond the IPY…" (WMO, 2009). This message echoed the sentiments from the October 2008 ICSU General Assembly at which IPY was described as "a resounding success" and its implementation was lauded as an effective model from which to draw lessons. ICSU members agreed "to extend deep appreciation to the members of the IPY Joint Committee, its subsidiary groups, and the International Programme Office for their tireless work in making the IPY a major success . . ."

The JC indeed fulfilled most of its tasks as stipulated in its Terms of References, established by ICSU and WMO in November 2004. It developed an overall implementation plan for IPY 2007–2008 as a network of 'core' projects in research, data management, education and outreach. It worked hard to encourage and support its subcommittees to develop IPY data policy and strategies to stimulate interest in polar research and polar regions among students, educators, general public and decision-makers. It organized several 'open meetings' (Open Consultative Forums) for the participating IPY scientists and science planners, and it reached out to many organizations and groups of stakeholders to encourage their participation in IPY (*Chapters 5.3, 5.4*). On the other hand, the JC was not very successful in raising additional funds for IPY planning and coordination, and for keeping a close supervision of its more than 200 constituent international projects and many other events.

It is difficult to compare the role of the JC in IPY 2007–2008 to that of CSAGI in IGY during the 1953–1958 period. The two guiding committees had radically different levels of available resources, administrative and governmental support, and the number of powerful personalities involved (*Chapter 1.1*). Future historians may discover JC shortcomings, but also as yet unseen successes. The unfinished tasks of the JC and of the entire IPY 2007–2008 process will be addressed in more detail in the *Epilogue*.

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Notes

[1] The original composition of the Joint Committee of 14 'science' members, with their respective country and field of expertise and of five *ex officio* members was announced in November 2004 (*Chapter 1.3*).

[2] I. Allison (nos. 105, 141,313), R. Bell (no. 67), K. Danell (no. 305), E. Fanta (no. 137), E. Fahrbach (nos. 8,35,379), G. Hovelsrud (nos. 157, PI), I. Krupnik (nos. 166, PI), J. López-Martínez (no. 77), T. Yamanouchi (nos. 9,99).

[3] Prior to JC-2, representatives of the Arctic Council and of the Antarctic Treaty System were officially invited to serve on the Joint Committee as observers. The composition of the JC underwent changes over five years: Paul Cutler replaced Leah Goldfarb as the ICSU representative (from 2007); Mahlon (Chuck) Kennicutt II, SCAR President from 2008, became the SCAR *ex officio* member instead of Colin Summerhayes (from 1 April, 2010); Helena Ödmark succeeded Vitaly Churkin as the AC observer (from 2007); and Manfred Reinke replaced Jan Huber as ATCM observer (from November 2009). Yoshiiyuki Fujii was replaced by Takashi Yamanouchi in 2007. Lastly, Edith Fanta passed away in May 2008 (Box 1). Her position on the JC was eventually offered to Colin Summerhayes, after his retirement from SCAR in early 2010.

[4] Meteorology and climate (Béland, Sarukhanian, and Allison); Oceanography (Fahrbach, Alverson, Carlson and Summerhayes); Glaciology (Kotlyakov, Qin, Fujii); Geology (Bell, López-Martínez); Geochemistry (Rachold), Biology (Danell, Fanta, Ellis-Evans); Sociology/Education and Outreach (Krupnik, Hovelsrud, Rogne); Space/Data/Legacy (Rapley, Mohr).

[5] There were four primary evaluation criteria for EoIs (significant advance within a theme or to EO&C; undertaken within a polar region and within the IPY timeframe; involves international collaboration; and includes preliminary plans for management, funding and logistic support) and six additional criteria (involves nations new to polar research; provides a legacy; builds on existing programmes or initiatives; links to other EoIs; is interdisciplinary; and is endorsed by an IPY National Committee).

[6] The selection panel for the Executive Director of IPO consisted of the Co-Chairs of the JC (Michel Béland and Ian Allison – also chair of the panel), representatives of ICSU (Leah Goldfarb) and WMO (Ed Sarukhanian) and a representative of the funding agency, BAS/NERC (Chris Rapley).

[7] David Carlson, the IPO Director, has degrees in biology and oceanography and a professional background in research management, including as Director of the International Project Office for TOGA COARE, a multi-year climate research program involving atmospheric and oceanic scientists from 12 nations. He was passionate and enthusiastic about the objectives of the IPY and came to be seen as the "face of IPY" to many of the project scientists and the general public. He was relentless in his efforts to communicate IPY ideals and achievements to the wider community.

[8] The nominated observers, Jan Huber (ATCM) and initially Vitaly Churkin and then Helena Ödmark (AC), were to join subsequent JC meetings and to provide very productive input to the work of the committee.

[9] That website later transformed into a permanent main IPY website www.ipy.org that was maintained out of IPO from 2006 till 2010.

[10] The full set of almost 900 EoI's submitted by March 1, 2005 was also copied onto CDs, given to all JC members and made available to the national IPY committees.

[11] National Committees represented at the first OCF were Belgium, Canada, Chile, Denmark, Finland, France, Germany, Iceland, India, Italy, Japan, Malaysia, Norway, Poland, Portugal, Russia, Spain and U.S.A.

[12] As a result of the JC review, all EoIs were divided in three categories. The EoIs assessed as "Category 1" were encouraged to advance with the full proposal. Applications in "Category 2" were recommended to look for additional options in coordination with other proposals and improvement, in adherence to IPY criteria. Most of the "Category 2" proposals were essentially applications from a single nation, which could become valuable IPY contributions if they were combined with other similar proposals. "Category 3" applications were advised to re-submit. All Education and Outreach proposals were encouraged to proceed.

[13] JC Review template for 'full proposals' included six 'primary' criteria (significant contribution; address of IPY themes; targets IPY geographical areas; targets IPY timeframe; evidence of international collaboration; and clear plans for project management) plus nine 'additional' criteria (provides essential infrastructure or other support; non-polar nations involvement; evidence of legacy; builds on existing initiatives, where appropriate; evidence of links to other clusters; evidence of interdisciplinarity; clear plans for data management; contribution to the development of the next generation (of scholars); and plan for Education and Outreach) (*Appendix 4*).

[14] The total number of endorsed proposal eventually grew to 231 – 171 in research; 59 in education, outreach and science dissemination; and one in data management, though three proposals were later withdrawn.

[15] The IPO received information on 172 'funded' international proposals and three were officially 'withdrawn' due to the lack of funds. The remaining 56 proposals did not report to the IPO on their funding status; evidently, many of them did not materialize. Nonetheless, several of those 56 proposals were actually implemented with funding from national sources or from individual researchers' grants.

[16] See, for example, www.ipy-api.gc.ca/intl/index_e.html for the Canadian IPY awards; www.ipyrus.aari.ru/scientific_program.html for Russian national IPY awards not related to international projects; www.nsf.gov/od/opp/ipy/ipy_awards_list.jsp for the list of U.S. NSF IPY awards; www.umea-congress.se/polar_final porgramme.pdf for Swedish activities, etc.

[17] National committees' reports from Sweden and the Netherlands were reviewed at JC-4 (September 2006); from Austria, Canada,

Portugal, Russia, Spain, and U.K. – at JC-5 (March 2007); from India, Japan, New Zealand, Poland, Spain, Ukraine, U.K., Sweden, U.S.A. and Portugal – at JC-6 (October 2007).

[18] Reports from major supporting organizations, such as ICSU, WMO, the Arctic Council, ATCM, SCAR, IASC, IOC, etc. were presented at almost every JC meeting by the respective *ex officio* JC members from these organizations.

[19] The theme of the SCAR/IASC Open Science Conference (8-11 July) was "Polar Research – Arctic and Antarctic Perspectives in the International Polar Year".

[20] While recognizing that some IPY-related research began prior to March 2007 and some continued beyond March 2009, the 'end' of the IPY observational period.

[21] Historians will be certainly looking for those 'debates and disagreements' as the clues to the dynamics within the JC and among its members. Among some of the most controversial and heated issues debated were: the level of representation of the intergovernmental bodies, such as Arctic Council and ATCM (at JC-1); the role of the Eurasian 'sub-office' (JC-2); the demand for IPY 'ethical principles' and the role of private sponsorship (JC-3); the prospective role of IASC and SCAR as caretakers of the legacy of IPY (JC-6); the low compliance of IPY projects with the established Data Policy (JC-6, JC-7, and JC-8); and of course, the type and the focus of the final summary report to be produced by the JC at the end of its term (JC-8).

1.6 International Programme Office (IPO): 2005–2010

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Introduction

It was recognized early in the planning process that an activity as large and complex as IPY 2007–2008 would require daily, full-time staff support, and that an International Programme Office (IPO) would be a crucial element of IPY implementation (Rapley et al., 2004). Such an office would be necessary to provide the day-to-day administrative support to the Joint Committee and its subcommittees, which would consist of volunteer members drawn from the academic community and from the stakeholder bodies.

Accordingly, in September 2004, ICSU and WMO solicited proposals from nations or organizations prepared to support and fund an International Programme Office that would serve as the central point of contact for IPY participants and stakeholders. The offer from the U.K. Natural Environment Research Council (NERC) to fund an IPY office for five years was accepted by WMO and ICSU in late 2004 (*Chapter 1.3*), and the International Programme Office for the International Polar Year 2007–2008 was established at the British Antarctic Survey (BAS) in Cambridge, U.K.

During the planning and implementation of IPY, the Programme Office and its enthusiastic and responsive staff became the key point of contact for IPY participants, and members of the public. In many ways the IPO became the "face of IPY", promoting the full and impressive extent of the program and making it more accessible and more inclusive to many people. At the conclusion of IPY, the achievements of the IPO can be broadly summarized as helping to enable major advances in polar knowledge and understanding; eliciting keen interest and participation from polar residents, schoolchildren, the general public and decision-makers worldwide; stimulating and supporting a community of engaged and enthusiastic volunteers; inspiring a new generation of polar scientists and engineers; and promoting new and enhanced approaches to data and information access and sharing.

The functions of the IPO

The functions of the International Programme Office were originally defined in the IPY Framework document (Rapley et al., 2004). In supporting the Joint Committee in its role of providing central planning and guidance of IPY, the Programme Office was required to serve as the secretariat for meetings and activities of the Joint Committee. This included the central handling of correspondence, archiving of key documentation, maintaining an IPY 2007–2008 activities database, tracking action items and assisting in the production of reports and synthesis documents.

As the "front office" for IPY, the IPO was the central point of contact for National IPY Committees, related international programs and all participating or interested organizations and individual researchers. The IPO supported and maintained the IPY 2007–2008 website (www.ipy.org) which, along with 37 short (2-4-page) monthly activity reports from the IPO ("IPY Reports")[1], became the main media for disseminating information and publicity on the program, including early notice of research outputs. The IPO promoted IPY 2007–2008 internationally and played the major role in development of IPY 2007–2008 outreach and education programs. It organized and coordinated international meetings and workshops concerned with the Polar Year, and led efforts to obtain additional funding to sustain IPY 2007–2008 coordination and oversight functions, although the latter met with limited success.

Although not specifically mentioned in its Terms of Reference, the IPO also played major roles in engaging volunteers to support IPY activities (predominantly education and outreach), and in promoting and supporting IPY meta-data and data sharing and archiving. Finally, the IPO provided the core promotion and support during the early stages of the development of the Association of Polar Early Career Scientists (APECS), a new international and interdisciplinary organization for undergraduate and graduate students, postdoctoral researchers, early faculty members, educators and others with interests in Polar Regions that was formed as one of the outcomes of IPY 2007–2008 (*Chapter 4.3*).

The NERC funding of €1.8 M for IPO was adequate to provide a core staff of only three people over the four-year period from 2005 to 2009, a very small resource considering the diversity and range of functions that the IPO had to undertake, and the enormous size to which IPY 2007–2008 eventually grew. To cover other IPO activities (missions, website maintenance, partial support to JC subcommittees meetings, etc.) an additional amount of USD 300K was provided to IPO during the period 2007–2009 from the ICSU/WMO IPY Trust Fund[2]. This had been established according to an MoU signed by ICSU and WMO in April 2006. Part of this amount (USD 67K) was used as a salary for an IPY operational data coordinator working in the Norwegian Meteorological Institute. Expenditure on the nine meetings of the IPY Joint Committee, shared evenly by ICSU and WMO in accordance with their MoU on IPY 2007–2008, totalled around USD 400 K. Over the lifetime of the IPO, some additional, but limited funding support was obtained from other national funding organizations and important additional capability was provided by part time advisors and seconded staff.

The effectiveness of the contributions of the IPO to the larger program and its overall achievements were also due in a large part to the enthusiasm of the staff to the objectives of IPY, and their dedication, commitment and hard work.

In 2006, an IPY Eurasian Arctic Sub-Office (IPY EASO) was established in St. Petersburg, Russia, hosted by the Arctic and Antarctic Research Institute (AARI) of Roshydromet[3]. It worked in close collaboration with the IPO in Cambridge, U.K., but with the specific responsibility of supporting the planning and implementation of IPY projects in the Eurasian Arctic, including the Russian area. EASO functions included improving cooperation and coordination in Eurasian polar research, undertaking pre-project studies focused on the expected environmental and climatic conditions and their impact on Eurasian IPY research and logistics, and collecting and distributing metadata on infrastructure facilities, logistics and observation programs in the region.

Development and staffing of the IPO

The British Antarctic Survey made resources available to maintain momentum for IPY development during the period between the disbandment of the ICSU Planning Group at the end of 2004 and the commencement of NERC funding for the formal IPY International Programme Office, and the first meeting of the ICSU/WMO Joint Committee, in early 2005. This transitional work was undertaken by Cynan Ellis-Evans, assisted by his administrator Kathy Salisbury, both BAS employees at the time. Ellis-Evans coordinated the international calls for IPY ideas, established a browser accessible database and devised the first IPY website (*Chapter 1.5*). He prepared the successful proposal that resulted in NERC funding the International Programme Office from the beginning of 2005 and further helped persuade NERC to be the first national agency to commit funding to IPY research.

An international search for the key position of an IPY Director was launched in November 2004. The IPO Director's responsibilities were to manage and support IPO staff and to supervise all aspects of the IPO functions, including integration, coordination and communication for the IPY, supporting the JC and various subcommittees, seeking additional funding to sustain and develop IPY management and providing a point of contact for researchers and stakeholders. Applications for this position closed on 20 January 2005, and the selection process was completed in early March 2005 (*Chapter 1.5*). The full-time position of IPO Director was offered to Dr. David Carlson from Boulder, Colorado (U.S.A.), who took up his duties on 9 May 2005. Carlson had a scientific background in oceanography and prior international project management experience as Director of the TOGA COARE (Tropical Ocean Global Atmosphere - Coupled Ocean Atmosphere Response Experiment) International Project Office. Carlson remained with IPO until its final closure on 30 September 2010, providing inspiration and enthusiasm in particular for the public profile of IPY throughout his tenure.

Somewhat earlier, in February 2005, Nicola Munro had been appointed as the IPO administrator and commenced the job in April. In this position, she assisted the director in daily operations and provided administrative support for IPO. Munro remained with IPO until 31 March 2010, with a short break for an assignment with the British Antarctic Survey at Halley, Antarctica between November 2007 and February 2008 during which Kathy Salisbury (BAS) provided cover. Melissa Deets took over as administrator between July 2009 and January 2010, and remained with the Office until it closed in September 2010.

The third full-time position in IPO was that of the EOC Coordinator. This position was the primary contact for IPY Education, Outreach and Communication activities, including managing and maintaining IPY presence on the web. Rhian Salmon, an Antarctic atmospheric scientist, served in this position from April 2006 until March 2009. Karen Edwards, who had been Coordinator of the Canadian IPY Secretariat, took over as EOC coordinator in June 2009 when the Canadian Secretariat closed, and remained with IPO until December 2009.

The three full-time IPO staff members were supported by several part-time advisors seconded from other organizations. Cynan Ellis-Evans, who had been involved in development of the IPY program since 2003, continued as a partner and BAS-supported senior advisor with IPO throughout. Similarly Odd Rogne, who had been an *ex officio* member of the Joint Committee in his role as the Executive Secretary of IASC until 2006, became a part-time IPO senior advisor, supported by the Norwegian Research Council, from when he left the JC until the end of 2009. Also, Camilla Hansen who was national IPY coordinator for Sweden was seconded to IPO by the Swedish Research Council to provide event support between May 2006 and September 2007. Both Rogne and Hansen worked mostly from within their home institutions (Fig.1.6-1).

The IPO staff worked closely together, in many ways more as a family than an office group, providing mutual support and covering each other's roles as necessary.

The original NERC funding for IPO was provided to cover the period from the beginning of 2005 until about March 2009. Nevertheless, by mid-2008, with IPY more than half way through its field period, it became apparent that to preserve the IPY legacy and to gather maximum benefit from the program, maintenance of some of the functions of IPO would be required for another 18 months (until September 2010). The major tasks to be completed during this extended period would include working to ensure access to and reliable preservation of IPY data, starting with acquisition of complete IPY metadata; preserving the education and outreach partnerships and networks established during IPY with scientific, educational, media and political organizations; and supporting assessments and evaluations of the program. In addition, support would be needed to sustain support for future researchers and to preserve the mountain of IPY documents and materials.

Hence, in September 2008, the Joint Committee sought further funding internationally to continue support for some IPO functions. Response was slow in coming, but additional funding of about €530K was eventually confirmed in June 2009. This funding came 1/3 from the U.K. National Environment Research Council, 1/3 from the U.S National Science Foundation, and 1/3 from essential contributions by Canada, Netherlands, Norway, Spain, Sweden and the U.S. National Academy[4]. This funding enabled continuation of IPO until September 2010, albeit at a reduced level of activity.

In St Petersburg, the IPY Eurasian Arctic Sub-Office was led by Dr Sergey Priamikov, and additional EASO staff included Elena Berezina (support), Roman Vlasenkov (data base) and Oleg Golovanov (mapping and news).

IPO support for the planning, coordination and implementation of the IPY 2007–2008

(i) Building the program: early 2005 to February 2007

The November 2004 call for "Expressions of Intent" for IPY projects saw nearly 900 submissions by 14 January, 2005 and 1232 submissions in total. These

Fig. 1.6-1. IPO staff members during the days of the JC-4 meeting on Svalbard, September 2006. Left to right: Cynan Ellis-Evans, Rhian Salmon, Nicola Munro, David Carlson and Odd Rogne.
(Photo courtesy: David. Carlson)

were compiled into a searchable web-based database and assembled against seven themes by the IPO and evaluated by the Joint Committee members prior to and at their first meeting in March 2005 (*Chapter 1.5*). Over the next nine months the IPO (now with full-time Director David Carlson), working with the Joint Committee, coordinated the entire process to ensure continuity and confidence, encouraged links and collaborations between the proponents of these many EoIs. That effort resulted in 422 full project proposals submitted in three batches between spring 2005 and winter 2006. The IPO undertook an enormous amount of information processing, coordination, promotion and solicitation in developing consensus and building project teams.

The IPO also played a major role in helping to develop many of the full proposals and in establishing the overall IPY science program through a fair, open and accessible international endorsement process. IPO staff interacted personally with the project coordinators (usually two coordinators per project), assisted in the application process, advised on improvements and revisions, helped identify and negotiate partnerships, and ensured a prompt review process for the submitted proposals by the JC members. The final 231 endorsed projects (170 with eventual funding – *Appendix 2*) were each represented on what became the iconic IPY honeycomb chart (which was itself an innovation of IPO Director Carlson – *Appendix 6)*.

During this period the IPO also broadly promoted IPY internationally and developed partnerships with key bodies and organizations. Among many invited and keynote speaking requests, IPO staff presented the concept and plans for IPY to the Foreign, Environment, and Research Ministers, and Prime Ministers of several countries; Arctic, EU, Nordic, and Saami Parliamentarians; the Executive Boards and General Assemblies of ICSU, WMO, and the Intergovernmental Oceanographic Commission (IOC); Presidents of International Scientific Unions; and to Global Climate Funding Agencies. They presented widely to IPY National Committees and at a wide range of relevant scientific conferences, symposia and workshops. They were particularly active promoting and explaining IPY at meetings of polar scientific and political bodies (e.g. European Polar Board, Arctic Science Summit Week, Arctic Council Senior Arctic Officials meetings, Antarctic Treaty Consultative Meetings, etc.) and at fora concerned with climate and climate change (e.g. UNFCCC Negotiations, WMO Commission on Atmospheric Sciences, etc.). The IPO Director David Carlson was particularly energetic and enthusiastic in his travel and advocacy in support of IPY (Box 1; Fig.1.6-2).

(ii) The IPY field period: March 2007 to February 2009

The IPO remained the prime point of contact for projects and National Committees during the implementation phase, and the main source of publicity concerning the many exciting IPY activities for the broader public. The IPO played a key role in raising the profile of IPY to a level that encouraged many countries to develop substantial programs and contributions from existing funds and in helping to stimulate specific new national IPY investments in several countries. The IPO also identified a core group of national IPY Secretaries and Directors and facilitated meetings of the heads of national IPY Secretariats and partners, which became established as the Heads of Arctic and Antarctic IPY Secretariats (HAIS) group (*Chapter 1.7*).

The IPO Director David Carlson continued a busy travel schedule supporting and promoting IPY over this period (Box 2).

(iii) Developing the legacy: March 2009 to late 2010

The IPY Oslo Science Conference (OSC) in June 2010 was the largest ever gathering of polar scientists (*Chapter 5.6*). The IPO was closely involved with the OSC Steering Committee and Local Organizing Committee in planning this meeting designed to celebrate the accomplishments of IPY 2007–2008, to display and explore the richness of IPY data, and to chart future directions for polar and global science. The IPO director David Carlson was a member of the steering committee of the conference. In particular, the IPO took the lead role in organizing a workshop associated with the OSC on 'Bringing Polar Science into the Classroom'. This was attended by 114 teachers from around the world (out of more than 400 who applied). More than 600 early career scientists submitted abstracts (almost 25% of the total abstracts) to the OSC and competed for 400 travel support stipends.

During this period, the IPO continued to advocate for the proper cataloguing and archiving of all IPY data, and for support from long-term polar science organizations and from global observation programs in developing IPY observational legacies: the evolving Sustaining Arctic Observing Networks (SAON) and the nascent Pan-Antarctic Observing System (PAntOS). The IPO Director attended a number of meetings dealing with legacy issues (Box 3).

IPO support for Education, Outreach and Communication

A key factor in the success of IPY communication was an active and engaged community of about 750 people from more than 30 countries connected and interacting via Google Groups. This community, which was initiated and supported by the IPO, included teachers, media officers, early career scientists, IPY national contacts and project coordinators, as well as more than 150 international journalists. They were regularly updated on IPY activities by direct email from the IPO and, in many cases, served as hubs for further propagation across their own local and national networks. The IPY focus on communication provided opportunities and mechanisms to build connections among individuals, many of whom worked in isolation prior to IPY. The IPO fostered expansion of the polar community by preparing materials and instructions in multiple languages, and by responding to any global partner willing to work with them to produce short, often quick-turnaround, translations.

Between September 2007 and March 2010 the IPO conducted a series of eight Polar Days (eventually extending to Polar Weeks to incorporate multiple events and time zones) focusing on "Sea Ice", "Ice Sheets", "Changing Earth, Past and Present", "Land and Life", "People", "Above the Poles", "Polar Oceans and Marine Life" and "What Happens at the Poles Affects Us All" (*Chapter 4.1*). These engaged more than 500 individual and institutional partners from 50 countries in easy and fun polar activities. The Polar Days/Weeks included nearly all the funded IPY Projects within one or more focus areas.

The IPO also ran a number of successful teachers' workshops, summer schools, polar science weekends and student expeditions in both hemispheres. Other prominent international media events included the IPY launch (March 2007) and IPY celebration (February 2009). The 2007 launch catalyzed more than 20 national events that attracted the attention of local, national, and international media (Rueth et al., 2008). Press clipping and media monitoring efforts by national and international organizations demonstrated the substantial global impact of both events.

The polar resource book, *Polar Science and Global Climate: An International Resource for Education and Outreach* (Kaiser, 2010), was edited, reviewed and pub-

Box 1 Meetings and conferences attended by the Director of IPO during the period when the IPY program was being built: June 2005 to February 2007.

Jun 2005 - XXVIII Antarctic Treaty Consultative Meeting (ATCM), Stockholm.

Jul 2005 - IPY EOC Conference, Boulder.

Sep 2005 - eGY, IHY, IPY and IYPE joint meeting, Rome.

Oct 2005 - Arctic Council (AC) Senior Arctic Officials (SAO), Khanty-Mansyisk, Russia; ICSU General Assembly, Suzhou, China; Polar Research Institute of China, Shanghai.

Nov 2005 - European Polar Board Coordination meeting, Copenhagen; ICARP-II, Copenhagen; IPY OCF, Copenhagen; JC-2, Geneva.

Dec 2005 - Arctic Leaders Summit, Hay River, Canada; American Geophysical Union (AGU), San Francisco.

Jan 2006 - EOC Subcommittee leadership meeting, Paris.

Feb 2006 - Polar art exhibition, Stockholm; Swedish National IPY Committee, Stockholm; Natural History Museum exhibit planning, London; Russian IPY National Committee, Moscow.

Mar 2006 - IPY Data Management meeting, Cambridge; American Association of Geographers, Chicago; U.K. IPY Countdown, London; European EOC meeting, Brussels; Arctic Science Summit Week, Potsdam; Polar Microbiology meeting, Innsbruck.

Apr 2006 - European Geophysical Union (EGU), Vienna; EGU Geosciences Information for Teachers, Vienna; SCAR/CliC/ICPM Workshop on High Latitude Reanalyses, Cambridge; JC-3, Cambridge; AC SAO, Syktyvkar, Russia.

May 2006 - U.K. SCAR National Committee, Cambridge; IPY events at the University Centre (UNIS), Svalbard; AGU, Baltimore; U.S. National Committee, Washington DC; Eco Polar, Ushuaia, Argentina.

Jun 2006 - Science and Technology Conference, Tromsø Norway; European network of science centres and museums, Brussels; XXIX ATCM, Edinburgh; Presentation to IOC, Paris.

Jul 2006 - ICSU 75th Symposium, Paris; SCAR Open Science Conference, Hobart, Australia; presentation to BAS, Cambridge.

Aug 2006 - Nordic Council of Ministers and Arctic Parliamentarians, Kiruna, Sweden; EOC planning meeting, Maine; IPY presentation, Bigelow Laboratory for Ocean Sciences, Maine.

Sep 2006 - British Council, Cambridge; Spanish Polar Research Conference, Granada; JC-4, Svalbard; presentation to U.K. Antarctic Funding Initiative, Cambridge.

Oct 2006 - American Association for the Advancement of Science, Arctic Division, Fairbanks; Heads of Arctic and Antarctic IPY Secretariats (HAIS), Washington DC; IPY EOC Subcommittee, Bremerhaven; ICSU Executive Board, Paris; Montana State University.

Nov 2006 - Michigan State University; Ohio teachers conference; Arctic Portal meeting, London; Netherlands National IPY Committee, The Hague; British Foreign and Commonwealth Journalists, Cambridge; ICARP-II Implementation meeting, Potsdam.

Dec 2006 - DAMOCLES Assembly, Bremen; British Geological Society, London; OECD Global Science Forum, London; AGU, GIIPSY project Data Management, U.S. briefing, San Francisco; IPY presentations at National Parks Service, San Francisco; Monterey Bay Aquarium Research Institute, Monterey; Google, San Francisco.

Feb 2007 - HAIS, Copenhagen; IPY Indigenous People's launch, Kautokeino Norway; JC-5, Paris.

Fig. 1.6-2. David Carlson, IPO Director, during the SCAR Open Science Conference in Hobart, Australia, July 2006. (Photo: Jerónimo López-Martínez)

Box 2 Meetings and conferences attended by the Director of IPO during the IPY field period: March 2007 to February 2009.

Mar 2007 - IPY launch, Paris; European Commission Polar Symposium, Brussels; Netherlands Launch Event; Arctic Science Summit Week (including meetings of U Arctic, Sustaining Arctic Observing Networks (SAON), HAIS) , Dartmouth, NH; Malaysian Antarctic Symposium, Kuala Lumpur; IPY teachers, Chicago.

Apr 2007 - AC SAO, Tromsø; U.K. IPY Launch, London; EGU, Vienna; ICSU Unions, Rome; American Polar Society, Ohio.

May 2007 - XXX ATCM, New Delhi; Midwest Geographers, Illinois; Royal Aeronautical Society, London; Natural History Museum Exhibit, London.

Jun 2007 - World Environment Day, Tromsø; EOC Subcommittee, Cambridge; SAON planning meeting, Stockholm; New Zealand National Committee, Wellington.

Jul 2007 - U.K. International Programme Offices meeting London; OECD Global Science Forum, London.

Aug 2007 - Science FOO Camp at Google, San Francisco.

Sep 2007 - U.K. Antarctic Funding Initiative, Cambridge; International Symposium on Cold Regions Development, Tampere, Finland; APECS start-up, Stockholm; Southern Ocean Observing System (SOOS), Bremen, Germany.

Oct 2007 - SAON planning, Bremen; Spanish IPY events, Barcelona; JC-6, Quebec City, Canada; International Group of Funding Agencies for Global Change Research (IGFA), Vienna.

Nov 2007 - International Ocean Institute, Malta; European Polar Board (EPB) Polar Summit, Rome; SAON workshop, Stockholm; DAMOCLES, Oslo; Euro Boat Show, London.

Dec 2007 - AGU (including IPY Press Conference, AGU - IPY exhibit), San Francisco.

Jan 2008 - U.K. Association for Science Education, Liverpool; Tara project interviews, Paris; ICSU, Paris; IASC planning, Stockholm; SAON planning, Stockholm.

Feb 2008 - AAAS, Boston; U.S. NAS, Washington DC; U.S. NSF, Washington DC; Teachers Conference, Illinois.

Mar 2008 - APECS, Iceland; Circumpolar Biodiversity Monitoring Programme, Washington DC; U.S. CLIVAR High-Latitude Flux WG; EOC Subcommittee, Strasbourg.

Apr 2008 - IPY Open Science Conference (OSC) planning, Oslo; SAO Svolvaer, Norway.

May 2008 - NSIDC, Boulder; New Generation of Polar Researchers, Colorado; Arctic Charter, Brussels; OSC planning meeting, Oslo; ICSU, Paris; Polar events, Portugal.

Jun 2008 - Report to IOC, Paris; Report to WMO, Geneva; Royal Meteorological Society, Southampton, U.K.; The Ny-Ålesund Symposium, Svalbard.

Jul 2008 - SCAR/IASC Open Science Conference, St Petersburg; JC-7, St Petersburg; EuroScience Open Forum 2008, Barcelona; City & Urban planning, Iqaluit, Canada.

Sep 2008 - Nordic Council of Ministers EU ministers, Ilulissat, Greenland; Media coordination for closing event, ICSU, Paris.

Oct 2008 - Society for the Advancement of Chicanos and Native Americans, Salt Lake City, U.S.A.; ICSU General Assembly, Mozambique.

Nov 2008 - OSC planning, Oslo; IGY Symposium, Japan; City of Science, Paris; Tara Press conference, Paris.

Dec 2008 - Geoscience Symposium, Copenhagen; Arctic Change, Quebec; AGU (multiple sessions and events, Geophysical Information for Teachers Workshop, AGU - IPY Exhibit), San Francisco.

Jan 2009 - Arctic Frontiers, Tromsø; HAIS, Cambridge.

Feb 2009 - IPY Space Task Group, Geneva; JC-8, Geneva; IPY celebration, Geneva.

lished under IPO auspices, and launched at the IPY Oslo Science Conference in June 2010. It was created to ensure that efforts catalyzed by IPY will continue to inspire educators, students and emerging polar researchers into the next generation. It received support from wide ranging parts of the IPY community. The book includes 29 reviewed and tested classroom activities, produced from hundreds of international contributions.

IPO stimulation and support of an IPY volunteer community

IPY 2007–2008 depended to a large extent on volunteer efforts, by busy people working additionally to their regular professional careers. Volunteers included most members of the Joint Committee, members of the IPY Data Management and EOC Subcommittees, all IPY project coordinators (a few of them received administrative support from their IPY National Committees), all the planners and translators for the Polar Day events, all the young scientists committing time to APECS, and the contributors to many other IPY activities. The effectiveness of many of these activities, particularly education and outreach, was sustained by IPO efforts to recruit and support a volunteer community. IPO endeavoured to cover practical communication costs, to find funding for critical face-to-face meetings, to keep the groups activities and accomplishments visible and prominent within IPY, and to provide mentorship. Effort by IPO in fostering and supporting an active, engaged and enthusiastic volunteer workforce serving as both project coordinators and science communicators was a key element in the success of IPY 2007–2008.

IPO made wide use of modern, affordable and accessible communication tools to connect and support the international volunteer workforce and to reach the public. With partners, they tested and evaluated state-of-the-art audio-conferencing, video-conferencing, web-conferencing, web portals, on-line discussions, streamed video and internet radio. They used Google Earth, YouTube, Google Groups and Documents, Gmail, Skype and Facebook. The ipy.org web site used a flexible content management system

Box 3 Meetings and conferences attended by the Director of IPO in developing the IPY legacy: March 2009 to July 2010

- Mar 2009 - Nordic Council of Ministers, Prime Ministers, Iceland; Gordon Conference on Polar Oceans, Barga, Italy; France-Germany Science Forum, Paris; Institute of Electrical and Electronics Engineers (IEEE) Data Engineering, Shanghai.
- Apr 2009 - XXXII ATCM, Baltimore (including IPY data, Joint ATCM & AC Polar Information Commons meeting; EGU, Vienna.
- May 2009 - U.S. Senate Arctic Hearing, Washington DC; PRB production meetings, London
- Jun 2009 - UN Framework Convention on Climate Change (FCCC), Bonn; IPY OSC planning, Oslo; IOC, Paris; IPY/APECS summer school, Svalbard.
- Jul 2009 - UNEP, London.
- Sep 2009 - World Climate Conference, Geneva; IPY Data Management, Ottawa.
- Oct 2009 - Association of Canadian Universities for Northern Studies (ACUNS), Whitehorse, Yukon, Canada; Presentations to public and schools, Yukon, Canada; WMO EC Panel of Experts on Polar Observations, Research and Services (PORS), meeting, Ottawa, Canada; IPY EOC meeting, Edmonton, Canada.
- Nov 2009 - DAMOCLES General Assembly, Brussels; WMO Commission for Atmospheric Sciences, Korea.
- Dec 2009 - APECS Workshop, Victoria, Canada; Arctic Net Conference, Victoria, Canada; AGU (multiple events and sessions including AGU - IPY exhibit), San Francisco.
- Jan 2010 - Arctic Monitoring and Assessment Programme (AMAP) review, Oslo; IPY OSC planning, Oslo.
- Feb 2010 - Preliminary planning for 2012 IPY science meeting, Ottawa; Canadian Early IPY Results Conference, Ottawa.
- May 2010 - Canadian National Research Council, Ottawa; American Polar Society, Boulder.
- Jun 2010 - UN FCCC, Bonn; Teachers workshop, Oslo; APECS workshop, Oslo; JC-9, Oslo; IPY OSC, Oslo.
- Jul 2010 - IPY/APECS summer school, Svalbard; EuroScience Open Forum 2010, Italy.

that allowed quick development of new features and allowed partners to easily contribute news and blog content. These services all had a focus on reliability, accessibility and minimum (toll-free) costs for international partners. This moved IPY science information systems much closer to information systems already in use by the global public.

Well-planned and advertised international events provided focus and a sense of progress and accomplishment to the volunteer networks. 'Live' events, connecting researchers directly to classrooms through radio, video, or web conferencing, proved a popular and effective community-building tool. Making IPY events truly international and accessible, during the school day in every time zone, often required arranging a minimum of three events in a 24-hour period. Free and easy access for participants, materials in local languages, spontaneous conversations between students and researchers and advance preparations with audiences and presenters contributed directly to the successful efforts of the IPO to build and maintain enthusiastic science communication networks.

IPO support for data management

IPO supported the IPY Data Management Subcommittee in all of its activities. IPO funds allowed the two Co-Chairs of that Subcommittee to attend the IPY Joint Committee meetings and supported occasional advocacy and travel activities by them. The IPO Director spoke constantly and vigorously in support of IPY's free and open data access policy and served as an external reference and supporter for several U.S. and European proposals submitted during IPY for new data services, none successful as it turned out. IPO took a leading and supportive role in the successful nomination of Data Subcommittee Co-Chair Mark Parsons for the 2009 AGU Charles S. Falkenberg award. This is awarded to an individual scientist under 45 years of age who has contributed to the quality of life, economic opportunities and stewardship of the planet through the use of Earth science information and to the public awareness of the importance of understanding our planet.

IPO stimulated and supported several data initiatives that have the potential to substantially change the ways in which polar scientists, and other data users, access and share data. The Polar Information Commons (PIC), led by the ICSU Committee on Data for Science and Technology (CODATA), is an initiative that grew out of IPY and which IPO helped to instigate (*Chapter 3.11*). The PIC draws inspiration from the Antarctic Treaty approach that established the Antarctic as a global commons, used only for peaceful purposes and greater scientific understanding. IPO promoted PIC as a shared virtual resource mirroring the geographic commons and serving the common interests of humanity.

IPO support for the next generation of polar researchers

The IPO provided stimulus, support, guidance, and for many months the initial financial resources for the Association of Polar Early Career Scientists (APECS). Today, APECS (*Chapter 4.3*) is an active network of over 1800 students and early career researchers engaged in polar studies. It provides internationally-coordinated support for career development, science communication and interdisciplinary research. In the U.K., IPO provided core support to the U.K. Polar Network, one of the national components of APECS.

Three months in the life of IPO: a case study

The scope and diversity of support tasks handled by IPO is illustrated here by the typical work undertaken during an approximate 3-month period from May 2007 to mid-August 2007, just after the IPY field phase commenced. The IPO had three full-time staff during that period, David Carlson (DC), Nicola Munro (NM) and Rhian Salmon (RS) (Fig. 1.6-3), with part-time support from Cynan Ellis-Evans (CEE) and Camilla Hansen (CH).

The primary foci during this period were: developing teacher networks and materials for teachers; working with IPY project coordinators to improve data compliance and to integrate across IPY endorsed projects; and science communication and public outreach, particularly to develop the profile of projects outside the Northern Hemisphere and beyond traditional geophysical disciplines. The office also undertook planning for the post-IPY legacy (CEE) and support for the newly-established APECS (DC, RS).

Fig.1.6-3. IPO staff members Nicola Munro (left) and Rhian Salmon (right) with JC member Jerónimo López-Martínez at the IPY Open Science Conference in St. Petersburg, July 2008. (Photo: Jerónimo López-Martínez)

IPO staff interacted with and provided high-level support to the Joint Committee (DC, CEE, NM), Project Coordinators (DC, NM), National Committees (DC, NM, CEE, RS), IPY Subcommittees (DC, RS) and external stakeholders (DC, NM, CEE). Routine administrative tasks included responding to about 140 emails/day that required some kind of action (ALL); responding to media requests (ALL); tracking national and project funding (DC); fortnightly reports to JC and National Committee contacts (DC) and May and July Newsletters to a much wider community (NM); writing science outreach articles (DC) and revising IPY leaflets in several different languages (DC, NM); work with the Media Working Group and the Education Working Group and teachers (RS, NM); and archiving IPY IPO materials at the Scott Polar Research Institute (RS, NM).

The www.ipy.org website was regularly maintained (under oversight from RS). This included continually adding and updating blogs, news, events and educational resource content (RS, DC, NM, CH); improving press, education and participants sections; developing a Google Earth component; and providing more materials and presentations for download.

IPO staff also participated in a number of international meetings during this period. In May, these included ATCM in New Delhi (DC) and a Royal Geographical Society Ice-EDGE Competition in London (CEE). In June there was an International Conference on Digital Earth at the University of California, Berkley and in July the International Science Summer School, in Sydney and World Science Teachers Conference in Perth (all attended by RS). In August, IPO was represented at the Societé Internationale de Limnologie Symposium in Montreal (CEE).

Overview of IPO accomplishments

IPO was much more than an administrative support centre for IPY 2007–2008. It provided a tangible focus of action and momentum, and established a vital link among researchers in different countries with common interests. It gave evidence that IPY was a substantial international research effort rather than a "science promotion year" and served as an easily identifiable information source and effective contact point for IPY. IPO provided effective advocacy for IPY through the numerous presentations given at scientific meetings and to international organizations through the global networks it initiated and coordinated, through the special events such as Polar Days, and its website. This advocacy championed the broad multidisciplinary objectives and international collaboration of IPY and provided important validation of the status and vitality of national scientific programs to their home funding and support agencies.

The IPO also contributed the many administrative and organizational functions necessary for the smooth running of such a large multi-disciplinary international initiative. IPO staff served as planning and steering committee members of numerous international events and conferences, and as organizers of workshops and sessions at many science conferences. IPO arranged and maintained regular contact with representatives of the JC and was an interface between the international stakeholders WMO, ICSU, IASC, SCAR, AC, ATS, IOC, and between National IPY Committees, Project Coordinators and Subcommittees.

While IPO was never large, it was staffed by an energetic and effective team with a genuine enthusiasm for the objectives of IPY. IPO staff members with their unique viewpoint from the centre of the program, were able to provide unbiased and substantial advice for consideration by the Joint Committee, project co-ordinators and National Committees.

IPO closed on 30 September 2010, three and a half months after the official closure of IPY at the Oslo Conference on 12 June 2010 (Fig. 1.6-4). IPO documentation and files have been deposited at the Scott Polar Research Institute (SPRI) in Cambridge, U.K. following the agreement between IPO and SPRI signed in 2008, and the IPO/IPY website was migrated to Arctic Portal (http://arcticportal.org/about) in mid-2009.

Fig.1.6-4. Melissa Deets, IPO administrator, at the IPO booth during the Oslo IPY Science Conference, June 2010.
(Photo: Igor Krupnik)

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Notes

[1] Altogether 37 monthly reports were produced between May 2007 and May 2010.

[2] The main contributors to IPY Trust Fund were Canada, the Netherlands and U.S.A.

[3] Financial support for EASO was provided by Russia, Norway, Sweden and U.S.A.

[4] These contributions included €178,000 from the U.K. National Environment Research Council, €178,000 from the U.S. National Science Foundation, €50,000 from Norway, €30,000 from Spain, €30,000 from Sweden and approximately €31,000 for two workshops from Canada.

1.7 National IPY Secretariats

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The initial planning for IPY 2007-2008 was undertaken by the IPY Planning Group (*Chapter 1.4*), and the oversight and coordination roles were taken on by the IPY Joint Committee (*Chapter 1.5*) and the International Program Office (*Chapter 1.6*). However, responsibility for the implementation of IPY was largely delegated to the IPY National IPY Committees (*Appendix 7*), national funding bodies and polar programs, and their various Secretariats and program coordinators. The role and responsibilities of National Committees were defined early in the IPY planning process (Rapley et al., 2004) and established the linkages between the National Committees and the Joint Committee necessary for the success of IPY (Box 1).

The activities of IPY National Committees and Secretariats were comprehensive and diverse, and were well documented on their various websites during the operational period of IPY 2007-2008. However most of this information is unfortunately no longer available, and this loss occurred very rapidly after March 2009. However, many IPY National Committees and Secretariats have reported on their activities to the national bodies that mandated and funded their activities. Copies of these final reports will eventually be available through the IPY Publications Database and various other IPY Archives (*Chapter 4.2*).

In the years leading up to IPY 2007-2008, most countries developed implementation strategies at national level that consisted of several core activities including promotion, funding and support for logistics in polar research.

Promotion

Promotion activities included selling the idea of an International Polar Year at a political level, to funding agencies, to the science community and to the general public. In the Arctic countries, efforts were also undertaken to promote IPY among northern residents and in the Indigenous communities. This promotion of IPY 2007–2008 was an important initial task, undertaken by many individuals and national polar organizations. Similarly, the ongoing communication of IPY activities required a coordinated effort involving many national and international partners (*Chapter 4.1*). Many national programs also developed their own IPY logos and outreach materials to promote IPY within their national networks (*Appendix 10*).

Funding

Funding solutions varied from country to country. In some countries, national bodies succeeded in securing additional new money for implementing IPY both for research projects and logistics. In other countries, IPY projects had to compete for regular research funding. Many national committees established a procedure for encouraging the submission of IPY proposals to the Joint Committee, and then subsequently to determine funding from various national programs.

Since the implementation of IPY activities depended on international cooperation among scientists from several countries as members of an international project team, high priority was placed upon coordination of funding and logistics. The coordination of funding opportunities and logistics was a difficult puzzle to solve and was not entirely successful, mainly because some scientists did not succeed with their national funding while others did. Several efforts were made by IPY organizers to raise awareness about the need to find ways to align national funding opportunities, but in many cases there was not sufficient time or proper mechanisms to develop accessible transnational funding opportunities.

Logistics

Logistics and Infrastructure requirements had to be identified during the planning stages, which meant that owners of specific platforms (research stations, research vessels, aircraft, satellites, etc.) needed to become fully involved with researchers and funders. In Antarctica, logistics are operated by national Antarctic programs who are members of COMNAP (Council of Managers of National Antarctic Programs, www.comnap.aq). COMNAP was established in 1988 and is an organization with experience in consulting and coordinating international logistics. Its Arctic counterpart, the Forum of Arctic Research Operators (FARO, www.faro-arctic.org) was created in 1998 to play a similar role. However, Arctic logistics and opportunities are quite different because transport solutions and infrastructure are generally more accessible and can include 'self-service' solutions including commercial airline transport and renting of local transport. Enhanced national funding for logistics and access to infrastructure was essential for the success of many IPY programs.

Two examples of efforts to facilitate coordination of national IPY activities

Building the Framework for Global Cooperation: A meeting of Funding and Mission Agencies towards implementation and Coordination during the International Polar Year 2007-2008. The European Polar Consortium (EPC) and the European Polar Board (EPB) invited national funding and mission agencies to a meeting in Copenhagen prior to the ICARP II conference in November 2005 to discuss opportunities and improve cooperation. Sessions at the meeting addressed aspects of coordination and communication between funding and mission agencies; funding (national and supranational); public and political visibility of IPY; IPY legacy; and contributions to building a framework for international cooperation and partnership.

EASO: The IPY Eurasian Sub-Office By special arrangement (*Chapter 1.6*), the IPY Eurasian Sub-Office (EASO) was created at the Arctic and Antarctic Research Institute in St. Petersburg, Russia. The EASO office and the web site (http://www.ipyeaso.aari.ru/) was very valuable for IPY scientists working in the Russian Arctic by providing information about Russian IPY activities and assisting with admission procedures for conducting research in Russia.

Heads of Arctic and Antarctic IPY Secretariats (HAIS)

Recognizing that better communication was required among the operational agencies of IPY, the Heads of Arctic and Antarctic IPY Secretariats (HAIS) group was established in 2006. HAIS members were the national representatives active in the planning and implementation of IPY programs within their own nation. All IPY National Committees and Secretariats were invited to join. Northern hemisphere countries were most active in the HAIS group, but most of these countries supported both Arctic and Antarctic activities during IPY. Several international organisations including AOSB (Arctic Ocean Sciences Board), EPB (European Polar Board), FARO (Forum of Arctic Research Operators), IASC (International Arctic Science Committee), SCAR (Scientific Committee on Antarctic Research) and IASSA (International Arctic Social Sciences Association) were invited as observers.

Between 2006 to 2009, seven HAIS meetings were held. A final meeting was held at the IPY Oslo Science Conference in June 2010. All HAIS agendas, meeting papers and minutes have been archived at: http://classic.ipy.org/national

The objectives of HAIS were to establish a working platform that would provide support and enhance capacity amongst national Secretariats, develop and facilitate collaboration among IPY countries, discuss common/practical challenges with the view to achieving and facilitating resolution, develop advice for consideration and implementation by the IPY International Program Office and Joint Committee, share information about international, national, and regional IPY programs and initiatives and assist each other in meeting common objectives. In the first year members of HAIS used the forum primarily to discuss issues related to the implementation of IPY activities. Later, issues related to IPY legacies and international cooperation, including access to transnational funding opportunities, were high on the agenda.

HAIS-1 (October 2006)

The first HAIS meeting was held 5-6 October 2006 at the National Academies of Science, Washington DC, USA. Participants from all countries with established IPY offices and National Committees were invited to participate, and the following individuals were able to attend (Box 2). The meeting was hosted and chaired by Chris Elfring (U.S. Polar Research Board).

This first meeting of the HAIS group focused on sharing information about various national IPY activities. There was also considerable discussion about opportunities to improve communication between international and national IPY organizations, related to communications and outreach, and the work of the IPY subcommittees. The HAIS members also discussed funding, data management, the potential legacies of IPY, and the program for the planned official launch of IPY by WMO and ICSU in March 2007.

HAIS-2 (February 2007)

HAIS-2 was held at the Danish Polar Center in Copenhagen, Denmark, 1-2 February 2007. The meeting was attended by David Hik, Scott Tomlinson (Canada); Henning Thing, Hanne Petersen (Denmark, chair and hosts); Paul Egerton (European Science Foundation); Paula Kankaanpää, Kari Laine, Riku Lavia (Finland); Tom Greiffenberg (Greenland); Odd Rogne, David Carlson (IPY IPO); Volker Rachold (IASC); Ragnar Baldursson (Iceland); Ito Hajime (Japan); Odd Rogne (IPY IPO); Marianne Walgreen (Netherlands); Olav Orheim (Norway); Alexander Guterch (Poland); Sergey Priamikov (Russia); Anders Clarhäll, Lars Nilsson (Sweden).

The main activities of HAIS discussed were the exchange of information about collaborative opportunities (including bilateral side meetings for solving IPY implementation issues), direct communication with IPO and other IPY Secretariats, and a general discussion about IPY legacies beyond the project level. Preliminary discussions about the new Sustaining Arctic Observing Networks (SAON) initiative (*Chapter 3.8*) were also discussed. Other topics included promotion and implementation of the IPY data policy, including how to react if project leaders did not comply, and some preliminary consideration of ideas for an IPY closing ceremony in March 2009. HAIS members also discussed the possibility of extending

Box 1 Role of IPY 2007-2008 National Committees
(Rapley et al., 2004)

The functional responsibilities of IPY 2007-2008 National Committees will vary between countries. In some countries, National Committees may be involved in funding processes. In all countries, these Committees are expected to work under the following general terms of reference:

1. To act as an information conduit from the Joint Committee to the national scientific community and National Meteorological Services to promote awareness of and interest in IPY 2007-2008;

2. To provide national input to the Joint Committee for the formulation of the IPY programme of activities;

3. To facilitate the planning and implementation of national activities contributing to IPY 2007-2008, including, where appropriate, the endorsement of IPY expressions of intent and/or proposals;

4. To ensure that nationally-collected IPY data are available to the international research community in accordance with protocols developed for data exchange within IPY 2007-2008;

5. To take a lead role on issues of outreach education and communication at the national level;

6. To encourage and facilitate the provision of necessary national funds, logistical support, and other support for the implementation of national activities contributing to the IPY 2007-2008 objectives;

7. To encourage and facilitate national contributions to the cost of the international scientific coordination and integration of IPY 2007-2008;

8. To assist the Joint Committee in the planning, implementation, data management, and delivery of IPY 2007-2008;

9. To host regional or international IPY 2007-2008 meetings.

the IPY Observing period beyond 2009, but concluded that there shouldn't be any change in the formal name (IPY 2007-2008).

HAIS-3 (March 2007)

The meeting was held 15 March 2007 in Hanover, New Hampshire, U.S.A. as a side meeting to the Arctic Science Summit Week. Participants included: David Hik (chair), Karen Edwards, Kathleen Fischer (Canada); Henning Thing (Denmark); Paul Egerton (EPB); Paula Kankaanpää, Kari Laine (Finland); Volker Rachold (IASC); David Carlson, Odd Rogne (IPY IPO); Louwrens Hacquebord (Netherlands); Olav Orheim, Fridtjof Mehlum (Norway); Alexander Guterch, Piotr Glowacki (Poland); Sergey Priamikov (Russia); Colin Summerhayes (SCAR); Sverker Sørlin (Sweden); Cynan Ellis-Evans (U.K.); Chris Elfring (U.S.A).

One of the main topics for discussion at HAIS-3 concerned various Observing Systems initiatives. HAIS was supported initiation of the Sustaining Arctic Observing Networks (SAON) initiative and SCAR informed that a similar initiative to SAON had been taken by SCAR with an Antarctic terrestrial observing system and a Southern Ocean observing system. The European Polar Board summarized possible multi-national funding approaches being discussed in Europe.

HAIS-4 (November 2007)

The meeting was held 5-6 November 2007 at the Arctic and Antarctic Research Institute (AARI) in St.

Box 2 Individuals attending the inaugural Heads of Arctic and Antarctic Secretariats (HAIS) meeting in October 2006

Canada:
David Hik, *Executive Director, Canadian IPY Secretariat*

Karen Edwards, *Coordinator, Canadian IPY Secretariat*

Denmark/Greenland:
Henning Thing, *Danish IPY Secretariat, Danish Polar Center*

Tom Greiffenberg, *Research Coordinator, Greenland Home Rule Government*

Iceland:
Ragnar Baldursson, *Chair of the Icelandic National IPY Committee, Ministry of Foreign Affairs, Iceland*

Italy:
Harry Beine, *National Research Council of Italy, Institute of Atmospheric Pollution*

Netherlands:
Marianne Walgreen, *Coordinator of the Dutch IPY Programme, NWO (Netherlands Organisation for Scientific Research)*

Norway:
Olav Orheim, *Head of the Norwegian IPY Secretariat, Norwegian Research Council*

Poland:
Alexander Guterch, *Chair of the Polish National IPY Committee, Institute of Geophysics, PAS*

Russia:
Valeriy Martyshenko, *Head, Russian IPY Organising Committee Secretariat*

Sergey Priamikov, *Head of the International Science Cooperation Department, Arctic and Antarctic Research Institute (AARI)*

Sweden:
Lars M. Nilsson, *Executive Secretary, Swedish IPY Committee, Swedish*

United Kingdom:
J Cynan Ellis-Evans, *Head of the Secretariat, National IPY Committee of the UK, British Antarctic Survey*

U.S.A.:
Chris Elfring, *Director of the Polar Research Board, National Academy of Science (NAS), and US National Committee for IPY*

Maria Uhle, *IPY Study Director, NAS*

Rachel Shiflett, *logistics for the Washington DC meeting*

IPY International Program Office:
David Carlson, Director, IPO

Odd Rogne, Senior Advisor, IPO

HAIS Partners:
Paul Egerton, *Executive Director, European Polar Consortium-European Polar Board*

Sara Bowden, *Executive Secretary, Arctic Ocean Sciences Board (AOSB)*

Simon Stephenson, *Chair, FARO (Forum of Arctic Research Operators), and National Science Foundation*

Petersburg, Russian Federation. Participants included Kari Laine (Finland); Volker Rachold (IASC); Ragnar Baldursson (Iceland); Odd Rogne (IPY IPO); Hajime Ito (Japan); Jacek Jania (Poland); Sergey Priamikov (Russia, chair and host).

This meeting provided an opportunity to visit the EASO: the Eurasian IPY Sub-office. HAIS members reviewed national status of IPY activities and Sergey Priamikov presented what he saw as three vital problems:

1. Access to data and exchange of information;
2. Development of a technical policy and strategy as to marine investigations;
3. Determine which study/observing sites should be given priority.

Other HAIS members reported their continuing interest in IPY legacy, for example Finnish activities related to education and young people; long-term observations and monitoring, and policy legacies, especially the Northern Dimension of EU. HAIS members also discussed the proposed IPY Policy Conference 2012 to be hosted by Canada and suggested that Arctic Council and the ATCM should be heavily involved in such a policy conference since they were considered the logical choice for advancing IPY legacies in the policy arena.

HAIS-5 (May 2008)

The meeting was held 26-27 May, 2008 at the Jagellonian University, Rectorate in Krakow, Poland. Participants included Kari Laine (Finland); Ragnar Baldursson (Iceland); Odd Rogne (IPY IPO); Hajime Ito (Japan); Olav Orheim (Norway); Jacek Jania, Alexander Guterch, Piotr Glowacki, Wieslaw Ziaja (Poland, hosts); Sergey Priamikov (Russia); Anders Clarhäll (Sweden); Colin Summerhayes (SCAR).

At HAIS-5 there was considerable discussion about how polar research is organized in various countries. For example, Poland was considering centralizing logistics and coordination by linking all 23 university and academy groups together in the form of a Polish Polar Research Network. Sweden had undertaken an 'International Evaluation of the Swedish Polar Research Organisation'. Iceland reported that all national research institutes are to a large degree engaged in polar research using the traditional research organizations, and a group is working on 'Icelandic Arctic Policy', which also will include research. Japan reported that changes to a rather complicated polar research organization were being discussed. Finland reported good coordination between the National Committee on Polar Research, which is a coordinating body which also includes activities in IASC, SCAR and IPY, and the main Arctic institutes at the University of Oulu and University of Lapland. Russia was undergoing a reorganization and the outcome was not yet known.

There was also discussion about IPY legacies included a review of the Norwegian proposal on 'Maximising the Legacy of IPY', which would focus on issues of potential interest to the policy community, such as societal use of research results; observations and data; accessibility; and circum-Arctic scientific cooperation including coordinated funding. HAIS members also requested IASC and SCAR to consider ways in which multinational, bipolar research funding could be obtained. They also urged compliance with the IPY Data Policy to all IPY funded projects, and noted the positive activities of the Association of Polar Early Carrier Scientists (APECS).

HAIS-6 (January 2009)

The meeting was held 26 January 2009 at the British Antarctic Survey, Cambridge, U.K. Participants included David Hik (Canada); Kari Laine (Finland); Volker Rachold (IASC); David Carlson, Odd Rogne, Nicola Munro, Rhian Salmon (IPY IPO); Hajime Ito (Japan); Martijn Los (Nethelands); Olav Orheim (Norway); Anders Clarhäll (Sweden); Colin Summerhayesj (SCAR); Cynan Ellis-Evans (U.K., chair and host).

HAIS members discussed efforts to secure funds to continue the IPY IPO until the 2010 IPY conference in Oslo, and supported the requests that had been sent to the international polar science community. Olav Orheim gave a status report about the Oslo Conference and preliminary ideas about the 2012 IPY Conference in Canada were discussed. HAIS members also discussed opportunities to participate in the IPY celebrations planned for February 2009. With respect to IPY legacy issues, HAIS determined that the IPY International Program Office was the logical body to secure more documentation about IPY legacies, so historians will know what was achieved during this IPY; that IASC and SCAR should clarify which legacies they are interested in, including science programs, observation programs, and data management; and that other IPY legacies will have to have defined and find a home before the IPY come to an end. There was a need for clarifying which potential IPY legacies exists, and who will take on the responsibility for carrying them forward. Creating and maintaining a simple IPY Legacy Inventory was the basic requirement.

HAIS-7 (October 2009)

The meeting was held 16 October 2009 at the Norwegian Research Council in Oslo, Norway. Participants included Odd Rogne (IPY IPO); Masaki Kanao (Japan); Olav Orheim (Norway, chair and host); Alexander Guterch (Poland); Sergey Priamikov (Russia); Anders Clarhäll (Sweden).

The meeting was held in conjunction with the IASC/SCAR Bipolar Action Group (*Chapter 5.5*). Much of HAIS discussion addressed aspects of IPY legacies and the future of HAIS. It was clear that participation in HAIS was declining, but not in all countries. While the Russian IPY Organizing Committee, Secretariat and website would continue, many other HAIS members would be leaving their IPY offices and duties in the next few months. The group discussed the need for HAIS after IPY, and concluded that while HAIS had been a useful forum for the IPY period, the long-term responsibilities for IPY legacies should rest with IASC and SCAR.

HAIS-8 (June 2010)

The meeting was held 10 June 2010 on the margins of the IPY Olso Science Conference in Oslo, Norway. Participants included David Hik (Canada); Odd Rogne (IPY IPO); Olav Orheim (Norway, chair and host); Jacek Jania (Poland); Chris Elfring (U.S.A.).

The meeting was brief and formally concluded the activities of the HAIS.

Summary

Members of HAIS believed that they made a valuable contribution to the planning and implementation of IPY 2007-2008. The personal contacts that were made at the national level among individuals involved in the day-to-day operation of IPY activities were an invaluable asset. Although it was not possible to include all countries in HAIS, the discussions were widely circulated and facilitated the necessary sharing of information, ideas and problems. Although HAIS existed informally within the organizational structure of IPY 2007-2008, it managed to facilitate a degree of coordination and understanding among national programs that would not have been possible without it.

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PART TWO

IPY Science Program

Coordinating Editors: Ian Allison and Jerónimo López-Martínez
Reviewer: Vladimir Ryabinin

Introduction

Ian Allison and Jerónimo López-Martínez

As an internationally coordinated research effort, science was at the core of the International Polar Year (IPY) 2007–2008. In this section, the IPY scientific projects undertaken in major fields and disciplines are summarized, and some of the preliminary results are presented. The scientific results of IPY are still evolving and, as was also the case for previous international polar years, will continue to do so for years after this report is published. The chapters included here were primarily written from late 2009 to early 2010, only a few months after the conclusion of the field campaigns. In some cases, data and samples are not yet analyzed and interpretation and publication of the results is ongoing. In many cases, synthesis of results from different IPY projects will contribute additional outcomes. Hence, this section must be considered only as an early and preliminary summary of IPY scientific outcomes.

The IPY science program was closely linked with other key IPY components, particularly with observational and data-management efforts. IPY projects exploited both existing and newly established observing systems. In many cases, new observing systems have been promoted and developed in connection with IPY scientific projects. Hence, some of the chapters included here in *Part 2* refer directly to observational efforts discussed in *Part 3* and vice versa. In this section, however, the focus is on the scientific problems addressed and on the preliminary results rather than on the observational systems. Throughout IPY planning and implementation, data management was always considered an essential component of each project (*Chapter 3.11*).

The IPY scientific projects also provided fundamental support for other IPY objectives. They were key to attracting and developing a new generation of polar researchers and for engaging the interest of students, polar residents, and the general public. In addition, all endorsed IPY science projects were required to include an integral component of education, outreach and communication.

IPY aimed to establish a scientific program that addressed the six research themes defined by the IPY Planning Group in consultation with the international polar community and relevant organizations (Rapley et al., 2004; *Chapter 5.1*). These were: Status, Change, Global Linkages, New Frontiers, Vantage Point and Human Dimension of the polar regions. Science projects and research teams were expected to be interdisciplinary and to address relevant questions and issues lying beyond individual disciplines.

Considerable effort was given to assembling an IPY science program that addressed these objectives and built on the enthusiastic contribution of a flood of proposals from the community and the great diversity of scientific fields that these encompassed. This process, undertaken in several steps, involved assessing, distilling and combining the 490 initial "ideas" submitted to the ICSU Planning Group by mid 2004 (*Chapter 1.3*), the more than 1100 'expressions of intent' submitted to the Joint Committee by mid 2005 and the 337 full proposals for science projects and data management submitted by February 2006 (*Chapter 1.5*). The IPO and the JC members reviewed and assessed the EoIs and full proposals against the stated IPY objectives. They strived to avoid overlap, to increase interdisciplinarity, to fill identified gaps and to integrate smaller proposals within multidisciplinary, internationally coordinated projects. The final outcome of this process resulted in 170 IPY endorsed scientific research projects, plus one integrating data management project: these formed the core IPY science (*Chapter 1.5*). This IPY science program was documented as it developed in two publications compiled by the Joint Committee (Allison et al., 2007, 2009). IPY 2007–2008 also included an additional 57 EO&C projects. Information available to the IPO at the conclusion of the IPY field period indicated that 170 of the 228 total projects received some support and were able to go ahead.

This section (*Part 2*) consists of 11 chapters, organized by broad disciplinary field. Each chapter summarizes scientific activities in both polar regions, except for the ocean science chapters (*2.2* and *2.3*) and the ice sheet chapters (*2.4* and *2.5*) which treat the Arctic and Antarctic research during IPY separately.

Chapter 2.1 covers research related to the polar atmosphere. It includes reference to 16 projects that are grouped under two main topics: i) physics of the troposphere and stratosphere, and climate change, and ii) tropospheric chemistry, air pollution and climate impacts. *Chapter 2.2* on the Arctic Ocean focuses on the present and future state of northern seas and their role in climate. It describes some of the main advances that were made in research of Arctic and subarctic seas during IPY, and shows how the integrated Arctic Ocean Observing System (iAOOS) served as a coordinating framework for northern oceanographic projects during IPY. This chapter reports on important achievements during IPY that build on existing knowledge of: i) the changing inputs to the Arctic Ocean from subarctic seas; ii) the changing oceanography of the Arctic Ocean itself; and iii) the changing outputs from the Arctic to subarctic seas. IPY research in the Southern Ocean is covered in *Chapter 2.3.* It summarizes preliminary results on the role of the Southern Ocean in the Earth system resulting from multidisciplinary IPY projects in the Southern Ocean carried out by scientists from more than 25 countries. Activities here are grouped into sections on: i) ocean circulation and climate; ii) biogeochemistry; iii) marine biology, ecology and biodiversity; and iv) Antarctic sea ice. Much of the research covered in this chapter is coordinated with similar activities in the Arctic (*Chapter 2.2*) providing a bipolar perspective.

New measurements during IPY led to important advances in knowledge of the Antarctic and Arctic ice sheets, and these are described in *Chapter 2.4* and *Chapter 2.5* respectively. IPY projects investigated ice shelves and the interaction between the ice sheets and the ocean; the subglacial domain; surface and subglacial measurements, including satellite, geological and geophysical observations; and field and numerical modeling studies of climate and glacial history. Advances in the study of subglacial aquatic environments during IPY are summarized in *Chapter 2.6*. During IPY 2007–2008, subglacial lakes and water movement beneath the ice was recognized as a common feature of ice sheets, with potential influence on ice sheet movement and possibly on past and future climate change.

Chapter 2.7 covers regional, bipolar and multidisciplinary permafrost research. Activities during IPY focused on assessment of the thermal state of permafrost and the thickness of the active layer; on the quantification of carbon pools in permafrost and their potential future remobilization; on quantification of erosion and release of sediment along permafrost coasts; and on periglacial process and landform quantification.

Chapter 2.8 deals with IPY projects studying Earth structure and geodynamics in polar regions. It includes research into the geodynamic, tectonic and sedimentary processes that drive the topographic formation and the location of the ocean basins and corridors between emergent land masses. These corridors, which determine ocean current paths, have changed over time, with consequences to global climate. New geodynamic observations in several regions during and just prior to IPY, using seismic, magnetic, gravity and ice-penetrating radar techniques, together with satellite imagery and geological observations, contributed to this research. Research into geodynamic processes at the base of polar ice sheets are also covered in this chapter. This chapter shows how the network of polar Earth and geodynamics observatories has been significantly improved during IPY.

The research carried out during IPY on terrestrial ecology is covered in *Chapter 2.9*. Parts of the Arctic and the Antarctic Peninsula are warming twice as fast as elsewhere on Earth and many impacts already affect biodiversity and ecosystem processes, some of which have global consequences. Therefore, IPY 2007–2008 took place in a very opportune time to document changes in polar terrestrial ecosystems and their impacts on the atmospheric, hydrological and nutrient cycles as well as on the human communities that occupy and use those ecosystems. Altogether, 30 international projects on polar terrestrial biology and ecology were implemented during IPY, and activity has been intense throughout the Arctic and in the Antarctic. Many IPY projects were multidisciplinary ventures and a common denominator for the research was climate change impacts across the polar regions.

IPY 2007–2008 was the first polar year to include social science and humanities, and to involve active leadership from polar residents, particularly indigenous people, in research projects. *Chapter 2.10* covers IPY activities of the 35 endorsed research projects in social science (anthropology, archaeology, economics, linguistics, political science) and the humanities (history, literature, arts). *Chapter 2.11* is about human health and medical research in the northern polar regions and it also includes a substantial social component. It provides an overview of the history, which informed health research activities during IPY 2007–2008, and highlight the IPY activities, which were undertaken within a circumpolar health context. This chapter points out the disparities in human health that currently exist across different Arctic nations and regions.

Although results from many IPY science projects are still being analyzed and interpreted, this chapter, and the recent publications and web pages referenced in it, provide a much-needed early snapshot of the results of the IPY science program by major fields and disciplines. Another attempt as assessing the IPY science outcomes across six cross-disciplinary themes that were pivotal to the IPY 2007–2008 design is offered in *Chapter 5.1*.

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2.1 Polar Atmosphere

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Introduction

While meteorology was the major focus of the first IPY (1882–1883), in the IPY 2007–2008 only 17 from the 170 officially endorsed scientific projects were assigned to the domain of "atmosphere". This does not mean, however, that the role of atmospheric research in polar sciences is not as high as it used to be. The modern atmospheric science has become inherently multi-disciplinary and there is a very significant "atmospheric dimension" in IPY projects carried out in all IPY domains such as ice, ocean, land, people and others. Many of the critically important changes in the Earth system are occurring in the atmosphere ,including the buildup of greenhouse gases with corresponding increase of temperatures, evolving statistical structure of precipitation and stratospheric ozone depletion - to name just a few.

The 17 IPY projects assigned to the domain of "Atmosphere" are listed in Table 2.1-1.

We present here an overview of the preliminary results of polar atmosphere studies obtained in the course of implementation of some the above projects. They are grouped into two main topics: (1) physics of the atmosphere, climate change and processes in the stratosphere and (2) tropospheric chemistry, air pollution and climate impacts.

Project No	Abbreviation	Main topic of the project
19	NobleMet	Pollution Trends
28	CARE/ASR	Climate of the Arctic
32	POLARCAT	Climate, Chemistry and Aerosols
41	Concordiasi	Antarctic Plateau Science
76	ATMOPOL	Pollution Monitoring Network
99	ORACLE-O3	Ozone Layer and UV Radiation
121	THORPEX-IPY	Polar Weather Forecasts
140	HIAA	Hydrological Impacts of Aerosols
171	POLAR-AOD-IPY	Aerosol Distribution Network
175	COPOL	Polar Region Contaminants
180	AC	Atmospheric Circulation and Climate
196	IASOA	Arctic Atmosphere Observing System
217	SPARC_IPY	Stratosphere = Troposphere Links
267	COMPAS	Comprehensive Meteorological Dataset of Active IPY Antarctic Measurement Phase for Scientific and Applied Studies
327	INCATPA	Pollution Transport to the Arctic
357	SCSCS	Climate System of Spitsbergen
443	RadTrace	Tracers of Climate Change

Table 2.1-1. IPY projects for polar atmosphere studies.

Atmospheric physics, climate and stratospheric processes

International Arctic Systems for Observing the Atmosphere **(IASOA no. 196)** aimed to enhance Arctic atmospheric research through intensive collaboration during the IPY and beyond. It includes the stations Abisko, Sweden; Alert and Eureka, Canada; Barrow, U.S.A.; Cherskii and Tiksi, Russia; Ny-Ålesund, Norway; Pallas and Sodankylä, Finland; and Summit, Greenland. Measurement and building upgrades took place at the stations Tiksi, Eureka, Summit and Barrow observatories (*Chapter 3.4*).

A new observatory building recently completed in Tiksi is available for installation of instruments (Fig. 2.1-1). A second Clean Air Facility (CAF) that is suitable for aerosol, chemistry, pollutant, greenhouse gases, fluxes and radiation measurements was completed in 2008. Instruments for continuous measurement of ozone and black carbon, and flasks for carbon cycle gas measurements for the new Tiksi station were obtained. Establishment of the Tiksi observatory is a significant step in the creation of an international circumpolar network of stations for monitoring of Arctic climate change. During the IPY period many Russian meteorological stations were substantially reconstructed. Twenty-three meteorological polar stations were upgraded. At several stations, upper-air and geophysical launches of radiosondes and meteorological rockets were restarted. Monitoring of cosmic rays in the Arctic atmosphere was also carried out. Fluxes of charged particles observed in the atmosphere from the ground up to altitudes of 30-35 km provide evidence of unusually profound and long-lasting minimum of the solar activity during the IPY period.

At the Eureka site many instruments including a flux tower, several CIMELs for the Aeronet Network and a Baseline Surface Radiation Network (BSRN) station were installed in summer 2007. With IPY funding, the level of technical support at the site has been increased to provide more reliable data collection and transmission.

The Summit, Greenland observatory has recently released a strategic plan highlighting climate sensitive year-round observations, innovative research platforms and operational plans to increase the use

Fig. 2.1-1. The new building of Tiksi Observatory.
(Photo: Alexander Makshtas; Makshtas, 2007)

renewable energy and maintain the pristine platform. Summit also has a new multi-channel gas chromotograph/mass spectrometer (GC/MS) for continuous measurement of trace halocarbon and CFC gas concentrations. All NOAA instruments were moved from the science trench to a new atmospheric watch observatory building.

The Barrow observatory has two new systems for measurements of aerosol size and chemistry composition, as well as persistent organic pollutants (POPs). The meteorological measurements and data system has been completely upgraded.

Current IASOA activities include the development of a web site (www.iasoa.org) that will serve as the "go-to" site for atmospheric Arctic researchers to obtain information about the member observatories. Information posted for each station includes a general overview of the observatory, a listing of available measurements and principal investigators, links to data bases and station contacts. These pages will help Arctic researchers find the data they need to complete their research. The development of these observatory webpages and the "observatories-at-a-glance" page has allowed us to identify gaps in atmospheric measurements in the Arctic (detailed information on this project is also given in *Chapter 3.4*).

Climate System of Spitsbergen (SCSCS no. 357): Intercomparison and analysis of radiation data obtained by Russian and Norwegian standard radiation sensors at Barentsburg and Ny-Alesund research stations

Joint analysis of historical and current data of radiation observations obtained in different countries indicates a need for comparing readings of instruments. This is especially true for the Russian and Norwegian stations on Svalbard (Spitsbergen). From the beginning of regular Russian radiation measurements on Svalbard (Barentsburg settlement), the observation program has used standard Russian sensors (Yanishevsky-Savinov pyranometers M-80 or M-115M). All radiation measurements carried out on the research stations of other countries involved in polar research (Norway, Germany, Italy, U.K., U.S.A., China, Republic of Korea and France) are compactly located in the Norwegian settlement Ny-Alesund (Kings Bay) and combined into one common network in the framework of the international "Kongsfjorden International Research Base" (Fig. 2.1-2).

The incoming global, diffuse and reflective radiations are recorded separately. As a rule, the aforementioned countries use universal common measurement

Fig. 2.1-2. *Yanishevsky-Savinov* (right) and *Kipp and Zonen* (left) pyranometers used in intercomparisons carried out at the Russian station Barentsburg (Svalbard) in April 2008.

(Photo: Boris Ivanov; Ivanov et al., 2008).

instruments on the basis of "Kipp & Zonen" sensors from The Netherlands (CMP6, CMP11 and CMP21). It seems to be both advisable and necessary to include the Russian observations conducted in Barentsburg into this network. Intercalibration studies in the framework of this program with the use of Russian and Norwegian instruments were carried at the Barentsburg research station in April 2007 and Ny-Alesund ("Sverdrup" research station of The Norwegian Polar Institute) in April 2008. The joint measurements by pyranometers M115M and CM11 have allowed us to obtain representative data for a combined analysis, reveal discrepancies between the Russian and Dutch sensors and take into account these corrections in the analysis of historical and current data aimed at comparative studies of radiation climate of this region. For comparative climatic studies, the data of the Russian station in Barentsburg and the Norwegian stations in Ny-Alesund were used as the reference and most representative and long-term stations. These studies granted mutual access to national data sources for the both partners thereby providing the data for their joint analysis. This project is a continuation and development of the Russian science program "Research of a meteorological regime and climatic changes on Svalbard", carried out by the AARI in the framework of the IPY and NPI projects "Arctic Climatic Diversity" (ARCDIV).

The conformity between diverse sensors (M115M and "Kipp & Zonen") is quite satisfactory as is apparent from Fig. 2.1-3. The discrepancies of average values are 6.3 ±5.6 W/m^2 for all observations. They were maximal at noon, reaching ~36 W/m^2. Nevertheless, in total, these discrepancies do not exceed absolute inaccuracy of measurements (for example, 8% for M115M).

Contribution of the POLAR-AOD (no. 171)

The principal aim of this project was to establish a bipolar network of sites, where multi-wavelength sun-photometers have been used to take regular measurements of aerosol optical depth (AOD) and optical properties of aerosols. Integrated regular measurements of aerosol physical and radiative properties at a number of polar stations were planned in order to (i) evaluate the seasonal background concentrations inferred from AOD measurements, (ii) define the spectral characteristics and patterns of the radiative processes induced by both natural and anthropogenic aerosols, and (iii) ameliorate the knowledge of physical, chemical and radiative properties of polar aerosols, and of their horizontal and vertical distributions and temporal variability, for better evaluating the role of polar aerosols in the

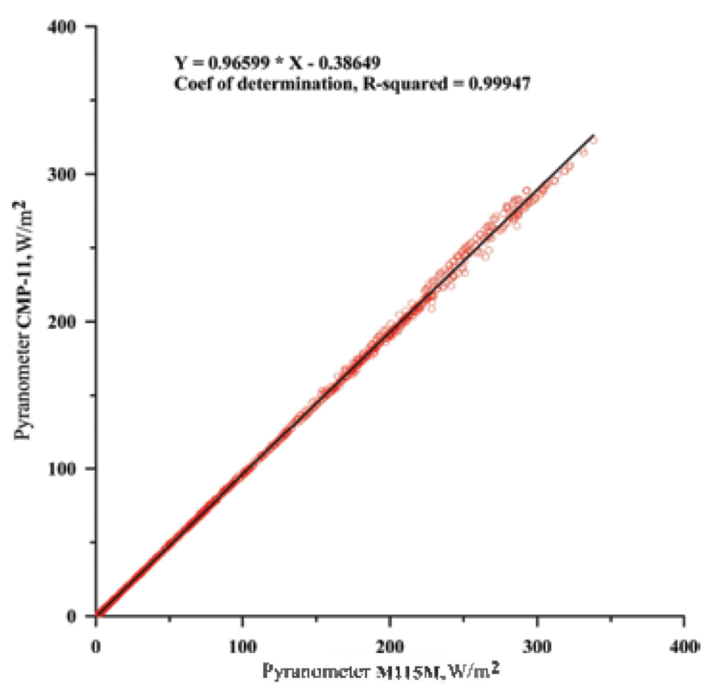


Fig. 2.1-3. Relationship between measurements by *Yanishevsky-Savinov* (M115M) and *Kipp and Zonen* (CMP11) pyranometers.
(Ivanov et al., 2008)

climate system.

Measurements at Arctic and Antarctic stations have been carried out during IPY with the logistic and financial support of established national programs, while archiving, data management, intercalibration and coordination of other activities have mainly been developed by the leading groups (Italy, Germany, U.S.A.) in cooperation with the other partners (43 research groups from 24 countries). During IPY, field data were recorded at 15 stations in the Arctic (Alert, Eureka, and Resolute Bay, in Canada; ALOMAR in Northern Norway; Barrow in Alaska; Hornsund in Poland; and Ny-Ålesund (five stations of Norway, Germany, Italy, Japan and China) in Svalbard, Norway, Pallas and Sodankylä in Northern Finland, Summit in Greenland and Tiksi in Siberia, Russia), and 23 stations in Antarctica (Aboa/Finland, Belgrano II/Argentina, Casey/Australia, Davis/Australia, Dome Fuji/Japan, Dome Concordia/Italy and France, Halley/U.K., Kohnen/Germany, Machu Picchu/Peru, Mastri/India, Marambio/Argentina, McMurdo/U.S.A., Mirny/Russia, Mario Zucchelli/Italy, Neumayer/Germany, Novolazarevskaya/Russia, Palmer/U.S.A., Princess Elisabeth/Belgium, South Pole/U.S.A., Syowa/Japan, Troll/Norway, Vechernaya Hill/Belarus and Zhongshan/China). All of these field data are still in the process of being archived and analyzed by the participating institutes.

The activities developed by the various partners primarily included: (1) management of long-term climate monitoring programs and/or performance of routine sun-photometric measurements over multiannual periods (groups from Italy, Germany, U.S.A., Canada, Japan, Russia, Norway, Switzerland and Finland); (2) implementation of sun-photometric observations and monitoring programs in the Antarctic and/or Arctic, over recent years (groups from Spain, Poland, Norway, France, Argentina, Australia, India, Belgium and Belarus); (3) development of programs to carry out *in situ* measurements of aerosol radiative parameters, chemical composition of particulate matter, and particle morphology and concentration (groups from U.S.A., United Kingdom, Sweden, Finland, Norway, Holland, Greece, Switzerland and China); and (4) improvement of radiative transfer models to simulate Rayleigh scattering (Tomasi et al., in press), gaseous absorption and aerosol extinction in the polar atmosphere (groups from Italy, U.S.A., Canada, Germany, Japan, Russia and Bulgaria).

Because sun-photometer measurement activities were performed by the various groups using different instruments, the POLAR-AOD project promoted two international intercalibration workshops with the purpose of attaining more homogeneous evaluations of AOD at the various visible and near-infrared wavelengths in the Arctic and Antarctic. The first workshop was held at the Japanese Rabben station (78° 56′ N, 11° 52′ E, 40 m a.m.s.l.) near the Ny Ålesund Airport, from 25 March to 5 April 2006 about one year before the official start date of the IPY (in February 2006), with the participation of ten research groups from nine countries (Canada, Finland, Germany, Italy, Japan, Norway, Poland, Spain and U.S.A.) using sun-photometers of different design already employed at a number of Arctic and Antarctic. The second workshop was held a few months before the end of the IPY field phase at the Izaña Meteorological Observatory at Tenerife, Spain (28° 19′ N, 16° 30′ W, 2368 m a.m.s.l.) from 5 to 20 October, 2008 with the participation of 13 research groups from ten countries (Canada, Finland, France, Germany, Italy, Japan, Norway, Poland, Spain and U.S.A.) and the participation of instruments employed in the AERONET and SKYNET networks.

Results obtained by the POLAR-AOD project are as follows:

1. The characterization of the radiative properties of Arctic aerosols made by plotting the daily mean values of Ångström (1964) exponent α versus the corresponding values of AOD (500 nm).
2. Large variations in AOD were often observed at the Arctic sites, passing from the background atmospheric loadings of aerosols (AOD < 0.04) in summer to the period of higher frequency of Arctic haze episodes (often with AOD > 0.30), as shown in Fig. 2.1-4.
3. Such enhanced turbidity characteristics of the Arctic atmosphere are not only due to the emission of anthropogenic pollutants from North America, Europe and Asia, but also to biomass burning, agricultural activities, dust plumes from Asian deserts and (in late spring and summer) smoke plumes from fires burning millions of hectares of boreal forest each year in North America and Siberia. The Arctic haze extinction levels were very high in the 1980s and early 1990s, mainly due to

anthropogenic pollutants, and were observed to decrease in the following years with the reduction of SO_2 emissions in North America and Europe. Nevertheless, simultaneous with the increasing patterns of AOD as shown in Fig. 2.1-4, both light scattering and light absorption (mostly due to black carbon) are now increasing (Sharma et al., 2006) along with the changes in atmospheric transport induced by the significant shifts recently observed in the atmospheric circulation. This implies that the deposition of black carbon particles and other light-absorbing aerosols, such as soot matter and dust, is increasing and is, therefore, expected to cause a lowering of the ice- and snow-surface albedo, leading to a positive and highly efficient radiative forcing and the most important positive feedback mechanisms in the climate system (melting of snow/ice → exposition of darker surfaces → decrease in the surface albedo → repetition of subsequent cycles).

4. The characterization of Antarctic aerosols, performed by plotting the daily mean values of α versus AOD (500 nm), has offered great evidence of the strong differences between coastal aerosol polydispersions (with predominant contents of sea-salt particles, and yielding AOD values ranging mainly from more than 0.02 to 0.10) and the High Plateau aerosols (with prevailing contents of non-sea-salt sulfates and methanesulphonate aerosols particles, presenting AOD values usually lower than 0.02). No relevant contents of black carbon were found in either coastal or Antarctic Plateau aerosol polydispersions, transported from mid-latitude regions and originated from biomass burning and tropical forest fires. In fact, the concentration of this highly-absorbing component was evaluated to assume values usually no higher than a few ng•m^{-3} at both coastal and internal high-altitude sites.

(5) The analysis of long-term variations of AOD (500 nm) in Antarctica over the last 30 years clearly indicate that solar radiation extinction produced by columnar Antarctic aerosols was quite stable, due to the long distance of Antarctica from the other continental sources of particulate matter.

A series of long-term spectral and photometric measurements of the solar radiation over the Atlantic Ocean and in the Antarctic was also performed by Russian researchers during the IPY period on board a research vessel to investigate the spatial distribution

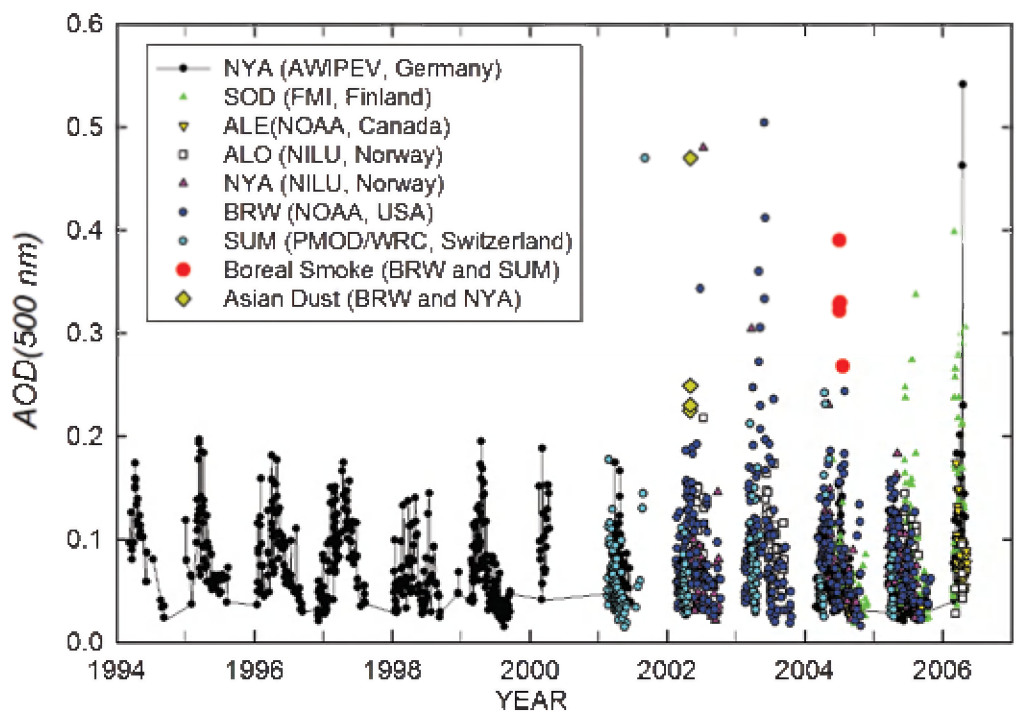


Fig. 2.1-4. Time-patterns of the daily mean values of aerosol optical depth AOD at the 550 nm wavelength, measured from 1994 to 2006 at seven Arctic stations. The strong aerosol extinction data observed in 1992 and 1993 and due to the Pinatubo eruption are excluded. Clearly seen is the sequence of gradually more marked aerosol extinction peaks due to the occurrence of an increasing annual number of Arctic haze episodes observed most frequently from December to April. Yellow diamonds refer to an Asian dust transport episode observed at Barrow in April 2002, and red circles to extinction by smoke aerosol clouds generated by forest fires in Alaska and Northern Canada in summer 2004 and subsequently transported over Greenland and Svalbard within a few weeks.

(Tomasi et al., 2007, Fig. 3)

of the aerosol component in the atmosphere over the Atlantic from 60° N to the Antarctic coast (Kotlyakov et al., 2010). A variable, called a spectral aerosol optical thickness (AOT) of the atmosphere, is used to characterize attenuation of the solar radiation by the aerosol particles within the whole air column. Magnitudes of the aerosol attenuation of the solar radiation measured in the Antarctic were the lowest values on the Earth, and they did not exceed limits of their natural variability. This is again the evidence of the fact that still to the present time the Antarctic atmosphere is not polluted by any aerosol of the anthropogenic origin.

ORACLE-O3 (no. 99)

LOLITA-PSC and MATCH-PSC campaigns

As part of the ORACLE-O3 ("Ozone layer and UV RAdiation in a changing CLimate Evaluated during IPY") global project, LOLITA-PSC ("Lagrangian Observations with Lidar Investigations and Trajectories in Antarctica, of PSC") is devoted to Polar Stratospheric Clouds (PSC) studies. Understanding the formation and evolution of PSC particles is an important issue to quantify the impact of climate changes on their frequency of formation and, further, on chlorine activation and subsequent ozone depletion. Statistical studies on PSC and temperature over the Dumont D'Urville in Antarctica have been updated (David et al., 2009) and a study based on the "Match" method, developed initially for ozonesondes, has been applied, for the first time, to lidar observations of PSC acquired during campaigns. These campaigns took place in Antarctica during winters 2006, 2007 and 2008, involving the three PSC lidar deployed in Antarctica, at Dumont d'Urville (66.67°S, 140.01°E), Davis (68.00°S, 78.50°E) and McMurdo (77.86°S, 166.48°E) and CALIPSO space-borne lidar observations. Observations were performed at each lidar station when the weather conditions permitted. Ten-days forward trajectories calculations from any station are performed each time a PSC is detected at the station. We consider a match when a trajectory issued from a station passes less than 200 km of another lidar station during a PSC observation period and when potential vorticity variations remain less than 40% along the trajectory. From the ground-based lidars, the evolution of scattering ratio can be drawn along the trajectories, completed with the CALIPSO values selected with a maximum time difference of 2.5 minutes and a maximum time distance of 200 km from the trajectories. As expected, a clear correlation appears between high scattering ratio values and the coldest temperatures, close or below the ice formation temperature [see Fig. 2.1-5, pers. comm. Nadège Montoux, LATMOS (Laboratoire atmosphères, Milieux Observations Spatiales), DNRS, France].

The impact of the model for trajectory and of the initialisation fields on the match determination was explored (Montoux et al., 2009 and publication in preparation). For cold temperatures, of interest for PSC formation, the pressure and altitude discrepancies are not significant. Time difference could occasionally impact, but do not seem to affect greatly, the lidar scattering ratios extracted. Yet, when close to PSC temperature thresholds, the temperature differences are a key issue and more realistic values for nitric acid and water vapour mixing ratios are needed to determine these thresholds (using, for instance, the Microwave Limb Sounder onboard the AURA satellite). The current step of the analysis is the modelling of PSC formation along the trajectories using the Danish Meteorological Institute microphysical box model (Larsen et al., 2000). The model includes microphysical Mie and T-Matrix modules, together with optical modules, and is able to simulate the size dis-

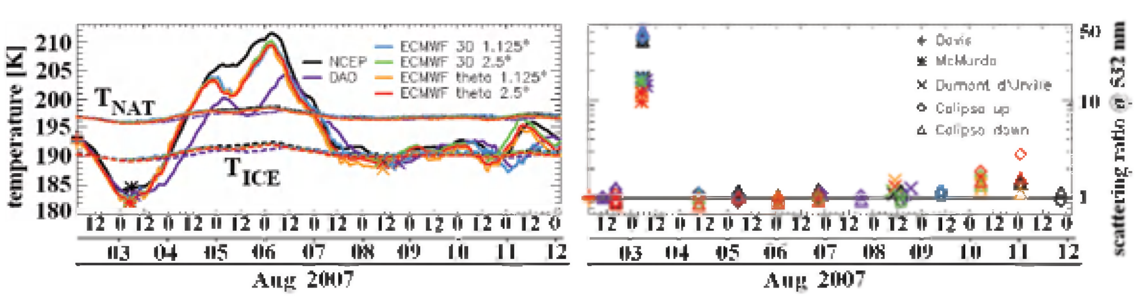
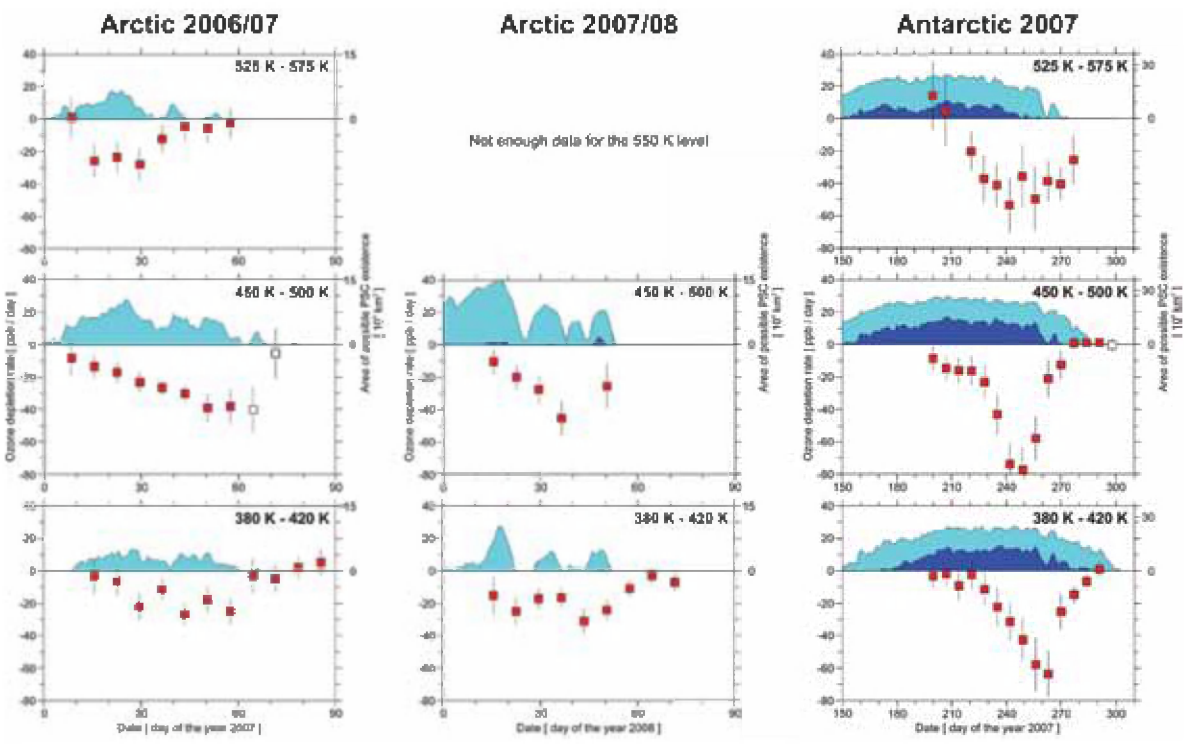


Fig. 2.1-5. Evolution of the temperature (left) and of the lidar scattering ratio at 532 nm (right) along different trajectories (color code) started from Davis station at 0300 UTC 2 August 2007 to 0300 UTC 12 August 2007.
(Courtesy: Nadège Montoux)

Fig. 2.1-6. Ozone loss rates (parts per billion by volume per day (ppb/day)) for three polar winters from Match campaigns. Three panels are shown for each winter, and each relates to a different atmospheric layer with a range of potential temperatures: top to bottom 525-575 K (approximate height 23 km), 450-500 K (19 km), 380-420 K (15 km). All data points (red and open square symbols) show temporal means spanning +/-10 days. The shaded portion of each panel shows the estimated areal coverage (in millions of square kilometres) of Polar Stratospheric Clouds of type I (light blue) and type II (dark blue). The loss rates in the two Arctic winters were moderate compared to earlier winters. Nevertheless, in 2007/08 the ozone loss occurred over a much wider vertical range than usual, leading to relatively greater ozone losses. The ozone loss rates in the Antarctic follow in general those of the first Antarctic Match campaign in 2003 reaching 60 to 80 ppb/day in the 450-500 K layer during September. Zero ozone losses at the end of the time period are not due to deactivated chlorine but due to already completely destroyed ozone.

(Graph: Peter von der Gathen, Alfred Wegener Institute, Potsdam)



tribution of PSC parameters and their optical properties at lidar wavelength.

Ozonesonde Match campaigns

In order to measure stratospheric ozone loss rates, three ozonesonde Match campaigns were performed – two in the Arctic and one in the Antarctic – during IPY. They followed one Antarctic and 12 Arctic campaigns in the past two decades (e.g. Rex et al., 2002). Primary results are shown in Fig. 2.1-6. In addition, the Arctic data fit well into a linear relation between winter integrated ozone loss and a winter mean temperature index (mean volume of possible PSC existence, V_{PSC}) as described in Rex et al., (2006). The whole data set is used to test our understanding of polar ozone losses in models. Past results showed more ozone losses than the models were able to explain. In consequence, the photolysis rate of the Cl-OO-Cl dimer is currently under discussion.

Arctic System Reanalysis (CARE/ASR no. 28): Synthesis Through Data Assimilation

The project "Arctic System Reanalysis" under the international Climate of the Arctic and its Role for Europe (CARE)/Arctic System Reanalysis activity is funded by the U.S. National Science Foundation to produce a high resolution re-analysis of the Arctic climate for the years 2000-2010. The project supports the interdisciplinary U.S. Study of Environmental Arctic Change (SEARCH) program to understand the nature and the future evolution of the Arctic system. The Arctic System Reanalysis (ASR) is a multi-institutional, interdisciplinary collaboration that provides a description of the region's atmosphere/sea-ice/land system by assimilating a diverse suite of observations into a regional model. Such a re-analysis may be considered an optimal blend of measurements and modelling. The project builds upon lessons learned from past re-analyses by optimizing both model physical parameterizations and methods of data assimilation for Arctic conditions. It represents a synthesis tool for assessing and monitoring variability and change in the Arctic system.

The domain considered extends well beyond the boundaries of the Arctic Ocean to include about one third of the Northern Hemisphere, so that all of the river basins that drain into the Arctic Ocean are included (see the inner grid in Fig. 2.1-7). The ASR output will include gridded fields of temperature, radiation, winds and numerous other variables at high spatial (10 km) and temporal (3 h) resolution, enabling detailed reconstructions of the Arctic system's state. A 30-km horizontal resolution prototype (June 2007 to September 2008) has been produced for distribution to the scientific community by March 2010. The prototype period includes the unprecedented (in the observational record) sea ice minima during late summer 2007 and 2008 as well as several Arctic field programs, including those for the IPY.

IPY funding from the U.S. National Science Foundation's Office of Polar Programs provides the backbone of support for advanced development, production and dissemination stages of the ASR. Start-up funding was supplied by the U.S. National Oceanic and Atmospheric Administration. Project administration requires close cooperation between the main participating institutions, facilitated by project meetings at least twice a year. The lead institution is the Polar Meteorology Group (PMG) of Byrd Polar Research Center at The Ohio State University. Other key partners are the Mesoscale and Microscale Meteorology Division (MMM) and the Research Applications Laboratory (RAL) of the National Center for Atmospheric Research (NCAR), the Cooperative Institute for Research in Environmental Sciences (CIRES) at the University of Colorado-Boulder and the Department of Atmospheric Sciences of the University of Illinois.

Extensive tests of the ASR's components are required before the high-resolution production phase is conducted. To represent the physical processes, the primary ASR tool is the polar-optimized version of the Weather Research and Forecasting (WRF) model (http://polarmet.osu.edu/PolarMet/pwrf.html, a regional coupled atmosphere-land model. The PMG has developed and extensively tested "Polar WRF" for the three main Arctic environments: ice sheets, ocean/sea ice and land. The stable boundary layer, mixed-phase clouds and surface energy balance were particularly emphasized. Arctic enhancements developed for this project are being channeled through NCAR for release to the scientific community. For example, the

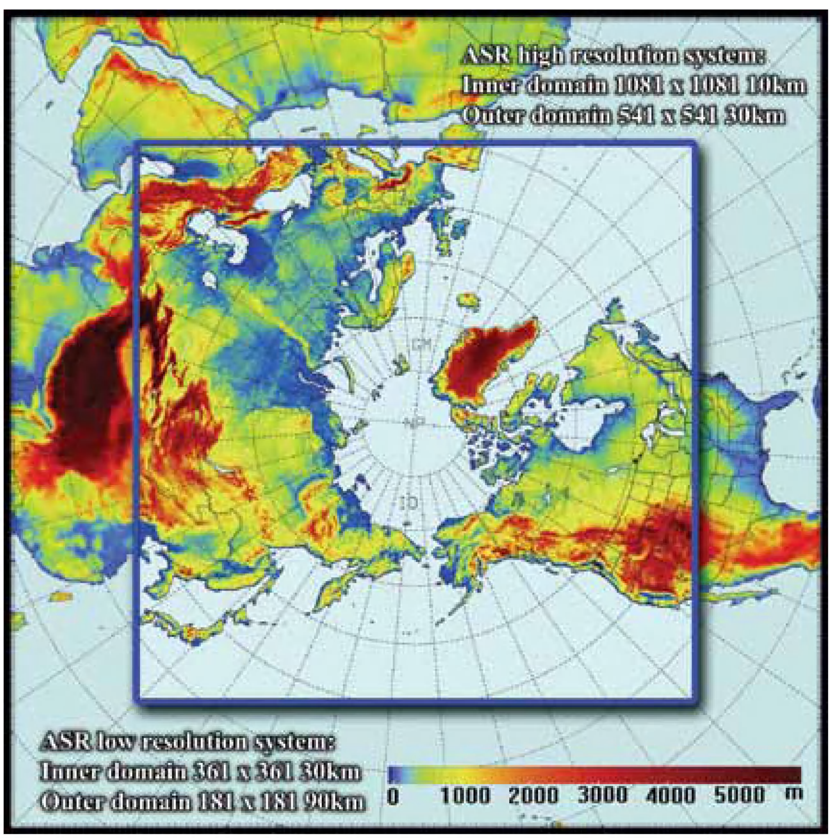


Fig. 2.1-7. Spatial coverage of the Arctic System Reanalysis includes 541×541 outer domain with 30-km horizontal resolution and 1081×1081 inner domain with 10-km horizontal resolution. The outer grid provides smooth boundary conditions for the inner grid. Grids are polar stereographic projections centered at the North Pole. Terrain height is shown by color scale. The low-resolution system summarized at the lower left is being used for the test assimilation spanning June 2007-September 2008.
(Bromwich et al., 2010)

fractional sea ice capability developed by the PMG is a standard WRF option beginning with version 3.1. The specified sea ice representation in the ASR is being enhanced by ice thickness distributions derived from remote sensing observations. Specified variable snow thickness over sea ice is also being represented.

Preparations for the ASR at RAL comprise improving the representation of Arctic land surface processes by the Noah Land Surface Model (LSM) that is coupled to WRF. In particular, key goals include improving the representation of spring snow-melt and the soil temperature profile. Detailed improvements to Noah include addition of an organic layer, deeper soil depths and a zero-flux bottom boundary condition. To best represent the land surface in the ASR, high quality fields will be obtained through High-Resolution Land Data Assimilation, driven by satellite data and run with the Noah LSM that interacts periodically with WRF.

A key challenge is fully assimilating the available Arctic observational data. The NCAR MMM has contributed considerable resources to enhance assimilation of in situ and remote sensing data in the polar regions, thus optimizing the advanced three-dimensional-variational (3D-Var) data assimilation capabilities of WRF-Var. In assembling the varied data that are to be processed by WRF-Var, Jack Woollen of the National Centers for Environmental Prediction (NCEP) has provided access to operational data streams and valuable advice on their usage. While conventional weather reports and satellite measurements make their way into the operational Binary Universal Format Representation (BUFR) database, other important Arctic data do not. These include the Greenland ice sheet automatic weather station reports, data from automated weather stations at northern Alaskan field sites, Multi-angle Imaging SpectroRadiometer (MISR) cloud-tracked winds supplied by the University of Illinois, Arctic snow water equivalent measurements supplied by CIRES and most of the IPY field measurements. The ASR eagerly solicits additional Arctic datasets from the community for assimilation into ASR or for testing its output. Completion of the ASR for 2000-2010 is scheduled for autumn 2011, and will be distributed to the community by the NOAA Earth System Research Laboratory (formerly CDC) and by NCAR.

World Weather Research Programme-THORPEX IPY cluster (no. 121)

From a weather forecasting perspective, the Arctic poses particular challenges for mainly two reasons: the observational data are sparse and the weather phenomena responsible for severe weather, such as polar lows, Arctic fronts and orographic influences on airflow, are inadequately represented in operational numerical weather prediction (NWP) models. The IPY-THORPEX cluster, comprising an international cooperation between ten individual IPY projects from nine countries, was set up to address these challenges. It has the following main objectives:

i) Explore the use of satellite data and optimised observations to improve high impact weather forecasts (from Polar THORPEX Regional Campaigns (TReCs) and/or provide additional observations in real time to the WMO Global Telecommunication System).
ii) Better understand physical/dynamical processes in polar regions.
iii) Achieve a better understanding of small scale weather phenomena.
iv) Utilise improved forecasts to the benefit of society, the economy and the environment.
v) Utilise the THORPEX Interactive Grand Global Ensemble (TIGGE) of weather forecasts for polar prediction.

A flavour of results from some of the projects is given below.

Focus of the **Greenland flow Distortion Experiment** (Renfrew et al., 2008) was upon Greenland tip jets, air-sea interactions, barrier winds and mesoscale cyclones with results that could be classified into all objectives above. The field campaign took place in February 2007. It provided a number of observational first looks at the strong winds and intense mesoscale weather systems that occur around the coastal seas of Greenland and Iceland. A number of detailed studies focusing on the structure, dynamics and associated air–sea interactions of the weather systems were performed, for example, with respect to the reverse tip jet, polar lows, lee cyclones and barrier winds (Fig. 2.1-8).

Aircraft and dropsonde data were used to assess the quality of a number of satellite products (e.g. QuikSCAT winds) and meteorological analyses. The

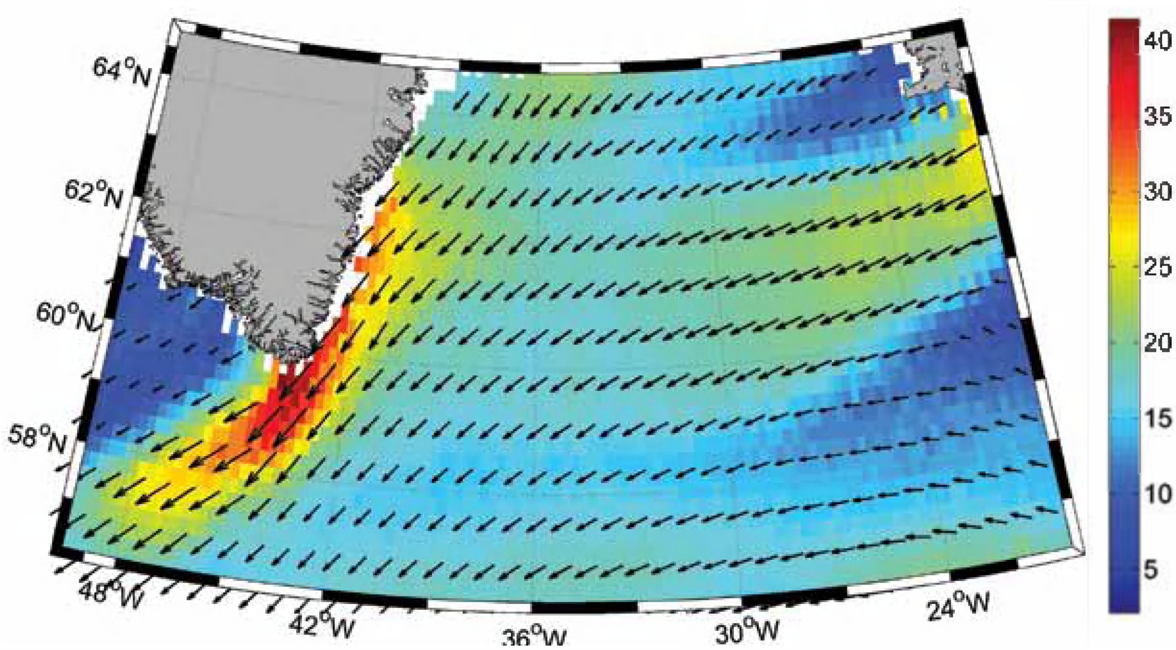


Fig. 2.1-8. Example of an easterly tip jet showing QuikSCAT-derived 10-m winds for the morning of 21 February 2007 (the satellite passes are from 0718 and 0900 UTC). The colours show wind speed (m s–1). The vectors are shown every third pixel (i.e. every 0.75°) (Renfrew et al., 2008).

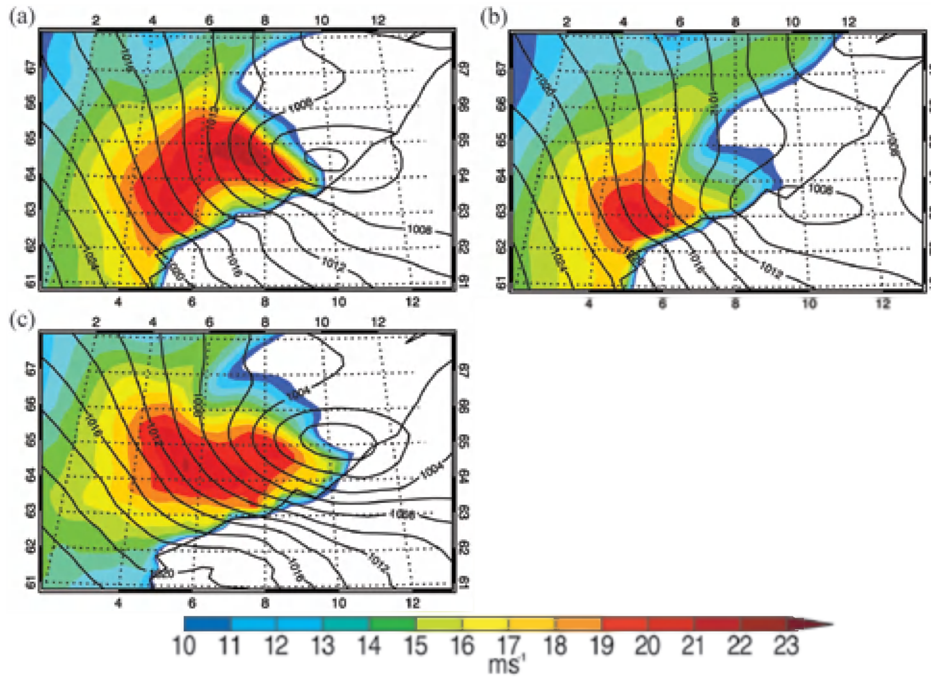
impact of the targeted observations was assessed by Irvine et al., (2009), who found that the impact of the sondes was mixed. Only two out of the five cases showed clear forecast improvement; the maximum forecast improvement seen over the verifying region was the reduction of approximately 5% of the forecast error 24 hours into the forecast. In one of these cases, the improvement propagates into the verification region with a developing polar low. The impact of targeted sonde observations on the 1-3 day forecasts for northern Europe was evaluated using the U.K. Met Office four-dimensional variational data assimilation scheme and a 24 km grid length limited-area version of the Unified Model (MetUM). Targeted sonde data was assimilated operationally into the MetUM.

A study that focused particularly on local communities (objective "iv" above) was Storm Studies of the Artic (STAR, Hanesiak et al., 2010). It was not an international IPY project, but cooperated closely with projects participating in the IPY-THORPEX cluster. It included enhanced observations in the eastern Canadian Arctic and studied gap flow, air-sea interactions, orographic precipitation and interaction of cyclones with topography etc. With 14 research flights from Baffin Island, surface- and satellite-based instruments, STAR aimed to improve understanding and prediction of severe Arctic storms and their hazards. One of the more important tasks included developing a conceptual model of storms and associated phenomena in the region. Another important task was to evaluate operational and model forecasts of events to examine where improvements need to be made and under what circumstances.

The Norwegian IPY-THORPEX project (Kristjansson et al., submitted) sought to improve weather forecasts of phenomena typical for the high latitudes through a combined modelling and observational effort (mainly objectives i, ii and iii). The crux of the observational effort was a 3-week international field campaign out of Northern Norway in early 2008, combining airborne and surface-based observations. The main platform of the field campaign was the DLR (German Aerospace Center) Falcon research aircraft, equipped with LIDAR systems for profiling of aerosols, humidity and wind, in addition to *in situ* measurements and dropsondes. A total of 11 missions were flown, providing unique observations of polar lows, an Arctic front and orographic low-level jets near Spitsbergen, the coast of Northern Norway and the east coast of Greenland. Two major polar low developments over the Norwegian Sea were captured during the campaign. One of them (3-4 March 2008) was reasonably well predicted by operational models, while in the other case (16-17 March 2008) the operational models had

Fig. 2.1-9. Sea-level pressure (black contours) and 10 m wind speed exceeding 10 m/s (coloured shading) for 18 UTC 4 March 2008, for 24-hour forecasts from 18 UTC 3 March 2008 containing (a) routine and targeted observations, (b) only routine observations and (c) ECMWF analysis.

(Kristjansson et al., submitted)



huge errors both in strength and position. In the former case, targeting observations by the aircraft in sensitive areas led to improvements in predicted track and intensity of the polar low. Fig. 2.1-9 shows that the forecast containing targeted observations from 18 UTC 4 March 2008 improves the polar low position and strength, although the region of strong winds extends too far south compared to the analysis. Further work is underway to confirm the impact of the targeted sondes on the forecast and the reasons for this impact.

Thorpex Arctic Weather and Environmental Prediction Initiative (TAWEPI) is a science and research project partly funded by the Government of Canada Program of the International Polar Year. The primary objective of TAWEPI is to improve the Environment Canada's NWP capacity over the Arctic during the IPY observational period and beyond. TAWEPI's research activities started in April 2007. A research version of the regional GEM model, covering the Arctic basin and surroundings is being used to study the representation of radiative and cloud processes in weather forecasts. A multi-layer snow model coupled to sea-ice and blowing-snow parameterizations, describing processes over the various types of surfaces of the Arctic environment, was tested and evaluated. A methodology to validate model forecasts of cloud and radiation using satellite hyperspectral radiances was developed. Climatology of the sensitivity of the Arctic weather to disturbances originated elsewhere was generated and archived for the IPY period of 2007–2008. A state-of-the-science sea-ice model is being adjusted to improve the sea-ice representation in the Arctic (Ayrton Zadra, Environment Canada, pers. comm., see www.ec.gc.ca/envirozine).

The IPY-THORPEX cluster projects have demonstrated that improvements in NWP for polar regions are possible and have increased our understanding of how to improve models and how to use data from the Arctic; they also deepen our understanding of the physical processes involved. In particular they have acquired data for improving physical parameterization in NWP models (-clouds, microphysics, surface fluxes); improved assimilation techniques for high latitudes with emphasis on satellite data; increased our understanding on the effect of the use of ensemble simulations for high latitudes; increased our understanding of the effect of targeting in high latitudes; increased our understanding of high-latitude dynamics and high-impact weather phenomena; demonstrated the effect of new instruments; and demonstrated the effect of increased Arctic and Antarctic observations for local and extratropical NWP forecasting.

Concordiasi project over Antarctica (no. 41)

Antarctica is operationally and climatologically data sparse due to highly limited surface observing facilities in the high southern latitudes. Satellite measurements have the potential to fill these data gaps, but they present their own unique challenges and difficulties. This is true, in particular, of the data provided by hyperspectral infra-red sounders such as IASI (Infrared Atmospheric Sounding Interferometer). These challenges must be overcome and errors need to be reduced to produce accurate reanalyses for climate studies that are based primarily on observed conditions.

Within the framework of IPY, the Concordiasi project (Rabier et al., 2010, www.cnrm.meteo.fr/concordiasi/) makes innovative observations of the atmosphere above Antarctica in order to:

- enhance the accuracy of weather prediction and climate records in Antarctica through the assimilation of *in situ* and satellite data, and
- improve our understanding of microphysical and dynamical processes controlling the ozone content of the polar air masses by quasi-Lagrangian observations of ozone and particle content and improved characterization of the polar vortex dynamics.

A major Concordiasi component is a field experiment during the Austral springs of 2008, 2009 and 2010 (Fig. 2.1-10). The field activities in 2010 are based on a constellation of up to 18 long duration stratospheric balloons deployed from the McMurdo station. Six of these balloons will carry GPS receivers and *in situ* instruments measuring temperature, pressure, ozone and particles. Twelve of the balloons are capable of releasing dropsondes on demand for measuring atmospheric parameters. In 2008 and 2009, radiosounding measurements were collected at various sites, including the Concordia station.

The atmospheric temperature profiles over the Antarctic plateau exhibit a very strong inversion at the surface, with surface temperatures colder by up to 20K than the lower troposphere, which is difficult both to model and observe. During the Concordiasi field campaign, special measurements were obtained measuring the atmospheric profiles together with surface parameters, synchronised with the track of the European MetOp platform with the hyperspectral IASI sensor onboard. They were then compared to IASI measurements and to the outputs of the meteorological model of Meteo-France, especially adjusted for this area (Bouchard et al., 2010). The available *in situ* obser-

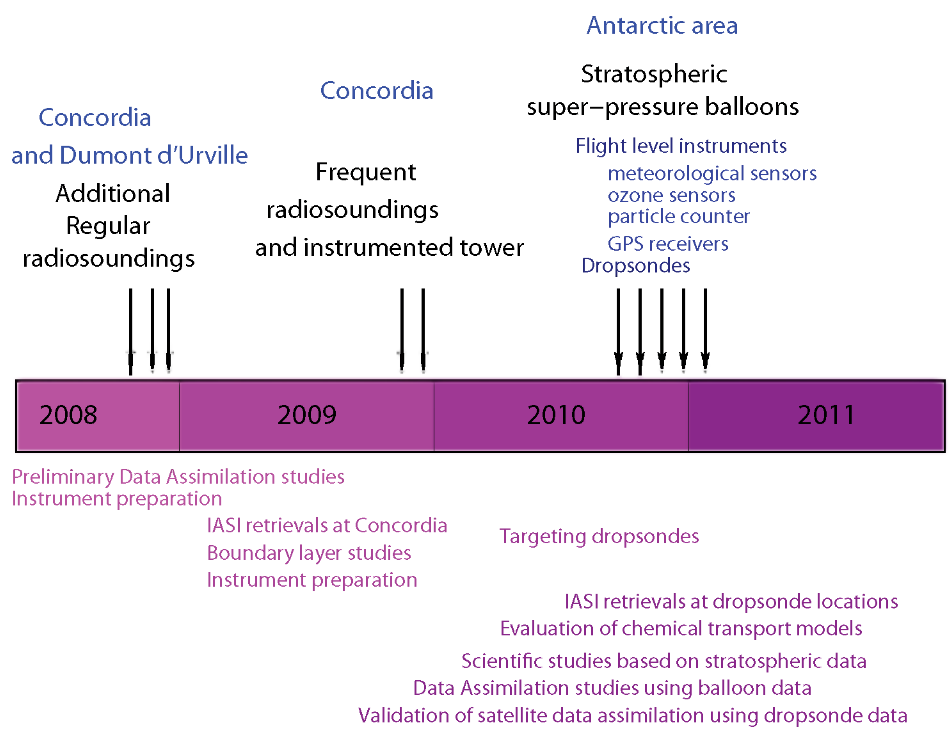


Fig. 2.1-10. The Concordiasi project timeline.
(Rabier et al., 2010)

vations obtained at Concordia were also compared to the results of IASI data retrievals. It was found that the problem of correct estimation of the surface temperature was the main limiting factor in the quality of IASI retrievals. A good prior estimation of skin temperature can be obtained using the radiative transfer equation together with IASI observations in a window channel. Results are presented in Fig. 2.1-11. In this figure, the skin temperature retrieved from a IASI window channel (blue line) is closer to the radiosounding surface temperature (black line) than the model skin temperature (red line) in terms of magnitude and time evolution. Based on this estimation of the skin temperature, retrievals have been performed over the same 44 cases during Austral spring 2008, with an improved analysis of the temperature profile above Concordia compared to a retrieval using the model surface temperature. In parallel, innovative approaches have improved the use of microwave observations from the AMSU (Advanced Microwave Sounding Units) instruments by better description of the surface emissivity, which is highly variable in space and time (Guedj et al., 2010). These studies have highlighted the potential of satellite observations to contribute to a monitoring of weather and climate over the polar areas, once particular attention has been paid to surface parameters.

***Structure and Evolution of the Polar Stratosphere and Mesosphere and Links to the Troposphere during IPY* (SPARC-IPY, no. 217)** was to document the dynamics, chemistry and microphysical processes within the polar vortices during IPY, with a focus on the stratosphere-troposphere and stratosphere-mesosphere coupling. One of the key outcomes was a collection of analysis products from several operational centres and several research centres, which was archived at the SPARC Data Center. The analysis products covered the period of IPY (March 2007 to March 2009) and represented the best available self-consistent approximations to the state of the atmosphere during this period (McFarlane et al., 2009; Farahani et al., 2009; Klecociuk et al., 2009).

A major goal of the SPARC-IPY program was to document as completely as possible the dynamics and chemistry of the polar middle atmosphere during the IPY period. It was anticipated that achieving a unique synthesis of data on the polar middle atmosphere would require analysis of available research and operational satellite data, as well as ground-based and aircraft data. This would clearly include data from new measurement systems, as well as from enhanced measurement programs with established systems. The intent of SPARC-IPY, in cooperation with

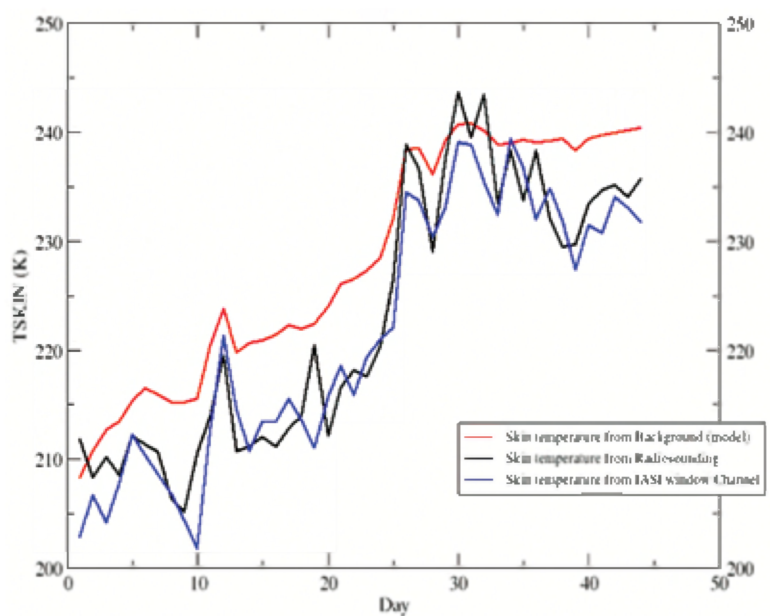


Fig. 2.1-11. Skin temperature (K) at Concordia in austral spring 2008 (44 daily cases at 0000 UTC from October to 29 November 2008) from model (red line), radiosounding (black line) and IASI window channel (blue line).
(Graph: courtesy Aurelie Bouchard and Florence Rabier)

related and linked IPY activities, was to facilitate such data acquisition, archiving and analysis activities. In addition to collecting the results of new measurement programs, SPARC-IPY also collected and archived objective analysis products from major centers during the IPY period. This activity was undertaken and coordinated within the SPARC-DA activity (Polavarapu et al., 2007). SPARC-IPY has also encouraged work on data assimilation and inter-comparison of the assimilated data sets.

Tropospheric chemistry: air pollution and climate impacts

Several IPY projects investigated the chemical composition of the Arctic troposphere. They studied a large range of different topics, such as the geographical and vertical distribution of pollutants in the Arctic, their sources, concentration trends on various time scales, the physical and chemical processes determining their concentration levels, and the climate impacts of aerosols and trace gases. Arctic ice cores also provide records of contaminant levels that are relevant not only for the Arctic itself, but also for the extra-polar regions where detailed historical records are more difficult to obtain.

The motivation for all of these projects arises either from the health and ecological impacts of contaminants or from the climate impacts of aerosols and short-lived trace gases. Arctic air pollutants are emitted mainly by sources in the middle latitudes and are carried northward by the winds in the troposphere. Some contaminants, such as POPs, can partition between different environmental media but the atmosphere generally provides the fastest transport pathway into the Arctic. Of particular concern is that even though Arctic sources are small, POPs can reach their highest concentration levels in the Arctic via a mechanism known as cold condensation whereby POPs (Persistent Organic Pollutants) are "extracted" from the atmosphere preferentially in the polar regions. POPs and heavy metals can furthermore bioaccumulate and biomagnify through food chains and thus pose significant health risks to humans and wildlife in the Arctic.

"Classical" pollutants, such as sulfate, can also reach surprisingly high atmospheric concentrations in the Arctic in winter and early spring, given that their local sources are relatively small. Nevertheless, in winter there is relatively efficient transport into the Arctic from high-latitude regions in Eurasia where strong pollution sources are located. The high static stability and dryness of the arctic troposphere in winter render removal processes such as dry and wet deposition inefficient and chemical degradation is also reduced by low temperatures and light intensity. This leads to long pollutant lifetimes and explains the high arctic pollution loads. Aerosol concentrations can reach such high levels that visible haze layers can form, which have become known as Arctic Haze. In the past, the main interest was in the acidifying properties and the high pollution loads of Arctic Haze. More recently, however, interest into the climate impact of the haze has grown. Aerosols affect the radiation transmission in the atmosphere and, because of the highly reflective surface in the Arctic, even small amounts of light absorbing material such as black carbon ("soot") can lead to a warming of the atmosphere. If light-absorbing aerosols are deposited on snow or ice, they can also reduce the surface albedo. Sufficiently large aerosols can also hinder the transmission of long-wave radiation and aerosols can also affect the properties of arctic clouds.

***Metal pollution in Canadian High Arctic: Pollution trend reconstruction of noble metals* (IPY no. 19)** project provides a reconstruction of the historical concentrations of heavy metals (lead, cadmium, mercury) and sulfate through snow, firn and ice core measurements. Based on background data back to 4,000 BP, it was found, for instance, that lead (Pb) contamination in the High Arctic has started much earlier than the Industrial Revolution. The first outstanding Pb peak found in Devon Ice Cap was at ~3,100 years ago, which corresponds to the Iberian Peninsula mining and smelting. The second peak was much broader (lasting a longer time) and located from the Roman Period to the Middle Ages. Starting 700 years ago, the lead/scandium (Pb/Sc) ratio exceeded the background value and has not returned to natural values since. In the 1840s, many years before Pb additives were used in gasoline, approximately 80% of the Pb deposition on the Devon Ice Cap was already from anthropogenic sources. Even in the 1920s, still pre-dating the use of leaded gasoline additives, about 90% of Pb deposition was anthropogenic. Clearly, the use of leaded gasoline is only the most recent chapter in a very long history of atmospheric Pb contamination. Since the 1970s, Pb enrichments in snow and firn from Devon Island have gone into decline in response to the gradual elimination of leaded gasoline. Nevertheless, using the natural, background Pb/Sc ratio and Pb isotope data, it is found that at least 90% of the Pb in the High Arctic is still from anthropogenic sources.

***INTerContinental Atmospheric Transport of Anthropogenic Pollutants to the Arctic* (INCATPA, no. 327** www.ec.gc.ca/api-ipy/default.asp?lang=En&n=8EBD7558-1) studied the risks associated with the emissions of POPs and mercury (Hg) in the Pacific region for the contaminant loads in the Arctic. Before IPY, air monitoring of POPs and Hg was performed mainly at Alert, Canada and Ny Ålesund, Norway in the 1990s under AMAP. Hg has also been continuously measured in air at Whistler, B.C. and Amderma, Russia under Environment Canada and Roshydromet for AMAP, respectively. During IPY, air measurements of POPs and/or Hg started at Little Fox Lake, Yukon, Canada; Valkarkai, Russia; Barrow, Dillingham and Fairbanks, Alaska, U.S.A.; Waliguan, Mt. Changbai, Wudalianchi and Xuancheng, China; and Ba Vi, Vietnam. At most stations, these measurements will continue until spring 2010. Soil and air samples were collected along the Chilkoot Trail, Yukon/Alaska, in summer 2007, at different elevations. The purpose is to investigate the atmospheric deposition of POPs and emerging chemicals on mountain ranges in the Kluane National Park, Yukon, Canada. Combined with the air concentration data collected at Little Fox Lake, this work will provide insight on the roles that mountains and forests play in intercepting POPs carried by trans-Pacific air masses. Another project, *Atmospheric Monitoring Network for Anthropogenic Pollution in Polar Regions* (ATMOPOL, no. 76), delivered the first annual data set on POPs in antarctic air. It also studied the influence of climate change on atmospheric distribution patterns of POPs and the identification of new emerging contaminants in arctic environments.

INCATPA models simulating the transport and fate of POPs showed that long-range atmospheric transport (LRAT) of POPs from sources in warm latitudes to the Arctic occurs primarily at the mid-troposphere. Cold condensation is also likely to occur at the mid-troposphere over a source region in warm low latitudes. The temperature dependent vapour pressures and atmospheric degradation rates of POPs exhibit similarities between the lower atmosphere over the Arctic and the mid-troposphere over a tropical region. Convection over warm latitudes transports the chemicals to a higher altitude where some of them may condense/partition to particles or to the aqueous phase and they become more persistent at the lower temperatures. Strong winds at the mid-troposphere then convey the condensed chemicals also to the Arctic where they can be brought down to the surface by large-scale descending motion and wet deposition. These studies provide a new interpretation on the cold condensation (Arctic trapping) effect and revealed major atmospheric pathways of POPs to the Arctic.

***POLar study using Aircraft, Remote sensing, surface measurements and modelling of Climate, chemistry, Aerosols and Transport* (POLARCAT, no. 32** www.polarcat.no) brought one of the largest atmospheric measurement campaigns ever conducted in the Arctic. Eight research aircraft from the United States, France, Germany, Russia, as well as research groups from many other countries, flew research missions in nearly all parts of the Arctic and sub-Arctic during spring 2007, spring 2008 and summer 2008. The campaigns were coordinated (Fig. 2.1-12) such that comparisons between the different parts of the Arctic can be made. The aircraft missions were complemented by a ship cruise in spring 2008, a railway campaign in Siberia in summer 2008 and measurement campaigns at several Arctic stations (e.g. Summit, Ny Ålesund). They were also supplemented with extensive use of satellite remote sensing products and a large range of different models. Detailed measurements of the gas-phase and particulate-phase chemical composition of the Arctic atmosphere, the optical properties of aerosols, the properties of clouds, etc. were made. In the result, the *POLARCAT* data set will provide a unique reference for future changes of the Arctic atmosphere.

While the data sets are still being processed and analyzed, several research highlights were already published in a POLARCAT special issue in Atmospheric

Fig. 2.1-12. The NASA DC8 research aircraft viewed from the DLR Falcon research aircraft during an intercomparison flight over Greenland as part of POLARCAT in summer 2008 (Photo: Hans Schlager, DLR).

Chemistry and Physics (www.atmos-chem-phys.net/special_issue182.html) and elsewhere. A substantial finding was the large influence of both agricultural and forest fires on the aerosol load of the Arctic atmosphere. Already in spring 2008, fires in Kazakhstan and Russia were a major source of Arctic aerosols, even over Alaska. In summer, extensive influence of burning was obvious, too, especially at higher levels in the Arctic atmosphere.

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2.2 Arctic Ocean

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Introduction

The integrated Arctic Ocean Observing System (iAOOS), originally conceived and sponsored by the Arctic Ocean Science Board (AOSB), was one of the proposals endorsed by the Joint Committee for International Polar Year. It was designed to optimize the cohesion and coverage of Arctic Ocean science during the IPY. As such, iAOOS is not a funded programme in its own right, but is rather a pan-Arctic framework designed to achieve optimal coordination of funded projects during IPY. It has a science plan (Dickson, 2006) based on the more than 1150 Expressions of Interest received by the IPY program office. Reflecting these proposals, its main concerns are with change in the Arctic, including all aspects of the role of the Northern Seas in climate, and it draws its primary focus on the present state and future fate of the Arctic Ocean perennial sea-ice. Because of its all encompassing aim and design, iAOOS is a suitable framework to use when presenting the oceanographic activities undertaken within IPY.

During the development of iAOOS, it became clear to the AOSB and to the investigators involved, that the scope of iAOOS could not be restricted to the Arctic Ocean. We know from major studies, such as the Arctic-Subarctic Ocean Flux Study, that the two-way oceanic exchanges that connect the Arctic and Atlantic oceans through subarctic seas are of fundamental importance to climate; that change may certainly be imposed on the Arctic Ocean from subarctic seas, including a changing poleward ocean heat flux that is central to determining the present state and future fate of the perennial sea-ice. The signal of Arctic change is expected to have a its major climatic impact by reaching south through subarctic seas, either side of Greenland, to modulate the Atlantic thermohaline conveyor. This report on the achievements during IPY is therefore arranged along three major themes or pathways: a) the changing inputs to the Arctic Ocean from the subarctic seas; b) the changing oceanography of the Arctic Ocean itself; and c) the changing outputs from the Arctic to the subarctic seas.

Observing the inputs to the Arctic Ocean

Fig 2.2-1 (Melling's compilation from Dickson, 2009) describes the distribution of all 173 current meter moorings and arrays deployed across the Arctic-subarctic domain during 2008 whether or not they were primarily intended for the support of IPY and its component programs. It is a considerable achievement. Though coverage continues to be thinly spread in places, this mooring network represents a slight increase on the first year of IPY (156) and was a healthy advance on the situation of earlier years, conforming well with the integrated Arctic Ocean Observing Plan (Dickson, 2006). All the main choke-points of ocean exchange between Arctic and subarctic seas are covered, historical time-series moorings have been continued and long-standing 'gaps' at climatically-important sites are now properly instrumented. In some key locations (offshore branch of the Norwegian Atlantic Current, Fram Strait, etc), the conventional coverage is now augmented by the use of gliders. Four of these gateway arrays may be picked out for special mention.

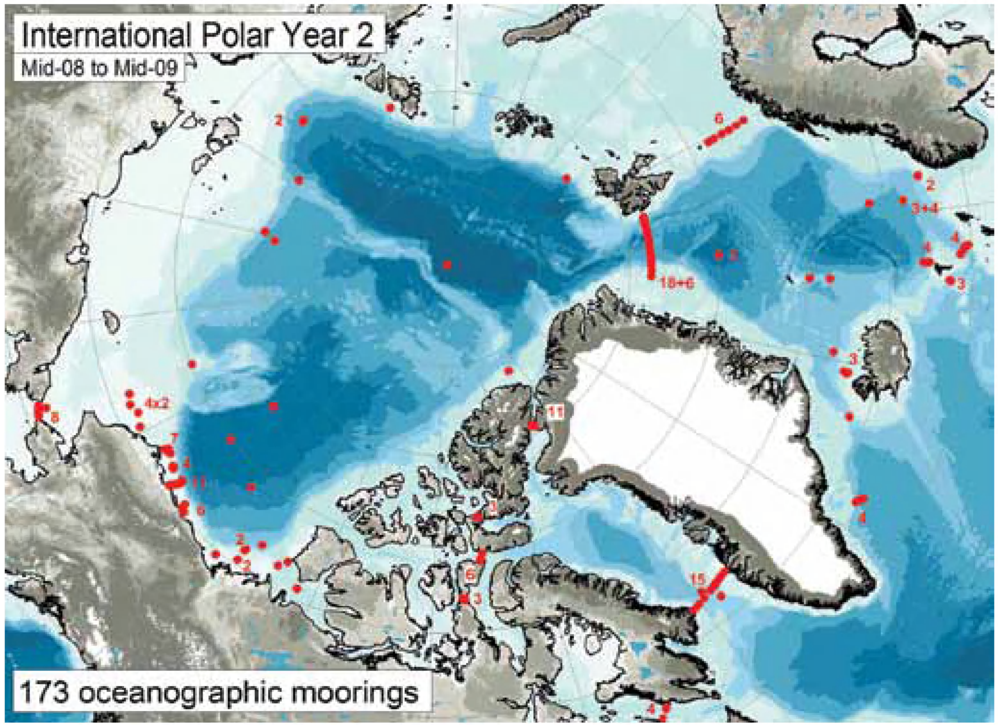


Fig. 2.2-1. Distribution of all 173 current meter moorings and arrays across the iAOOS domain in 2008. Compilation by Humfrey Melling, IOS Canada. Small numerals in red refer to the number of moorings in an array, where these are too numerous to distinguish individually.
(Map: Dickson and Fahrbach, 2010)

The development of the Svinøy section. A conspicuous highlight of IPY was the first concerted attack on the 'other half' of the northward ocean heat flux west of Norway. Briefly, although the 12-year time-series of transport had by then been recovered from the inshore branch of the Norwegian Atlantic Current against the Norwegian Slope, giving some sense of its local and remote forcing, the offshore branch, passing north through the Norwegian Sea as a free jet, had remained unmeasured. In an attack on this critical but difficult measurement, satellite altimetry, hydrography and conventional current meter moorings were combined to calculate the volume, heat and salt transports of both NAC branches between 1993 and 2007 (Mork and Skagseth, 2009). In the eastern branch these results agree well with previous estimates (Orvik et al., 2001), but in the western branch they differ substantially from SeaGlider based estimates reported in Mauritzen et al., (2009). During IPY, iAOOS-Norway continued its aim of "developing the Svinøy Section into a complete, sustainable, simple and robust upstream reference system for monitoring Atlantic inflow towards the Arctic Ocean moved during CTD and current IPY", adding conventional moorings, profiling instruments (MMP CTD/RCM) and SeaGlider transects. Apart from capturing the successive waves of warmth that have passed through towards the Arctic in recent years, this key array continues to highlight the independence between the flow field and temperature field, with the flow field dominating annual variability and with temperature variations dominating on longer timescales.

Table 2.2-1. Estimates of volume, heat and freshwater transports for the two branches of the Norwegian Atlantic Current west of Svinøy.

Inflow branch	Volume transport (Sv)	Heat transport (TW), Tref=0oC	Freshwater transport (mSv) Sref=34.93	Reference
Eastern	4.2 3.7	133 157	-45	Orvik et al., (2001). Mork and Skagseth (2009)
Western	3.5 1.4 6.5	39	-13	Orvik et al., (2001). Mork and Skagseth (2009) Mauritzen et al., (2009)
Total	7.7 5.1	179	-58	Orvik et al., (2001). Mork and Skagseth (2009)

The instrumenting of Fram Strait. Fram Strait represents the principal entry-point for heat, salt and mass to the Arctic Ocean, so these quantities and their variability are of considerable importance to our understanding of arctic change. The overall objective for Fram Strait in IPY was to augment the conventional (ASOF) picket fence array of current meters with a range of new systems designed to improve the monitoring of volume, heat and freshwater transports, including the building, testing and use of an ocean acoustic tomography system across both the West Spitzbergen Current and the East Greenland Current, establishing and validating a high resolution (2 km) ice-ocean model, and combining ship-borne hydrography, acoustic thermometry, satellites, sub-surface moorings, gliders and coupled ice-ocean modelling through advanced assimilation techniques. Using three vessels, the field aims were largely accomplished through the use of seven main observing systems. A comparison of the main ocean fluxes carried to the Arctic by these two Atlantic inflow branches can be attempted below (Schauer et al., 2008; Schauer and Beszczynska-Möller, 2009).

Table 2.2-2. Volume- and heat transports through the Barents Sea Opening and Fram Strait 1) calculated for zero net volume transport, for details see Schauer and Beszczynska-Möller, 2009 2) mean for the whole observation period in Fram Strait 3) mean for the period of observations by the optimized, high-resolution moored array.

(Source: A. Beszczynska-Möller, AWI)

	Volume transport (Sv)	Heat transport (TW)
Barents Sea Opening	2	46
Fram Strait Atlantic water inflow[1)]	6 (sd 1.5)	38 (sd 15)
Fram Strait total mean 1997-2008[2)] mean 2002-2008[3)]	 2.6 southward (sd 4.2) 2.9 southward (sd 2.5)	-

New insights on the Bering Strait throughflow. The Bering Strait is the only Pacific gateway to the Arctic Ocean. The flow through the Strait, typically ~ 0.8 Sv in the annual mean, is an important source of heat, freshwater, nutrients and stratification for the Arctic Ocean and beyond. Mooring work in the Bering Strait region has been carried out almost continuously since autumn 1990 except for a 1-year gap in 1996-1997, but prior to IPY had employed only small numbers of moorings (maximum four), usually in the centre of the channels of the Strait, with an extra mooring in some years to measure the warm, fresh Alaskan Coastal Current (ACC), found seasonally in the eastern Strait. For the IPY, however, an expanded high-resolution array was deployed (Fig 2.2-2; Rebecca Woodgate, pers. comm.) consisting of eight moorings – three spanning the western (Russian) channel; four in the eastern (U.S.) channel; and one (A3) at a "climate" site located just north of the Strait in U.S. waters and hypothesized to provide a useful average of the total flow properties. This monitoring is integral to the RUSALCA (Russian-American Long-term Census of the Arctic) program (www.arctic.noaa.gov). All moorings measured lower layer temperature (T), salinity (S) and velocity. A novel aspect of the IPY deployment was that six of the moorings also carried upward-looking ADCPs to measure water velocity in 2m layers to the surface plus upper-level TS sensors, the latter in the form of the ISCAT sensor (a microcat in a trawl resistant housing, with inductive telemetry of data to a deeper logger). Two bottom pressure gauges and some bio-optics sensors are also included in the array (for full details see http://psc.apl.washington.edu/

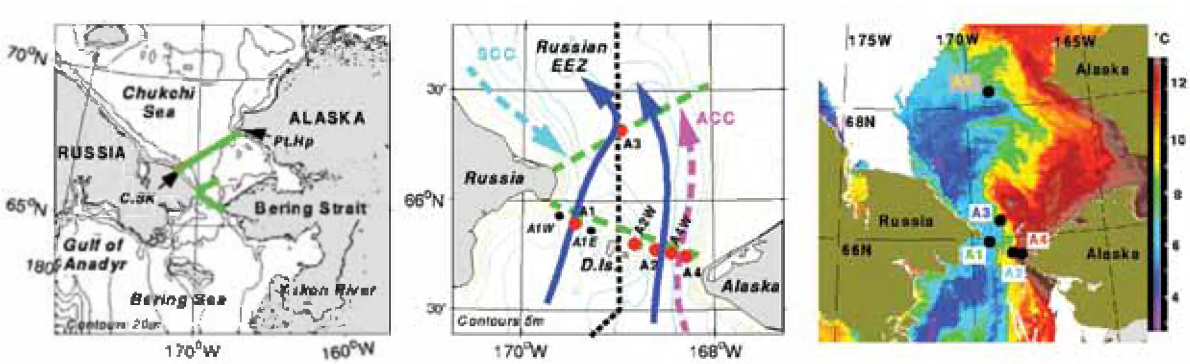


Fig. 2.2-2: Left: The Bering Strait, with preferred CTD lines (green). Middle: Detail of Bering Strait, with schematic flows, mooring locations (red and black dots) and CTD lines (green). The main northward flow passes through both channels (dark blue arrows). Topography diverts the western channel flow eastward near site A3. The warm, fresh Alaskan Coastal Current (ACC) (pink dotted arrow) is present seasonally in the east. The cold, fresh Siberian Coastal Current (SCC) (light blue dotted arrow) is present in some years seasonally in the west. All these currents reverse on time scales of days to weeks. Right: MODIS sea surface temperature image, courtesy of NASA, from August 2004, with historic mooring locations (A1, A2, A3, A3′ and A4), occupied variously since 1990.

(Maps: Dickson and Fahrbach, 2010)

BeringStrait.html). The expansion of the array during IPY provided a number of important insights. First, the new sensor systems have provided the first year-round measurements of stratification in the Bering Strait region. Second, although instruments are still being calibrated, preliminary results suggest that the annual mean 2007 transport had strengthened to around 1Sv, comparable with the previous high northward flow of 2004, which had been related to a reduction in the southward winds. The increased flow, coupled with a very modest warming, suggests the Bering Strait heat flux in 2007 was also at a record-length high. Servicing of these moorings also took place during the fall and summer of 2008 and 2009 on board the *Akademik Lavrentiev* and the *Professor Khromov.*

Tracking the inflows downstream: the NABOS arrays across the circum-Arctic Boundary Current are our main source of information on the Atlantic inflow branches once they enter the Arctic Ocean and subduct to intermediate depths. The cruises of the RV *Viktor Buynitsky* in 2007 and of the *Kapitan Dranitsyn* in 2008 were the sixth and seventh in an annual series designed to service an increasingly international array of instruments set across the circum-Arctic boundary current (Fig. 2.2-3). The program has had major successes, notably the recovery of two-year-long datasets from at least two of the moorings (M4, M6; Fig. 2.2-3), which confirmed the presence of strong seasonal oscillations in the Atlantic Water, and the hydrographic cross-sections, which confirmed the continuation of warming along this boundary [based on a standard JOIS/C3O transect, Fiona McLaughlin and Eddy Carmack (pers. comm., 2009), later confirm the arrival of the latest warm pulse in the Atlantic-derived sublayer at the southern margins of the Canada basin in 2007]; one very long MMP record near Svernaya Zemlya showing bursts of very warm (2°C) Atlantic water up to 90m right through the halocline in 2008.

The losses of equipment and data in this difficult environment have also prompted certain changes in NABOS strategy for the future however, (i) a limited number of very well equipped moorings capable of surviving deployments of at least two year's duration now seem appropriate to form the frame of a climate-oriented observational network; (ii) no MMPs will be used for these moorings in future because, at this location and in this boundary current, they have shown low reliability; (iii) NABOS will deploy cluster-like groups of several (five or more moorings) each year, moving this cluster from one climatological mooring location to another so as to investigate the processes responsible for driving change at these sites. As the behaviour of the Atlantic Current branches in the Nansen Basin is still of considerable scientific interest, the continuation of the NABOS array in some form remains a priority.

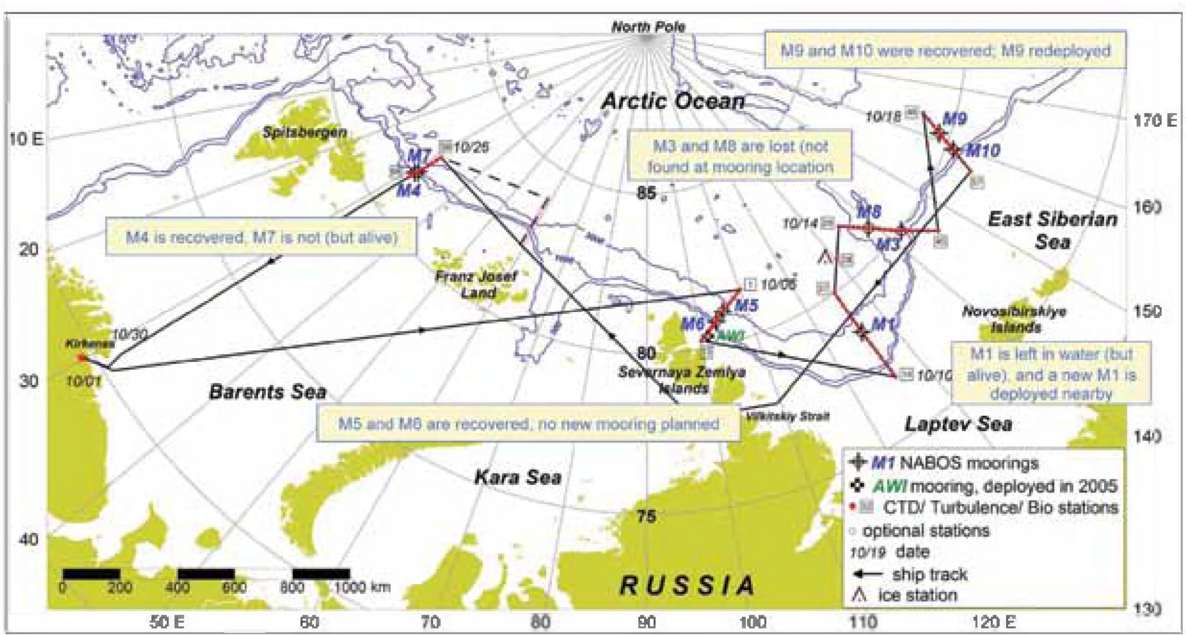


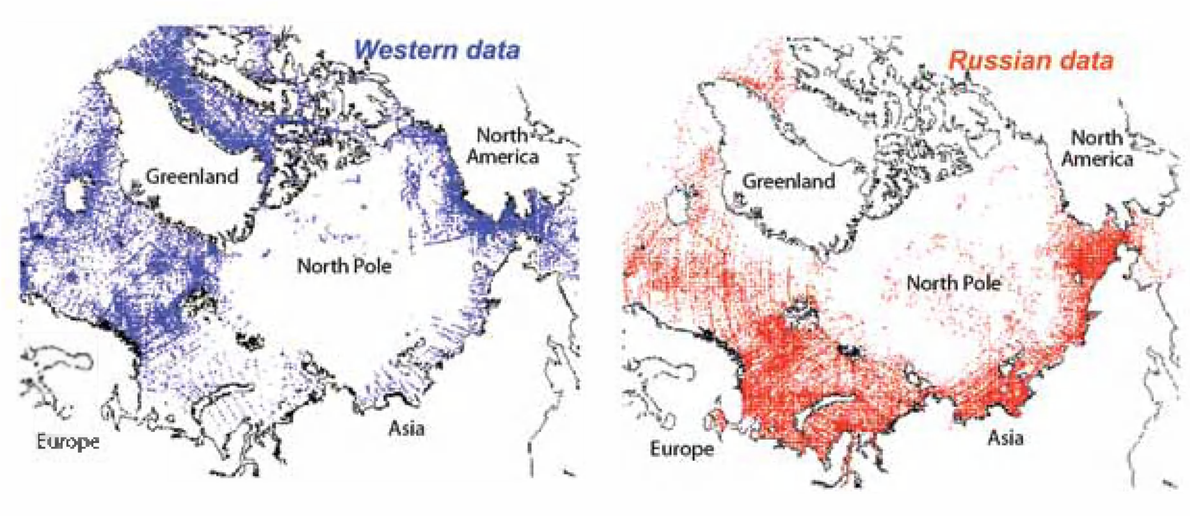
Fig. 2.2-3. Track of the NABOS Cruise aboard R/V *Kapitan Dranitsyn* showing mooring locations and affiliations in October 2008.
(Source: Igor Polyakov, IARC, November 2008)

The spread of SeaGliders support of Arctic-subarctic exchanges. The SeaGlider (usually the UW version) has proved a versatile and effective means of solving long-standing observational problems of oceanic exchanges between Arctic and subarctic seas. Drawing these uses together into a single paragraph will underscore their versatility. On the Greenland-Scotland Ridge, Eriksen and Rhines employed three UW seagliders to map and measure the small, thin, dense water overflows that have eluded measurement by any more conventional means (see Dickson, 2008). In the case of iAOOS-for-Norway, as we have seen, the observational difficulty was to find some means of observing the offshore free jet of the Norwegian Atlantic Current where it passes north through the Svinøy Section, carrying half the northward heat flux through the Norwegian Sea; this was solved by the use of a UW SeaGlider from July 2008. In the case of the Fram Strait throughflow, the need was to resolve the filamented two-way flow through the Strait in a way that even a dense 'picket fence' of current meter moorings cannot do; AWI introduced glider surveys for this purpose in both 2007 and 2008 and intend, with Craig Lee's continued collaboration, to expand this effort westward to recover data from the ice-covered part of the Strait. In the case of Craig Lee's Davis Strait Monitoring effort, to be described below, the observational need was to measure the totality of ocean exchanges to the west of Greenland, in particular the freshwater flux passing south under the seasonal ice cover in the western part of the Strait. After first trials in December 2006, this was solved in 2009 by a SeaGlider operating autonomously (acoustic navigation, ice-sensing, independent decision-making) to avoid the surface and continue its westward transit after encountering the ice edge. Prospectively, acoustic gliders operating under the perennial ice of the Arctic deep basins will form the essential third component of the DAMOCLES system to monitor ice keel-depth, acting as the data link between upperward looking sonar (ULS) floats and their acoustic Ice Tethered Platforms (ITP). A first full deployment is intended in spring 2010 at the North Pole. In all five of these examples, a measurement of considerable importance to our understanding of the Arctic climate system had stalled until the unique capabilities of SeaGliders were introduced to help solve the observational problem. The new Deepglider development will add a further dimension. Deepgliders are expected to be able to survey oceanic variability autonomously over the entire water column on deployments and recoveries made on successive summers, making them well-suited to observing subpolar as well as subtropical and tropical seas. To give only one example, the development of Deepgliders capable of cruising the watercolumn of the subpolar gyre has been called for (Dickson et al., 2008) as a necessary aid to capturing the baroclinic adjustments that cause interannual changes in the transport of the dense water overflows from Nordic Seas. We note that the cost of fabrication is estimated to be less than half again that of SeaGliders, while the cost of operation will be perhaps half that of their upper ocean relatives (Charlie Erikson, pers. comm., January 2009). Testing of the first full ocean depth Deepglider took place in mid-2009.

Observing the Arctic Ocean and Circum-arctic shelves.

We need little reminding that barely a decade ago, the Arctic Ocean was a data desert. If we did, Fig. 2.2-4 would be all that was needed to remind us. That situation has now changed. In addition to the expanded ship-based CTD coverage achieved during IPY (described in Dickson, 2008; 2009), the rapid elaboration and expansion of the ice-top observatory brought a range of new autonomous systems to bear on the Arctic Ocean and its ice cover that hardly existed before the Millennium. In particular, the spectacular expansion of CTD coverage throughout the Arctic deep basins is principally the result of the WHOI Ice Tethered Profiler and JAMSTEC Polar Ocean Profiler Systems. In consequence – and probably for the first time – it is now impractical for a summary such as this to provide a complete accounting of what was achieved, voyage by voyage or instrument by instrument, during IPY. Instead, we attempt to provide a flavour of that achievement by describing an inconsistent selection of voyages, instruments and ideas whose novelty, difficulty, effort, complexity, climatic importance or collaborative nature fulfilled one aspect or another of what IPY set out to do. In paring down our description to a few voyages, it is important that we don't discard all of the detail: one suspects that it will be the multi-layered and often internationally-provided complexity of the field

Fig. 2.2-4. Distribution of the oceanographic stations over the Arctic Ocean for the summer period according to the findings of the Environmental Working Group (EWG, 1997).



programme that will generate the new insights that IPY set out to provide.

Instrumenting the Western Arctic: the 2008 voyage of F/S Polarstern ARK-XXIII/3 (ECDAMOCLES). This cruise, from 12 August to 17 October 2008, was designed as a contribution to the Synoptic Pan-Arctic Climate and Environment Study (SPACE), designed by Ursula Schauer (AWI) for IPY, but with input from a range of multinational programs including, principally, EC-DAMOCLES. The cruise was remarkable for its geographic scope (from the NW to the NE Passage), for the international breadth of its collaborations and for the range of novel instrumentation that it deployed across this climatically-active sector of the western Arctic. These novel systems included the first two deployments of the Polar Area Weather System (PAWS; Metocean; Burghard Brümmer, UHH) designed to collect air temperature, ice temperature, barometric pressure, relative humidity, wind speed and direction, and position, with one-year life; two WHOI Ice-tethered Platforms (ITP; John Toole and Richard Krishfield, WHOI); five Surface Velocity Profilers (SVP; Meteo France; Pierre Blouch, EUROMETNET Brest) providing ice-top position, temperature and pressure; two Polar Ocean Profiler buoys (POPS, JAMSTEC, Takashi Kikuchi); ice-tethered systems providing profiles of water temperature, salinity and pressure to 1000 m; and a single Ice-tethered Acoustic Current Profiler (ITAC; Optimare + RDI 75 kHz Long Ranger ADCP; Jean-Claude Gascard of DAMOCLES) – essentially an ice-tethered ADCP providing profiles of ocean current velocity to 500m every two hrs – employing Kikuchi's system of 2 GPS units placed some 100m apart to obtain not only position, but also the orientation of the ice floe in areas of weak horizontal field strength.

Revolutionizing the hydrographic record of the Arctic Deep Basins: the contribution of Ice tethered Profiler systems. Of the many new systems that have revolutionized the Arctic Ocean data set in recent years, a principal success has been the rapid expansion of CTD coverage throughout the Arctic deep basins, provided largely by the autonomous use of ice-tethered profiler systems. The two main types are the WHOI ITP system (Krishfield et al., 2008) and the JAMSTEC POPS (Inoue and Kikuchi, 2007; Kikuchi et al., 2007).

The rapid expansion of the ITP system since 2004, but principally during IPY, is documented in Table 2.2-3 (next page). It is now a fully-international effort with contributions from the EC-DAMOCLES and with IPY collaborations between WHOI and AWI, Arctic and Antarctic Research Institute (AARI, St Petersburg), French Polar Institute (IPEV), Shirshov Institute of Oceanography and the U.K. Arctic Synoptic Basin-wide Oceanography (ASBO) project. In 2008, in collaboration with Canadian, U.K., Russian and German colleagues, the WHOI team collectively deployed a dozen systems from the *Borneo* ice camp near the N. Pole (1), the *Louis St.Laurent* in the Canada Basin (five systems) and well upstream in the Transpolar Drift from the *Fedorov* (4) and *Polarstern* (2). Since April 2006, the Polar Ocean Profiler (POPS) has used a similar system with an inductive modem providing data transfer between ice platform and profiler. Trials confirm that POPS can measure temperature and salinity with conservative accuracies better than 0.01 C for temperature and 0.01 for salinity.

	Completed missions	Active missions
2004	ITP 2	
2005	ITP 1, ITP 3	
2006	ITP 4, ITP 5	ITP 6
2007	ITP 7	ITP 8, ITP 9, ITP 10, ITP 11, ITP 12, ITP 13, ITP 14, ITP 15, ITP 16, ITP 17, ITP 18
2008		ITP 19, ITP 20, ITP 21, ITP 22, ITP 23, ITP 24, ITP 25, ITP 26, ITP 27, ITP 28, ITP 29, ITP 30

Table 2.2-3. Expansion of the WHOI ITP program between 2004 and 2008, from www.whoi.edu/itp.

Altogether, the ITP array has now returned something in excess of 20,000 CTD profiles between ~7 and ~750 m depth since the first unit was deployed in 2004 (pers. comm., John Toole WHOI, October 2009), transforming the former data-desert into one of the most-densely-observed oceans on the planet. Though still a work in progress (part of the data-set remains to be calibrated), Fig. 2.2-5 by Ben Rabe, AWI Bremerhaven, illustrates the barely believable progress that has been made by combining the recent output of autonomous profiling systems with conventional ship-based CTD-hydrography (Rabe et al., in press). In fact, Fig. 2.2-5 illustrates three recent advances, all of them important to the success of IPY. First (it goes almost without saying), usefulness is linked to the extent and density of coverage; the pan-Arctic distribution of 'freshwater content' is an output of direct relevance to the role of the Arctic in climate that could only have been obtained by merging the full expanded sets of CTD profiles, from all sources. Second, our ability to merge these data sets stems from a quite new attitude to the accessibility and availability of data. Thus the ITP data are rapidly provided by the WHOI ITP Program via www.whoi.edu/itp; the POPS data are provided by EC-DAMOCLES and by JAMSTEC through the international ARGO programme. Data can be found at www.ipev.fr/damocles/ and ftp://ftp.ifremer.fr/ifremer/argo/dac/jma/4900904/. The ship-based CTD data are courtesy of AWI and were acquired during the RV *Polarstern* cruises ARK- XXII/2 (Aug/Sep 2007) and ARK-XXIII/3 (September - October 2008); these data can be found at www.pangea.de. Having merged the data, the third comment made in Fig. 2.2-5 concerns the general

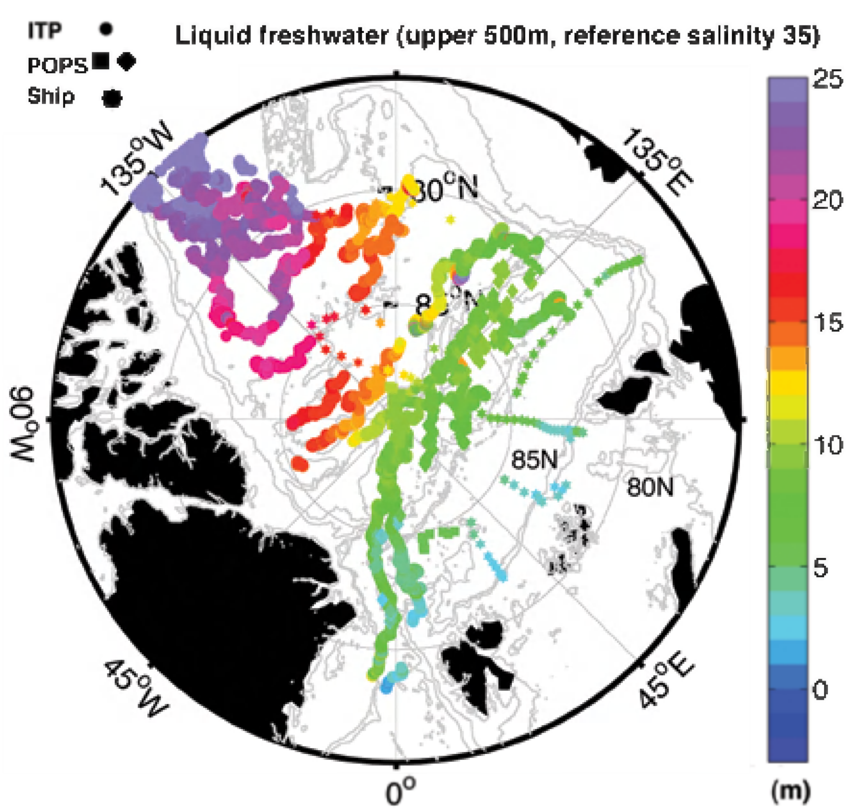


Fig. 2.2-5. The distribution of liquid freshwater content in the upper 500m of the Arctic Ocean from ITP (2006 to 2008), POPS (DAMOCLES and JAMSTEC/ARGO, 2006 to 2008) and *Polarstern* cruises ARK-XXII/2 (2007) and ARK-XXIII/3 (2008). The freshwater content is expressed in metres. This analysis, kindly provided by Ben Rabe AWI, is not yet finalised; the ITPs (no. 6 to 18) have been salinity-corrected using non-autonomous CTD observations but the POPS data have not yet been corrected in this way. The *Polarstern* CTD data have been fully post-processed and corrected using *in situ* salinity bottle samples and pre-/post-calibration of the sensors.

(Map: Dickson and Fahrbach, 2010)

quality of the data; though not yet fully calibrated, the component data sets merge without obvious inhomogeneities.

A broad range of problems in arctic oceanography have been addressed by this powerful new technique. *Inter alia,* its data-set has been used to: document space-time variability since AIDJEX (1975) and SCICEX (1997) in the major water masses of the Canada Basin; describe the double-diffusive thermohaline staircase that lies above the warm, salty Atlantic layer; measure the seasonal deepening of the surface mixed layer and its implications; explore the structure of mesoscale eddies (Timmerman et al., 2008); support a broad range of process studies; and facilitate the initialization and validation of numerical models. To achieve the prospect of having ITPs sweep through a large fraction of the Arctic over the next few years, the surface buoy of both systems has been redesigned to better survive thin ice and even open water and from 2009–2010, the WHOI system will operate with just a clonical float. NSF OPP has recently agreed to continue the ITP program for another five years.

Satellite remote sensing. Fig. 2.2-6, from (Morison et al., 2007 and pers. com.) will serve to introduce the subject of the use of satellite altimetry and time-variable gravity in improving our understanding of Arctic Ocean hydrography and circulation, showing something of what has been accomplished to date. GRACE Release 4 bottom pressure trends in the Arctic Ocean during 2005-08 describe a declining trend in bottom pressure throughout in the Beaufort Sea and eastern Canada Basin (green tones) due to the persistent freshening trend. In the central Arctic, a rising trend in 2005–2008 (red tones) is associated with the advance of salty Atlantic-derived water. A correspondence between measured steric and bottom pressure trends (not shown here) seems consistent with the idea that changes in bottom pressure at long time-scales are dominated by steric changes as opposed to sea surface height changes (Vinogradova et al., 2007). From radar altimetry, a real goal – already partly realised (Katharine Giles and Seymour Laxon, UCL-CPOM, pers comm.) – is to derive maps of sea surface height (SSH) for the Arctic Ocean even in the presence of ice.

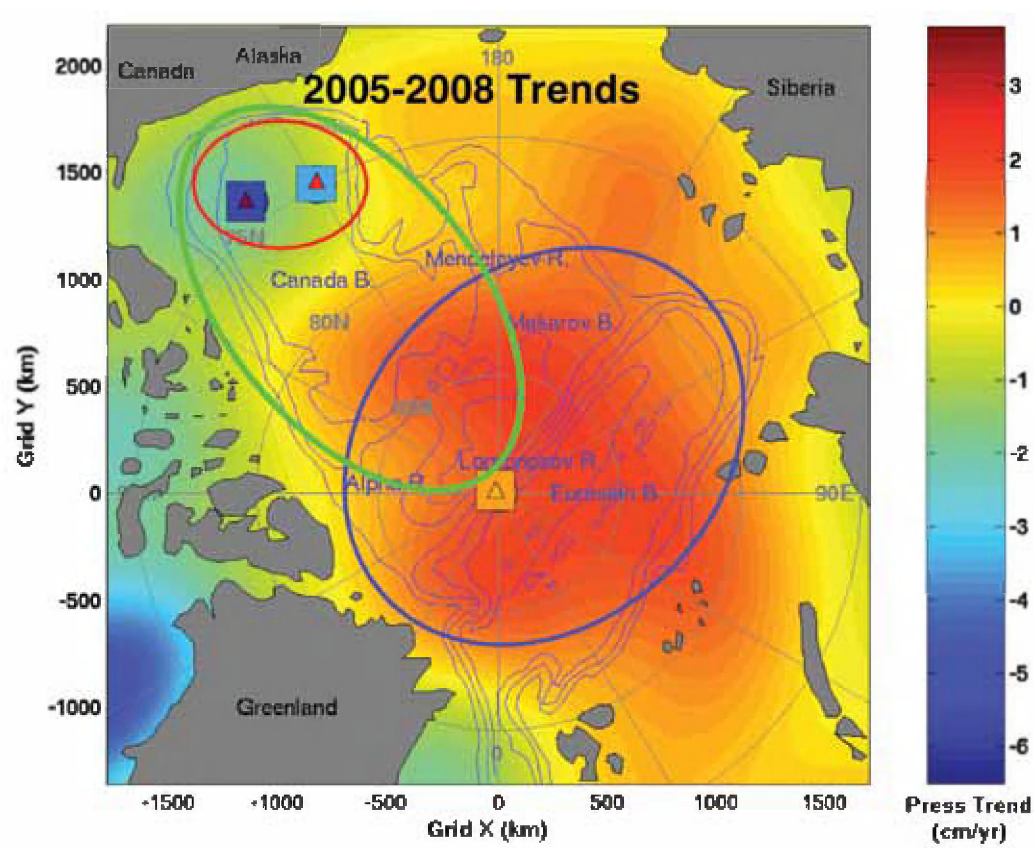


Fig. 2.2-6. GRACE Release 4 bottom pressure trends in the Arctic Ocean during 2005-2008, from (Morison et al., 2007 and pers. com.).

Towards a new autonomous sub-ice system for monitoring the keel depth of sea-ice; the collaboration between EC-DAMOCLES and the Chinese National Arctic Research Expedition (CHINARE) in 2008. Ice thickness is an important parameter. The 22 ice-prediction groups that participated in the SEARCH-for-DAMOCLES (S4D) Sea Ice Outlook exercise concluded that an improved measure of ice thickness in spring was the prime requirement for improved prediction of ice extent at the time of the late summer minimum. Supplementing remote sensing techniques, including the laser and radar altimetry on ICESAT and ENVISAT, and the use of ice-surface sensors (e.g. tiltmeter buoys), a new autonomous system based on the use of isobaric sub-ice floats fitted with upward-looking sonar has been developed by EC-DAMOCLES during IPY and is now on the point of completion. The ULS floats are designed to drift at a constant depth of 50m beneath the arctic ice for up to two years. The equally-new acoustic ice-tethered platforms (AITP; now 'amphibious' rather than ice-tethered) are designed to form the link between ULS floats and satellite transmission, with the EC-DAMOCLES plan calling for ten AITPs and eight ULS floats in total. The first deployment of two ULS floats and four AITP systems were deployed by Canadian twin-otter aircraft above the Alpha Ridge in April 2008, together with seven PAWS weather monitors (Broemmer, UHH) and three ice mass-balance buoys (IMBs; Richter-Menge et al., 2006). The remainder of the 2008 deployment, including four more AITPs, an extensive CTD grid and a complex ice camp of instruments was later set by the Chinese CHINARE 2008 Expedition aboard R/V Xue Long (11 July - 24 September, 2008). The full realization of data retrieval from ULS-floats will depend on the development of acoustic gliders as the third component of the system. DAMOCLES began the stepwise development of such an acoustic glider, starting in autumn 2008, followed by trials off Svalbard in spring 2009 and leading to a first planned deployment in spring 2010 at the North Pole. In the meantime, data retrieval will involve ships approaching ULS floats and forcing a download to an acoustic modem (Gascard, pers comm). Altogether, ten AITPs plus four ULS floats have been deployed to date fulfilling most of the DAMOCLES plan and the unequivocal requirement of the S4D Sea-ice Outlook exercise for data on sea-ice thickness commends the continued use of this technique into the IPY legacy phase. A further four ULS floats and four new 'hybrid' AITPs are being constructed; in addition to having a profiling hydrophone, the new AITPs will begin to contribute to the ITP dataset by carrying a CTD profiler for the first time.

The drift of the Russian Ice Island North Pole-35 and the Arktika-2008 expedition aboard R/V Akademik Fedorov. Since 1937–1938, the Russian Arctic and Antarctic Research Institute (AARI) has operated a total of 34 drift stations in the Arctic Ocean making this type of observational platform something of a Russian specialization. After a considerable search for a suitable floe, NP-35 was established on September 25, 2007 at 81°26'N 103°30'E by the *Akademik Fedorov* working in conjunction with the nuclear icebreaker *Russia* as part of the "Arktika 2007" expedition. For most of the following year, NP-35 was occupied by AARI as a contribution to IPY, contributing new results in polar oceanography, sea ice studies, processes of greenhouses gas exchange in presence of ice cover and polar meteorology.

During the first 7-month winter drift of NP35, the Russian team was joined by Jürgen Graeser from the Potsdam Research Unit in Germany and, during this phase, the investigations of the ocean upper layer, the characteristics of the sea ice, the snow cover and the energy balance above the ice surface were supplemented with further atmospheric data (temperature, moisture, wind and air pressure) collected by ascents of a tethered balloon up to a height of 400 metres as well as by balloon-borne sensor ascents up to an altitude of 30 kilometres. Both contributed rarely-obtained winter data with high temporal and spatial resolution to the improvement of global climate models. The exchanges of heat and moisture in the atmospheric boundary layer to an altitude of ~400 metres, now measured for the first time during the complete polar night, were of especial value. As the layer that determines the lower boundary conditions for all model calculations, a realistic representation of the planetary boundary layer in the Arctic is crucial for the construction of climate models; hitherto, temperature profiles from regional climate models have shown considerable deviation from those measured on the floe. The data set of NP 35 will also contribute significantly to the determination of how much of the ozone destruction in the Central Arctic is caused by human activities. In fall 2008, the Russian Federal Service for Hydrometeorology and Environmental Monitoring (Roshydromet) conducted the "Arktika-2008" research expedition in the Arctic basin and the Arctic seas aboard *R/V Akademik Fedorov* of AARI. The expedition was the biggest in Russia in 2008, within the framework of IPY, and deployed a series of experiments into the processes responsible for the changes in the arctic climate system and the environment in ocean, sea ice and atmosphere. Apart from evacuating NP-35 at the end of its long drift, this expedition also established a new drifting research station NP-36.

The transpolar drift of the polar yacht Tara. On 3 September 2006, at a point north of the Laptev Sea, the polar schooner *Tara* embarked on its transpolar drift, embedded in the arctic ice-pack as *Fram* had been, drifting along a more-or-less parallel track, but twice as fast as expected. Scientists on board were responsible for running ten different research programmes under EC- DAMOCLES: collecting data related to sea ice, atmosphere and ocean, servicing a sophisticated web of autonomous buoys spread within a 500 km range around the ship, and with IAOOS-for-Norway contributing installations of radiometers and optical measurements. *Tara* passed out of the Arctic Ocean through 80N in December, was picked up by the ice off east Greenland and was finally released into the western Greenland Sea, 300 km north of Jan Mayen on 21 January 2008, some 500 days and 5000 km since her drift began. We have space in this brief summary to describe just two areas of *Tara's* work-program that have some ice-ocean connection and that already seem to be of lasting significance. 1)

In the context of arctic change, the albedo feedback process has been identified to play a key role for snow and sea ice melting. This process operates on different spatial scales, from snow metamorphosis involving snow grain changes, to processes where the dark surface of open water in leads absorbs more heat and contributes to enhanced melting of sea ice. Besides its importance for the surface energy and mass balance in the Arctic Ocean, the light budget above and below the sea ice is of crucial importance for the arctic marine ecosystem and for remote sensing calibration and validation. During her long drift across the Arctic Basin, a setup with three radiometers and a data logger was installed near *Tara* in April 2007; detailed optical measurements of spectral surface albedo and snow and ice transmissivity were made automatically and autonomously until September 2007. 2)

Melt ponds have a substantially lower surface albedo than other ice and snow surfaces, so the *Tara* program on the role of melt pond formation for the arctic sea ice and climate, including the improved detection of melt ponds (using a mast-mounted time-lapse camera) and their consideration in climate models, will also be of lasting significance.

First Iron Section through the Arctic Deep Basins. Dissolved iron is an essential trace nutrient for all living organisms and is often limiting for the plankton ecosystem in the world oceans. The low

Fig. 2.2-7a. Ultrapure all-titanium frame holding 24 teflon-coated water samplers of 12 Liters each, deployed with a Kevlar cable. Upon recovery the complete frame is placed inside an ultraclean room for subsampling. The frame never touches the steel ship and thus permits reliable sampling of ultralow concentrations of dissolved Fe in pristine ocean waters.

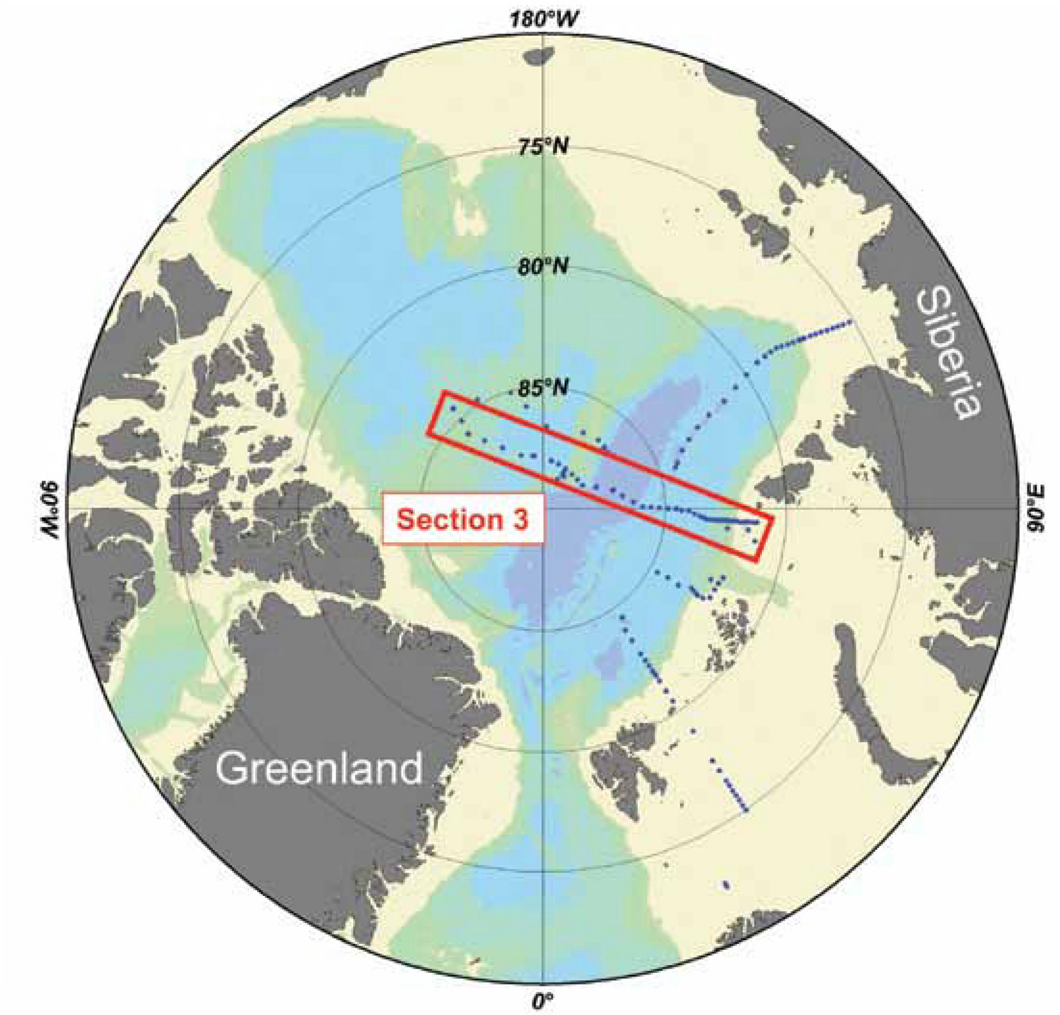


Fig. 2.2-7b. Sampling stations for dissolved iron in the Arctic Ocean.

(Map: Dickson and Fahrbach, 2010)

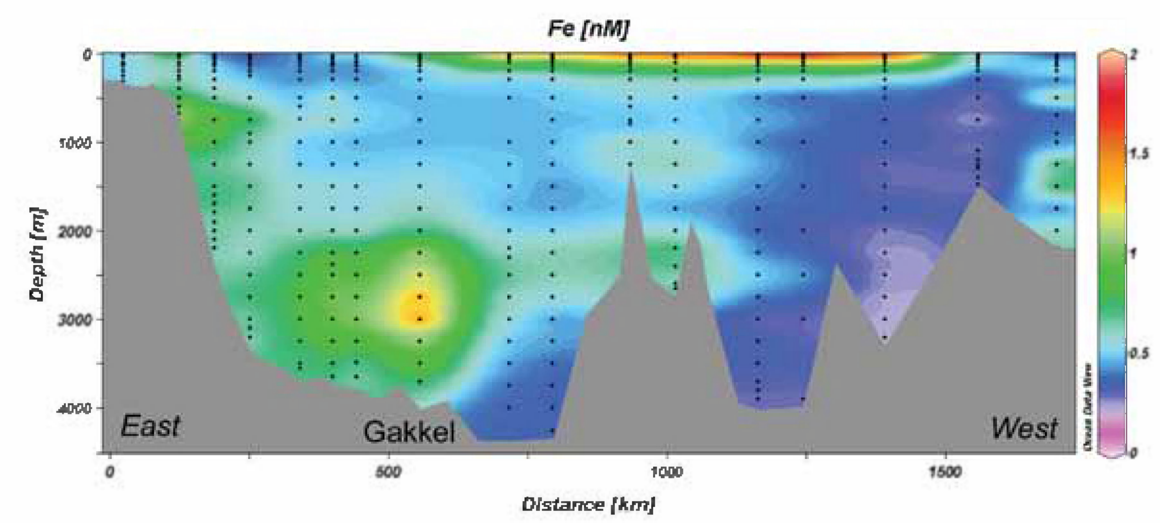


Fig. 2.2-7c. Vertical distribution of dissolved iron along Section 3 in the central Arctic Ocean. High values in surface waters are due to river input and sea-ice. The very large plume over Gakkel Ridge is due to hydrothermal vent supply.

(Graph: Dickson and Fahrbach, 2010)

concentration makes it difficult to quantify Fe in seawater. Samples were taken with a novel ultraclean CTD sampling system (Fig. 2.2-7a) deployed during the IPY-GEOTRACES program aboard R.V. *Polarstern* ARK-XXII/2 in July-October 2007. The results are the first ever comprehensive overview of the distribution of dissolved Fe in the deep basins and surface waters of the Arctic Ocean. Shipboard analyses by flow injection were calibrated with excellent agreement versus certified standard (SAFe) seawater (Johnson et al., 2007). Along the long trans-Arctic section 3 (Fig. 2.2-7b), the dissolved iron showed high (>2nM) concentrations in the upper 100m with a negative correlation ($R^2 = 0.80$) with salinity. This, together with corresponding manganese maxima (by Rob Middag, not shown) and low light transmission values, points to fluvial input and input via melting of sea-ice to be main contributors of iron to the surface waters. Hydrothermal activity above the Gakkel Ridge (Fig 2.2-7c) is a major input source of iron as confirmed by a very similar pronounced dissolved manganese maximum (by Rob Middag, not shown) and anomalies of potential temperature and particle abundance (less light transmission). Decreasingly, very low concentrations of iron with depth below 3000 m in the Amundsen and Makarov Basins are most likely due to net removal caused by a high scavenging regime and relatively little remineralization.

Exploring the biogeochemistry and geophysics of the entire Eurasian-Arctic continental shelf in IPY: the International Siberian Shelf Study 2008 (ISSS-08). The ISSS-08 study aboard *RV Yakob Smirnitski* involved 30 scientists from 12 organizations in Russia, Sweden, U.K. and U.S.A., including three from DAMOCLES responsible for physical oceanography. The motivation for ISSS-08 was to alleviate the scarcity of observational data on transport and processing of water, sediment and carbon on the East Siberian Arctic Shelves (ESAS). The ESAS, composed of Laptev, East Siberian and Russian part of Chukchi Sea, is the world's largest continental shelf and at the same time the most understudied part of the Arctic Ocean. It is characterized by tundra discharge through the Lena, Indigirka and Kolyma rivers, coastal erosion, methane seeps from subsea-permafrost reservoirs and shelf-feeding of the Arctic halocline. The region is of particular interest from the perspective of carbon-climate couplings as it has witnessed a 4°C springtime positive temperature anomaly for 2000-2005 compared with preceding decades.

The coplex program included the sampling of river-borne organic material, trace elements, methane, CO_2, freons and nutrients, with sampling from air, watercolumn and sediments. Additionally, a Russian group carried out a seismic program using towed equipment. Sampling was accomplished during a 50-day cruise in August – September 2008 using two vessels. The main vessel *R/V Yacob Smirnitskyi* travelled the entire length of the Siberian coast from Kirkenes, Norway to Herald Canyon, Chukchi Sea and back along the outer shelf. A second ship sampled the Lena River and the southeastern Laptev Sea. Significant at-sea findings included new methane seeps and bubble plume fields in both the Laptev and East Siberian Sea, several associated with geophysical gas-chimney structures. The cruise also studied the Pacific inflow through Herald Canyon and remnants of salty and cold bottom waters on the shelf break. A vigorous mixing zone was encountered just north of Herald Canyon between warm north-flowing Pacific Summer Water and cold winter water. Still planned are the analyses of collected air, seawater, eroding soil and sediment material including molecular and isotopic biomarker composition as well as trace element and isotope characterizations (GEOTRACES protocol) to elucidate provenance, remobilization of "old" terrestrial matter, the relative importance of river versus erosion sources, degradation of organic matter in seawater and sediments and variations in these processes with dynamic climate forcing.

Deploying Canada's 'climate antenna' through its Northern Seas: the 15,000 km annual transects of the Canada Three Oceans (C3O) Program. The three oceans that surround Canada are connected by waters that flow from the Pacific to the Arctic and then into the Atlantic; changes in the ice cover and ecosystems of the Arctic are tightly linked to the global climate system in general and to the bordering subarctic Pacific and Atlantic oceans in particular. C3O (Canada's Three Oceans, led by Eddy Carmack) links all of Canada's three oceans and investigates the interconnectedness of arctic and subarctic domains. During IPY, C3O joined under the iAOOS cluster with the ongoing JOIS (Joint Ice Ocean Studies, led by Fiona

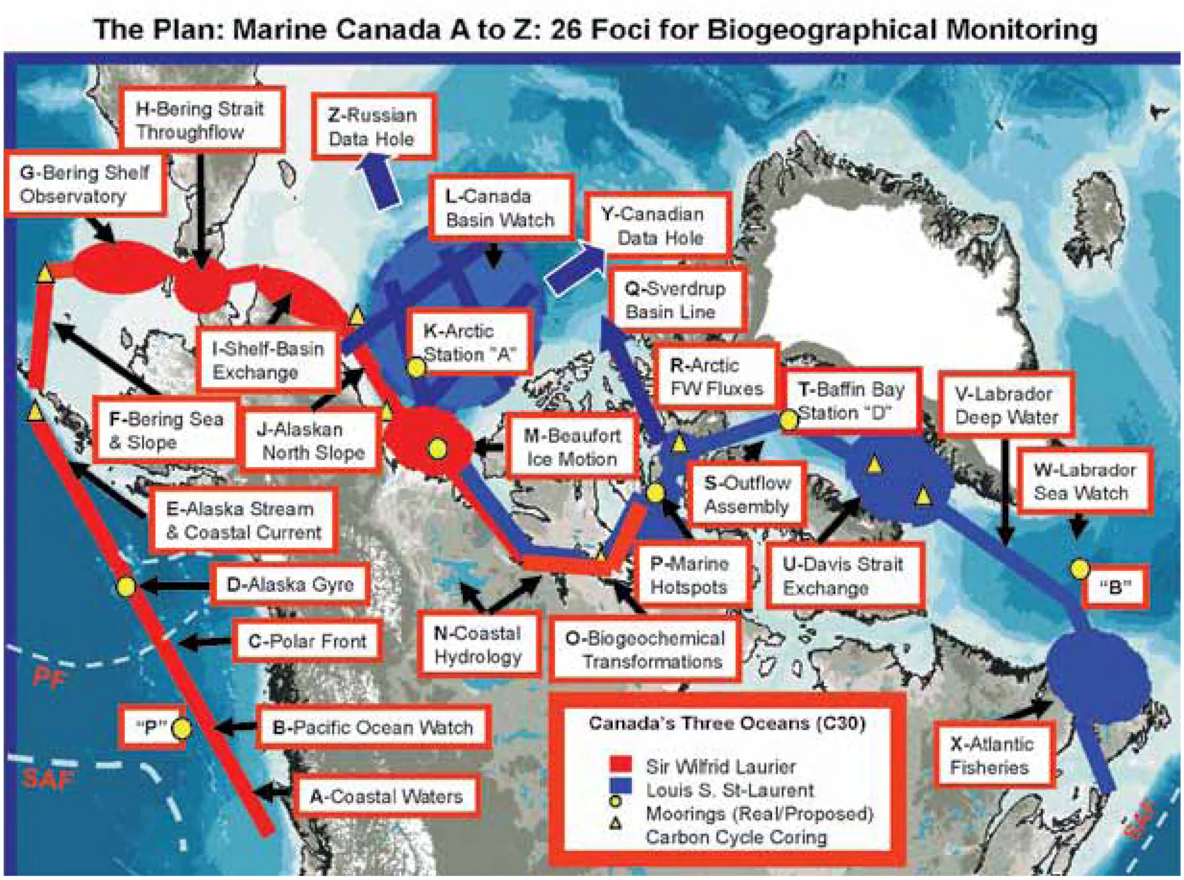


Fig. 2.2-8. The 26 sites and subjects that are presently monitored under the two-ship Canadian C3O program, designed to assess the progress of global change throughout Canada's three oceans.
(Source: Eddy Carmack, IOS)

McLaughlin) and the BGEP (Beaufort Gyre Exploration Project, led by Andrey Proshutinsky) to optimize use of available resources.

In 2007 and 2008, C3O used two science-capable icebreakers of the Canadian Coast Guard whose current mission tracks encircle Canada (Fig. 2.2-8) to obtain a snapshot of large-scale ocean and ecosystem properties and thus establish a scientific basis for sustained monitoring of Canada's subarctic and arctic seas in the wake of global warming. C3O collected fundamental data on temperature, salinity, nutrients, oxygen, the carbon system, virus, bacteria, phytoplankton, zooplankton, fish, benthos and whales, with the goal of establishing connections between the physical environment and the living nature. The following observations were made in the two-year period: 551 CTD/rosette stations; 324 underway CTD and expendable CTD stations; 148 zooplankton net hauls; 64 biological stations (viral abundance, DNA/RNA, primary production); and approximately 24,000 km of underway sampling. The ultimate goal of C3O is to establish a 'scientific fence' around Canada with observations that will allow both observers and modellers to gauge the progress and consequences of global change and thus provide policy makers and the Canadian public with information essential to governance, adaptation and resilience-building in the Canadian North. Regular repetition through to 2050 would reveal the expected redistributions of oceanic boundaries and biomes (Carmack and McLaughlin; 2001; Grebmeier et al.; 2006) and give scientists and policy makers access to the time-scales of change that have the greatest social relevance and impact. Nevertheless, the value of C3O will not rest entirely with its own findings. With 26 separate study sites covering a broad range of disciplines, the 'connectivity' of C3O with the results of other major IPY projects can be expected to be high. These expected yet unpredictable linkages between project results represent, in many ways, the unplanned 'profit' of IPY, developing a more thorough and a more complex understanding of the processes of arctic change than might be evident from any single project. One emerging example – from

Jackson et al., (in press) – will illustrate the point.

For more than a decade, we have known of the existence of a narrow temperature maximum just below the surface (~25m) of the Canada Basin in summer (Maykut and McPhee, 1995), Jackson et al., (in press) have recently combined CTD profiles from four of the Woods Hole ITPs (nos. 1, 6, 8 & 18; Table 2.2-3 above) with shipborne CTD data from IPY (C3O) and from earlier years (JOIS 1997; JWACS 2002-6) to reveal much of what is important about this seemingly-delicate, but in fact extensive and rather robust layer. The Near Surface Temperature Maximum (NSTM) that they describe is first formed in June-July when sufficient solar radiation enters the upper ocean through narrow leads and melt ponds to warm the near-surface waters. Ice melt from these warmed surface waters then accumulates to form a strengthening near-surface halocline, effectively capping-off the NSTM and trapping solar radiation in the ocean until late September when sea ice begins to form once again, allowing penetrative convection (from brine rejection) and air-ocean or ice-ocean stresses to deepen the surface mixed layer. This is not an unvarying process. As the ice has retracted from the western Arctic in what Overland et al., (2008) have called the "Arctic Warm Period" (2000-2007), Jackson et al., (in press) reveal that the temperature of the NSTM in the Canada Basin has increased north of 75°N at a rate of 0.13°C per year since 2004. Some of the interconnections between this result and others *within* the C3O project are already evident: the idea that the warming of the NSTM is closely linked to sea-ice melt receives strong support from the fact that the warmest NSTMs were found in the same region of the Canada Basin that Yamamoto-Kawai et al., (2009) have recently described; a threefold increase in the ice-melt component of the freshwater in the watercolumn between 2003 and 2007. But the *external* implications of these results have the potential to be even more significant. If the warmer NSTM persists later in the year, which is one scenario discussed by Jackson et al., (in press) *'heat from the NSTM might maintain thinner sea-ice through winter which would then melt sooner in spring'.* As they also point out, thinner sea-ice is likely to alter the effect of wind stress on sea ice, increasing ice drift and air sea coupling in the manner suggested by Shimada et al., (2006). Hence their conclusion that *'the dynamics of the NSTM should be considered when modelling climate change in the Arctic'.*

Observing the outputs from the Arctic Ocean

First long term measurements of the freshwater flux east of Greenland. De Steur et al., (2009) report the results of a decade of observations of the freshwater flux in the East Greenland Current at 78° 50'N. The special nature of this result lies in the considerable achievement of recovering 10 years of moorings from these difficult waters and in the usefulness of this result as a missing term in our understanding of the freshwater balance around Greenland. The main finding itself is rather less dramatic: over this decade of measurements, the annual mean liquid freshwater flux passing south through the western Fram Strait proved to be surprisingly constant at ~1150 km^3 y^{-1} (36 mSv). Though based on an earlier dataset, Dodd et al., (2009) have recently used a mix of tracers (hydrographic, oxygen isotope ratio and dissolved barium concentration) to determine the sources and fate of the freshwater carried in the East Greenland Current. Rabe et al., (2009) use hydrographic data and $\delta^{18}O$ values with modelling (NAOSIM) to distinguish changes in the various freshwater components and transports in the Fram Strait since the late 1990s, showing *inter alia,* that the high transport of meteoric water (precipitation and riverine sources) in the Fram Strait in 2005 is in agreement with the temporary storage of river water on the Siberian shelf in the mid-1990s, which reached the north of Greenland in 2003.

Ocean Currents of Arctic Canada; new insights on the Canadian Arctic Through-flow during IPY. The Canadian Arctic Through-flow (CAT) study is the culmination of ten years of effort within Canada and the international community to measure flows of freshwater, saltwater and ice through the Canadian Arctic Archipelago (CAA; see Kleim and Greenberg, 2003; Prinsenberg and Hamilton, 2005; Münchow et al., 2007; Falkner et al., 2008; Melling et al., 2008). Although first attempts date back to the early 1980s, the recent revival in activity was stimulated by the development of techniques for measuring the current direction near the geomagnetic pole and for observing the hazardous zone beneath drifting ice pack. The installations in Lancaster Sound and Cardigan Strait have been maintained since 1998. The installation in Nares Strait was discontinued after loss to icebergs of both moorings in Smith Sound during 1999. Nevertheless, four years later in 2003, a large array of sub-sea instruments was installed from *USCG Healy* across Kennedy Channel, much further north in Nares Strait where icebergs are less common. Most of these instruments were retrieved using *CCGS Henry Larsen* in 2006. The array for IPY was complete by late August 2007. In July 2007, two moorings were placed from *CCGS Louis S St-Laurent* in Bellot Strait, the narrowest and only unexplored choke point for CAT; one of these moorings carried a variety of sensors for biological parameters (chlorophyll, turbidity, dissolved gases, acoustic backscatter and marine vocalization). In early August 2007, moorings in western Lancaster Sound was recovered and replaced from *CCGS des Groseilliers.* By the end of that month, the array at the southern end of Kennedy Channel (Nares Strait) had been re-established from *CCGS Henry Larsen* and the long-standing installations in Cardigan Strait had been recovered and re-deployed. The high logistic cost of working in Nares Strait precluded the recovery and re-deployment of moorings in this remote area in 2008, but the full array was recovered in August 2009. With this recovery, one of the hardest observational tasks in oceanography was successfully accomplished. The 'point' of making these measurements remains; carrying the main freshwater flux between the Arctic Ocean and North Atlantic west of Greenland, the passageway-flows of the Canadian Arctic Archipelago carry significant inputs to the Atlantic MOC and are thus of importance to climate. The task now will be one of maintaining these difficult arrays over years to decades, but at lesser cost.

A major advance in monitoring ocean fluxes through Davis Strait; the first autonomous sub-ice glider profiles. The Davis Strait carries all of the exchanges of mass, heat and freshwater between the Arctic and the Northwest Atlantic west of Greenland and thus acts as a vital monitor of Arctic and subarctic change. Beginning in autumn 2004, Craig Lee (U. Washington) has devised a system of moorings and extended-endurance (9-12 months) autonomous gliders capable of monitoring oceanic exchanges across the full width of the Strait. The major milestone was achieved in December 2006 with the first successful operation of a glider beneath the ice-covered western Davis Strait; a single SeaGlider successfully navigated from the ice-free eastern Strait westward to 59°W, shifting to fully autonomous behaviour, avoiding the surface and continuing its westward transit after encountering the ice-edge. Significantly, all aspects of the ice-capable glider system functioned properly, including acoustic navigation, ice sensing and autonomous decision making. The entire section was conducted without human intervention, with the glider making its own decisions and surfacing to report its data after navigating back to the ice-free eastern side of Davis Strait. By returning observations to within a few meters of the ice-ocean interface and at roughly 5 km horizontal resolution, the technique successfully resolved the south-flowing, surface-trapped arctic outflow from CAA. Unfortunately, a hydraulic failure and faulty Iridium modems and Iridium/ GPS antennas caused the temporary suspension of under-ice SeaGlider operations for 2007–2008. Nevertheless, in 2009, operations resumed with a second major milestone: an autonomous glider, engineered for extended operation in ice-covered environments, completed a six-month mission sampling for a total of 51 days under the ice-cover of the western Davis Strait during which the glider traversed over 800 km while collecting profiles that extended to within a few meters of the ice-ocean interface.

Applying iAOOS: Linking environmental- and ecosystem-changes in Northern Seas

Much of the point of expanding the observing and modeling effort in northern seas during IPY has had to do with the ecosystem and its changes. Many of the projects that were funded for IPY had the ecosystem as their prime focus. Nevertheless, it is clear that after two years of effort, many of these studies will be at an early stage so it will take some care if we are to do these projects justice. Here, we adopt the approach of trying first to identify those aspects of environmental variability that are most likely to drive change through the ecosystem of northern seas, 'ecosystem: temperature' and 'ecosystem: ice' relations seem to be the most fundamental. We then describe some of the hypothetical linkages between the ecosystem and its environment that have been put forward in studies of longer duration than IPY. Finally, we seek out cases where these hypotheses are being tested, altered, developed or predicted in either our observations or models during IPY. Rather than attempt the task of describing the many dozens of IPY ecosystem projects, mostly at an early stage, these descriptions of IPY work take the form of regional essays focused on the Bering Sea', Jackie Grebmeier, the 'Canadian Arctic shelf', David Barber, and 'the Barents Sea', Jorgen Berge and Finlo Cottier. It is hoped that their large geographic spread and their varied content – a flaw lead/polynya study, an investigation of small scale ocean processes important to large scale expected change and, what might be termed, the more-traditional region-scale studies of ecosystem change – will provide a representative flavour of ecosystem science during the IPY.

Atlantic Sector

The warming of Northern Seas. The poleward spread of extreme warmth must form an important part of any description of the present state of arctic and subarctic seas. The temperature and salinity of the waters flowing into the Norwegian Sea along the Scottish shelf and Slope have recently been at their highest values for more than 100 years (Bill Turrell, FRS, pers. comm., 2006). At the 'other end' of the inflow path, the Report on Ocean Climate for 2006 by The International Council for Exploration of the Sea (ICES, 2007) shows that temperatures along the Russian Kola Section of the Barents Sea (33°30'E) have equally never been greater in more than 100 years. Holliday et al., (2007) have described the continuity of the spread of warmth along the boundary. Most recently, Polyakov et al., (2007 and pers. comm.) have documented the arrival of successive warm pulses at the Slope of the Laptev Sea (Polyakov, 2005), their continued eastward spread beyond the Novosibirskiye Islands (Polyakov et al., 2007) and the beginnings of their offshore spread along the Lomonosov Ridge, all neatly confirmed in simulations using the NAOSIM model (Karcher et al., 2007). A very similar warming has been recorded in the Bering Sea of the Pacific sector.

Northward shift of zooplankton assemblages in the NE Atlantic and Nordic Seas. There is an accumulating body of evidence to suggest that many marine ecosystems, both physically and biologically, are responding rapidly to changes in regional climate caused predominately by the warming of air and sea surface temperatures (SST) and to a lesser extent by the modification of precipitation regimes and wind patterns. The biological manifestations of rising SST have variously taken the form of biogeographical, phenological, physiological and species abundance changes. Since it is unexploited by man, the planktonic ecosystem is a valuable index of environmental change. From the 108 copepod taxa that it records, the Continuous Plankton Recorder (CPR) surveys have already identified that during the last 40 years there has been a northward movement of warmer water plankton by 10° latitude in the north-east Atlantic, a similar retreat of colder water plankton to the north and a large shift in phenology (seasonal timing) of plankton communities of up to six weeks. The precise mechanism is not known; SST has direct consequences on many physiological and reproductive attributes on marine life both directly and indirectly (e.g. by enhancing the seasonal stability of the water-column and hence nutrient availability). Equally, the consequences of such changes on the function and biodiversity of arctic ecosystems is at present unknown. Nevertheless, SAHFOS (Sir Alister Hardy Foundation for Ocean Science) has recently developed two new statistical tools, one to measure ecosystem stability and predict potential tipping points and the second to model the changes of niche that may develop under various forcing mechanisms. Using these tools, SAHFOS intends to develop its capability to predict the probable habitat of organisms, including commercially important fish species, in the north-east Atlantic and Arctic Oceans over the next century.

The CPR route network extends northwards. To cover the temporal and geographical shifts in the planktonic ecosystem, an agreement has been reached between SAHFOS and the Research Council of Norway to introduce regular CPR sampling along two routes – the old 'T' route to OS M and a new route from Tromsø to Svalbard. A next step under consideration by SAHFOS is a possible eastwards expansion into Russian waters where significant changes in marine production are anticipated both from natural and anthropogenic causes (Peter Burkhill, SAHFOS, pers. comm.).

Northward shift in the spawning location of the arcto-Norwegian cod stock along the Norwegian coast. Throughout the past century, though its time of spawning has remained relatively insensitive to temperature, it is now apparent from historical records (Sundby and Nakken, 2005) that the Arcto-Norwegian cod stock has made subtle adjustments to temperature in terms of its spawning location: a clear relative shift into the two northernmost spawning districts (Troms and Finnmark) and out of the southernmost district (Møre) during the earlier and recent warm episodes; and with a reverse southward shift during the cool periods prior to the 1930s, and in the 1960s and 1970s (Fig. 2.2-9). The recovery of the East Finnmark spawning areas after a 40-year absence (arrowed in Fig. 2.2-9) is, therefore, the expected response to the most recent waves of warming along the Norway coast. Other non-commercial fish species appear to have participated in the same poleward shift in distribution, one of the more conspicuous being the snake pipefish, which has rapidly spread from the North Sea to the Svalbard shelf and Barents Sea since 2003 (Harris et al., 2007).

Projected effects of climate change on the environment and ecosystem of the Barents Sea. The Barents Sea is not only an important high latitude nursery and feeding area for commercial fish stocks such as cod, capelin and herring; its ecosystem is divided by the presence of the Ocean Polar Front (OPF) into cold-Arctic and warm-Atlantic ecotypes making it potentially liable to a large space-time variability. Its 'environment: ecosystem' relations provide a valuable test of skill and a source of management advice in simulating the effects of climate change. Ellingsen et al., (2008) have conducted such a study, providing a modern account of the expected changes. Combining a hydrodynamic model (SINMOD) with an ecosystem model (Wassman et al., 2006), they compare a baseline scenario (1990-2004) based on realistic forcing and observational data with a 65-year climate change run (1995-2059) using atmospheric input from a hydrostatic regional climate model REMO that has been run for the ECHAM4/OPYC3 IPCC-SRES B2 scenario by the Max-Planck-Institut for Meteorology, Hamburg. Their main conclusions are first, that there will be no change in the decade-mean inflow to the Barents Sea over the next 50 years. Nevertheless, the temperature of the inflow will become substantially higher (increase of 1°C during the simulation period) so that the temperature of the Barents Sea will increase, the fraction of water in the Barents Sea warmer than 1°C will increase by 25% and the fraction occupied by the Arctic watermass will decrease. Second, the position of the Ocean Polar Front will move toward the north and east. Third, primary production in the Barents Sea will increase during the next 50 years, primarily in the eastern and northeastern Barents Sea (Fig. 2.2-10). Fourth and final, the zooplankton biomass of Atlantic species will increase by 20% in the eastern Barents Sea, but this will not be enough to offset the 50% decrease in the abundance of Arctic zooplankton species that will accompany the

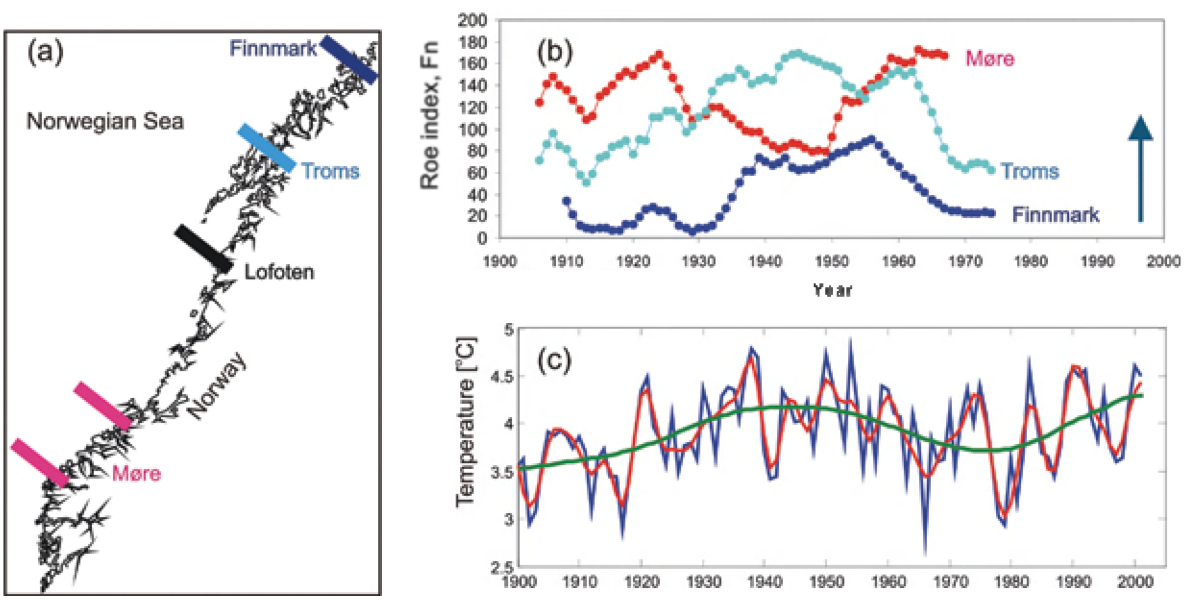


Fig. 2.2-9. Relative north-south shifts in the spawning location of the Arcto-Norwegian cod stock over past century in response to long-term changes in ocean temperature. Based on a roe index defined by Sundby and Nakken (2005), panels (a) and (b) show the relative shift in spawning activity from More in the south (red bars) to the Troms and Finmark spawning areas in the north (blue bars) during the warmer middle decades of the past century. The arrow to the right of panel (b) indicates the recovery of East Finmark spawning areas during the most recent wave of warming in 2004 and 2005 after 40 years of absence, while panel (c) shows the long-term changes in Barents Sea temperature along the Kola Section at 33°30'E.

decrease in the Arctic watermass (Fig. 2.2-10).

Even though the biophysical model predicted rather modest changes in the climate and plankton production of the Barents Sea (Ellingsen et al., 2008), these changes were nevertheless sufficient to produce responses in capelin abundance, spawning area and adult distribution.

New insights into temperature effects on the distribution of capelin of the Barents Sea. The capelin stock of the Barents Sea has long been recognized as a principal food fish for cod and, therefore, as a key component of the ecosystem on the Norwegian arctic shelf. The importance of temperature as a control on distribution of capelin has also long been recognized, in general terms, but the specifics of that relationship have now been examined in a study by Randi Ingvaldsen, IMR Bergen. She finds that when the temperature increases, the capelin spread northwards and the distribution-area increases. When the capelin stock is large, the feeding area is normally extended eastwards. Consequently, the largest distribution areas occur when the temperature is high and the stock is large at the same time.

Complementing this study, Huse and Ellingsen (2008) have modelled the likely consequences of global warming on capelin distribution and population dynamics. With input on physics and plankton from a biophysical ocean model, the entire life cycle of capelin including spawning of eggs, larval drift and adult movement is simulated. The model generates output on capelin migration/distribution and population dynamics; simulations are performed using both a present day climate and a future climate scenario. For the present climate, the spatial distributions resemble the typical spatial dynamics of capelin, with the Murman and North Norway coasts as the main spawning areas. Nevertheless, for the climate change simulation, the capelin is predicted to shift spawning eastwards and also utilize new spawning areas along Novaya Zemlya. There is also a shift in the adult distribution towards the north eastern part of the Barents Sea and earlier spawning associated with the warming. As the authors point out, it remains an open question whether capelin will take up spawning at Novaya Zemlya as predicted by the model, but there is some evidence that such easterly spawning has taken place in the past (see Gjøsæter, 1998).

The IPY in the NW Barents Sea. The Svalbard archipelago in the NW Barents Sea is the eastern gateway for Atlantic Water flowing into the Arctic. Consequently the oceanography of the region is characterized by the distinct water masses of Atlantic or Polar origin, contrasting strongly in their temperature and salinity. The sea ice conditions around the archipelago reflect these contrasts, with northern and eastern coasts having seasonal ice cover while the west coast is relatively ice-free. Such a range of conditions permits comparative studies of ecosystem function to be conducted and has enabled the investigation of the likely impact of warm, ice-free conditions on arctic ecosystems (Willis et al., 2006) and of how ecosystems might respond to changes in the seasonal timing of retreat of the ice-edge.

Two sites in the archipelago have proved ideal for such studies. Rijpfjorden, a fjord in Nordaustlandet that faces north to the Arctic Ocean, represents the Polar extreme while Kongsfjorden in NW Spitsbergen is a site that is dominated by warm Atlantic Water with water temperatures in excess of 6°C (Cottier et al., 2007). The ice-covered nature of Rijpfjorden and the relatively ice-free conditions in Kongsfjorden provide a natural setting to investigate the role ice plays in structuring arctic ecosystems. A key observational capability is the placement of moored instruments in each fjord, to provide background environmental data or as a means of studying the shelf processes. These moorings have been maintained by the Scottish Association for Marine Science (www.arcticmarine.org.uk) since 2002, with the logistical assistance of Norwegian institutes, particularly University Centre in Svalbard (www.unis.no).

The issue of ecosystem response to changes in sea ice conditions have been captured in a Norwegian IPY project called CLEOPATRA (Climate effects on planktonic food quality and trophic transfer in Arctic Marginal Ice Zones). CLEOPATRA was conducted in Rijpfjorden which can be considered as a mesocosm site representative of Arctic processes. The main objectives of the IPY CLEOPATRA project were to study:

(1) the timing, quantity and quality of ice algal and phytoplankton spring bloom;

(2) how variations in light and UV radiation affect algal food quality; and

(3) the importance of timing and available food

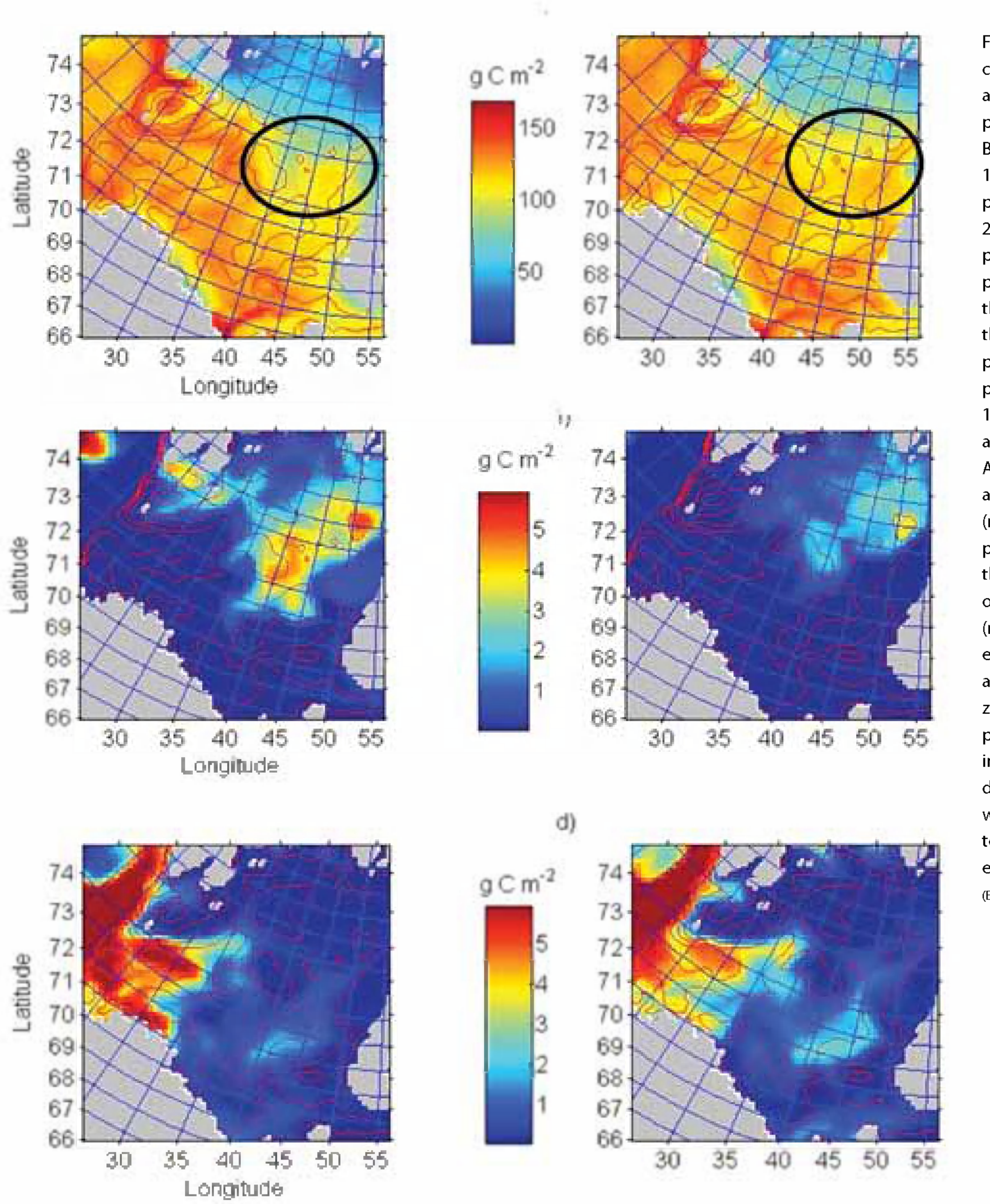


Fig. 2.2-10. Simulated changes in the primary and secondary production of the Barents Sea, between 1995-2004 (left hand panels) and 2045-2054 (right hand panels). Comparison of production between these dates suggests that annual primary production (top pair of panels) will increase by 10-15%, mainly due to a higher production in Arctic waters caused by a reduction in sea ice (more light). The lower panels suggest that the mean distribution of Arctic zooplankton (middle row) can be expected to decrease and of Atlantic zooplankton (bottom pair of panels) to increase in August between these dates as the Barents Sea warms and the OPF shifts towards the north and east.

(Ellingsen et al., 2008)

for reproduction, and growth of the dominant herbivorous zooplankton species in Arctic shelf seas: *Calanus glacialis.*

The CLEOPATRA hypotheses are centred on the Marginal Ice Zone (MIZ) as the key productive area of Arctic shelf seas. The ongoing warming of arctic regions will lead to a northward retreat of the MIZ and to an earlier opening of huge areas in spring. This may result in a temporal mismatch between the phytoplankton spring bloom and zooplankton reproduction (Melle and Skjoldal, 1998). Less ice will also reduce the ice algae production that may be an important food source for spawning zooplankton prior to the phytoplankton spring bloom. Quantity and quality of primary production in seasonally ice-covered seas is primarily regulated by light and nutrients. Excess light, however, is potentially detrimental for algae and can reduce algal food quality. A decrease in the relative amount of essential polyunsaturated fatty acids (PUFAs) in algae, due to excess light, may affect the reproductive success and growth of zooplankton (Leu et al., 2006) and thereby the transport of energy to higher trophic levels, such as fish, birds and mammals.

One of the key results of CLEOPATRA has been to demonstrate the critical importance of ice algae for high latitude ice covered ecosystems. In Rijpfjorden in 2007, ice algae was the only available food for grazers during the months from April to June. Ice broke up and left the fjord mid-July while a phytoplankton bloom developed in late-June to early-July. This phytoplankton bloom peaked two months after the ice algae bloom. The food quality of the ice algae and phytoplankton blooms was the same, but highest food quality, i.e. highest amount of polyunsaturated fatty acids (PUFAs), was early in the growth phase of each bloom. *Calanus glacialis* is the key grazer in ice covered shelf ecosystems and is a very important, energy rich food item for larger zooplankton, fish and sea birds. Observations from Rijpfjorden have shown that *C. glacialis* can time its reproduction to match both the ice algae and phytoplankton blooms. Ice algae fuelled high egg production in *C. glacialis,* allowing early reproduction so the offspring can then fully exploit the later-occurring phytoplankton bloom. By utilizing both ice algae and phytoplankton, *C. glacialis* extends its growth season substantially, which can explain the success of this species (up to 80% of the mesozooplankton biomass) in arctic shelf seas. Future climatic scenarios with less or no sea ice may have negative impacts on the population growth of *C. glacialis,* which may have severe impacts on higher trophic levels in arctic shelf seas.

A second main result of the project concerned the study of the impact of sea ice cover on zooplankton behaviour. One of the great unknowns of arctic ecosystems is the status of winter communities and the processes that are active. The classic paradigm of marine ecosystems holds that most biological processes will slow or cease during the polar night and one key process that is generally assumed to cease during winter is Diel Vertical Migration (DVM) of zooplankton, the biggest synchronized shift of biomass on the Planet. Using acoustic data collected from the moorings in Kongsfjorden and Rijpfjorden, it can be demonstrated that synchronized DVM of zooplankton continues throughout the Arctic winter, in both open water and under sea ice (Fig. 2.2-11; Berge et al., 2008). It is possible that the sensitivity of these organisms to light is so acute that even during the high arctic polar night, DVM is regulated by diel variations in illumination at intensities far below the threshold for human perception. The full winter data set shows that DVM is stronger in open waters compared to ice-covered waters, implying that the active vertical flux of carbon will become more effective if there is a continued retreat of the arctic winter sea-ice cover.

Pacific Sector

Northward shift in the ecosystem of the Bering Sea. Drawing together a large body of evidence, Grebmeier et al., (2006) have described a major ecosystem shift in the Northern Bering Sea since the late 1970s. A system characterized by extensive seasonal sea-ice cover, high water column and sediment carbon production, and a tight pelagic-benthic coupling of organic production gave way to a reduction in sea ice, an increase in air and ocean temperatures, an increase in pelagic fish and a geographic displacement of marine mammal populations coincident with a reduction of their benthic prey populations. A telling point of detail has been the reduction in sediment oxygen uptake south of St Lawrence Island between 1988 and 2004, from ~40 to about 12 mmol O_2 m^{-2} day^{-1} (Grebmeier

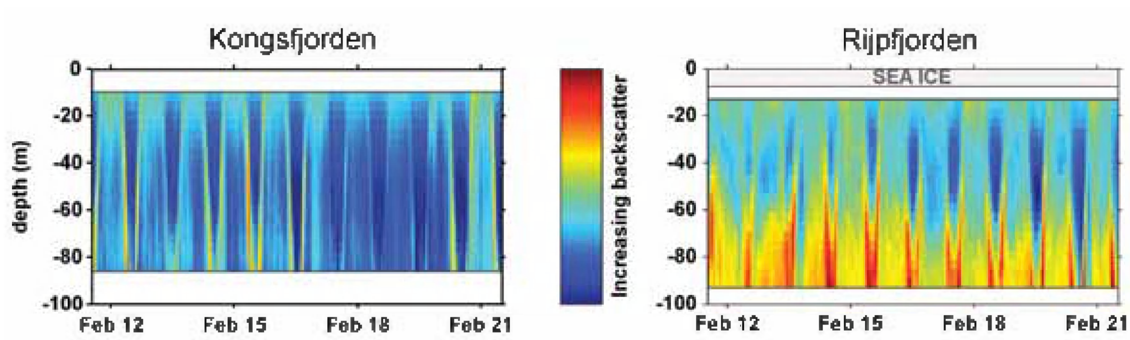


Fig. 2.2-11. The acoustic data from ADCPs (acoustic Doppler current profilers) provides a means of monitoring the backscatter levels (linked to biomass) through the water column. The banded pattern of backscatter is characteristic of DVM with biomass remaining deep at noon and ascending into the surface at night (Cottier et al., 2006).

et al., 2006), since this exemplifies the reduced carbon supply to the benthos.

The proximate cause of the change is a northwards retraction of the subsurface cold pool, formed as a result of ice formation in winter but persisting beneath warmer surface waters in summer, that normally extends near-freezing temperatures across the Bering Sea floor. As warming caused the cold pool to retract, the subarctic-Arctic boundary defined by its southern margin also retracted northwards, allowing a northward shift of the pelagic-dominated marine ecosystem that had previously been confined to the warmer waters of the southeastern Bering Sea.

In Fig. 2.2-12, which is unpublished, but based on the data in Mueter and Litzow (2008), Franz Mueter (UAF) quantifies this ecosystem shift by showing the rate of northward movement (km/25y) in the center of distribution of 45 species over 25 years (1982-2006). As Mueter points out, these rates are a community-level phenomenon and are similar to those recently reported for the North Sea (Perry et al., 2005) though we note that in the latter case, there was a parallel tendency for species to deepen as part of their response to warming (Dulvy et al., 2008). In agreement with other studies including Grebmeier et al., (2006), Mueter and Litzow conclude that the proximate cause of these distributional changes is changing bottom temperature and provide a figure of ~230 km for the northward retreat of the southern edge of the summer cold pool in the Bering Sea since the early 1980s (Fig. 2.2-12): *'other climate variables explained little of the residual variance not explained by bottom temperature, which supports the view that bottom temperature is the dominant climate parameter for determining demersal community composition in marginal ice seas'.*

Establishing a mechanism for the Influence of climatic regime-shifts on the ecosystem of the Bering Sea: new evidence for the Oscillating Control Hypothesis. Though it predates these studies, the Oscillating Control Hypothesis (OCH) of Hunt et al., (2002) is an attempt to rationalize these changes in terms of ecosystem function. Basically, the hypothesis predicts that pelagic ecosystem function in the southeastern Bering Sea will alternate between bottom-up control in cold regimes and top-down control in warm regimes. The timing of spring primary production is determined mainly by the timing of ice retreat. *Late* ice retreat (late March or later) leads to an *early*, ice-associated bloom in *cold* water, whereas *early* ice retreat before mid-March, leads to a *late* open-water bloom in May or June in *warm* water. Zooplankton populations are not closely coupled to the spring bloom, but are sensitive to water temperature.

In years when the (early) spring bloom occurs in cold water, low temperatures limit the production of zooplankton, the survival of larval/juvenile fish and thus (eventually) the recruitment of large piscivorous fish, such as walleye pollock. Continued for decades, this will lead to bottom-up limitation and a decreased biomass of piscivorous fish. Alternatively, in periods when the (late) bloom occurs in warm water, zooplankton populations should grow rapidly,

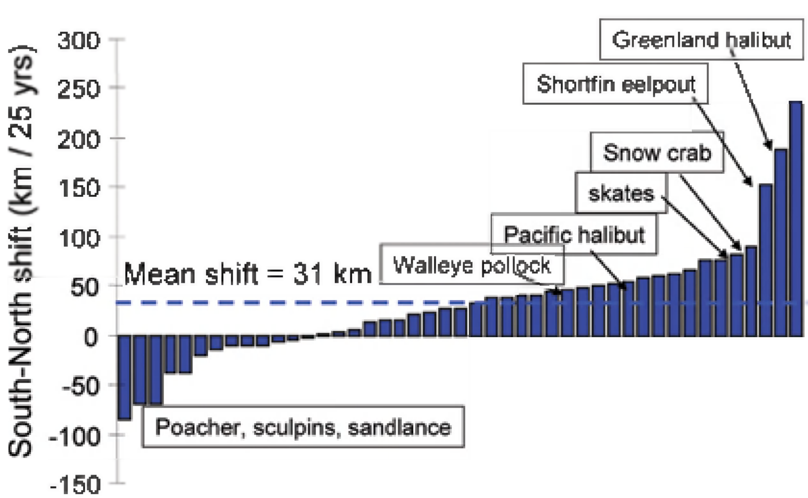


Fig. 2.2-12. The rate of the northward shift in the center of distribution of 45 species in the Bering Sea, 1982-2006. Unpublished, courtesy of Franz Mueter, UAF, pers comm.

providing plentiful prey for larval and juvenile fish and the abundant zooplankton will support strong recruitment of the predatory fish that control forage fish. Piscivorous marine birds and pinnipeds may achieve higher production of young and survive longer in cold regimes, when there is less competition from large piscivorous fish for coldwater forage fish, such as capelin *(Mallotus villosus).* Piscivorous seabirds and pinnipeds may also be expected to have high productivity in periods of transition from cold regimes to warm regimes, when the young of large predatory species of fish are numerous enough to provide forage. The OCH predicts that the ability of large predatory fish populations to sustain fishing pressure will vary between warm and cold regimes. The OCH also underscores the relationship between the timing of ice retreat and water temperatures during the spring bloom and the 'direction' of coupling between zooplankton and forage fish. In essence, the early bloom in cold water tends to go to the seabed providing better survival of demersal species; the later bloom in warm conditions tends to favour pelagics (for details see Hunt et al., 2002). It is Hunt's point that an ecosystem approach to management of the Bering Sea and its fisheries is necessary if all of the ecosystem components valued by society are to thrive; since climatic regimes may fundamentally alter relationships within the ecosystem, there is a demonstrable need to develop an understanding of the causal relationships between climate, primary and secondary production, and the population dynamics of upper trophic-level organisms. The Oscillating Control Hypothesis is Hunt's attempt to supply it.

So, is it valid? Once again we are indebted to unpublished work by Franz Mueter. Based on the data series described in Mueter et al., (2007) the inverse correlation between the survival anomalies of yellowfin sole and walleye pollock does appear to offer support to Hunt's Oscillating Control Hypothesis, though as Mueter et al., point out, many details of this relationship remain to be explained and tested, including the time-varying roles of cannibalism, larval transport, ice cover and wind mixing.

The IPY in the Bering Sea: results from BEST, BSIERP, C3O, CHINARE and other IPY-relevant research in the northern Bering Sea. The longest biological time series data in the northern Bering Sea (NBS) are from sites south of St. Lawrence Island where significant changes have occurred in the benthic biomass and community structure over the last few decades. Bivalves dominate the benthic biomass in the region and are the key prey base for benthic-feeding spectacled eiders and walrus. Both the recent decline of overall infaunal biomass and the change in species dominance in this region are impacting the coincident decline in spectacled eider populations (Lovvorn et al., 2003; Grebmeier et al., 2006). The time-series studies indicate that chlorophyll biomass differs significantly during a similar timing of ice-melt, but under different oceanographic conditions. Repeat sampling shows that even within-season variation is large and blooms are highly localized both in the water column and underlying sediments, the latter a further indicator of food availability to benthic populations. Sediment oxygen uptake measurements, an indicator of carbon supply to the benthos, show a similar finding that fresh organic matter settles to the benthos quickly. Water mass and nutrient variation, wind mixing and late winter brine formation are potentially important variables that will also impact spring productivity in addition to the timing of ice retreat. The BEST/BSIERP study initiated during IPY (2008) includes late winter field sampling, along with retrospective studies, to evaluate benthic infaunal populations, sediments and oceanographic conditions in the context of walrus feeding sites, both historical and tagged. The study is evaluating a grid of benthic infaunal collections in the walrus feeding area at various spatial scales (<5-20 nautical miles) to evaluate variable prey patches and food quality as well as undertaking a videographic evaluation of epifauna. Within the collaborative program, both helicopter survey and on-ice tagging of walruses are employed to track the their location and feed areas to evaluate predator-prey patch dynamics.

As part of the C30 program in 2007 and 2008, stations were occupied in July in the NBS. Both the winter-produced cold pool and now subsurface chlorophyll maximum from the spring bloom are evident looking at the 1000 km point on the Dutch Harbor to Barrow, Alaska transect (Fig. 2.2-13). Repeat of our time series measurements of hydrography, water and sediment chlorophyll, carbon tracers and infaunal populations also occurred. Repeat measurements at our time-series stations for the BEST/BSIERP patch dynamics cruise allow us to evaluate seasonal aspects of this ecosystem. Benthic sampling in the NBS area on the CHINARE program also occurred during summer 2008 and the data from this collaborative IPY program will also add to the time-series study in this region.

Monitoring Change in the Chukchi Sea: RUSALCA. Unprecedented minima of the sea ice area have occurred in the Arctic Ocean during the International Polar Year. In surrounding seas there has been a northward shift of ice-dependent marine animals. NOAA proposed the Russian American long-term Census of the Arctic (RUSALCA) with its partners to carry out observations in this area to measure fluxes of water, heat, salt and nutrients through the Bering Strait, gather observations about physical change in the state of the ocean in the Bering and Chukchi Seas, and study impacts of physical change on marine ecosystems as a consequence of the loss of sea ice cover. In 2007, the first U.S. to Russia chain of moorings was completed with the partnership of the National Science Foundation. Greater coverage of this region took place with the RUSALCA missions in 2008 and 2009, including a team of participants from the Korean Polar Research Institute.

RUSALCA is organized so that the Pacific-Arctic Ocean ecosystem can be monitored for change every four years. Planned for summer 2008 but delayed until 2009, the RUSALCA mission hosted 50 scientists who worked as teams representing the following disciplines: ocean acidification, benthic processes, zooplankton biomass and processes, epibenthos, fish assessments, hydrography, nutrients and productivity, geology and geophysics, methane microbiology, and marine mammal observations. Due to the extreme reduction in sea-ice cover, the vessel was able to carry out observations on the Chukchi Plateau at a latitude of 77°N (more than 400 km north of the 2004 expedition).

Highlights of the 2009 expedition include the following: the Eastern Strait of the Bering Strait was fresher and cooler than in 2008; 134 CTD and Rosette stations were taken; and a high-speed hydrographic survey of the Herald Canyon (a notable canyon that transports Pacific water north into the Arctic Ocean) was undertaken. The results showed that the hydrographic conditions were greatly different from those observed during 2004. Water masses on the western side of Herald Canyon were warmer in 2009 and on the eastern side the summer water reached much further north than in 2004. In addition the Siberian Coastal current was discovered to extend more than 70 km offshore. It was not present during the 2004 expedition into this region.

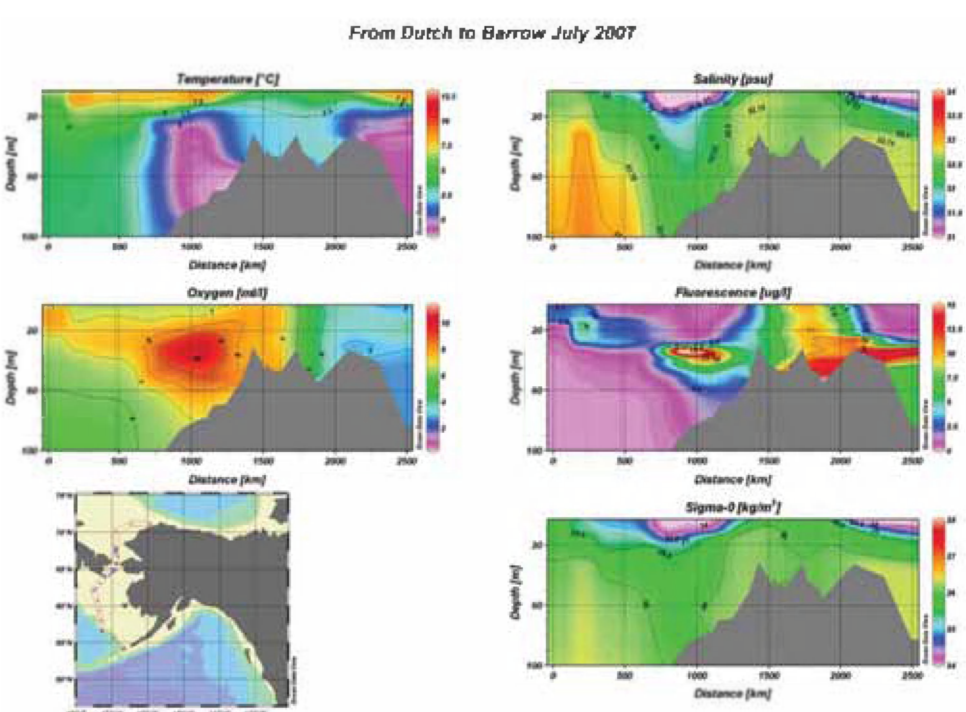


Fig. 2.2-13. Hydrographic data collected during the C3O program in transit from Dutch Harbor to Barrow, Alaska in July 2007. (Image: Bon van Hardenberg)

Sampling of the field of pockmarks on the Chukchi Plateau by a team of geologists did not reveal any evidence of present-day flux of methane from the seafloor.

Ecosystem observations revealed that the pockmark area at around 600 m depth was the site of the lowest observed benthic biomass. (The highest was located at the head of Herald Canyon.) ROV operations show clearly that the benthic biomass is underestimated when determined by standard sampling techniques.

Fish were sampled from the water column and near the seafloor at 25 stations ranging from west of Wrangle Island (in the East Siberian Sea) and north to 77°30'N. This northerly sampling was the furthest north fish trawl ever deployed in the Pacific Sector of the Arctic. Several fish were sampled at a depth of about 550 m that had previously only been located in the Atlantic side of the Arctic. The question remains of how and when did these fish get to the Pacific Side of the Arctic.

Plankton sampling in the region clearly showed a reduction in the numbers of meroplankton and larvaciae in the waters of the Chukchi Sea than sampled in 2004. Strong across-Chukchi Shelf difference in the populations of plankton occurred in the northern domain and strong E-W gradients were detected in the southern part of the Chukchi Sea.

The RUSALCA mission in 2009 provided a rare opportunity for marine mammal scientists to search for marine mammals in the East Siberian Sea and further north. Seven species of marine mammals were observed. More than 100 gray whales were spotted over the benthic "hot spot" at 67.5°N and 169.5°W. Gray whales were also spotted north of Wrangel Island and these may be a northern range record. Walrus were observed to be concentrating (hauled out) on narrow slivers of ice in a nearly ice free sea.

Analyses of these observations will take place during 2010 and 2011 with the next biodiversity and change mission occurring in 2012.

The Arctic Ocean

Changes in the extent and concentration of sea-ice can be expected to exert dominant control on the ecosystem of the Arctic Ocean shelves and basins, operating on a range of space and time scales from the localized scale of small polynyas and the 'ice: nutrient' relations of the circumarctic shelf-break in summer to the complex impacts of a shrinking ice-cover on marine production.

The influence of tidal mixing on the distribution of small polynyas. Polynyas are an important component of both the physical and biological system in ice covered seas (Hannah et al., 2009; Smith and Barber, 2007) and are widely distributed across the Canadian Arctic Archipelago (Fig. 2.2-14). From the physical point of view, polynyas are areas of enhanced air-sea fluxes in winter relative to the neighbouring ice-covered regions; from the biological perspective, polynyas that reliably occur each year are thought to be of particular ecological significance, especially for marine mammals and seabirds (e.g. Stirling 1980).

Hannah et al., 2009 use a tidal model of the Canadian Arctic Archipelago to explore the idea that tidal currents make an important contribution to the formation and maintenance of many of these recurring polynyas. By mapping three parameters in particular – the strength of tidal currents, tidal mixing (h/U^3) and the vertical excursion associated with the tidal currents driving water up and down slope – they are able to show that the hot spots in these quantities do indeed correspond to the location of many of the small polynyas in the Archipelago. A known polynya was identified with every region that had $\lambda<3$ and vertical excursion > 10 m ($\lambda = \log10\ h/U^3$), including the polynyas at Hell Gate, Cardigan Strait and Dundas Island, and a tidal contribution was also indicated in the case of the polynyas at Fury and Hecla Strait, Lambert Channel, Committee Bay and the Karluk Brooman polynyas. Though the link between h/U3 and summer plankton productivity has not yet been demonstrated in the Archipelago, it is likely that the hot spots of h/U3 that correspond to polynyas have the potential to be biologically important year round.

What changes are anticipated as the Arctic ice-cover retracts from the circumarctic shelves? As Carmack and Chapman (2003) point out, the efficiency of shelf-basin exchange (SBE) in summer is strongly moderated by the location of the ice-edge in relation to local topography. Their model suggests that upwelling-favourable winds generate very little SBE so long as the ice-edge remains shoreward of the shelf-break but an abrupt onset of shelf-break upwelling takes place when the ice-edge retreats beyond that point. Thus if the shelf break is covered by ice, only shelf water circulates. Nevertheless, as the summer ice-cover continues to retract, it will expose more and more of the shelf-break for longer periods of time to upwelling-favourable winds. The depth to which upwelling extends will increase as the slope waters become ice-free and salty nutrient-rich water will be permitted to cross the whole shelf in a thin bottom boundary layer. To Carmack, Williams, McLaughlin and Chapman (pers. comm.) Fig. 2.2-15 illustrates the extraordinary sensitivity of shelf conditions to ice edge location; in effect the position of the summertime ice edge acts as a 'switch' for exchange between the shelf and the deep basin of the Arctic Ocean. If valid, the implication of this modelling exercise by Carmack et al., is that systems important to production on the circumarctic shelves are liable to change. At present, strong stratification due to ice melt and rivers acts to limit nutrient availability in the euphotic zone on the shelf and a chlorophyll maximum typically forms at the top of the halocline, characteristic of nutrient limitation. Increased upwelling at the shelf-break as the ice retracts will increase the nutrient flux to the shelf, where it is likely to relieve nutrient limitation and support enhanced primary production. Their second conclusion is also of interest; that some shelves, particularly the Beaufort and Chukchi shelves, will experience greater upwelling than others and that the increase in the on-shelf nitrate flux (i.e. the modelled onshore Ekman Transport multiplied by the maximum nitrate in the water column) will reflect this. They suggest a need to survey the present day conditions of the pan-Arctic shelf break and to plan their long-term monitoring.

Impact of a shrinking ice cover on the primary production of the Arctic Ocean: new estimates. By

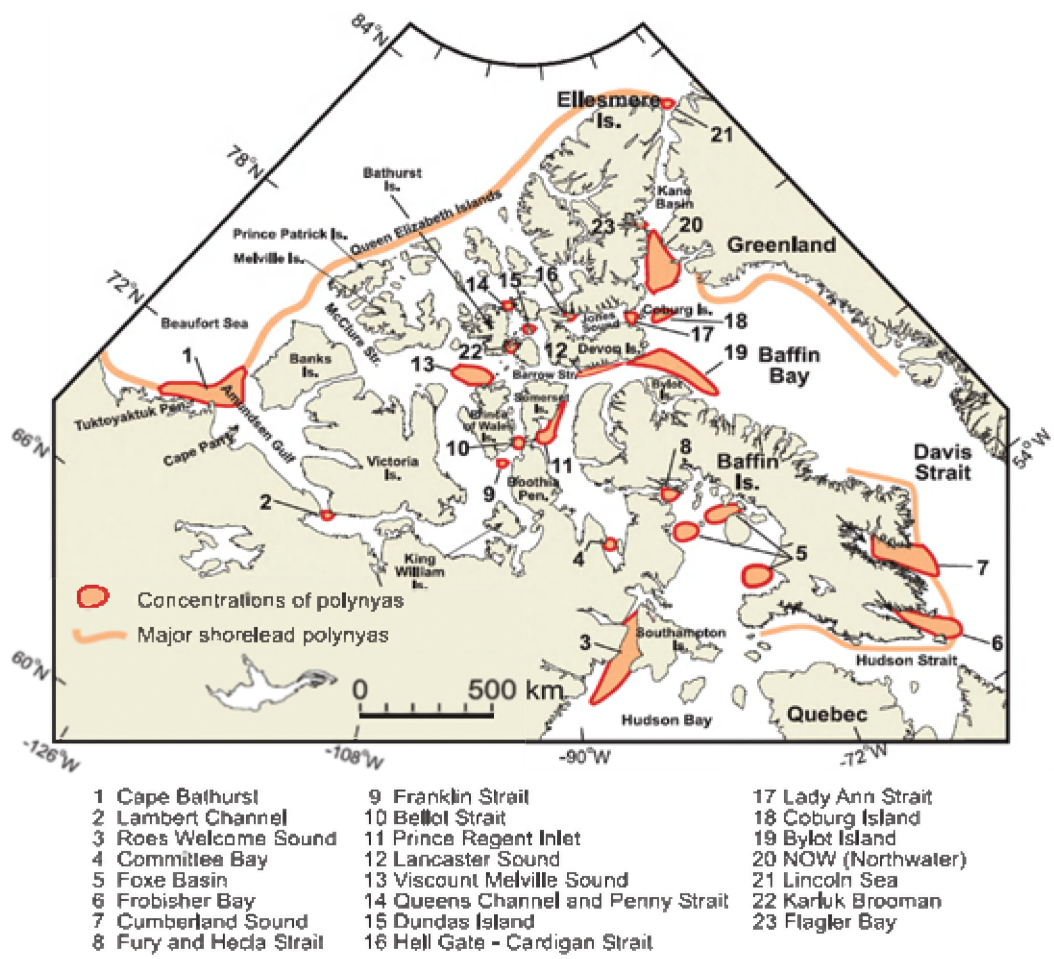


Fig. 2.2-14. A map of known polynyas in the Canadian Arctic Archipelago.

(Adapted from a range of sources by Hannah et al., 2009) exposing an ever increasing fraction of the sea surface to solar radiation and increasing the habitat suitable for phytoplankton growth, we can well appreciate that the unprecedented loss of arctic sea-ice in recent years must have had some significant effect on marine primary production across the Arctic basins and shelves. Hitherto, however, we have had no clear idea of where and how much. In two recent papers (Pabi et al., 2008; Arrigo et al., 2008), a Stanford Group have now quantified that impact. By coupling satellite-derived sea ice, SST and chlorophyll to a primary production algorithm parameterized for Arctic waters, they find 1) that annual pan-Arctic primary production (419 ± 33 Tg C a-1 on average during 1998–2006) was roughly equally distributed between pelagic waters (less productive, but greater area) and waters located over the continental shelf (more productive, but smaller area); 2) that annual primary production in the Arctic has increased yearly by an average of 27.5 Tg C yr^{-1} since 2003 and by 35 Tg C yr^{-1} between 2006 and 2007; and 3) that 30% of this increase is attributable to decreased minimum summer ice extent and 70% to a longer phytoplankton growing season. Arrigo et al., (*op cit*) suggest that if these trends continue, the additional loss of ice during Arctic spring 'could boost productivity >3-fold above 1998–2002 levels, potentially altering marine ecosystem structure and the degree of pelagic-benthic coupling. Changes in carbon export could in turn modify benthic denitrification on the vast continental shelves'.

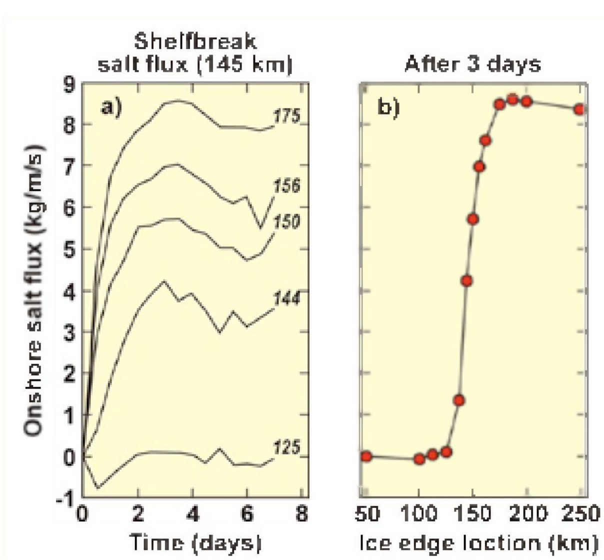


Fig. 2.2-15 The position of the ice edge relative to the circum-Arctic shelf-break acts as a sensitive 'switch' for the onshore flux of salt (Carmack et al., pers. comm.).

IPY on the Canadian Arctic shelf: the Circumpolar Flaw Lead System Study. The Circumpolar Flaw Lead (CFL) system study was a Canadian-led multidisciplinary initiative for IPY with over 350 participants from 12 countries. The CFL is a perennial characteristic of the Arctic, that forms when the central pack ice (which is mobile) moves away from coastal fast ice, opening a flaw lead which occurs throughout the winter season. The flaw lead is circumpolar in nature, with recurrent and interconnected polynyas occurring in the Norwegian, Icelandic, North American and Siberian sectors of the Arctic. Due to a reduced ice cover, these regions are exceedingly sensitive to physical forcings from both the atmosphere and ocean and provide a unique laboratory from which we can gain insights into the changing polar marine ecosystem. This study examines the importance of climate processes in the changing nature of a flaw lead system in the northern Hemisphere and the effect these changes will have on the marine ecosystem, contaminant transport, carbon flux and greenhouse gases. The CFL study was 293 days in duration and involved the overwintering of the *CCGS Amundsen* icebreaker in the Cape Bathurst flaw lead throughout the winter of 2007–2008. This represented the first time an icebreaker had overwintered an entire winter in the Arctic while remaining mobile in a flaw lead.

The CFL field season commenced in fall 2007. Between 18 October and 27 November 2007, 74 unique open-water sites were sampled (Fig. 2.2-16a) and multiple moorings were collected and redeployed throughout the Amundsen Gulf region. On November 28 2007, the ship entered its 'drift mode', during which the ship parked in a piece of ice that was large, thick and homogeneous enough for setting up equipment and collecting samples, until conditions or ice movement necessitated a move to another location. A total of 44 drift stations averaging 3 ± 4 days (max. 22 days) were sampled between 28 November 2007 and 31 May 2008, generally located on the northern side of the Amundsen Gulf to the south of Banks Island (Fig. 2.2-16b). Though the initial project plan had called for the establishment of a semi-permanent ice camp on the ice bridge that typically forms between Banks Island and Cape Perry, this ice bridge never in fact formed. During the melt season of May and June, several fast ice sites were sampled to follow the ice melt from a thick winter ice cover through to complete break-up, concluding with open water stations. The majority of these sites were located on the south side of the Amundsen Gulf at the entrance of two shallow coastal bays (Franklin Bay and Darnley Bay) where a SCUBA diving program aided sample collection (Fig. 2.2-16b). Fast ice was also sampled in the Prince of Wales Straight and near the north end of Banks Island; a total of 17 fast ice stations were sampled averaging 1.3 days (max. 9) in duration. Distributed open-water sampling fully resumed at the end of June 2008. Between this time and 7 August 2008 (the end of the field season), a total of 96 unique sites were sampled (Fig. 2.2-16a), many of which were long-term sampling sites also used by the ArcticNet and CASES projects. In July, a series of moorings were again collected and redeployed. In 2008, transects were sampled across the Amundsen Gulf, along the Amundsen Gulf, up the west side of Banks Island, across McClure Strait, as well as several transects from open water into fast ice or mobile pack ice. A total of 295 people spent time aboard, including 102 research scientists, 113 graduate students and post-docs, 55 technicians and research associates, and 76 for outreach.

The diversity of physical and biological sampling conducted around *CCGS Amundsen* is illustrated in Fig. 2.2-17. This included CTD-rosette, zooplankton nets, meteorological sensors, box coring equipment and a remotely operated vehicle (ROV), as well as various kinds of moorings that were deployed throughout the project. Specialized features were the moonpool within the ship allowing deployment of equipment in winter conditions, the specialized labs including a Portable Lab for Mercury Speciation (PILMS) with a class-100 clean room allowing for trace metal analysis, and a range of sampling vehicles including snowmobiles, ATV, half-track and helicopter. Due to its size and complexity, the delivery of new science from the CFL project can be expected to take up to 3 years. Here, we have space for just two early examples of these novel results, one physical and one biological.

Eddies in the Amundsen Gulf. Mesoscale eddies in the Arctic Ocean transport salt and heat and are considered critical for the ventilation of its cold halocline layer (Muench et al., 2000; see also Timmermans et al., 2008; Spall et al., 2008). They are also a source of nutrients and zooplankton for the Canada Basin (Llinas et al., 2008), and could play the same role for the less productive regions of the Amundsen Gulf. Three eddies have been observed in the Amundsen Gulf, one at the CASES winter station in Franklin Bay in December 2003 and two more – in January 2008 and March 2008 – while the *CCGS Amundsen* was in drift mode in the CFL program. What make these observations important is the suite of concurrent meteorological, biological and chemical observations that the CFL Study provided. The March 2008 eddy, for example, was a subsurface feature with a core centered at 90 m. The ship-mounted ADCP captures the structure of the eddy showing a reversal of the northward flow at its center. The *Amundsen* eddies were generated by shallow brine convection at freezing time. As the surface water of the lead freezes, brine is rejected in the surface layer; this then sinks and settles at mid-depth because of the strong local stratification. The Amundsen data set is thought to be the first complete set of

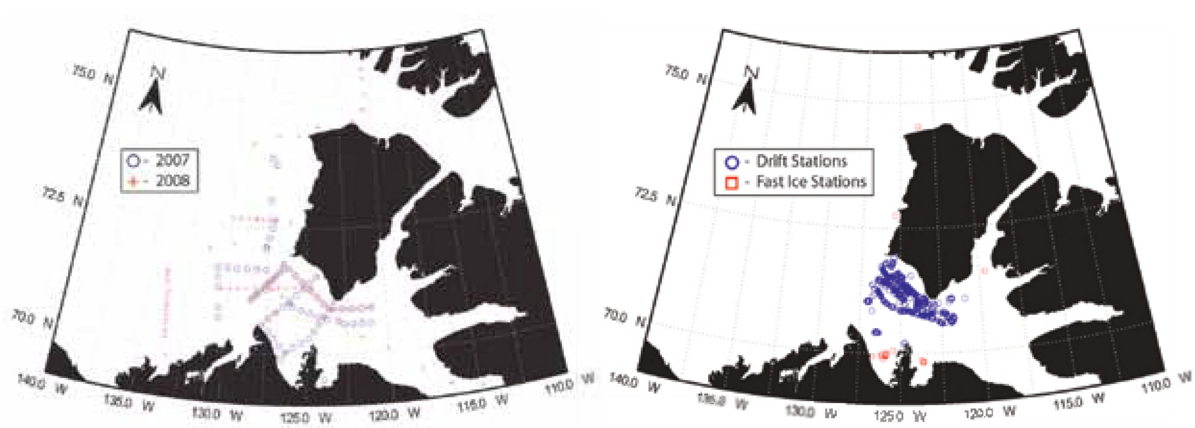


Fig. 2.2-16a. Distributed open-water sites sampled in the fall of 2007 and the summer of 2008. b. Drift stations and fast-ice stations sampled in the winter and spring of 2007–2008.
(Maps: David Barber)

multidisciplinary observations during the formation of a subsurface eddy.

Ice Edge Upwellings. Phytoplankton blooms are common events in polar waters where primary productivity greatly exceeds losses, resulting in a rapid accumulation of algal biomass. Due to their latitude, polar regions experience a strong seasonal pulse of insolation supplying one of the key elements for initiation of a vernal phytoplankton bloom. During winter in polar regions, mixing processes (e.g. wind, cold atmospheric temperatures and brine rejection during sea ice formation) and the lack of sufficient light for primary production permit replenishment of surface water nutrients. Nevertheless, the degree of new nutrient replenishment during winter depends on the balance between mixing forces and surface water stability. Polar Surface Water (PSW), categorized as low salinity (< 31.6 in the Beaufort Sea), low temperature (< -1°C) and nutrient-depletion, blankets most of the western Arctic Ocean, and the stability of the PSW is seasonally maintained by freshwater input from the perennial sea ice cover, by precipitation and by run-off from the numerous large rivers along the Eurasian and North American coasts. Furthermore, PSW has historically been protected from wind mixing forces due to the perennial ice cover. In the coastal Beaufort Sea, PSW is underlain by an intermediate layer (32.4 – 33.1 core salinity; < -1°C; ~250 m maximum depth) of relatively nutrient-rich (maximum values of ~15, 2 and 30 mmol m-3 for nitrate, phosphate and silicate, respectively) Pacific origin waters (IPW) (Carmack et al., 2004). IPW is of great importance to the Beaufort Sea and the Canadian Arctic for its potential to enhance biological production where it mixes into the PSW (Carmack et al., 2004). A recent annual study in the Canadian Beaufort Sea showed that winter mixing processes were too weak to overcome PSW stability (Tremblay et al., 2008) thus hindering the injection of nutrients from the IPW into the surface layer and limiting primary production. Nevertheless, we are now aware that passing eddies can locally enhance production by mixing IPW into surface waters; as with coastal upwelling, surface water divergence and upwelling of nutrients can be produced by winds blowing parallel to a relatively straight ice edge. The CFL program will examine the coupled physical-biological linkages associated with upwelling at ice edges and contrast this to the productivity of the marginal ice zone and open water of the polynya.

Concluding Remarks

This brief account has attempted to describe some of the main advances that were made in the difficult business of observing the Arctic and subarctic seas during the special focus period of IPY. It has also attempted to describe some of the main results and new ideas that are still emerging from these observations. A

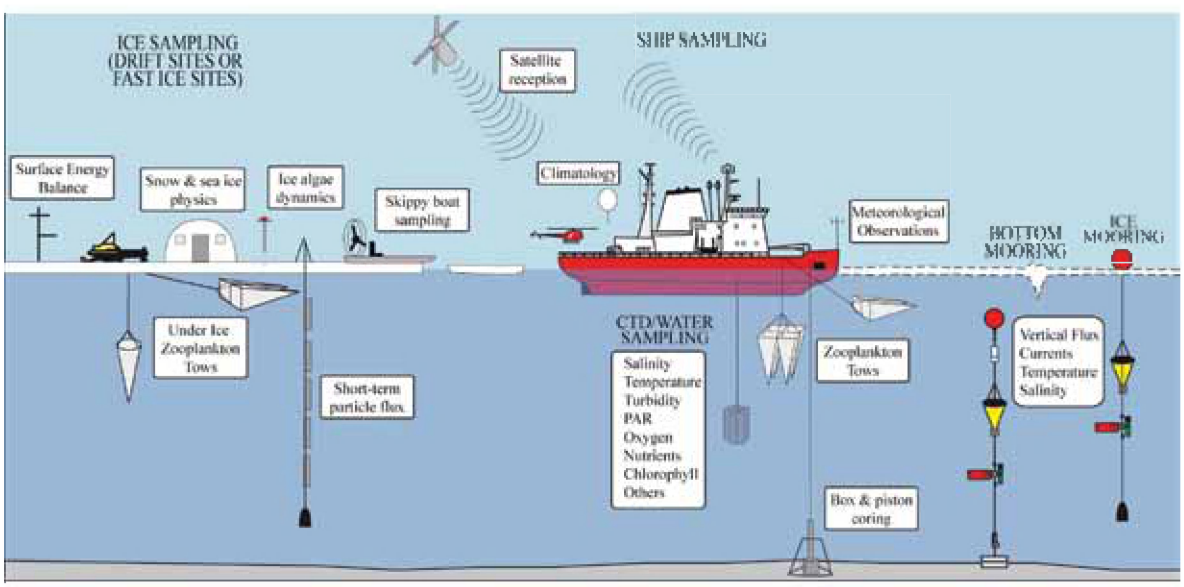


Fig. 2.2-17. Schematic of the scientific equipment used on the Amundsen and at ice camps nearby.
(Image: David Barber)

final third element, provided in *Chapter 3.3*, attempts to use these results and ideas to make the case for which mix of observations to sustain into the future. The reason for attempting such a forward look is clear: if we are to develop the predictive skills and utility of climate models, we will need to observe, understand and 'build in' a list of processes that are not yet represented realistically (or at all) in climate models. In fact, the list is quite long (Dickson et al., 2008). It is also clear that it will be the 'legacy phase' of IPY, sustained over years to decades, rather than the two-year project itself that will develop our understanding of these processes, their changes, their feedbacks and their likely climatic impacts to the point where they can be of practical use to climate models. We cannot continue everything; even if we could, it would surely be ineffectual simply to continue to observe the Arctic according to what we *thought* we knew before IPY. What have we *learned* in IPY that might help us design its observational 'legacy phase'? At the Arctic Science Summit Week (ASSW) in Bergen in March 2009, the Arctic Ocean Sciences Board (AOSB) set itself the task of developing a proposal for an integrated, sustained and pan-Arctic observing effort focused on the role of northern seas in climate in Oslo in 2010. To achieve maximum focus, this plan is being structured around the following three questions: *1) Following IPY, how would we now define the role of the Northern Seas in Climate? 2) What questions should we be testing to help us understand that role? 3) How should we design an ocean observing system to test these questions?*

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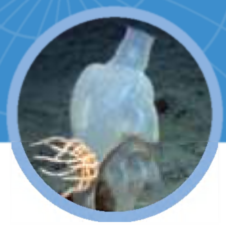

2.3 Southern Ocean

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Introduction

Recent scientific advances have led to growing recognition that Southern Ocean processes influence climate and biogeochemical cycles on global scales. The Southern Ocean connects the ocean basins and links the shallow and deep limbs of the overturning circulation, a global-scale system of ocean currents that influences how much heat and carbon the ocean can store (Rintoul et al., 2001). The upwelling of deep waters returns carbon (e.g. le Queré et al., 2007) and nutrients (e.g. Sarmiento et al., 2004) to the surface ocean; the compensating sinking of surface waters into the ocean interior sequesters carbon and heat and renews oxygen levels. The capacity of the ocean to moderate the pace of climate change is controlled strongly by the circulation of the Southern Ocean. The future of the Antarctic ice sheet, and therefore sea-level rise, is increasingly understood to be determined by the rate at which the relatively warm ocean can melt floating glacial ice around the margin of Antarctica (Rignot and Jacobs, 2002). The expansion and contraction of Antarctic sea ice influences surface albedo, air-sea exchange of heat and of gases, such as carbon dioxide and oxygen, and the habitat for a variety of marine organisms (Thomas and Dieckmann, 2002). The Southern Ocean is also home to unique and productive ecosystems and rich biodiversity.

Given the significance of the Southern Ocean to the Earth system, any change in the region would have impacts that extend well beyond the high southern latitudes. Recent studies suggest change is underway: the Southern Ocean is warming and freshening throughout most of the ocean depth (Gille, 2008; Böning et al., 2008); major currents are shifting to the south, causing regional changes in sea-level (Sokolov and Rintoul, 2009a,b) and the distribution of organisms (Cubillos et al., 2007), and supplying additional heat to melt ice around the rim of Antarctica (Jacobs, 2006); and the future of the Southern Ocean carbon sink is a topic of vigorous debate (le Queré et al., 2007; Böning et al., 2008). Climate feedbacks involving ocean circulation, changes in sea ice (hence albedo) and the carbon cycle have the potential to alter rates of climate change in the future, but the magnitude and likelihood of such feedbacks remains poorly understood.

Progress in understanding Southern Ocean processes has been slowed by the historical lack of observations in this remote part of the globe. Growing recognition of the importance of the Southern Ocean has resulted in an increasing focus on the region; at the same time, new technologies have led to great improvements in our ability to observe the Southern Ocean. International Polar Year 2007–2008 effectively harnessed the human and logistic resources of the international community and exploited technology developments to deliver an unprecedented view of the status of the Southern Ocean, provided a baseline for assessing change and demonstrated the feasibility, value and timeliness of a Southern Ocean Observing System (*Chapter 3.3*). During IPY, a circumpolar, multidisciplinary snapshot of the status of the Southern Ocean was obtained for the first time; many properties, processes or regions had not been measured before. Scientists from more than 25 nations participated in Southern Ocean IPY.

Here, we summarize the rationale, field programs and early scientific highlights from IPY programs in the Southern Ocean to show that the IPY has provided significant advances in our understanding of the Southern Ocean.

Southern Ocean Research During IPY

IPY activities in the Southern Ocean spanned a vast range of phenomena, in many disciplines. Some projects focused on the role of the Southern Ocean in the Earth system, through its influence on global climate and the carbon cycle; some projects focused on understanding the processes that control the biophysical and ecological systems, and their interactions; others were concerned with past or future change in the Southern Ocean system. For the purpose of this overview, it is useful to group IPY activities into four themes along broadly disciplinary lines, although most IPY projects had a strong interdisciplinary flavour:

1. Ocean circulation and climate
2. Biogeochemistry
3. Marine biology, ecology and biodiversity
4. Antarctic sea ice

We discuss the overall objectives, achievements and scientific highlights in each of these themes, with a focus on the larger projects of circumpolar scale. A total of 18 IPY projects with a Southern Ocean focus were endorsed (Table 2.3-1).

Table 2.3-1. IPY projects in the Southern Ocean. The projects are grouped by the primary theme to which they contribute, but many of the projects spanned disciplines and themes.

		Ocean Circulation and Climate
8	SASSI	Synoptic Antarctic Shelf – Slope Interactions
13	Sea level/tides	Sea Level & Tides in Polar Regions
23	BIAC	Bipolar Atlantic Thermohaline Circulation
70	UCAA	Monitoring Upper Ocean Circulation between Africa and Antarctica
132	CASO	Climate of Antarctica and the Southern Ocean
313	PANDA	Prydz Bay, Amery Ice Shelf & Dome A
Biogeochemistry		
35	GEOTRACES	Biogeochemical cycles of Trace Elements and Isotopes in the Arctic and Southern Oceans
Marine biology, ecology and biodiversity		
34	ClicOPEN	Impact of CLImate induced glacial melting on marine and terrestrial COastal communities on a gradient along the Western Antarctic PENinsula
53	CAML	Census of Antarctic Marine Life
71	PAME	Polar Aquatic Microbial Ecology
83	SCAR-MarBIN	The information dimension of Antarctic Marine Biodiversity
92	ICED	Integrated Climate and Ecosystem Dynamics
131	AMES	Antarctic Marine Ecosystem Studies
137	EBA	Evolution & Biodiversity in Antarctica: the Response of Life to Change
153	MEOP	Marine Mammal Exploration of the Oceans Pole to Pole
304	DRAKE BIOSEAS	SEAsonality of the DRAKE Passage pelagic ecosystem: BIOdiversity, food webs, environmental change and human impact. Present and Past
251	Circumpolar Population monitoring	Circumpolar monitoring of the biology of key-species to environmental changes
Sea Ice		
141	Sea Ice	Antarctic Sea Ice

Ocean circulation and climate

A number of major IPY projects aimed to improve understanding of the circulation of the Southern Ocean and its role in the climate system. The overall goal of CASO was to collect a circumpolar, multi-disciplinary snapshot of the Southern Ocean. SASSI had similar aims, with a focus on waters over the continental shelf and slope of Antarctica, including ocean interactions with the Antarctic ice sheet. A number of other individual projects contributed to these two large umbrella programs (e.g. BIAC, MEOP, Sea Level & Tides, UCAA, PANDA and ClicOPEN).

The ocean circulation and climate theme of Southern Ocean IPY was motivated by scientific questions such as: What is the strength of the Southern Ocean overturning circulation and how sensitive is it to changes in forcing? Where do water masses form in the Southern Ocean and at what rate are they subducted into the ocean interior? How and why are water properties and ocean current patterns changing in the Southern Ocean? What is the role of the Southern Ocean in the global transport and storage of heat, freshwater and carbon? How much mixing takes place in the Southern Ocean?

IPY observations

To answer these questions, observations spanning the entire Southern Ocean were required, extending

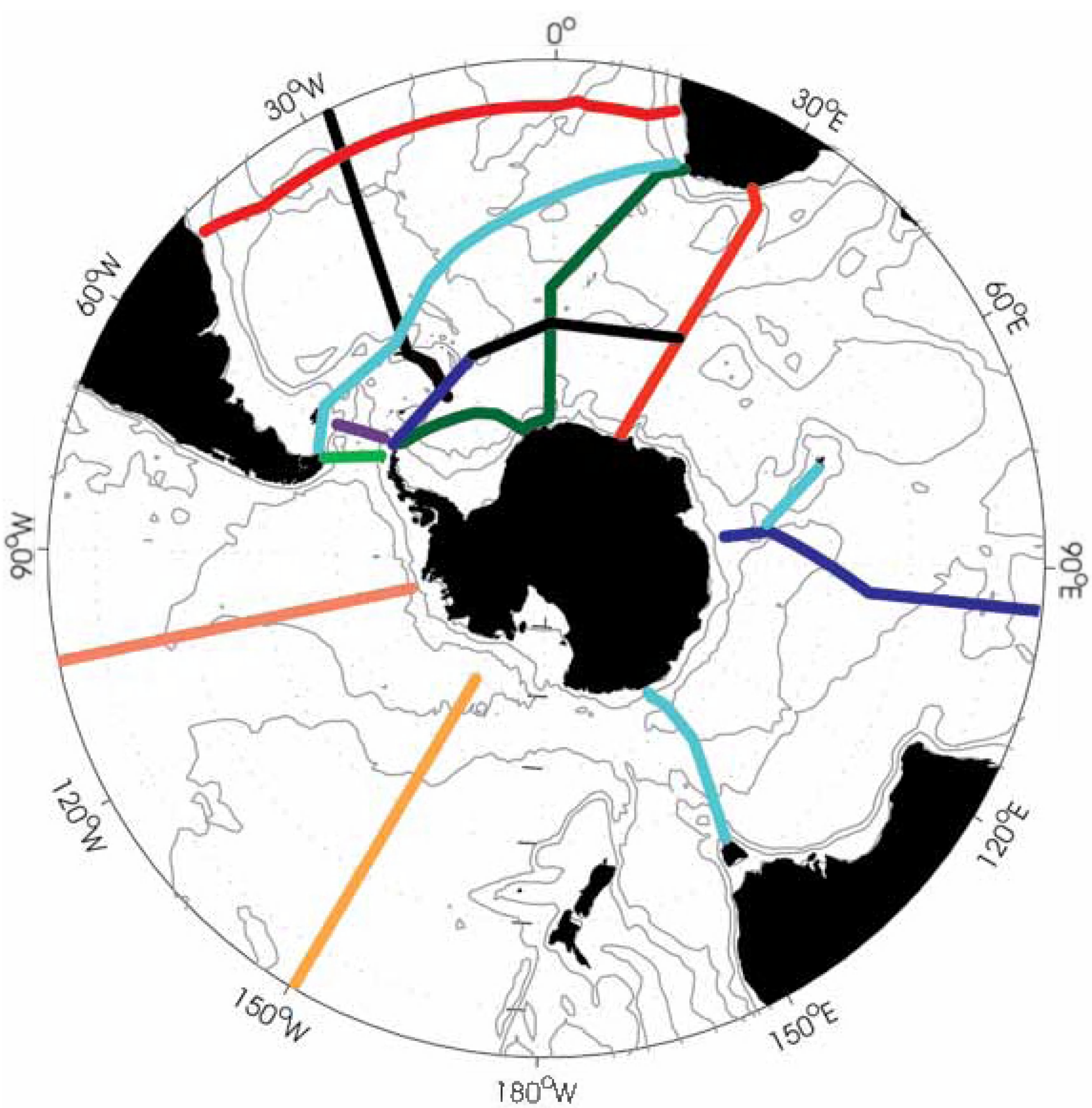


Fig. 2.3-1a. Location of deep hydrographic sections in the Southern Ocean completed between March 2007 and March 2009 as a contribution to IPY. Each of the sections includes full-depth measurements of temperature, salinity and oxygen and most included a broad suite of chemical tracers (e.g. nutrients, carbon, CFCs, trace elements and isotopes). Colors indicate voyages carried out by expeditions of different countries. (Base map: Kate Stansfield)

from the subtropical front to the Antarctic continental shelf and from the sea surface to the deep ocean. IPY used a variety of observational tools to complete the first synoptic, multi-disciplinary, circumpolar survey of the Southern Ocean:

- Hydrographic sections allowed a wide variety of physical, biogeochemical and biological variables to be sampled throughout the water column (Fig. 2.3-1a). Most of these sections repeated lines occupied during previous experiments like the World Ocean Circulation Experiment (WOCE) and the CLimate VARiability and predictability project (CLIVAR) of the World Climate Research Programme, allowing an assessment of rates of change in ocean properties. Additional hydrographic sections were completed over the continental shelf and slope of Antarctica as a contribution to the SASSI program (Fig. 2.3-1b). Underway multi-disciplinary measurements of surface and upper ocean waters, collected as part of the ongoing Voluntary Observing Ship program, extended the spatial and temporal coverage of IPY sampling (Fig. 2.3-1c).
- Argo profiling floats provided broad-scale, quasi-synoptic, year-round sampling of the upper 2 km of the Southern Ocean for the first time (Fig. 2.3-2). The floats drift with ocean currents, ascending typically every 10 days to measure a profile of temperature, salinity and sometimes of additional water mass properties, which is transmitted by satellite. In remote regions like the Southern Ocean, Argo floats

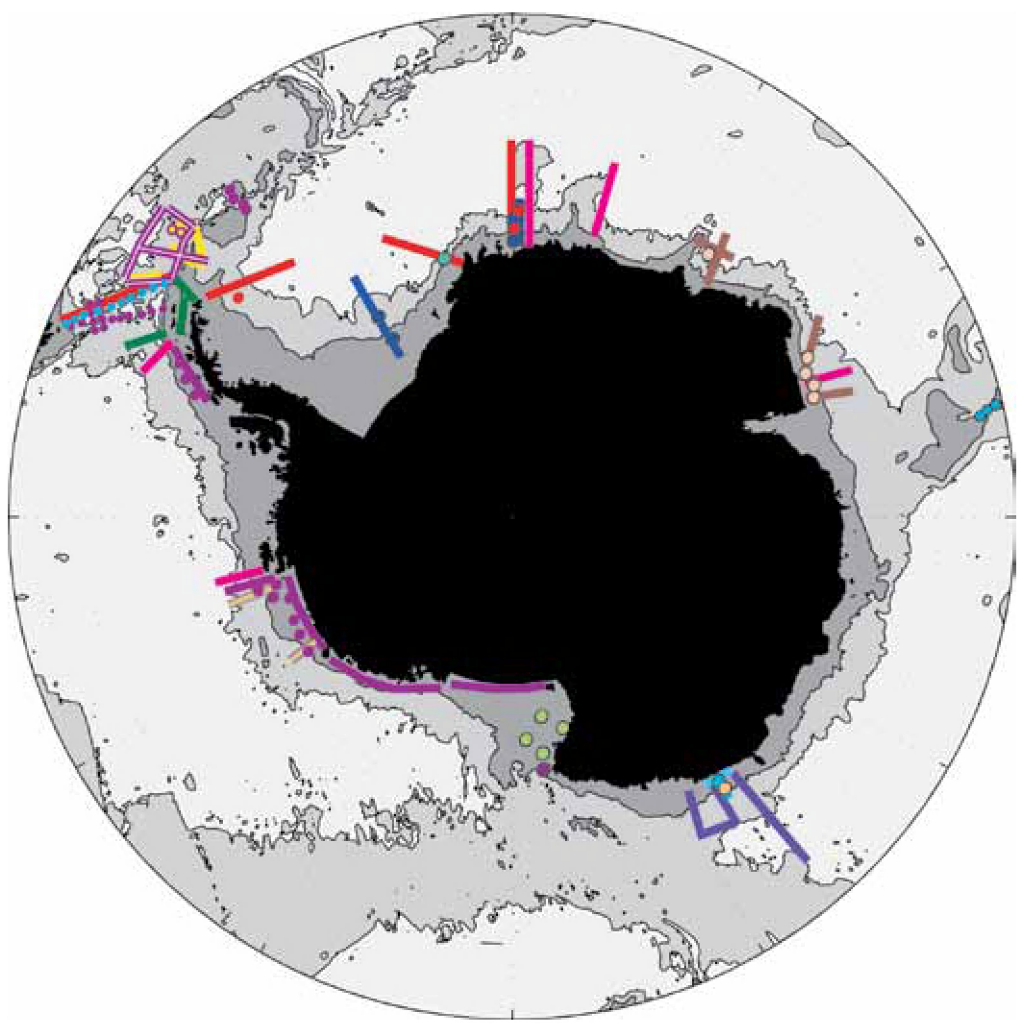


Fig. 2.3-1b. Hydrographic sections (lines) and moorings (circles) around the Antarctic margin completed during the IPY largely under SASSI. Colors indicate voyages carried out by expeditions of different countries. (Base map: Kate Stansfield)

are measuring the ocean interior on basin-wide scales and in all seasons (away from sea ice at least) for the first time. IPY provided an opportunity to enhance the coverage of the global Argo program in the Southern Ocean. Floats designed to stop their ascent to the surface when ice is present and to be tracked by acoustic ranging under the ice (Klatt et al., 2007) allowed data to be obtained in parts of the Weddell Sea that were previously inaccessible.

- Oceanographic sensors on marine mammals provide measurements from regions where traditional oceanographic instruments have difficulty sampling, including in the sea ice zone in winter. The MEOP program expanded the use of oceanographic tags on marine mammals, in particular seals, in the Southern Ocean, providing the first winter measurements from broad regions of the Southern Ocean (Fig. 2.2-3). Many more oceanographic profiles have now been collected south of 60°S using seal tags deployed by MEOP and the earlier SEaOS (Southern Elephant Seals as Oceanographic Samplers) program than in the entire history of ship-based oceanography.
- Moorings provided quasi-continuous time-series measurements in many locations during IPY, including dense water overflows and boundary currents, major currents like the Antarctic Circumpolar Current and the Antarctic Slope Front, and were used to measure coastal sea level (e.g. Fig. 2.3-1b). In many cases, IPY moorings provided the first time-

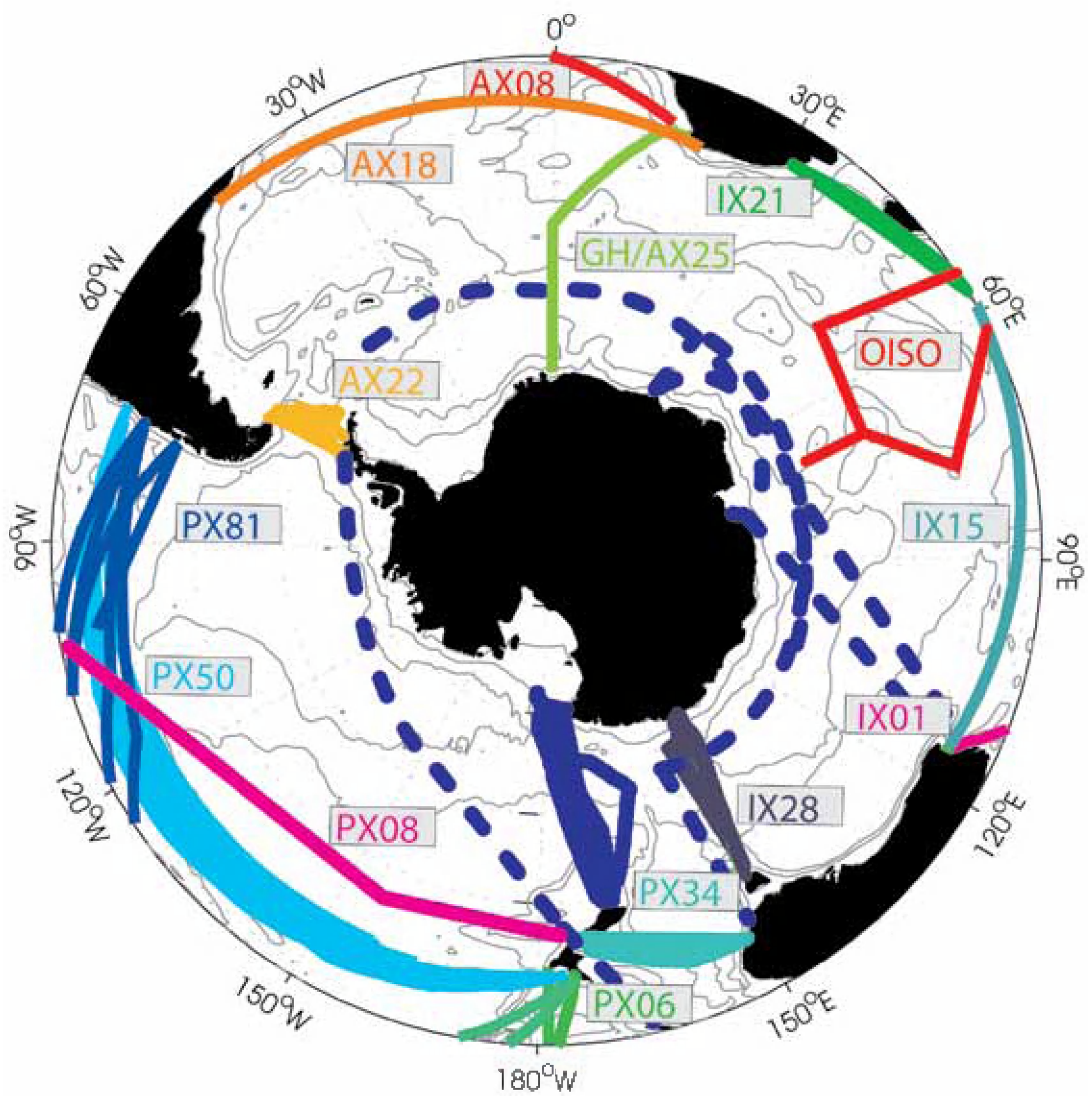


Fig. 2.3-1c. Underway measurements of physical, biogeochemical and biological properties in the surface and upper ocean were collected by Volunteer Observing Ships along these lines.
(Base map: Kate Stansfield)

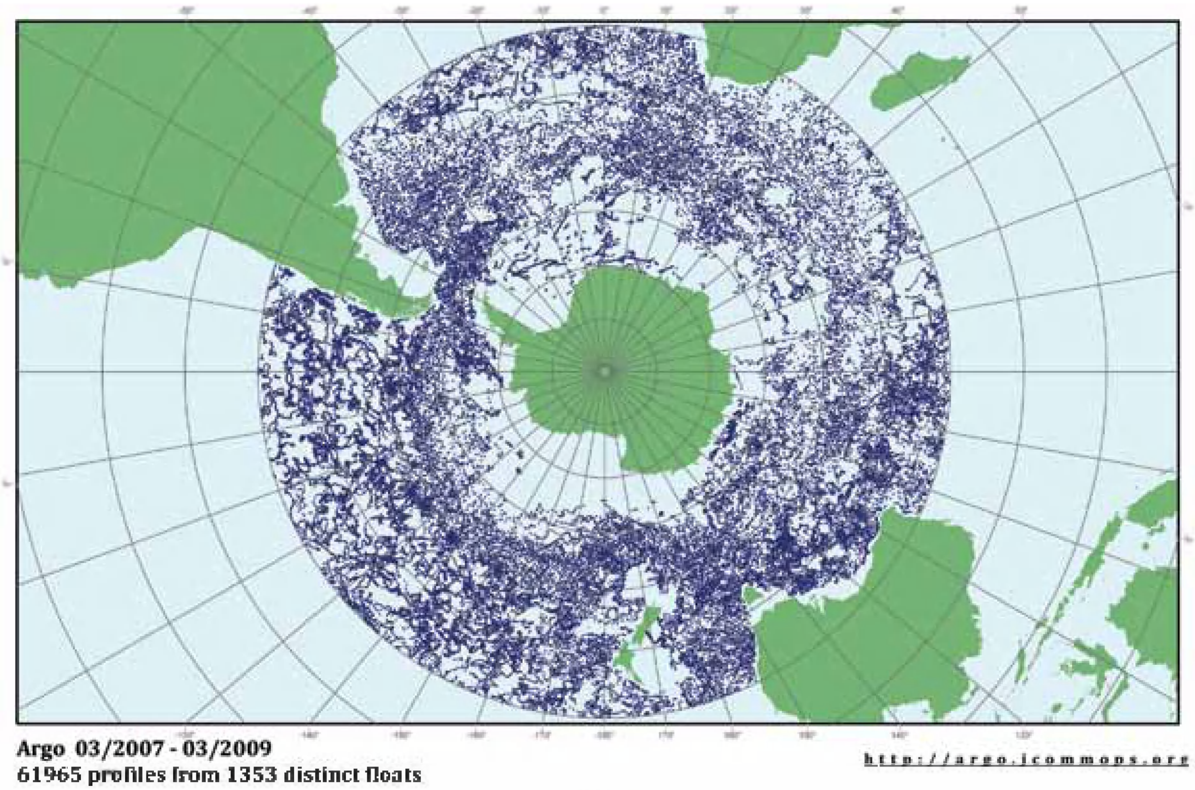


Fig. 2.3-2a. A total of 61,965 profiles of temperature and salinity were collected by Argo floats during the IPY period (March 2007 – March 2009).

(Base map: M. Belbeoch, Argo Information Centre, JCOMMOPS)

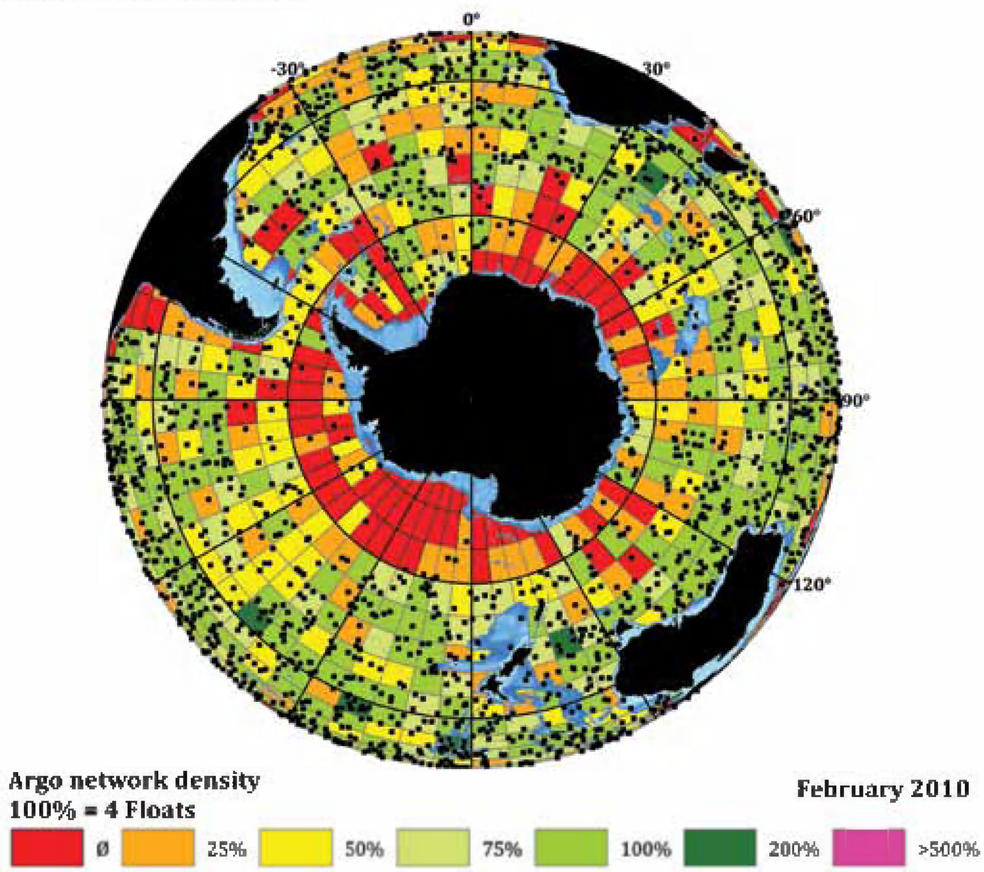


Fig. 2.3-2 (b). Estimate of density of float distribution. The IPY helped to enhance the coverage of Argo floats in the Southern Ocean, including the deployment of ice-capable floats in the sea ice zone. Nevertheless, the Southern Ocean remains significantly under-sampled (bottom).

(Base map: M. Belbeoch, Argo Information Centre, JCOMMOPS) series measurements ever made in these locations.

- Process studies were carried out at a number of locations. In particular, the first direct measurements of mixing in the deep Southern Ocean were made during IPY as part of the Diapycnal and Isopycnal Mixing Experiment in the Southern ocean (DIMES) and Southern Ocean FINEstructure (SO-FINE) projects.
- Measurements beneath the floating ice shelves and glacier tongues that fringe much of Antarctica were made at several locations. Observations within the sub-ice shelf ocean cavities are very scarce, due to the obvious difficulties of sampling the ocean beneath hundreds of metres of ice. Nevertheless, these measurements are needed to improve understanding of how the interaction between the ocean and the ice shelf can influence the dynamics of the Antarctic ice sheet and how ice shelf melt/freeze processes modify the ocean water. The AUV Autosub3 made a number of long transits beneath the Pine Island Glacier, where thinning, acceleration and grounding line retreat have been observed by satellites, measuring water properties and the shape of the cavity (Jenkins et al., 2009). Access to the ocean can also be gained by drilling holes through the ice shelf and deploying oceanographic instruments. IPY measurements were made beneath the Amery Ice Shelf (70°E) and Fimbul Ice Shelf (Greenwich Meridian; Lars Smedsrud, pers. com.) as part of ongoing programs.
- Long-term sampling programs made a significant contribution to IPY goals, including underway measurements and remote sensing by satellites. Model studies were carried out under the IPY banner and contributed substantially to addressing the scientific questions identified above.

Research highlights

The unprecedented spatial coverage of IPY observations is providing new insights into the Southern Ocean and its connection to the rest of the globe. The deep hydrographic and tracer sections, Argo floats and animal sensors have delivered a circumpolar snapshot of the state of the Southern Ocean. The IPY repeat hydrographic sections continue time-series established in recent decades, allowing assessment of changes in a variety of parameters throughout the full depth of the Southern Ocean. Such studies have been used to document the uptake of anthropogenic CO_2 by the ocean (e.g. Sabine et al., 2004), and the warming (Johnson and Doney, 2006a,b; Johnson et al., 2007, Fahrbach et al., 2010) and freshening (Aoki et al., 2005; Rintoul, 2007) of Antarctic Bottom Water (AABW). For example, Fig. 2.3-4 shows that freshening of the Adélie Land and Ross Sea sources of AABW, observed in those earlier studies, has continued through the IPY

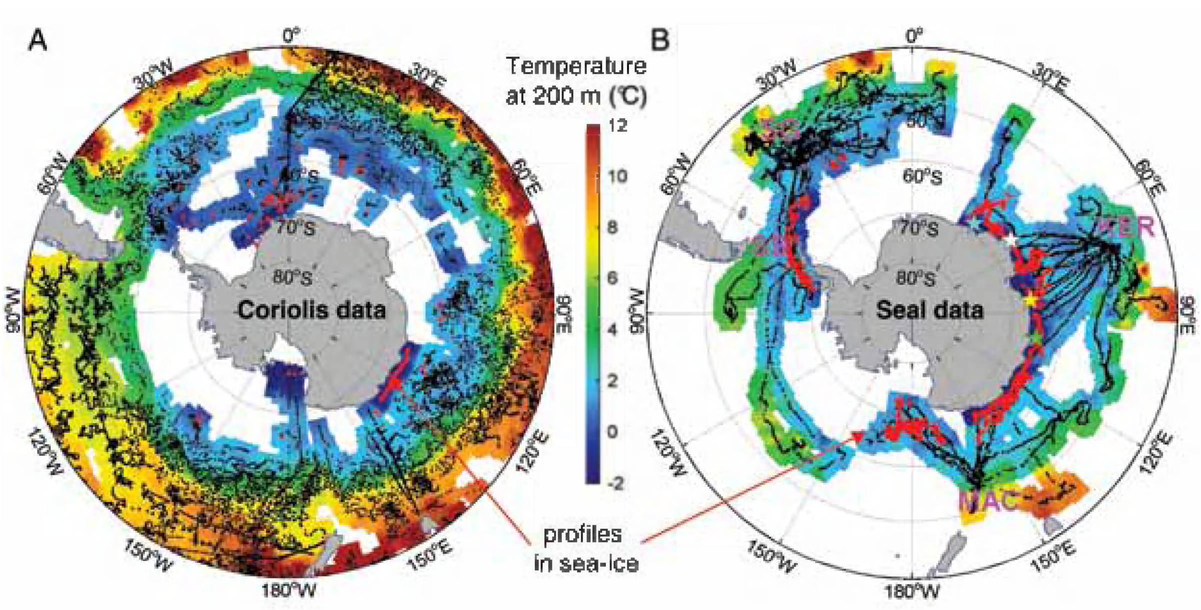


Fig. 2.3-3. Temperature at 200 m depth, as measured by traditional oceanographic platforms and provided by the Coriolis data centre (ships and floats, left) and by seals equipped with oceanographic sensors (right). The seals significantly increase the number of profiles obtained in the sea ice zone in winter (red).

(Images: Charassin et al., 2008)

period. These previous studies underpinned the conclusion in the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report that significant changes were underway in the Southern Ocean (Bindoff et al., 2007). Time-series collected during IPY also show that decadal and higher frequency fluctuations (Fahrbach et al., 2009; Gordon et al., 2010) and differences between regions (Heywood et al., 2009) can complicate the detection of longer-term trends.

The repeat hydrographic measurements have been used to develop proxies that allow the temporal and spatial variability of the Antarctic Circumpolar Current (ACC) to be assessed in unprecedented detail during IPY. For example, the hydrographic data reveal tight relationships between sea surface height, subsurface water mass properties, and the transport and structure of ACC fronts (e.g. Watts et al., 2001; Rintoul et al., 2002; Sokolov and Rintoul, 2007). Using these relationships and satellite measurements of sea surface height, variability of the ACC can be determined for the last 15 years with temporal resolution of a week and spatial resolution of about 100 km. These approaches have been used during IPY to measure ACC variability south of Africa (Luis and Sudhakar, 2009; Swart et al., 2008; Swart et al., 2010a,b) and along the circumpolar path of the current (Sokolov and Rintoul, 2009a,b).

During IPY, hydrographic measurements were also made in a number of locations where few or no measurements had been made in the past. Examples include the Fawn Trough, a deep gap in the Kerguelen Plateau, which as IPY measurements show, carries a substantial fraction (43 Sv out of 147–152 Sv) of the ACC transport (Park et al., 2009).

The SASSI program used moorings and profiling instruments (Conductivity-Temperature-Depth probes, CTDs) to measure the Antarctic Slope Front along much of the near-circumpolar extent of the current (Fig. 2.3-1b). The measurements have revealed an eastward undercurrent beneath the Antarctic Slope Front in the southeast Weddell Sea (Chavanne et al., 2010) and improved knowledge of the structure and the dynamics of the slope and coastal currents at the Greenwich Meridian (Núñez-Riboni and Fahrbach, 2009a,b). Eddies and upwelling events were shown to deliver heat to drive the melting of the glacial ice on the western Antarctic Peninsula. Closely spaced CTD sections were used to quantify the export of dense Weddell Sea waters across the South Scotia Ridge and

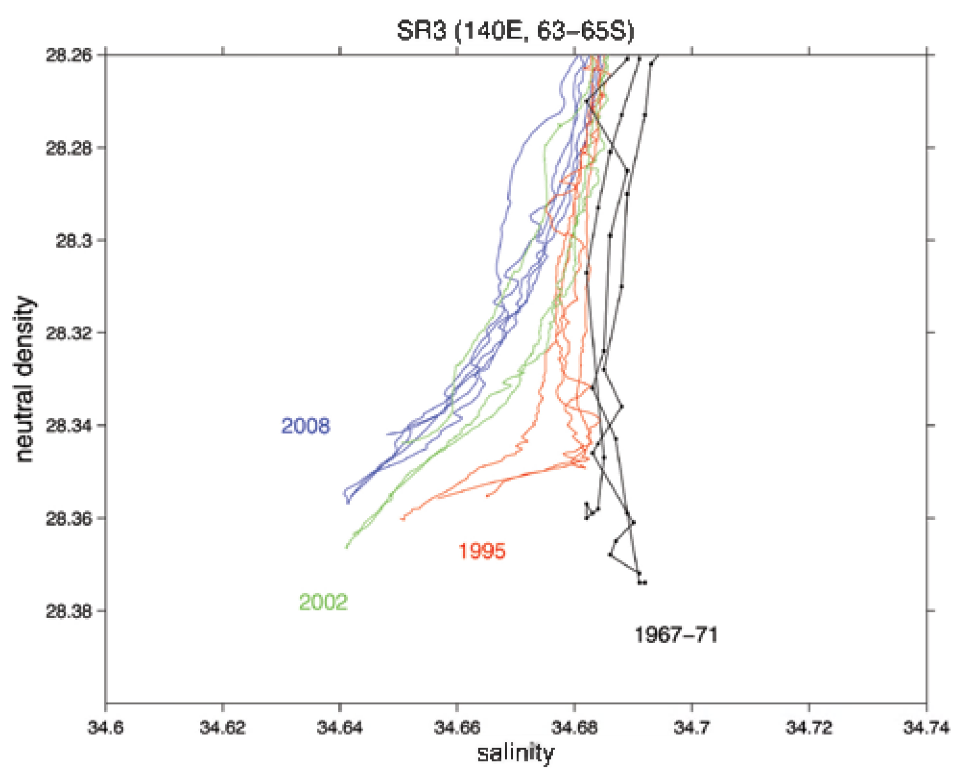


Fig. 2.3-4. Salinity of dense waters over the continental slope at 140°E, plotted as a function of neutral density. AABW formed in the Ross Sea and Adelie Land has freshened on density surfaces between the early 1970s, 1995 and the IPY section in 2008. The most extreme AABW has also become less dense with time.
(Graph: Stephen Rintoul)

the variability of the Antarctic Slope Front (Thompson and Heywood, 2008). A turbulence profiler was used to measure entrainment in the dense overflow for the first time. In the Prydz Bay area, along 15° E in the Riiser-Larsen Sea and in the Amundsen Sea, CTD surveys were carried out. In Prydz Bay, Ice Shelf Water was observed entering the region to the west of Prydz Channel (~72° E) to form Prydz Bay Bottom Water, which is colder and less saline than AABW (Antipov and Klepikov, 2007, 2008). The section in the Pine Island Bay, Amundsen Sea, shows significant penetration of Circumpolar Deep Water to the shelf area (Antipov et al., 2009a,b).

The Argo project has dramatically improved the observational coverage of the upper 2 km of the Southern Ocean. These observations have been combined with measurements from ships and satellites to document change and to quantify Southern Ocean processes that could not be measured using the sparse historical data. Comparison of Argo data to a historical climatology showed that the Southern Ocean as a whole has warmed and freshened in recent decades, reflecting both a southward shift of the ACC and water mass changes driven by changes in surface forcing consistent with expectations of a warming climate (Böning et al., 2008). Argo data have been used to resolve the seasonal cycle of the mixed layer depth (Dong et al., 2008), an important parameter for physical, chemical and biological studies, and its response to modes of climate variability (Sallée et al., 2010a). Variability of mode water properties has also been linked to modes of climate variability, like the Southern Annular Mode and El Niño (Naveira Garabato et al., 2009). The year-round coverage of Argo has also been exploited to quantify the rate at which surface waters are subducted into the ocean interior, revealing "hot spots" of subduction that help explain the interior distribution of potential vorticity, anthropogenic carbon and other properties (Sallée et al., 2010b).

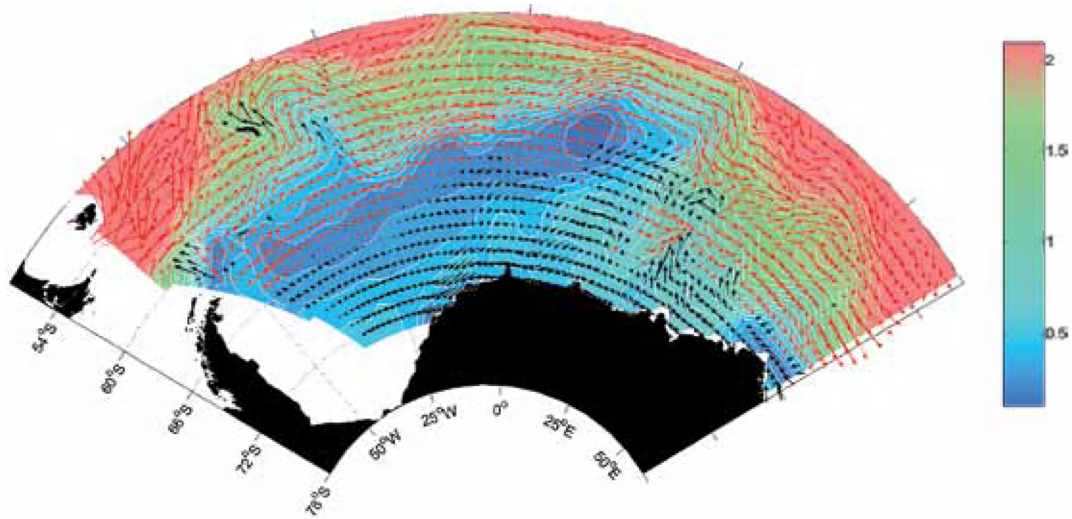
IPY provided the first broad-scale measurements of the ocean circulation beneath the Antarctic sea ice. Several nations collaborated to acoustically track profiling floats beneath the sea ice in the Weddell Sea, resolving the current structure and water mass properties in greater detail than previously possible (Fig. 2.3-5, Fahrbach and de Baar, 2010). Oceanographic sensors deployed on southern elephant seals have revealed the structure of ocean currents in regions where traditional oceanographic platforms are unable to sample (Fig. 2.3-3 right, Charassin et al., 2008; Roquet et al., 2009; Boehme et al., in press; Costa et al., 2008). The increase in salinity beneath the ice has been used to provide the first estimates of the growth rate of sea ice from the open pack ice typical of the Antarctic continental shelf (Charassin et al., 2008).

Moorings deployed during IPY will provide robust transport estimates from a number of locations where direct velocity measurements did not exist. Examples include dense water outflows from the Weddell, Cape Darnley and Adélie Land coasts; the Antarctic Slope Front; the Weddell Sea; and the ACC at Drake Passage, south of Africa, the Fawn Trough and the Macquarie Ridge. The quasi-continuous measurements allow long-term trends in water mass properties to be distinguished from energetic low frequency fluctuations (Fahrbach et al., 2009; Gordon et al., 2010). A number of experiments conducted just prior to IPY also contribute to IPY goals. For example, a two-year deployment of moorings in the deep boundary current east of the Kerguelen Plateau showed that this current was a major pathway of the deep global overturning circulation, carrying 12 x 10^6 m^3 s^{-1} of AABW (potential temperature < 0°C) to the north, with 5 x 10^6 m^3 s^{-1} recirculating to the southeast (Fukamachi et al., 2010).

Lack of knowledge of where and at what rate mixing takes place in the ocean remains a key gap in understanding the dynamics of the global ocean circulation. The interaction of the strong deep-reaching currents of the Southern Ocean with rough bathymetry may result in enhanced mixing levels there (Naveira Garabato et al., 2004). Two experiments set out to test this hypothesis during IPY. The DIMES experiment used a variety of tools (a deliberate tracer release, floats, moorings, ship transects and turbulence profilers) to measure mixing upstream of Drake Passage. The SO-FINE experiment carried out similar work where the ACC interacts with the northern end of the Kerguelen Plateau.

Preliminary results from the Autosub mission beneath the Pine Island Glacier show how sea floor topography modifies the inflow of warm Circumpolar Deep Water into the inner cavity and impacts the degree to which it mixes with the cooler melt water (Jenkins et al., 2009). Borehole observations from

Fig.e 2.3-5. The Weddell gyre flow and *in situ* temperature in 800 m depth derived from the data of 206 ice-compatible vertically profiling floats between 1999 and 2010.
(Image: Fahrbach et al., submitted)



the Amery Ice Shelf have provided new insights into melting and re-freezing processes in that sub-ice shelf cavity (Craven et al., 2009). The Amery Ice Shelf experiences rapid melt rates near its grounding line. Most of this melt water re-freezes to the base of the floating ice-shelf, forming a marine ice layer up to 200 m thick. This marine ice layer is highly permeable, even at a distance of 100 m above the ice-shelf base. The permeability of the marine ice layer suggests that marine ice at the base of the ice-shelf may be particularly vulnerable to changes in ocean properties.

Biogeochemistry

Most of the deep hydrographic sections occupied by the CASO and SASSI programs also collected observations of biogeochemical parameters, including carbon and major- and micro-nutrients. In addition, IPY-GEOTRACES contributed to 14 research cruises in the oceans around Antarctica and the Arctic, as part of the overall GEOTRACES study of the global marine biogeochemical cycles of trace elements and their isotopes (Measures et al., 2007).

A primary goal of the biogeochemistry program during the IPY was to quantify the evolving inventory of carbon dioxide in the Southern Ocean and to understand how the physical and biological processes responsible for ocean uptake and storage of CO_2 might respond to climate change (Gloor et al., 2003; Hoppema, 2004; Takahashi et al., 2009). Another important issue in the Southern Ocean is the vulnerability of the cold surface waters to acidification. Here, the already low concentration of carbonate ion is further reduced by considerable uptake of anthropogenic CO_2, possibly leading to under-saturation of aragonite (a form of $CaCO_3$) within the next decades (Orr et al., 2005; McNeil and Matear, 2009). This in turn could have an impact on $CaCO_3$ utilizing organisms by reducing the rate of calcification. For example, pteropods, planktonic snails that form shells from aragonite, are a key part of the Southern Ocean food chain and may be at risk as the Southern Ocean becomes progressively more undersaturated in aragonite. Since not all organisms act similarly and the distribution of organisms around the circumpolar ocean is inhomogeneous, spatial variability of ocean acidification and its impact on the carbon cycle is expected. Measurements made during IPY are being used to document the evolving inventory of anthropogenic CO_2 and changes in ocean acidity.

The Southern Ocean is of particular interest to GEOTRACES as iron limits primary productivity in much of this region, and change in the delivery and availability of iron will arguably be the single largest forcing of Southern Ocean ecosystem productivity and health in the next century, and thus is intrinsically linked with changes in climate. Moreover, all living organisms require trace elements (such as zinc, copper, manganese and cobalt) for many functions including as co-factors in enzymes thus co-limitation by such elements in the Southern Ocean is likely under certain environmental conditions (Morel and Price, 2003).

The scientific questions of primary interest to the biogeochemical theme of Southern Ocean IPY included: How much CO_2 is absorbed (and released) by the Southern Ocean and how sensitive is the Southern Ocean carbon "sink" to climate change? How is the absorption of CO_2 changing the chemistry of the Southern Ocean, and what impact will acidification have on organisms and ecosystems? What is the distribution and supply of iron and other trace elements and isotopes, and what do they tell us about the sources and sinks of CO_2 and the control of primary productivity? What processes control the concentrations of geochemical species used as proxies for past environmental conditions, and what are the implications for interpretation of past climate?

IPY observations

Biogeochemical measurements (including oxygen, nutrients, carbon and tracers) were made along most of the hydrographic lines shown in Fig. 2.3-1a. IPY-GEOTRACES work was carried out on a number of additional sections shown in Fig. 2.3-6, including process studies in the Amundsen Sea, in the subantarctic and polar frontal zones to the south and east of Australia and New Zealand (e.g. Ellwood, 2008; Bowie et al., 2009) and in the sea ice zone (van der Merwe et al., 2009) as well as in the Atlantic sector and Drake Passage (Fahrbach and de Baar, 2010). The trace metal work required clean sampling techniques, which were widely used in the Southern Ocean for the first time during IPY. Water samples were collected using non-metallic rosettes and cables, with analyses conducted in special clean containers using agreed protocols (Johnson et al., 2007; Fahrbach and de Baar, 2010).

Research highlights

Knowledge about the carbon cycle of the Southern Ocean has increased significantly during IPY. Nevertheless, most of these data have still to be included in global studies to further improve estimates of interior ocean storage of anthropogenic CO_2 and the air-sea exchange of CO_2 that were determined in studies (Sabine et al., 2004; Takahashi et al., 2009) made before IPY. Le Quéré et al., (2007)

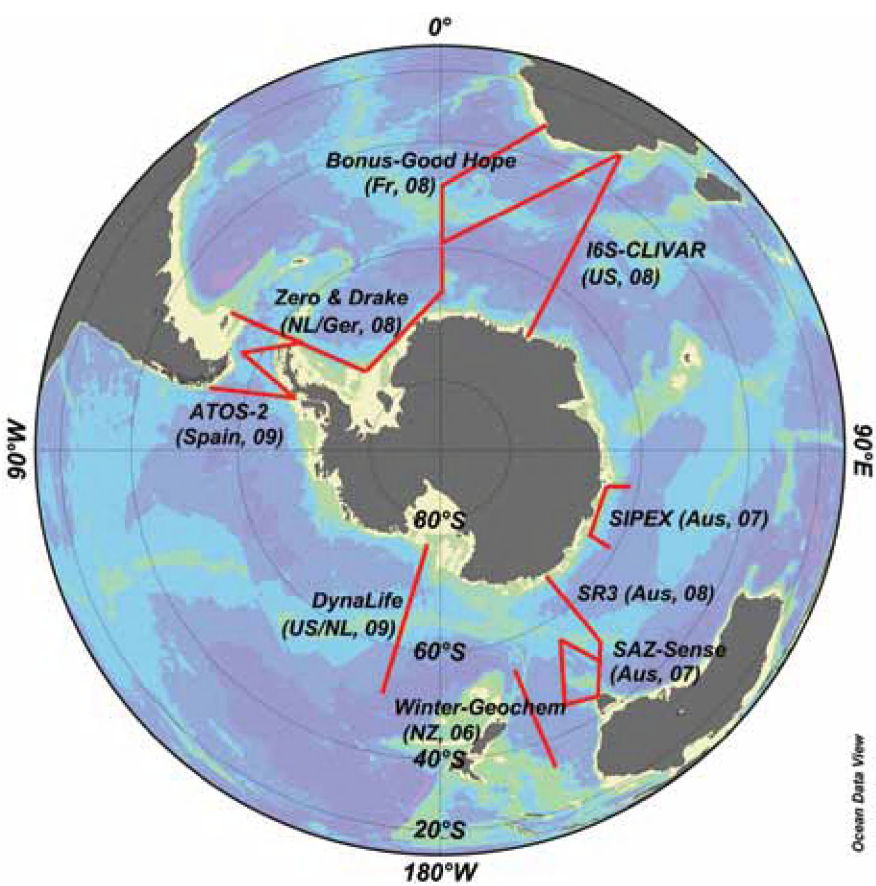


Fig. 2.3-6. GEOTRACES transects and process cruises in the Southern Ocean during IPY.
(Map: Andrew Bowie)

suggested that, based on atmospheric observations and modelling, the sink function has recently been decreasing due to a southward shift of the westerly winds associated with changes in the Southern Annular Mode. This suggestion in turn has been challenged by several investigators and is the subject of ongoing research. Although Le Quéré's conclusions have been supported by another modelling study (Lovenduski et al., 2008), it should be noted that Böning et al., (2008) have questioned this saturation of the Southern Ocean CO_2 sink, arguing that the effect of increased eddy formation could compensate for the extra energy imparted to the ocean by the winds, with no significant change in the overturning.

While the exploitation of the wealth of carbon data is still underway, first results are starting to emerge. The precipitation of $CaCO_3.6H_2O$ (ikaite) was observed for the first time in sea ice, a process likely to have a significant impact on the carbon cycle in ice covered areas (Dieckmann et al., 2008). CO_2 oversaturation was observed under the sea ice in the eastern Weddell gyre at the end of winter and early spring, with a shift to undersaturation within a few days as a result of biological activity thus preventing CO_2 outgassing to the atmosphere (Bakker et al., 2008). This mechanism may well be responsible for the annual sink function of this region. Drifters measuring pCO_2 in the surface ocean developed in the CARIOCA program (www.lodyc.jussieu.fr/carioca) indicated the Subantarctic Zone is a strong sink for atmospheric CO_2 (Boutin et al., 2008). Decadal trends of anthropogenic CO_2 in the Weddell Gyre were estimated from repeat sections along the prime meridian, providing a benchmark for future investigations (Hauck et al., 2010; Van Heuven et al., 2010).

A significant achievement of IPY was the first full-depth measurements of iron and other trace elements in the Southern Ocean (e.g. Klunder et al., 2010). For example, the distribution of dissolved iron along the SR3 section south of Tasmania (Fig. 2.3-7) shows maximum surface water concentrations between the latitudes of 60° and 65°S. The salinity (Fig. 2.3-7, lower left panel) and oxygen (Fig. 2.3-7, lower right panel) distributions along this section indicate that high salinity, low-oxygen, nutrient-rich circumpolar deep water upwells within this latitude band. These results, in combination with much lower dissolved iron concentrations north of 60°S, support the view that upwelling is more

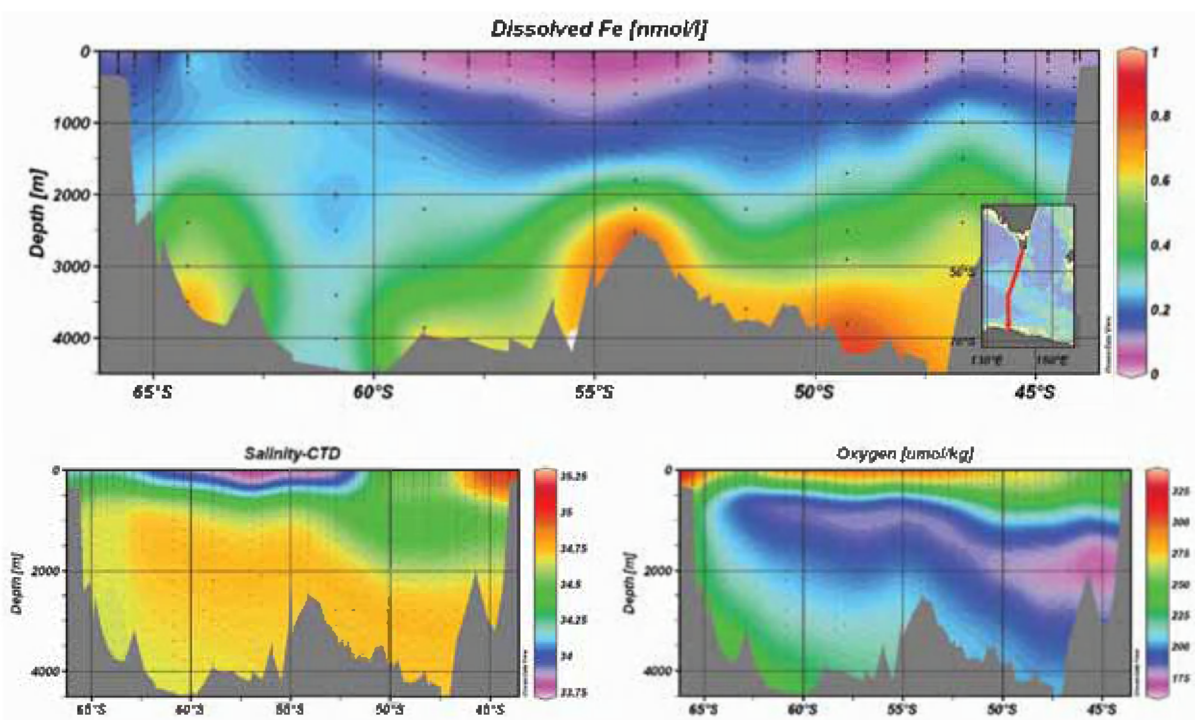


Fig. 2.3-7. Dissolved iron, salinity and oxygen distributions in the full-water column along the SR3 transect between Tasmania and Antarctica. The position of the transect is shown in the insert in the upper panel. (Image: Bowie et al., unpublished data)

significant than deposition of aerosols as a source of iron to this polar region during autumn. Furthermore, the iron distribution indicates the importance of bottom sediments and hydrothermalism as sources of iron to the deep Southern Ocean (Tagliabue et al., 2010), sources that have been neglected in previous biogeochemical models for the region. Distributions of total dissolvable iron (TDFe), dissolved iron (DFe) and soluble iron (SFe) were investigated during the BONUS-GoodHope cruise in the Atlantic sector of the Southern Ocean (34°S/17°E, 57°S/0°E) along a transect from the subtropical domain to the Weddell Sea Gyre, in February-March 2008. The highest concentrations of DFe and TDFe were observed in the sub-tropical domain, where continental margins and dust input might be the main Fe sources. Complexation with ligands from biological and continental origin could explain the distributions of SFe and CFe along the transect (Chever et al., submitted).

The first measurements of methylmercury in the Southern Ocean were made during IPY, showing high concentrations and an increase in the ratio of methylmercury to apparent oxygen utilization in Antarctic waters (Cossa et al., submitted). The distribution can be explained by the co-location in Antarctic waters of a large atmospheric source of mercury (through mercury depletion events mediated by halogens released during sea ice formation), bacterial decomposition of organic matter produced by intense phytoplankton blooms and upwelling of methylmercury-enriched deep water. These results have improved our understanding of the global mercury cycle, confirmed evidence of open ocean methylation and helped explain the elevated mercury levels observed in Antarctic biota.

IPY experiments in the Australasian region revealed that subantarctic phytoplankton blooms during summer were driven by both seasonal iron supply from southward advection of subtropical waters and by wind-blown dust deposition, resulting in a strong decoupling of iron and nutrient cycles (Bowie et al., 2009). These observations have important longer-term climatic implications since the frequency and scale of dust emissions and the poleward extension of western boundary currents are both predicted to increase in the future, resulting in a greater influence of subtropical water on the subantarctic zone.

The origin of the iron in the ocean can be derived by correlating properties of related trace metals such as aluminium and manganese. Dissolved aluminium in the surface waters is a tracer of aeolian dust and dissolved manganese can help to trace iron input from the bottom. On the Greenwich meridian the near surface concentration of aluminium is low (Fig. 2.3-8 top), whereas manganese displays a maximum over the mid-ocean ridge (Fig. 2.3-8 bottom) correlating with dissolved iron (not shown) suggesting an iron input from hydrothermal activity (Middag et al., 2010a,b).

A comprehensive examination of the distribution, speciation, cycling and role of iron in fuelling sea ice-based and pelagic algal communities showed that primary productivity in seasonally ice-covered waters around Antarctica is primarily driven by temporal variations in iron supply (seasonal and inter-annual, driven by sea ice formation and melting processes) rather than large-scale spatial forcing (van der Merwe et al., 2009), with strong vertical iron resupply during winter, rapid release from sea ice and uptake during spring, and substantial depletion during summer (Lannuzel et al., 2010).

Marine biology, ecology and biodiversity

Several major programs, CAML, EBA, ICED, MEOP and SCAR-MarBIN, numerous individual IPY projects, PAME, AMES and certain components of PANDA, focused on the broad issue of marine biology, ecology and biodiversity in the Southern Ocean. These overarching programs included contributions from numerous regional programs, such as DRAKEBIOSEAS and ClicOPEN, which focussed on the effect of climate change on coastal communities at the western Antarctic Peninsula.

The objective of the SCAR project Census of Antarctic Marine Life (CAML, see www.caml.aq) was to determine the distribution and abundance of life in the Southern Ocean around Antarctica, providing a benchmark against which future change can be assessed. The Arctic and the Antarctic Peninsula are currently experiencing rapid rates of change (IPCC, 2007; Steig et al., 2009; Mayewski et al., 2009; Convey et al., 2009). The uniquely adapted organisms of the polar regions may be vulnerable to shifts in climate and ocean circulation patterns. The major scientific question for CAML is how the marine life around

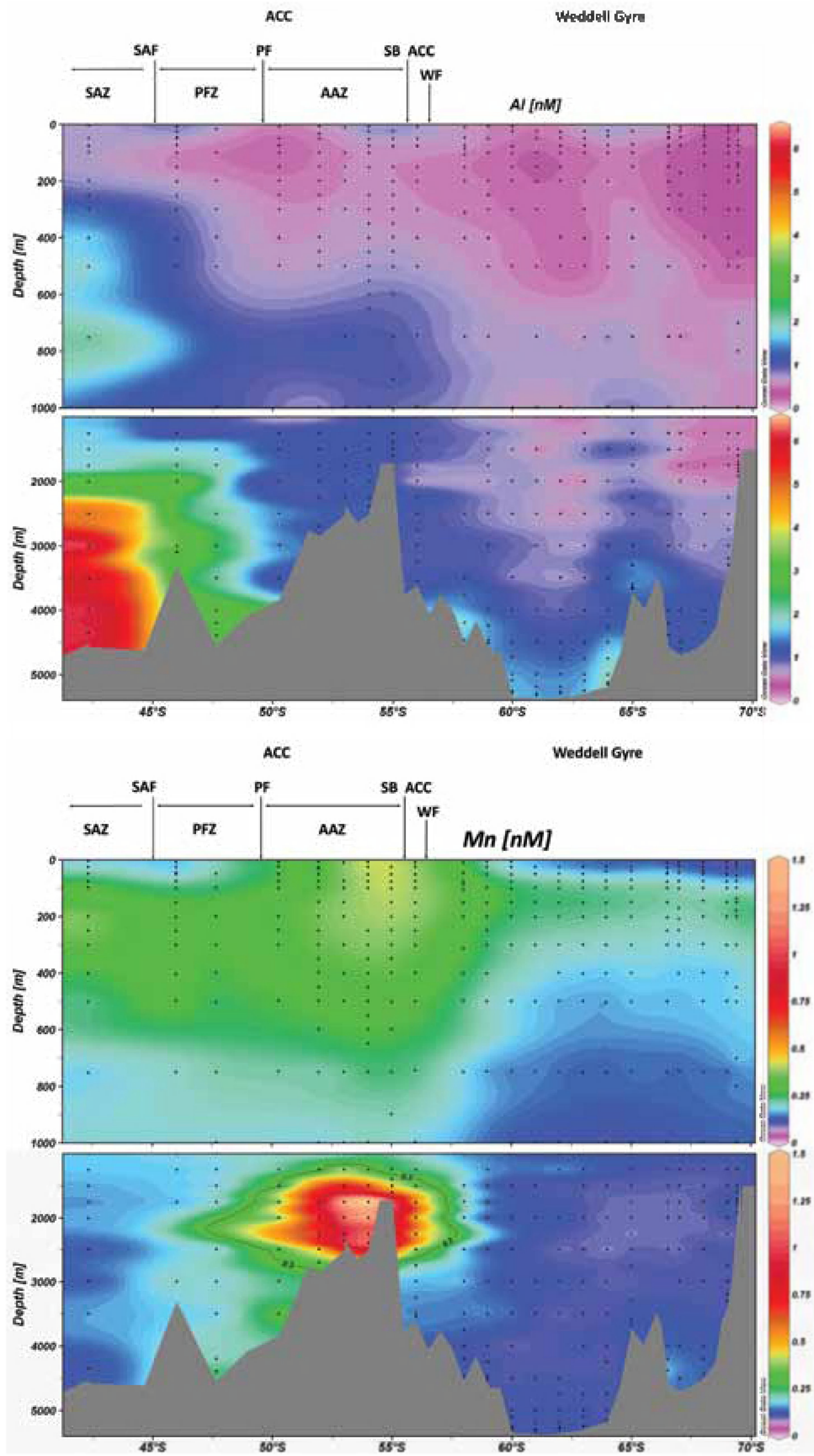


Fig. 2.3-8. Vertical distribution of aluminium (top) and of manganese (bottom) in nM on a transect along the Greenwich Meridian.
(Image: Middag et al. in press, (a) and (b))

Antarctica will be affected by change and how change will alter the nature of the ecosystems of the Southern Ocean. More specific questions include: How does biophysical coupling in the marine environment drive biological diversity, distribution and abundance of species? Which species hold the key to ecosystem functioning? What are the critical ecological processes and historical factors affecting diversity? How will communities respond to future change (and how have they responded to past change), including warming, acidification, increased UV irradiance and human activities? What is the role of the Southern Ocean in driving marine speciation to the north? As a contribution to CAML, ANDEEP-SYSTCO (ANtarctic benthic DEEP-sea biodiversity: colonisation history and recent community patterns - SYSTem COupling) builds on the precursor program ANDEEP, moving the focus from distributional patterns of the largely unexplored abyssal benthos in the Southern Ocean to processes in the abyssal ecosystem and their connections to the atmosphere and water column (Brandt and Ebbe, 2009).

The Integrating Climate and Ecosystem Dynamics (ICED) program is focused on integrating Southern Ocean ecosystem, climate and biogeochemical research (Murphy et al., 2008; 2010). The multidisciplinary activities and collation of past studies undertaken as part of ICED-IPY have already furthered our understanding of ecosystem operation in the context of climate processes, physics, biogeochemistry, food web dynamics and fisheries (www.iced.ac.uk). For example, the Synoptic Circum-Antarctic Climate-processes and Ecosystem (SCACE) study identified clear changes in the food web across water mass boundaries. These changes are related to carbon fluxes associated with blooms and to changes in sea ice cover. AMES including the Antarctic Krill and Ecosystem Survey (AKES, Krafft et al., 2008) focused on the abundance, size structure and demographic characteristics of krill, a major component of the Antarctic ecosystem. In addition AKES also focused on acoustic properties of salps (Wiebe et al., 2009), krill and mackerel icefish. VIRPOL (The significance of VIRuses for POLar marine ecosystem functioning) a contribution to PAME investigated the abundance and composition of viruses and their hosts at both poles, with the goal to identify the significance of viruses and their impact on microbial mortality and geochemical cycling, and to unravel the impact of climate and global change on viruses and their role in the marine ecosystem.

IPY Observations

During the CAML, 18 vessels sampled biodiversity in the Southern Ocean (Fig. 2.3-9). Sampling and observation methods included shipboard gear such as towed video and camera systems, continuous plankton recorders, nets and benthic grabs; biologgers on seals; and systematics and DNA barcoding. Many of these voyages were carried out in partnership with IPY projects focused on physics and biogeochemistry (e.g. CASO, SASSI and GEOTRACES), providing a unique multidisciplinary data set to relate patterns of biodiversity to physical and chemical processes. A larger number of vessels completed underway sampling, including continuous plankton recorder transects across the Southern Ocean at many longitudes. A major legacy of CAML is the SCAR-MarBIN data portal, which contains data collected on some 15,500 species.

Close cooperation of pelagic and benthic specialists allowed investigation of many aspects of abyssal ecology during the ANDEEP-SYSTCO cruise (Bathmann, 2010). SYSTCO scientists aimed to study the biology of abyssal species, the role of the bottom-nepheloid layer for recruitment of benthic animals, the influence on abyssal life of the quantity and quality of food sinking through the water column, feeding ecology and trophic relationships of abyssal animals. The effects of topography, sedimentology and biogeochemistry of sediment and pore water on benthic life and microhabitat formation were investigated. As the benthic fauna depends on deep carbon export from the pelagic production and particle sedimentation, a station was re-occupied on the return leg to estimate seasonal and episodic variability of the particle flux (Bathmann, 2010). The spatial distribution of the fluxes (Fig. 2.3-10) could be derived on the basis of pre-IPY and IPY data (Sachs et al., 2009).

In the context of AMES a multidisciplinary survey targeting the pelagic ecosystem was carried out in 2008 in the Atlantic sector of the Southern Ocean. Various sampling strategies and new observation techniques, as well as on-board experiments, were used to study abundance and population characteris-

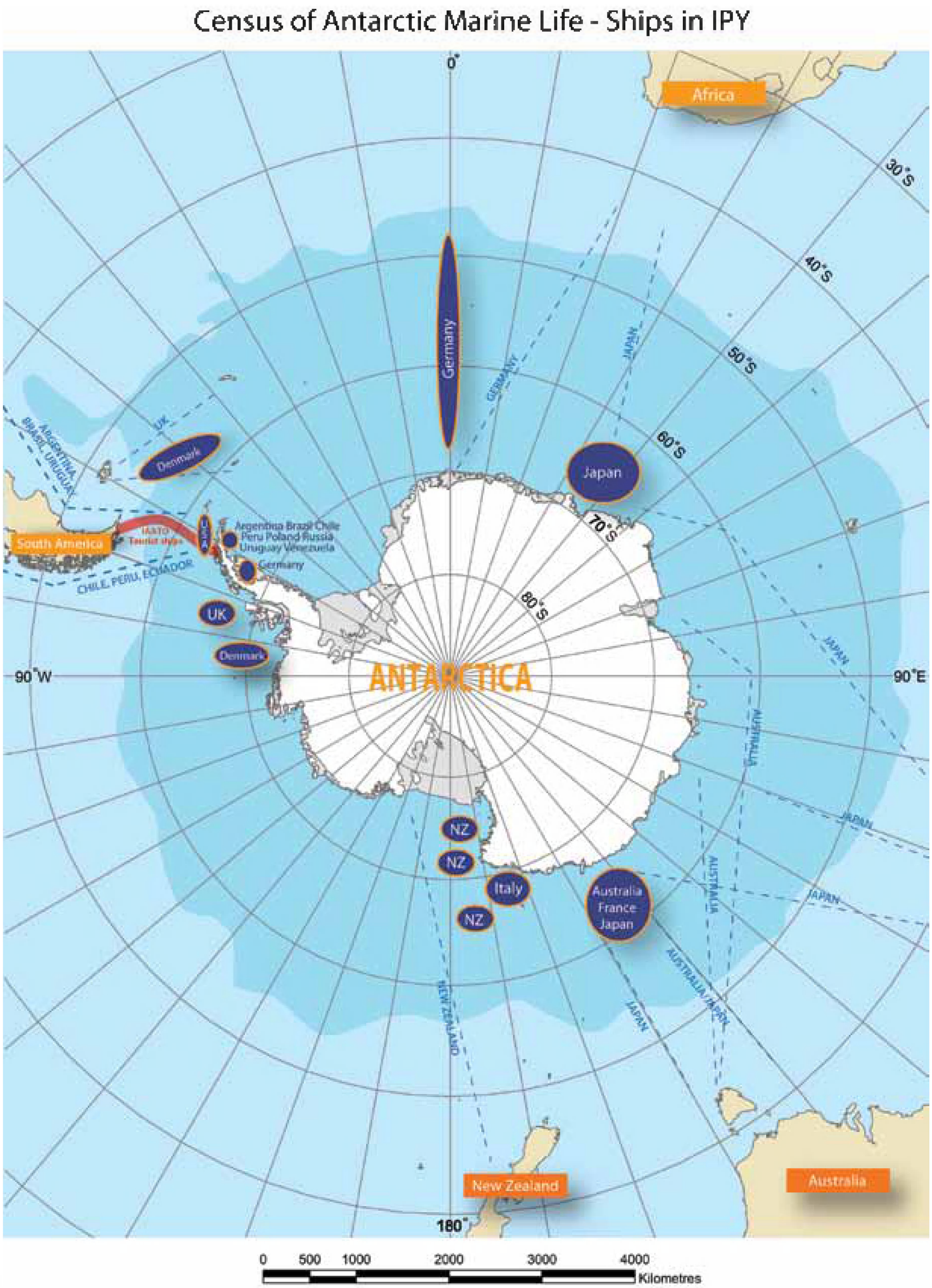


Fig. 2.3-9. CAML ship sampling during IPY, dark blue areas denote benthic sampling, following the plan at www.caml.aq. The locations are shown for each national program. The dashed lines are transects using the Continuous Plankton Recorder. The shaded red area near South America was sampled by tourist vessels under the International Association of Antarctica Tour Operators IAATO. The boundary between the darker and lighter of the two ocean colours indicates the position of the Subantarctic Front.
(Map: Victoria Wadley)

tics and their relationship to the physical environment. High phytoplankton abundance seems to be related to fronts and bathymetric features that also govern regional circulation patterns. The abundance, size structure and demographic characteristics of the Antarctic krill, *Euphausia superba,* varied systematically throughout the study region. VIRPOL carried out two major campaigns in the Southern Ocean: one survey in the Australian sector of the Southern Ocean (Evans et al., 2009) and a second campaign in the Atlantic sector (Evans et al., 2010). During both cruises, comprehensive measurements of the abundance of a range of microbes including viruses and bacteria (with high and low DNA), cyanobacteria and eukaryotic algae were made. In addition, a range of incubation experiments were conducted to determine viral mortality and grazing of bacteria and picophytoplankton.

Research highlights:

The CAML investigated the evolution and function of life around Antarctica, stimulating new areas of enquiry about the biodiversity of the Southern Ocean. Over one million geo-referenced species records are already available in the data portal. These records include species inventories of the Antarctic shelf, slope and abyss; of the benthic fauna under disintegrating ice shelves; of the plankton, nekton and sea ice-associated biota at all levels of biological organization from viruses to vertebrates; and assessed the critical habitats for Antarctic top predators.

Results from the CAML have challenged the concept that the diversity of marine species decreases from the tropics to the poles; the Antarctic boasts unparalleled diversity in many taxonomic groups and, in the Arctic, an unexpected richness of species compared to the tropical oceans has been documented (Clarke et al., 2006; Barnes, 2008). New species have been discovered in all ocean realms, notably deep-sea isopods (Brandt et al., 2007). The multiple bioregions described by Hedgpeth (1969) have been overturned in favour of a single bioregion united by the Antarctic Circumpolar Current, at least for sessile benthic invertebrates (Clarke et al., 2006; Griffiths et al., 2009). The ANDEEP-SYSTCO program discovered differences in benthic diversity and abundance in different locations of the Weddell Sea (Brandt and Ebbe, 2009), including a distinct bivalve-dominated fauna on Maud Rise, suggesting high availability of particulates to support filter feeders there, and low diversity and abundance beneath the Polar Front (Bathmann, 2010). The findings support

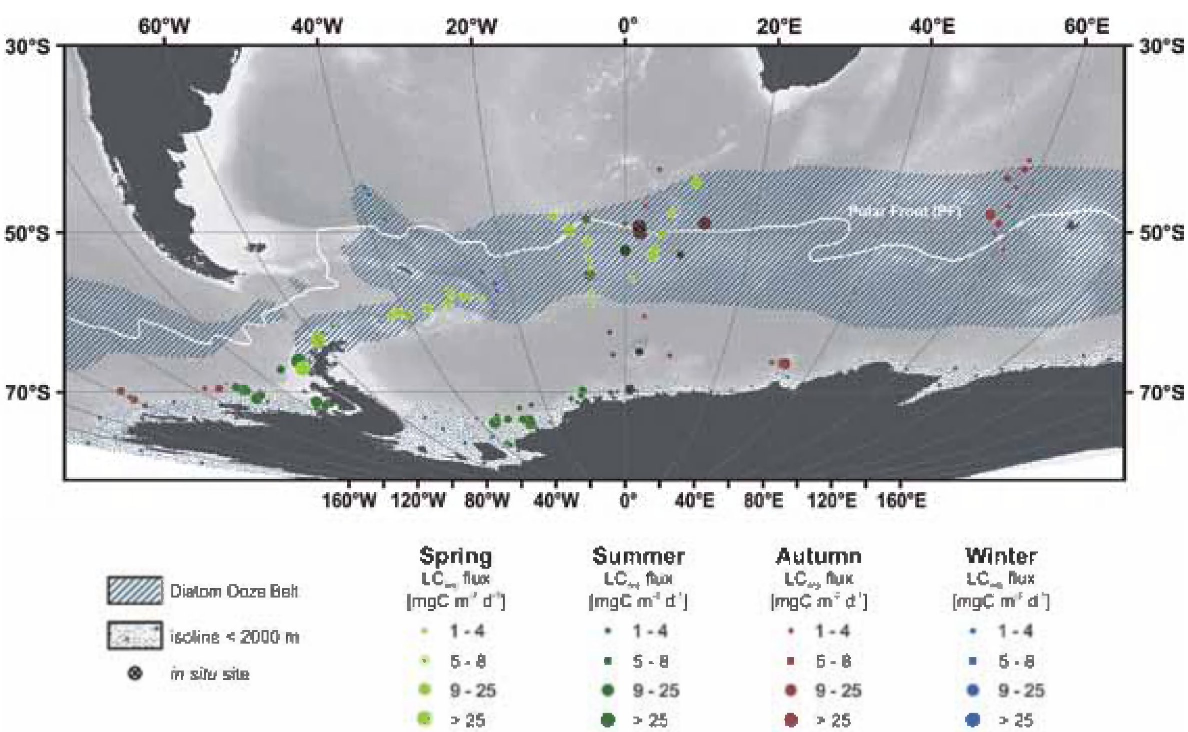


Fig. 2.3-10. Spatial distribution of the fluxes of organic carbon (LC_{org}) from the water column into the seafloor derived from measurements in the water column and the sediment during the IPY DOMINO project which is a contribution to ICED.

(From Sachs et al., 2009 and references cited therein) the theory that the high diversity found in some deep-sea taxa could have been developed and sustained through the occupation of distinct ecological niches. In addition to detritus originating from phyto- and zooplankton, foraminifera seem to play an important role in the nutrition of certain polychaete and isopod families. Bacteria were not found to play a significant role in the diet of any polychaetes analysed.

The effect of a dramatically changing environment on the benthic realm was observed by monitoring the former ice shelf sea floor with a Remotely Operated Vehicle (ROV, Fig. 2.3-11) after the Larsen A and B ice shelves had collapsed. Species that were adapted to the oligotrophic under-ice conditions will become extinct in that area. Immigration and growth of pelagic key organisms and benthic pioneers contribute to a potential new carbon sink in such areas (Peck et al., 2009). Nevertheless, it will require centuries if not millennia before complex benthic communities like those observed in the Eastern Weddell Sea are established (Gutt et al., 2008).

Octopuses provide unequivocal molecular evidence of the colonization pathway from the Antarctic to the deep sea (Strugnell et al., 2008). The research suggests that the Antarctic provides a frozen incubator of biodiversity, which has radiated to other oceans with the advent of the global thermohaline circulation, as Antarctica cooled at the end of the Eocene (37 million years ago). With the sibling IPY project, Arctic Ocean Diversity (ArcOD), CAML has discovered 251 "bipolar" species that are shared by both the Arctic and Antarctic oceans. The question of whether they are genetically the same, or simply look alike, is being answered with DNA barcoding.

Russian studies of the marine ecosystem in Nella Fjord, Prydz Bay, contributed to the goals of ICED. Observations were focused on both sea ice cores and under ice water samples at a profile across the Nella Fjord. It was shown that sea ice flora consists of mainly dinoflagellate cysts. Marine diatoms were present only as single cells, probably caused by freshening associated with the formation of sea ice (Melnikov and Gogorev, 2009; Melnikov et al., 2010).

Observations collected from Southern Ocean marine mammals by the MEOP program and its predecessor SEaOS have provided new insights into the foraging behaviour of seals and other marine mammals and the factors influencing their population dynamics (as well as the oceanographic discoveries mentioned above). Changes in the rate of ascent or descent during passive drift dives have been used to infer the distribution of productive and unproductive foraging areas visited by southern elephant seals (Biuw et al., 2007). The study concludes that the decline in elephant seal populations at Kerguelen and Macquarie Islands relative to those at South Georgia can be related to the greater energy expenditure required to reach more distant Antarctic foraging regions.

The VIRPOL cruises showed viruses were abundant throughout the Southern Ocean and the virus data correlated well with the distribution of their potential microbial hosts (bacteria, cyanobacteria and eukaryotic algae). Higher virus and microbial concentrations were observed in the Subantarctic Zone (SAZ) with concentrations decreasing near the Polar Front (PF). Microbe concentrations were relatively low in the Antarctic Zone (AZ), but elevated at costal stations. Levels of viral production indicated that viral infection of bacteria was very high in the Southern Ocean relative to other open ocean environments, particularly in the SAZ.

ClicOPEN examined the effect of regional rapid warming on the coastal biota of the Western Antarctic Peninsula (WAP) region and concluded that local sediment discharge and iceberg scouring are the two major effects, whereas changes in sea water temperature and salinity have little impact. At King George Island and other WAP areas the volume of fresh water discharged from the land has doubled between 2002-2006, with highest monthly yields in glacial catchment areas measured in January (Dominguez and Eraso, 2007). As a consequence of both fresh water release from melting land glaciers and starvation of the animals due to reduced primary production under the coastal sediment run-off plume, dead krill were washed on to the beach (Fig. 2.3-12). The annual disturbance of the sea floor by icebergs from 2001 to the present day was quantified (Smale et al., 2008). Iceberg scour disturbance on the benthos was found to be inversely proportional to the duration of local sea ice, as icebergs become immobilized by solid sea ice cover. Results of hydrographic and sediment monitoring programs can be linked to observed

Fig. 2.3-11. Sea floor organisms observed with an ROV after the Larsen A/B ice shelves collapsed (left and centre) and in the Eastern Weddell Sea (right). Species that were adapted to the oligotrophic under-ice conditions (stalked brittle stars, left) will become extinct in that area. Pelagic key organisms and benthic pioneers (sea-squirts, centre) immigrate and grow. Complex benthic communities, as in the Eastern Weddell Sea (sponges, right), will establish in centuries.
(Photo: J.Gutt ©AWI/MARUM, University of Bremen)

shifts in coastal marine productivity and biodiversity. Surveys on the colonization of newly ice-free areas under water and on land were conducted. Species like the Antarctic limpet, *Nacella concinna,* expand the time during which they stay in the Antarctic intertidal zone. Near the U.K. Rothera station, limpets were shown to overwinter in the intertidal zone (Waller et al., 2006), while at King George Island this is still not absolutely clear. Adaptive strategies under environmental strain include self-induced hypoxia in limpets trapped outside the water during low tides. Limpets lacking the adaptation in shell morphology could not produce the hypoxic response when exposed to air (Weihe and Abele, 2008).

Antarctic sea ice

Two major Antarctic sea ice field programs were undertaken under the umbrella of "Antarctic Sea ice in IPY". The Sea Ice Physics and Ecosystem eXperiment (SIPEX) was an Australian-led program that took place in East Antarctica (115-130°E). The Sea Ice Mass Balance of Antarctica (SIMBA) experiment was a U.S.-led program that focussed on the Bellingshausen Sea region (80-120°W). The voyages were near coincident in time and provided a unique opportunity to examine regional differences in sea ice conditions.

The experiments were highly multi-disciplinary, with the overarching goals of improving our understanding of the relationships among the physical sea ice environment, the biological systems within the ice habitat and the broader links to Southern Ocean ecosystem dynamics and top predators. Key questions that motivated the effort during the IPY include: What is the relationship between ice thickness and snow thickness over spatial scales measured by satellite laser altimetry? How is the distribution of sea ice algae and krill under the ice related to the ice and snow thickness distribution? How is biological primary and secondary productivity affected by winter sea ice extent and properties? And what are the drift characteristics, and internal stresses, of sea ice in the region?

IPY observations

Sea ice and snow thickness affect the interaction between atmosphere and ocean, biota and ocean circulation, and are therefore essential measurements of any sea ice field campaign. In both programs, the thickness of snow and ice were measured in a number of different ways including drill-hole measurements across ice floes (Fig. 2.3-13), airborne altimetry and ship-based techniques such as electromagnetic induction, underway observations using the ASPeCt (www.aspect.aq/) protocol and downward-looking video cameras.

Satellite laser altimetry calibration and validation using a combination of in situ and aircraft-based measurements was a key goal of both programs. The schedule of NASA's Ice Cloud and land Elevation Sat-

Fig. 2.3-12. Dead krill on the beach at King George Island as a consequence of increased fresh water and sediment discharge. (Photo: Eva Philipp)

ellite (ICESat) was adjusted to ensure that the 33 day L3I mission of the onboard laser altimeter coincided with the two IPY field programs thus ensuring near-coincident field and satellite overpass data. The possibility of collecting coincident data in the field was, unfortunately, thwarted by bad weather, but regional calibration and validation studies were possible.

Under-ice measurements were made using a ROV during SIPEX to determine the abundance of algae under the ice, along transects marked out from the surface. Additionally, a Surface and Under-ice Trawl (SUIT) system was specially made to trawl for krill under ice floes adjacent to the ship's track.

Process studies formed an integral part of both the SIPEX and SIMBA programs, including the deployment of two arrays of GPS-tracked drifting buoys to measure ice drift and dynamics (SIPEX) and ice mass balance stations to measure *in situ* changes in ice and snow thickness over a 30 day period (SIMBA). Geophysical measurements assessed the presence of flooded sea ice; ice structure, including the presence of snow ice, was determined from laboratory analysis of sea ice cores. Biogeochemical analyses were conducted to measure, among other things, the accumulation of iron in the sea ice and the processes by which it is concentrated from the water column during ice growth. The brine channel structure of the ice and its importance for biological and biogeochemical processes was also examined using standard geophysical techniques.

Research highlights

The IPY programs afforded a rare opportunity to conduct coincident field studies in the Antarctic pack ice, on different sides of the continent. The results show that the sea ice in east Antarctica was more dynamic, swell affected and more heavily deformed in some areas than in west Antarctica where more compact, homogenous ice was encountered, particularly at the southern-most end of the ship transect. The *in situ* ice and snow thickness data show generally good agreement with the satellite data, but provide new insights into the buoyancy theory calculations used to calculate sea ice thickness from satellite freeboard measurements (Worby et al., in press; Xie et al., in press). In particular, the relationship between ice and snow thickness varies between the two study regions. Negative ice freeboards were common in both east and west Antarctica, as was the formation of flooded layers and snow ice, however, an empirical relationship equating mean freeboard to mean snow thickness appears to hold generally for west Antarctica, but not for the heavily ridged areas in east Antarctica. The regional differences in sea ice and snow thickness distribution, and their formation processes, indicate that a regionally (and perhaps seasonally) varying empirical relationship for converting satellite-derived snow freeboard to ice thickness must be developed. Field results from SIPEX showing the use of radar for measuring ice freeboard and the complications caused by internal layering of the snow cover have been reported by Willatt et al., (2010). Intrusions of warm air can cause surface melt and the subsequent formation of icy layers within the snow structure. These, in addition to the effects of floe ridging caused by larger-scale ice dynamics, also result in seasonal changes that must be taken into account when interpreting satellite altimetry data (Giles et al., 2009).

Stammerjohn et al., (in press) showed a regional and circumpolar assessment of sea ice conditions from satellite data during IPY that provides the contextual environmental setting for the field campaigns. The results show clearly how winds, sea ice drift, sea surface temperature and precipitation affected regional ice conditions during IPY. The *in situ* measurements reflect a number of these regional changes. For example, Meiners et al., (in press) shows for the SIPEX region in east Antarctica that bottom ice algal biomass has a wide range of values and is generally dominated by pennate diatoms. Chlorophyll A concentrations in the lower-most 0.1 m of the sea ice contributed, on average, 63% to the integrated sea ice standing stocks. Nevertheless, the results indicate that East Antarctic sea ice has generally low algal biomass accumulation due to a combination of effects, including low snow-loading, low porosity and a relatively early break-up that prevents the development of significant internal and surface communities. The more southerly, consolidated, less dynamic sea ice in the SIMBA region of west Antarctica was generally thicker and had a heavier snow cover (Lewis et al., in press).

A key research activity as part of IPY has been the development by the Australian program of an airborne imaging capability that integrates a laser altimeter, snow radar and digital camera with an inertial navigation system. The system is designed to fly in a helicopter and, when fully operational, will provide regional ice and snow thickness data over horizontal scales of tens of metres to hundreds of kilometres (Fig. 2.3-14). IPY has provided a genuine push in the development of the system, which provides an intermediate scale

Fig. 2.3-13. An ice thickness transect across an ice floe in East Antarctica out during the IPY project SIPEX onboard Aurora Australis, between 110°E and 130°E in September-October 2007. Sea ice and snow cover thickness were measured *in situ* and related to aircraft measurements. The black strip at the beginning of the transect is mesh sheet that acts as a radar reflector for the aircraft.
(Photo: Anthony Worby)

and resolution of data between highly localised *in situ* measurements and coarser resolution satellite data. The work conducted during IPY will be crucial for the calibration and validation of new satellite sensors, such as the radar altimeter aboard CryoSat-2 which came online during 2010.

Turner et al., (2009a) analysed sea ice patterns in relation to climate parameters to show that the growth in Antarctic sea ice extent, by around 1% per decade since the late 1970s, seemed to be controlled by a 15% increase in the strength of circumpolar winds, which were in turn driven by winds propagating down to the surface from the polar vortex around the ozone hole in summer and autumn. The stronger winds also accentuate the Amundsen Sea Low, which brings warm air south down the Antarctic Peninsula, melting or delaying the onset of sea ice there. These winds then pass over West Antarctica cooling as they go, to emerge cold over the Ross Sea where they cause sea ice to grow. The decrease in sea ice in the one area is more or less balanced by the increase in the other area.

Summary and Legacy

During IPY, the Southern Ocean was measured in a truly comprehensive way for the first time. IPY measurements spanned the circumpolar extent of the Southern Ocean, from the subtropical front to the Antarctic continental shelf. Many measurements (e.g. Argo, marine mammal tags and moored time-series) covered the full annual cycle. New technologies allowed many characteristics of the Southern Ocean to be measured for the first time, including ocean currents and properties beneath the sea ice, trace metal concentrations throughout the full ocean depth and the discovery of many new species. Perhaps most importantly, the IPY activities spanned all disciplines of Southern Ocean science, providing the integrated observations that are essential to address questions of high relevance to society, including climate change, ocean acidification and the future of the Southern Ocean ecosystem. The multi-disciplinary view of the state of the Southern Ocean obtained during IPY provides a benchmark against which past and future measurements can be compared to assess rates of change. This achievement was the result of the work of hundreds of scientists from numerous nations.

IPY aimed to determine the present environmental status of the polar regions; to understand past and present change in the polar regions; to advance our understanding of polar-global teleconnections; and to investigate the unknowns at the frontiers of science

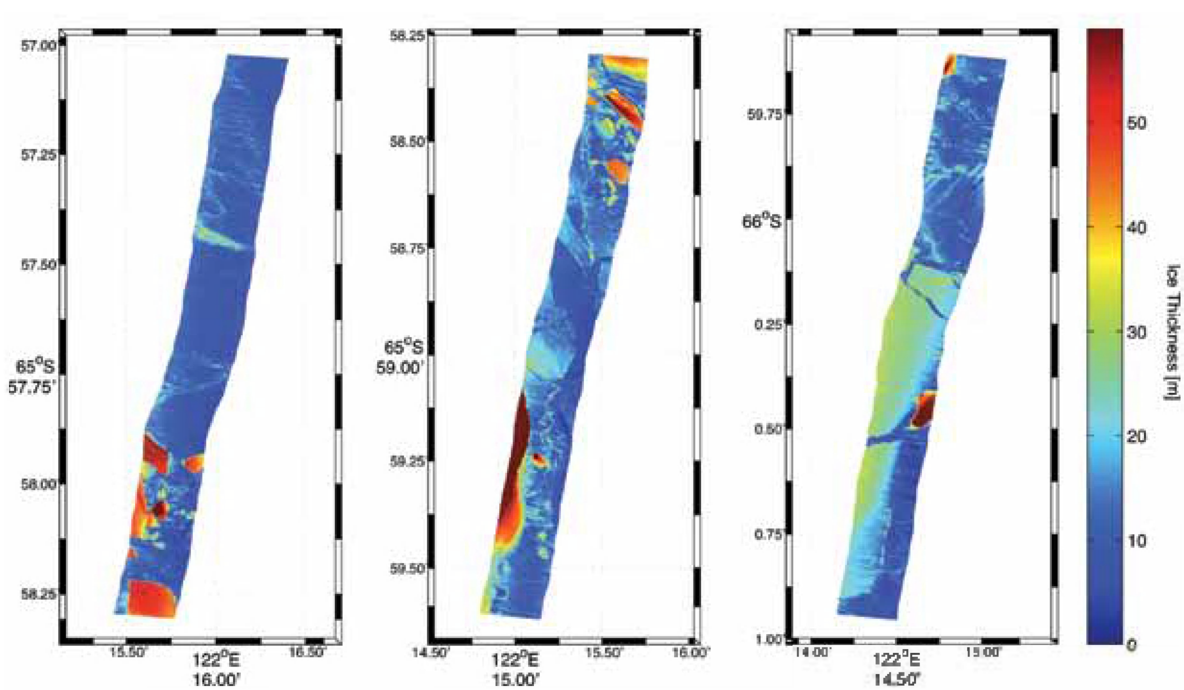


Fig. 2.3-14. Laser altimeter swath over Antarctic fast ice (and grounded icebergs) during the IPY SIPEX experiment, showing freeboard height (the height of the ice or snow surface above sea level).
(Graph: J. Lieser)

in the polar regions. Southern Ocean IPY has made a significant contribution to achieving all four of these aims. Much of the research in the Southern Ocean has been closely coordinated with similar activities in the Arctic, which together provide the integrated bipolar perspective required to address the goals of IPY.

Southern Ocean IPY leaves a number of legacies. First and foremost, Southern Ocean IPY has demonstrated that an integrated, multi-disciplinary, sustained observing system is feasible, cost-effective and urgently needed (Rintoul et al., 2010a,b; Turner et al., 2009b). Other legacies include a circumpolar snapshot to serve as a benchmark for the assessment of past and future change; models capable of simulating interactions among climate, ecosystems and biogeochemical cycles, providing vastly improved projections of future change; a well-integrated interdisciplinary and multi-national polar research community; and inspiration to a new generation of polar researchers.

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2.4 Greenland Ice Sheet and Arctic Glaciers

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Background

The Arctic Climate Impact Assessment (ACIA, 2005), which was released at the time that IPY 2007–2008 was being planned, provided an exhaustive compilation of the ongoing warming in the Arctic and the consequent decrease in sea ice, increased surface melt on the margins of the Greenland Ice Sheet, shrinking Arctic glaciers, degradation of permafrost, and many impacts on ecosystems, animals and people. The Arctic was observed to be warming much faster than temperate regions of the planet, possibly because of the positive surface albedo feedback whereby reduced sea ice, in particular, increases solar heat absorption. There were indications that, in the decade prior to IPY, the rate of reduction of many Arctic terrestrial ice masses had accelerated.

The IPY *Framework* document (Rapley et al., 2004) clearly identified determination of the status and change to Arctic ice as a key objective. The total terrestrial ice volume in the Arctic is estimated at 3.1 million km^3 (Dowdeswell and Hagen, 2004), or about 8 m of sea level equivalent, most of which is in the Greenland ice sheet, the largest body of freshwater ice in the Northern Hemisphere. Greenland will be highly susceptible to continued warming over coming decades and centuries, and quantification of the ice sheet mass balance and the consequent changes to global sea level were a key goal of IPY.

Improved estimates of the Greenland mass balance would be based upon a variety of techniques including large-scale surface and airborne observational projects, in conjunction with space observations. Satellite-borne sensors would provide a unique snapshot and new satellite systems available during IPY included the laser altimeter on ICESat and the Gravity Recovery and Climate Experiment (GRACE) satellite mission. Airborne and over-snow surveys would also image ice sheet internal features and, together with the ground measurements, could be used to link the data records from the major deep ice core sites on the ice sheet. Automatic instruments would be deployed in remote regions by air or during over-snow surveys.

As noted above, the future response and stability of Greenland to ongoing warming need to be better understood to project future global sea level rise. Warming above a certain "threshold" level will cause the surface mass balance of the ice sheet to become negative every year, with more mass lost by surface melt than is gained from snowfall. The ice sheet would thus thin and reach a state of "irreversible" decline. This mass loss from surface processes could be compounded by increased ice discharge to the ocean. Over the past decades, many of Greenlands fast-flowing glaciers and ice streams have accelerated dramatically, with observations showing that ice discharge can double within one to two years, and may also be slowed. The dynamic processes controlling the discharge are poorly understood, but possible causes are the impact of relatively warm ocean currents on the stability of glacier termini and the effect of surface melt water penetrating to the glacier base and enhancing ice flow by lubrication. These issues were also identified as IPY topics.

The Greenland Ice Sheet contains an important archive of palaeoclimatic information within the ice. Previous deep ice core drilling and analysis programs in Greenland have provided an outstanding record of so-called Dansgaard-Oeschger events; very abrupt, millennial-scale, climatic shifts that occurred during the last glacial period. Understanding the cause of these events has implications for predicting future change. Nevertheless, none of the previous ice cores from Greenland provided an undisturbed climate record of the last interglacial, the Eemian, which occurred between about 115,000 and 130,000 years ago and was warmer in the Arctic than our present interglacial period. Obtaining a record of this period from Greenland was an important IPY target.

About 50% (in number) of all world glaciers and ice caps are found in the Arctic and, although the surface area of the Greenland ice sheet is about four times the area of all other Arctic glaciers and ice caps, the smaller ice masses are generally at lower elevation and have warmer mean annual temperatures, and so are susceptible to greater percentage mass loss in response to warming. Globally, glaciers and ice caps, including those surrounding the Greenland and Antarctic ice sheets, store ~ 0.5 to 0.7 m of sea level equivalent, and are currently contributing at about the same rate to sea level rise as the combined contributions from the ice sheets in Greenland and Antarctica (IPCC, 2007). They will continue to contribute into the 21st century and beyond. Many of the Arctic glaciers and ice caps terminate in the oceans and 30-40% of their mass loss is from iceberg calving. Nevertheless, the uncertainty both in the surface mass balance and the calving fluxes of the Arctic glaciers is still large. Hence, IPY aimed to obtain baseline glaciological data on extent, dynamics and mass balance of the irregularly distributed Arctic ice masses in regions such as Alaska, the Canadian Arctic, Iceland, Svalbard, Franz Josef Land, Novaya Zemlya, Severnaya Zemlya and northern Scandinavia. The variations in space and time of the monitored ice bodies in polar and mountain regions could then be extrapolated to estimate regional contributions to sea level change and linked to the global hydrological cycle.

Developing Greenland and Arctic Glacier IPY projects

The ICSU-WMO call for "Expressions of Intent" (EoI) for IPY projects elicited approximately 30 EoIs between November 2004 and January 2005 which were focused on the terrestrial ice masses of the Arctic. These can be broadly categorized into five groups.

- Characteristics and status of the Greenland ice sheet. This group included EoIs 74, 94, 581, 607, 883, 933, 951 and 1120.[1] Two geoscience EoIs, 763 and 784, were also linked to this group as they planned to share logistics to explore the geophysics of Greenland, including characteristics of the bedrock beneath the ice sheet.
- Future response and stability of Greenland. This included EoIs 69, 136, 187, 245, 334, 381, 418 and 765.
- The record of past environments from Greenland ice cores; EoIs 62, 203 and 561.
- Satellite remote sensing of the Greenland ice sheet; EoI 910, which was bipolar and also included study of the Antarctic ice sheet.
- Changes to Arctic glaciers and ice caps; EoIs 30, 233, 654, 684, 756 and 1007.

Over the next several months the proponents of these EoIs, encouraged by the IPY Joint Committee and the International Programme Office, worked to combine their ideas and resources into larger full IPY proposals. Ultimately, seven full proposals that dealt with the Arctic ice sheets and glaciers were endorsed by the IPY Joint Committee (JC) in 2005–2006 (Allison et al., 2007; *Chapter 1.5*).

Two of these (no. 91 and no. 125 - see below) were satellite remote sensing projects that also included investigation of the Antarctic, and two were "umbrella" projects submitted on behalf of international organizations. These latter projects, which generally did not propose specific research activities but sought to synthesize the results of other relevant projects in the Arctic and Antarctic, were no. 105 (State and Fate of the Polar Cryosphere) linked to the WCRP Climate and Cryosphere (CliC) Project, and no. 117 (International Partnerships in Ice Core Science - International Polar Year Initiative) linked to the International Partnerships in Ice Core Science.

IPY projects on the Greenland ice sheet

IPY project no. 118 (The Greenland Ice Sheet – Stability, History and Evolution), led by scientists from Denmark and U.S.A., was a very large and multi-faceted study that linked palaeoclimate, observational and modelling components to investigate past and future stability of the Greenland Ice Sheet, ice dynamics, sea level change and change in fresh water supply to the ocean, which affects the global thermohaline circulation of the ocean. Airborne measurements with a radar capable of array processing in the cross-track direction and synthetic aperture radar (SAR) processing in the along-track direction for sounding of ice and imaging the ice-bed interface, and scanning laser ranging (lidar), were planned to provide baseline measurements of the discharge of ice from outlet glaciers around the margin of the Greenland Ice Sheet. These measurements would also allow detection of elevation changes by comparison to earlier airborne missions and to satellites (CryoSat, ICESat). Automatic weather and mass balance stations were to be located on the ice in order to relate mass balance changes with meteorological conditions and to investigate the ablation processes in detail. In addition, the radar profiles would be used to map the melting under the ice in north Greenland and under the fast moving glaciers and ice streams, allowing inclusion of basal melt in the mass balance of the ice sheet. Traverses and field camps were proposed to collect GPS and geophysical data (magnetic, gravity), seismic profiles, and borehole logging and ice drilling along air survey routes. Combined with satellite data, they would be used to determine the crustal structure in Greenland and history of the sub-ice bedrock and sediments, and hence to map the heat flow and basal melt beneath the ice sheet. The dynamics of the ice stream Jakobshavn Isbrae, which has recently accelerated, was to be investigated using borehole instrumentation reaching to the base. Detailed studies of the response of ice dynamics in West Greenland to changes in surface melt through the penetration of runoff to the glacier bed were also proposed (Fig. 2.4-1).

The North Eemian Ice Core Project (NEEM) was a major component of the overall work plan of "The Greenland Ice Sheet – Stability, History and Evolution" project. NEEM aimed at retrieving an ice core from northwest Greenland (77.45°N, 51.06°W) reaching back through the previous interglacial, the Eemian, during part of which the Arctic was warmer than the Holocene, thus offering an analogy for the conditions expected in the Arctic due to an anthropogenically-warmed world. It was also hoped that the Holocene period from this deep ice core would provide a better isotopic record of the present climate than those from

Fig. 2.4-1. Surface melt water penetrating the interior of the Greenland Ice Sheet via a moulin. (Photo: K. Steffen)

other Greenland ice cores. The deep NEEM core was to be supplemented with a series of shallow to intermediate length ice cores providing information on the climate during the last thousand years. Many of these were planned at existing core sites, which would be revisited, to extend the available climate records from these up to modern times with new shallow cores.

Another endorsed IPY project focused on the Greenland Ice Sheet was called 'Measurement and Attribution of Recent Greenland Ice Sheet chaNgeS' (MARGINS, IPY no. 339), led by researchers from the U.S.A. and U.K. This sought to improve communication, coordination and collaboration among a diverse collection of proposed research initiatives, which were aimed at understanding the changes in surface elevation and discharge speed in outlet glacier systems along the margins of the Greenland Ice Sheet. These studies covered a range of activities from expansions of ongoing efforts to new projects, from individual investigators to consortia of several nations, and a range of observational and modeling techniques exploiting evolving capabilities in atmospheric modeling, remote sensing for measurement of ice motion and surface conditions, and surface-based and aircraft-based measurements.

IPY 2007–2008 occurred at a time when new sophisticated and dedicated space-borne instruments were available to directly detect changes to the Greenland and Antarctic ice sheets by measuring gravitational and surface elevation changes. These missions had been initiated well before IPY and, although the scientists involved in these worked closely with those IPY projects making *in situ* ice sheet observations, they did not generally seek IPY endorsement. One exception, however, that did seek and receive IPY endorsement was the project "Antarctica & Greenland ice and snow mass balance by GRACE satellite gravimetry" (IPY no. 125) led by France.

Nevertheless, a very significant contribution to IPY was the coordination of diverse satellite observations made within the 'Global Inter-agency IPY Polar Snapshot Year' project (GIIPSY, IPY no. 91). The objective of GIIPSY was to coordinate space-borne observation of the polar regions and polar processes in order to maximize the scientific benefit and to obtain a benchmark of processes during IPY. The GIIPSY science community was linked to national and international space agencies through the Space Task Group (STG) of the IPY Subcommittee on Observations (*Chapter 3.1*). The GIIPSY project aimed to target satellite data acquisitions towards those science problems best served by a focused, time-limited data campaign and by the availability of diverse but integrated observations. A primary data acquisition objective was to obtain pole-to-coast multi-frequency interferometric SAR measurements for determining the ice surface velocity over Greenland and Antarctica. GIIPSY planned to contribute to other IPY activities by making the resulting data and derived products available to the international science community.

IPY projects on Arctic glaciers and ice caps

The status of, and changes to, Arctic glaciers and ice caps were addressed by the project 'The dynamic response of Arctic glaciers to global warming' (GLACIODYN, IPY no. 37), coordinated by the Netherlands and Norway. The overall aim of GLACIODYN was to reduce the uncertainties in estimates of the contribution of Arctic glaciers and ice caps to sea level change.

A key question was to what extent a warmer climate may also change the dynamics of the glaciers and not only near-surface processes such as snow accumulation, refreezing both internally and of superimposed ice, and ablation. This involves including iceberg calving in mass budget calculations, improving understanding of calving and basal sliding processes and including dynamics in modeling the future response of glaciers. The specific objectives to achieve this were to: (1) study the current mass budget of selected target glaciers, including the surface mass balance and the calving flux where applicable; (2) study sub-glacial processes such as sliding and basal hydrology; (3) study calving processes; (4) include the dynamics in modeling of future response; and (5) predict future changes of the ice cap or glacier.

Predictions of future mass balance and dynamic response require knowledge of boundary conditions such as the thermal structure of the ice, the surface mass balance, meteorological data, surface and bed topography, and ice flow. These were addressed by field and remote sensing investigations.

The GLACIODYN proposal was based on an already established network of glaciologists who were members of the IASC Working Group on Arctic Glaciology (IASC-WAG; now called the IASC Cryosphere WG). The annual IASC-WAG meetings and subsequent GLACIODYN workshops were the main venues for discussion of results, planning of combined fieldwork and shaping of the output. A GLACIODYN workshop has been held every year during and since IPY.

Research groups from 17 countries contributed to GLACIODYN. However, the funding was derived from national research councils and varied considerably from country to country. Strong support was received in Canada, The Netherlands, Norway, Denmark, Russia and Poland, with more limited support in Sweden, Finland, Germany, U.K., Iceland and U.S.A., however, all 17 countries contributed in some way to the project.

IPY field and analysis activities of Arctic terrestrial ice, 2007–2010

The Greenland ice sheet

Numerous resources were allocated to augment our understanding of the mass and energy balances of the Greenland ice sheet through improved data on snow-ice accumulation, run-off and bottom melting as well as iceberg production. In 2007, 19 different field teams were deployed and active on the ice sheet; 13 of them funded by the National Science Foundation and headed by U.S. scientists, and six funded by Europe and headed by scientists from Denmark, United Kingdom, Norway and the Netherlands.

In addition, NASA regularly made low-level flights with laser altimeters over the ice sheet to update data on ice volume changes. The U.S., Denmark and Greenland shared efforts to operate more than 20 automatic, satellite-linked weather stations that monitor and record climate parameters on all parts of the ice sheet (Fig. 2.4-2).

An increasing research focus was directed to the surging glaciers in southeast Greenland and, in particular, to Ilulissat Glacier that had shown remarkable change in the five years prior to IPY. Research teams from the U.S., Germany and Denmark measured the ice stream dynamics, mapped the morphology of the extensive sub-glacial trough beneath the trunk, calculated the annual discharge and the catchment area, and modelled how this unique glacier may behave in the future.

Scientists from 14 nations participated in the NEEM ice coring activity, the most international ice core effort to date. More than 300 ice core researchers, including many young scientists, rotated through the NEEM camp during the four years of field operations. Like all deep ice coring projects, NEEM was a multi-year effort requiring massive logistic support. In

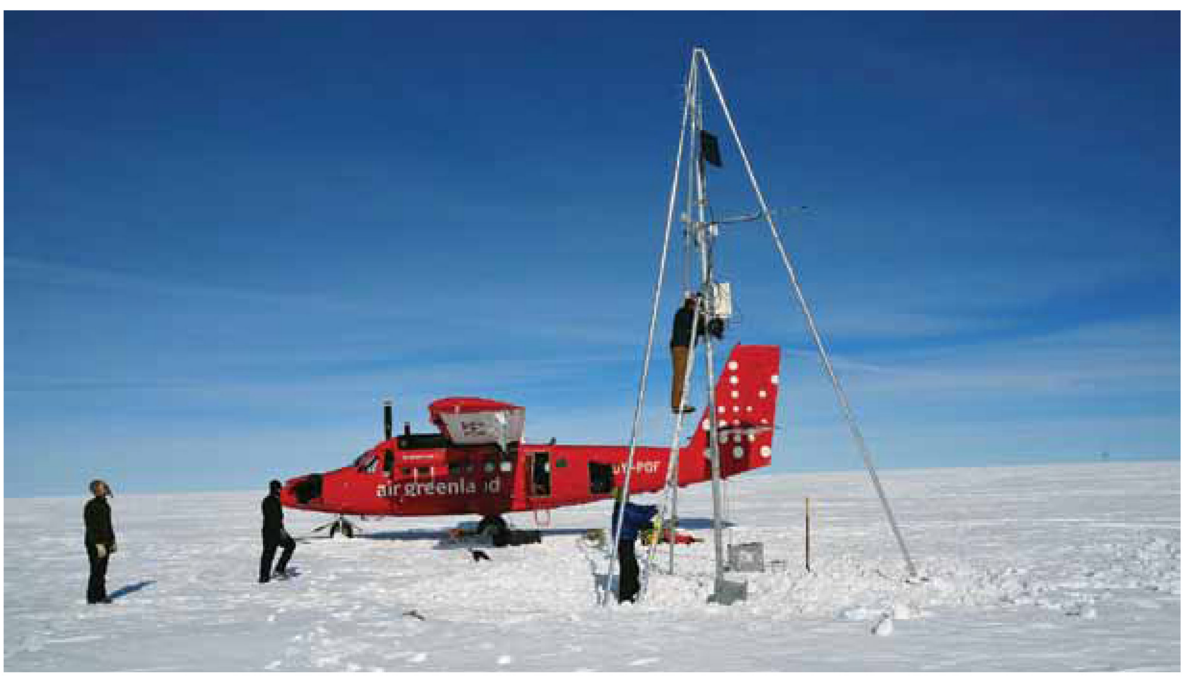


Fig. 2.4-2. Deploying an automatic weather station on the Greenland ice sheet during IPY.
(Photo: K. Steffen)

Fig. 2.4-3. The newly completed NEEM camp, August 2008.
(Photo: NEEM ice core drilling project, www.neem.ku.dk)

Fig. 2.4-4. Drilling a shallow ice core near the NEEM site on the Greenland Ice Sheet, July 2008.
(Photo: NEEM ice core drilling project, www.neem.ku.dk, Henning Thing)

July 2007, the first IPY year, an international traverse team transferred heavy equipment from a previous Greenland deep drilling site (NGRIP) to the NEEM site. They undertook radar and GPS surveys and collected shallow ice cores along the route, and made a detailed radar survey over a 10-km by 10-km area to locate the best site for the NEEM core. A seed camp and a skiway were constructed at the chosen site. In 2008, the living, drilling and core analysis facilities were established at the NEEM site (Fig. 2.4-3). Shallow test cores were collected at the NEEM site in the 2008 season (Fig. 2.4-4), but it was not till mid May 2009, after the end of the formal IPY fieldwork and observation period that the deep ice coring commenced at NEEM. Drilling continued more or less continuously throughout the 2009 season and by the end of the season in October, the borehole depth had reached 1758 m. Bedrock was not finally reached, at 2537 m depth, until 27 July, 2010. The full core contained ice from the warm interglacial Eemian period, 130,000 to 115,000 years before present, and even older ice was recovered. The bottom 2 m of ice contained rocks and other material that has not seen sunlight for hundreds of thousands of years, and is expected to be rich in DNA and pollen that can tell us about the plants that existed in Greenland before the site became covered with ice, perhaps as long as 3 million years ago.

Detailed measurements were made on the NEEM core in a sub-surface science trench as the core was extracted. State-of-the-art laser instruments for water isotopes and greenhouse gases, online impurity measurements and studies of ice crystals are among the impressive instruments deployed at the NEEM site, at one of the most inaccessible parts of the Greenland ice sheet. Full laboratory analysis of the NEEM ice core, however, has only just commenced.

In September 2007, a survey of the ice sheet was conducted out of Thule and Sondrestrom from a NASA P-3B (Orion) aircraft as a part of the NASA Instrument Incubator Program and as a continuation of NASA measurements to monitor the Greenland ice sheet. A 150/450 MHz ice radar system, developed by the Center for Remote Sensing of Ice Sheets (CReSIS) at the University of Kansas, was used to conduct this survey, with six receiving antennas and two transmitting antennas, which enabled formation of interferometric SAR images with variable baselines. The project was a collaborative effort between the Ohio State University, the Jet Propulsion Laboratory, VEXCEL Inc. and the University of Kansas, and was aimed at demonstrating the concept of sounding ice and imaging the ice-bed interface with orbital radars. The aircraft was flown at altitudes as high as 6700 m above sea level and as low as 500 m above the ice sheet surface. Flight lines were designed to capture surface clutter conditions across outlet glaciers discharging into the ocean, down the length of the floating portions of Petermann and Jakobshavn glaciers, and to cross from the wet percolation facies of the ice sheet into the dry snow zone. A flight extending from Camp Century to Dye-2 passing over the NEEM, NGRIP, GISP-2, GRIP and DYE-2 ice-core sites was also conducted with the primary objective of connecting all the deep ice cores with the radar operating at 150 MHz. The 2007 flight lines are shown in Fig. 2.4-5.

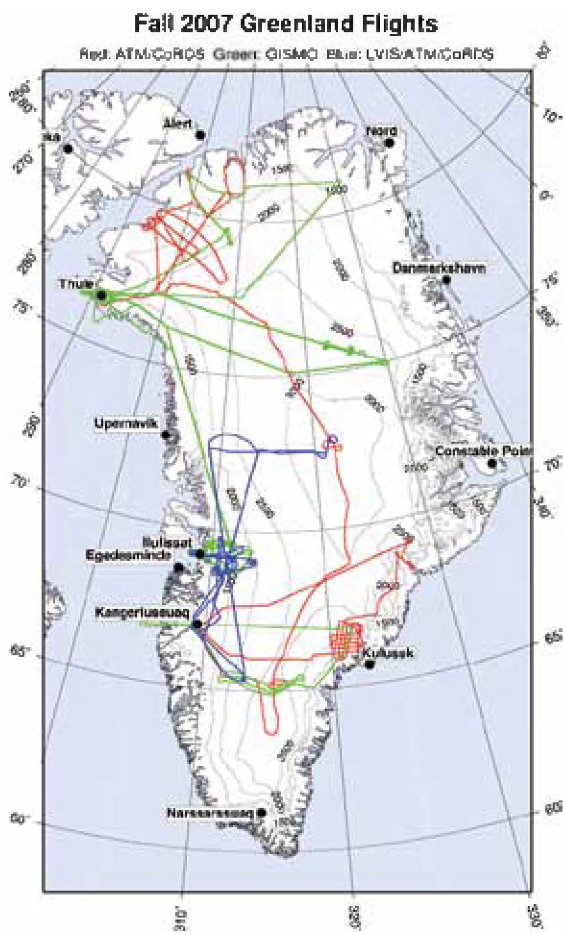


Fig. 2.4-5. Greenland aerial radar survey lines in 2007 (IPY no. 118). The red central flight line, extending from Camp Century to Dye-2, was flown to obtain radar data to connect ice cores.
(Courtesy: Center for Remote Sensing of Ice Sheets, U. Kansas)

In July-August 2008, a Twin Otter aircraft fitted with the CReSIS radars and a NASA Airborne Topographic Mapping laser system was deployed to Ilulissat, Greenland. This undertook an extended survey of the Jakobshavn Isbræ (Fig. 2.4-6) which involved 88.9 flying hours and the collection of 9.0 Terabytes of data along more than 19,000 kilometers of survey grid. Despite severe surface melt conditions, the radar was able to map the basal channel of the ice stream. This survey was supplemented with additional Twin Otter flights during April 2009 over three major outlet glaciers — Jakobshavn, Helheim and Kangerdlugssuaq — to more accurately define the bed topography. The data collected during 2007-2009 over these glaciers have been combined with earlier measurements made as a part of the NASA Program for Arctic Climate Assessment (PARCA) to produce bed topography maps for these glaciers. Figs. 2.4-7 and 2.4-8 show the resulting bed maps for Jakobshavn and Helheim glaciers, respectively.

A small, surface survey grid around the NEEM coring site was made with sled-mounted InSAR radar to map the ice sheet bed in order to ensure the suitability of the drilling site for obtaining undisturbed Eemian ice. These data are processed to generate the 3-D topography of the ice bed (Fig. 2.4-9). Surface radar traverses were also made toward the NGRIP and Camp Century former drilling sites.

Arctic glaciers and ice caps

The GLACIODYN project identified a set of target glaciers for intensive observations (*in situ* and from space) for the period 2007-2010 (Fig. 2.4-10). These glaciers covered a wide range of climatic and geographical settings and took maximum advantage of prior long-term studies. The target glaciers were:

- Academy of Sciences Ice Cap (Severnaya Zemlya, Russia)
- Glacier No. 1 (Hall Island, Franz Josef Land, Russia)
- Austfonna (Svalbard, Norway)
- West Svalbard tidewater glaciers: Hansbreen, Kronebreen (Fig. 2.4-11), Kongsvegen, Nordenskiöldbreen, Norway
- North Scandinavia transect: Langfjordjøkelen, Storglaciären, Marmaglaciären (Norway and Sweden)
- Vatnajökull, Hofsjökull and Langjökull icecaps (Iceland)
- Kangerlussuaq basin (West Greenland)
- Hellheim Glacier (East Greenland)
- Devon Ice Cap (Canada)
- McCall Glacier (Alaska, U.S.A.)
- Hubbard Glacier and Columbia Glacier (Alaska, U.S.A.).

Since the funding varied in different countries the field programs on these glaciers also varied in scope.

The two large ice caps, Devon Ice Cap (14,400 km^2) in the Canadian Arctic and Austfonna Ice Cap (8,000 km^2) on Svalbard were both studied in detail for the first time. These are two of the largest ice masses outside the polar ice sheets. Similar field programs were conducted on both ice caps, and included measurements of surface mass balance by ablation stakes, snow cover distribution by ground penetrating radar, topography changes by surface GPS profiles combined with airborne data and satellite data, and ice dynamics studied by ground GPS-stations running continuously year round combined with remote sensing data (Fig. 2.4-12). Both ice caps were also selected as calibration/validation sites for the new ESA CryoSat II altimetry satellite that was launched in April 2010 and these investigations continue beyond IPY. An analysis of changes since the IGY in the extent of all Yukon Glaciers, Canada, was also made as part of the "State and Fate of the Cryosphere" project (IPY no. 105).

Russian scientists contributed to the work of GLACIODYN through three sub-projects. The subproject *Current state of glaciers and ice caps in the Eurasian Arctic* investigated the area changes, mass balance, hydrothermal state and potential instability of glaciers and ice caps in the Russian Arctic islands and Svalbard. The main fieldwork during IPY included airborne and surface radio echo-sounding surveys of ice thickness, bedrock and surface topographic surveys of ice caps and glaciers, which were supported by analysis of satellite remote sensing data. The subproject *Formation, dynamics and decay of icebergs in the western sector of the Russian Arctic* collected new data on the formation, distribution and properties of icebergs in the Barents and Kara Seas, and estimated the current state of outlet glacier fronts in the Russian Arctic archipelagos. In September 2007, iceberg-producing glaciers on Franz Josef Land, Novaya Zemlya and some other islands were surveyed from the Russian research vessel *Mikhail Somov*. Helicopter

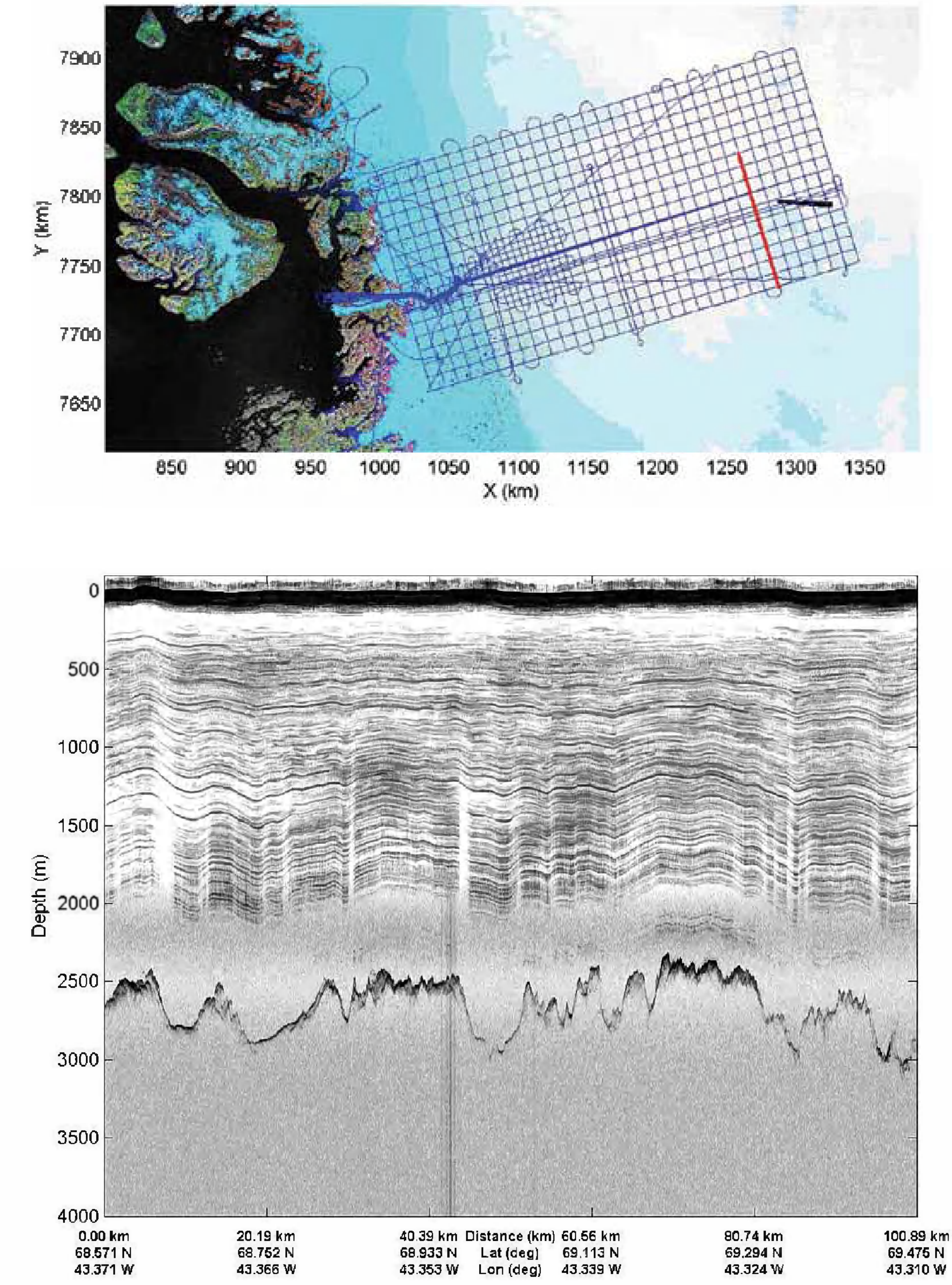


Fig. 2.4-6. Grid over which data were collected for Jakobshavn Isbræ during 2008 (top) and a sample echogram for one of the flight lines highlighted in red (bottom).

(Courtesy: Center for Remote Sensing of Ice Sheets, U. Kansas)

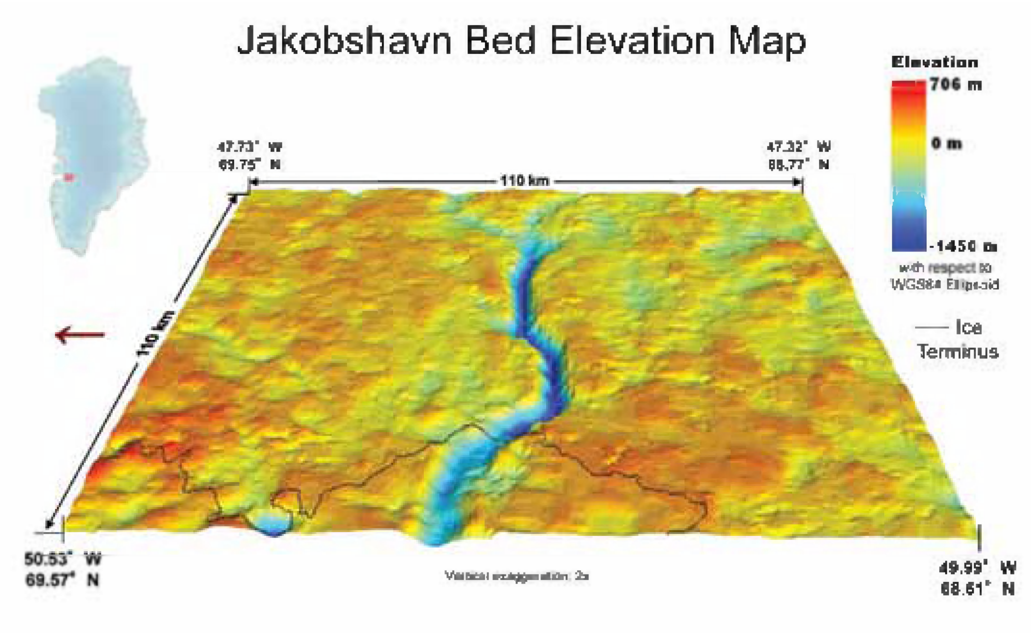


Fig. 2.4-7. Bed topography map for Jakobshavn Isbrae generated by combining 2008 and 2009 radar data with other data sets [Plummer et al., in review].
(Courtesy: Center for Remote Sensing of Ice Sheets, U. Kansas)

radio echo sounding and aerial photography surveys were made of glaciers across the Franz Josef Land archipelago, on Prince George Land, Salisbury Island, Luigi and Champ Islands, Hall Island and Wilczek Land. Observations were also made on some glaciers of ice movement, the vertical distribution of ice temperature (down to 20 m depth) and surface energy balance. The glaciological studies were supplemented with oceanographic temperature and salinity profiling in the Franz Josef Land straits. A similar survey, which was repeated in fall 2008, was undertaken of the glaciers of the northern end of the Northern Island of Novaya Zemlya (Buzin et al., 2008). Another Russian sub-project, *Climatic factors in the contemporary evolution of Northeast Siberia glaciations,* continued studies of climate–glacier interactions in the poorly explored region of Northeast Siberia. The climate of this region is influenced by both Atlantic and Pacific air masses. Climatic changes such as weakening of the Siberian High, increase of surface temperature and changes in the cryosphere have recently been detected there.

In Iceland, a major IPY activity involved digital terrain mapping of the surface topography of Icelandic ice caps with lidar. The results from this work, which continues after IPY, will be used to compare photographic maps from 1990s to quantify the ice volume changes that have occurred to these ice caps over the last 10-20 years.

Research Highlights

The Greenland ice sheet

Since 1985, West Greenland has experienced a warming of 2 to 4°C, primarily driven by winter temperature anomalies. The few and scattered direct climate records from observations on the Greenland Ice Sheet also reveal a warming trend since 1985. As a result, the mass balance of the Greenland Ice Sheet has changed. The high interior parts of the ice sheet have thickened because of the increased snowfall, with the area above 2000 m elevation having gained an average of 5 (±1) cm in altitude each year since 2000. This has added 60 (±30) Gt of mass to the ice sheet annually.

Nevertheless, this mass gain is more than offset by the increased loss of ice mass from melting and by discharge into the ocean. About half of the total mass loss from the Greenland Ice Sheet is caused by surface melt and run-off, but the area experiencing surface melting has increased significantly in extent since 1979. The annual net gain in surface mass (snowfall minus mass lost by melt), has a 50-year average value of 290 Gt, but has been reduced by 45 Gt over the past 15 years, a trend that is above the background variability caused by normal fluctuations in climate. Mass is also lost at the margin of the Greenland Ice Sheet, mostly from fast-flowing outlet glaciers and ice streams that discharge into the ocean. Many of these have experienced accelerated flow and the annual mass loss through ice discharge has increased by 30%, from 330 Gt in 1995 to 430 Gt in 2005.

The total loss in ice sheet mass, the difference between net surface mass balance and ice discharge, has increased in recent years from 50 (±50) Gt/yr in the period 1995-2000, to 160 (±50) Gt/yr (equivalent to 0.44±0.14 mm/yr of sea level rise) in the period 2003-2006.

An improved regional atmospheric climate model, with a horizontal grid spacing of 11 km and forced by ECMWF re-analysis products, has been developed to better represent processes affecting ice sheet surface mass balance, such as melt water refreezing and penetration (Ettema et al., 2010). This was used to simulate 51 years (1957–2008), and the temporal evolution and climatology of the model was evaluated against *in situ* coastal and ice sheet atmospheric measurements of near-surface variables and surface energy balance components. The model has been shown to be capable of realistically simulating the present-day near-surface climate of Greenland, and is a suitable tool for studying recent climate change over the ice sheet.

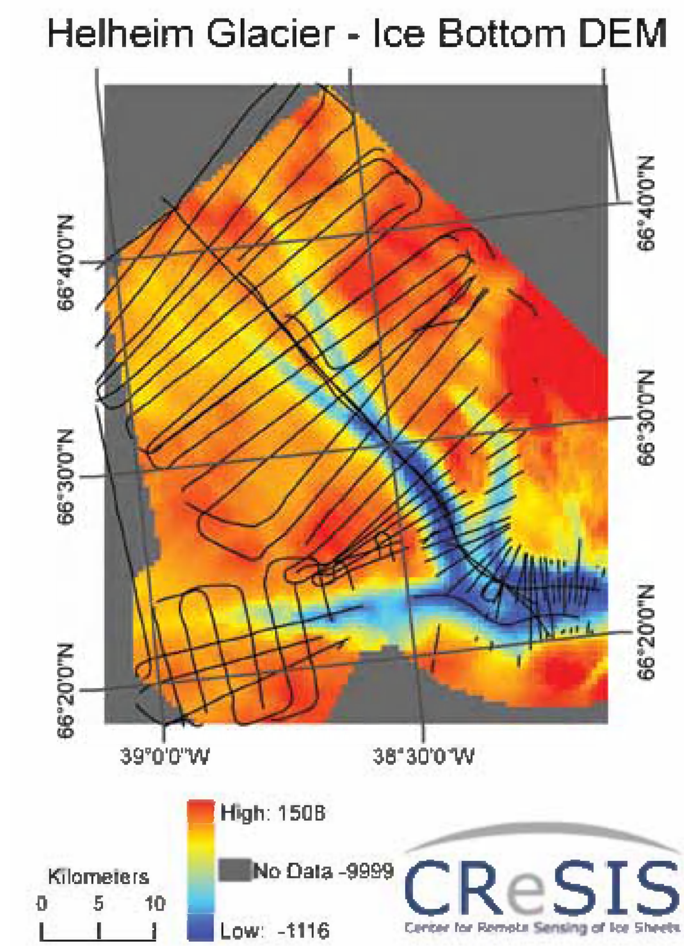


Fig. 2.4-8. Ice-bed topography for the Helheim Glacier with superimposed flight lines over which discernable bed echoes were obtained. These data were collected from a Twin Otter aircraft by CReSIS during April 2009.

(Courtesy: Center for Remote Sensing of Ice Sheets, U. Kansas)

Projections of the future response of the Greenland Ice Sheet to climate warming indicate that the loss of mass will increase. The IPCC climate scenarios for the high Arctic region predict temperature increases around 50% higher than those predicted globally (IPCC, 2007). This will increase the length and intensity of the summer melt season and so will increase the extent of the area experiencing summer melt. Current climate models estimate that Greenland's surface mass balance will become negative with a global warming of 3.1 ± 0.8 °C (a warming over Greenland of 4.5 ± 0.9 °C). Current projections with coupled ice sheet and climate models indicate an annual average mass loss of the order of 180 Gt for the 21st century, equivalent to a 5 cm sea level rise by 2100, primarily due to increased melting and run-off. First attempts to include in the models the increasing ice discharge via the marine outlet glaciers have predicted an additional 4.7 cm of sea level rise by 2100.

Nevertheless, new studies on previously collected ice core records indicate that the Greenland ice sheet melted much more rapidly as a result of warmer temperatures in the recent past than previously estimated. The ice sheet lost 150 m in height at its centre and shrank by 200 km at the edges during an unusually warm period between 9000 and 6000 years ago when temperatures were 2–3 °C warmer than today (Vinther et al., 2009). Present ice sheet models do not show this behavior and future warming could have more dramatic effects on the ice than estimated. The NEEM ice core record from the warmer Eemian period should help to further resolve this response of the ice sheet.

With sustained warming over Greenland, the ice sheet will likely contribute several meters to sea level rise over the coming millennium.

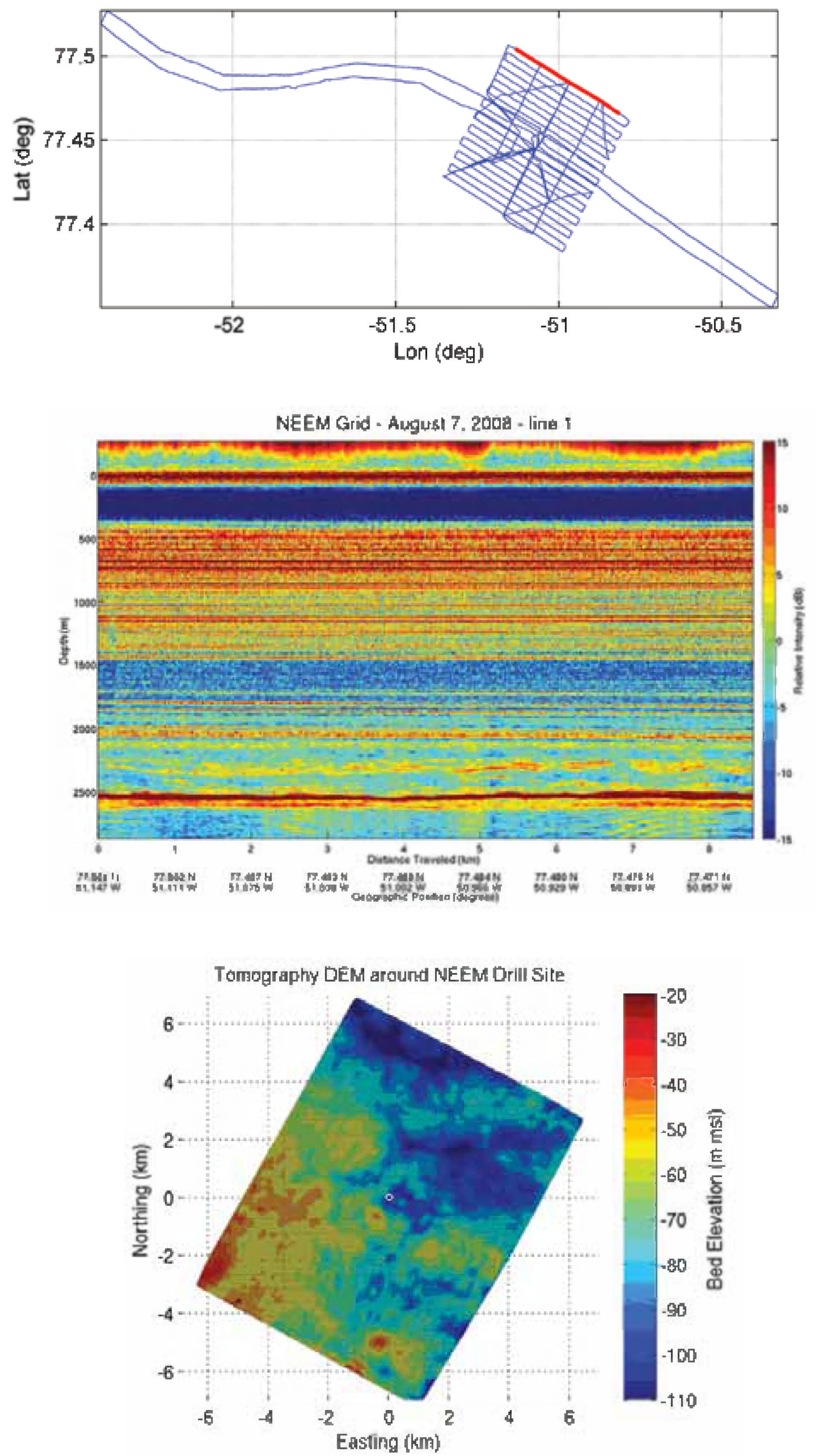


Fig. 2.4-9. The grid over which data were collected at the NEEM drill site (top); an echogram generated with traditional processing of data collected over one of the grid lines (middle); and a 3-D topography derived from array and SAR processing techniques described in Paden et al., [2010] (bottom). The drill site is marked by a circle in the bottom figure. (Courtesy: Center for Remote Sensing of Ice Sheets, U. Kansas)

The wealth of satellite data collected under coordination of the IPY GIIPSY project is now enabling new SAR image mosaics, interferometrically derived ice sheet velocity fields at various frequencies, and high-resolution SPOT Digital Elevation Models for Greenland to be produced and distributed.

Arctic glaciers and ice caps

The Arctic glaciers and ice caps in most regions are experiencing strong thinning at low elevations, while the pattern at higher elevations varies from slight thinning to slight thickening (Moholdt et al., 2010a, b; Nuth et al., 2010). There are also examples of local anomalous elevation changes due to unstable glacier dynamics such as glacier surging (Sund et al., 2009).

For the Austfonna ice cap on Svalbard, the net surface mass balance is slightly negative (-0.1 m water eq. yr^{-1}), but less negative than for the westerly ice masses in Svalbard (Moholdt et al., 2010a). Iceberg calving is important and contributes 30-40% of the total mass loss, so the overall mass balance is a loss of ~2 Gt yr^{-1} (Dowdeswell et al., 2008), however, the elevation change measurements on Austfonna show a thickening in the interior of ~ 0.5 m yr^{-1}, and an increasing thinning closer to the coast of 1-2 m yr^{-1}, indicating a large dynamic instability (Dunse et al., 2009; Moholdt et al., 2010a). This dynamic instability is not seen on the Devon Ice cap.

Results from several IPY related research projects have contributed significantly to characterizing short- and long-term variations in the flow of several major tidewater glaciers in the Canadian high Arctic. RADARSAT-2 Fine and UltraFine beam mode data acquired over the Devon Ice Cap since early 2009 reveal sub-annual cycles of alternating accelerated/reduced flow along the upper/lower reaches of Belcher Glacier. Analysis of the LandSat image archive over major outlet glaciers that drain the Devon Ice Cap and Manson and Prince of Wales Ice Fields, indicates significant (up to a factor of 4) inter-annual variability in tidewater glacier velocities since 2000. Some, but not all, of this is surge-related. Repeat mapping of glacier velocity fields over the Devon Ice Cap from 1995 ERS 1/2 and RADARSAT-1 data and 2009 RADARSAT-2 Fine beam data indicates that (within limits of error) there has been no net change in ice discharge from the ice cap as a whole over this period of time. Finally, annual glacier velocity measurements derived from RADARSAT-1 and RADARSAT-2 Fine beam data indicate a net decrease in the rate of flow of 11 target glaciers across the Queen Elizabeth Islands between 2000 and 2010. This trend was driven primarily by a few surge-type glaciers entering the quiescent mode of glacier flow. Ongoing IPY related glaciological research in Canada is focused on understanding linkages between external climate forcing and glacier dynamics and the impact of changing glacier dynamics on the net mass balance and geometry of ice caps in the Canadian Arctic.

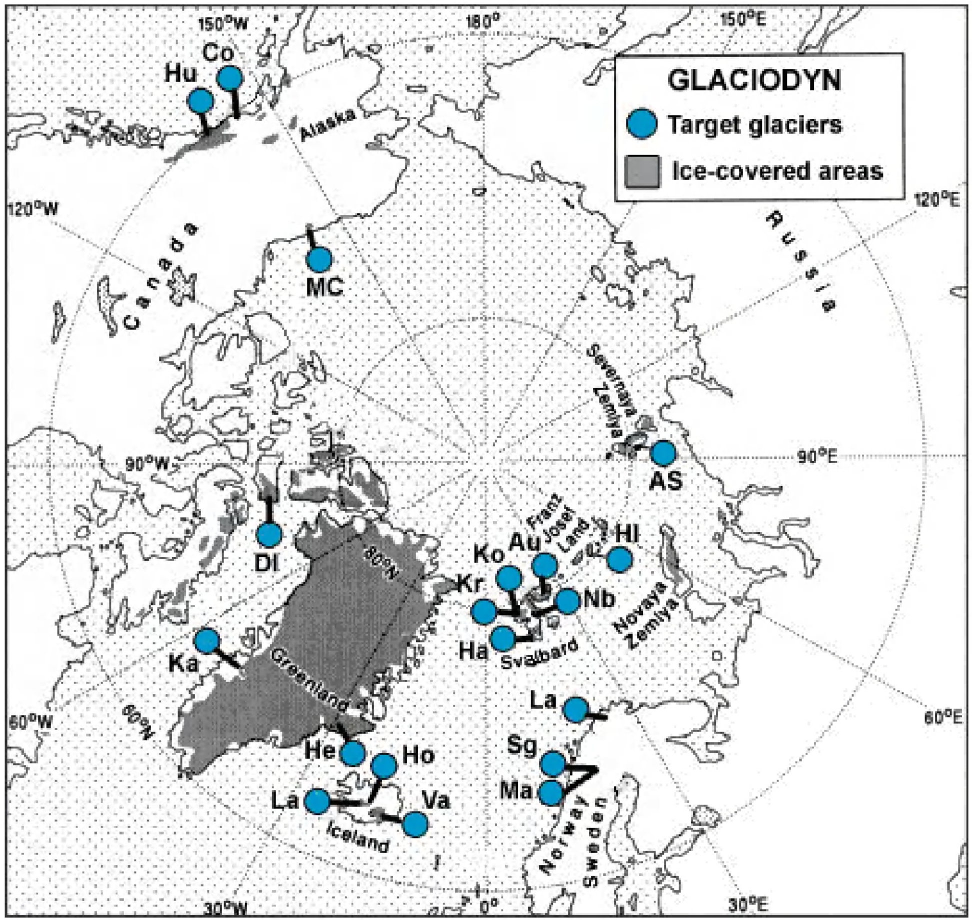
Continuous GPS-receivers were used to monitor several valley glaciers and outlet ice streams from the ice caps, mainly in Svalbard and the Canadian Arctic. Clear linkages between high melt events and increased flow velocities can be seen at all (Ouden et al., 2010).

The recent increase in mass loss from the Canadian ice caps is a result of strong summer warming, especially since 2005, that is largely confined to the North American side of the Arctic and also affects northern and western Greenland. The IPY boreal summers 2007 and 2008 were two of the warmest five observed since 1948. This warming seems to be attributable to anomalously warm sea surface temperatures in the NW Atlantic, and development of a high pressure anomaly that extends from Iceland over the northern 2/3 of Greenland and the Canadian Arctic islands and into the Canada Basin (sometimes reaching Northeast Siberia). The circulation anomaly associated with this latter feature favours atmospheric heat transport from the northwest Atlantic up Baffin Bay into the areas where strong warming in summer is detected.

An impact of this warming has been a major change in the firnification regime of the Canadian ice caps such that any semblance of a dry snow zone has been eradicated and the upper limit of the wet snow zone has risen substantially. Rates of firnification have probably increased along with this.

On the basis of radio echo-sounding surveys of glaciers on Franz Josef Land and Novaya Zemlya and satellite altimetry data, characteristic heights and thicknesses of glacier fronts producing icebergs have been determined. This includes data for Glacier No. 1 and the Moscow Ice Cap on Hall Island, the northern part of the glacier complex on George Land (Franz Josef Land), and the glaciers in the Inostrantsev Bay area, Novaya Zemlya. New criteria for the estimation

Fig. 2.4-10. Target glaciers for the GLACIODYN project (IPY no. 37).
(Courtesy: Jon Ove Hagen)



of iceberg hazards from the glaciers of Novaya Zemlya and Franz Josef Land have been developed. Franz Josef Land has the greatest potential for regular formation of icebergs with thicknesses of up to 150-200 m and extents of more than 1-2 km (Kubyshkin et al., 2009). Photogrammetry has been used to reconstruct the geometry of glacier fronts and the above-water parts of icebergs. Several groups of large tabular icebergs with a weight of over one million tonnes were found not far from their calving areas (Elena Guld Bay on Wilczek Land, the straits between Salisbury, Luigi and Champ islands, Geographers' Bay on Prince George Land). The majority of large icebergs were already drifting. Under favourable meteorological conditions, some of them may drift to the Barents Sea through the deep straits.

In Northeast Siberia, meteorological parameters were measured along a transect from Magadan to Oymyakon, and in the northern massif of Suntar-Khayata (Fig. 2.4-13). A study of glacier change in the region based on modern satellite images and data from the USSR Glacier Inventory has been completed. Infrared, visual and aerial photo surveys have been made for the Suntar-Khayata glaciers in order to update the Glacier Inventory (Ananicheva and Kapustin, in press).

Remote sensing data combined with the field validation results show a negative mass balance over most of the Arctic. The largest losses occurred in the Canadian Arctic, with increased loss since the mid 1990s and accelerating loss after 2005. This is in good agreement with coincident mass balance estimates from GRACE satellite gravity measurements, with surface mass balance field data and with mass balance modelling using meteorological reanalysis data (Boon et al., 2009; Gardner et al., in press).

Several GLACIODYN PhD projects were focused on the calving of glaciers both in Svalbard and the

Canadian Arctic, on glacier surge dynamics, on subglacial hydrology and on different aspects of geodetic mass balance from space-data and ground data. More than one hundred presentations have been made by GLACIODYN partners at different meetings during and after IPY.

Summary and Legacy

Overview of achievements

An important outcome of IPY activities on the Greenland ice sheet and Arctic glaciers has been the wide use of IPY results in the Arctic Council's cryosphere project – *Snow, Water, Ice and Permafrost in the Arctic* (SWIPA; *Chapter 5.2*). The project is coordinated by the Arctic Council Arctic Monitoring and Assessment Programme (AMAP) in cooperation with the International Arctic Science Committee (IASC), the International Arctic Social Sciences Association (IASSA) and the Climate and Cryosphere (CliC) Project of WCRP.

The SWIPA report on the Greenland Ice Sheet (Dahl-Jensen et al., 2009) was the first in a series of the AMAP reports presenting the results of the SWIPA project. Although the SWIPA Greenland report was not an IPY project *per se*, most experts involved in IPY Greenland Ice Sheet projects contributed to the report and the results and findings of IPY research on the Greenland Ice Sheet were included in it. Future SWIPA reports will include an update of the information concerning the Greenland Ice Sheet, in particular the sections dealing with potential impacts on biological systems and human populations.

Work undertaken on Arctic terrestrial ice during IPY 2007–2008 will undoubtedly also contribute to the next IPCC assessment of climate change.

Legacy for the future

Most Arctic cryospheric activities during IPY provided enhanced project opportunities and funding to support post-graduate students. A large number of Ph.D. students, many of whom will go on to become the next generation of leading polar researchers,

Fig. 2.4-11. Time-lapse cameras were used to monitor ice flux and calving on Kronebreen, Svalbard. (Photo: Monica Sund)

Fig. 2.4-12. Airborne lidar and ground-based measurements on Austfonna, Svalbard.
(Photo: Andrea Taurisano)

Fig. 2.4-13. Three glaciers of the Suntar-Khayata Range, a continuation of the Verkhoyansky Range, in the Sakha Republic, Northeast Siberia. Little was known about the glaciers in this region prior to IPY 2007–2008.
(Photo: Maria Ananicheva)

participated and were trained within the IPY projects.

The NEEM project has provided a deep ice core reaching back beyond the Eemian period that will provide a record to advance our knowledge of the North Atlantic climate and to provide needed data for a bipolar comparison. This ice core record will continue to be exploited over the next decade or longer. NEEM has also helped to reignite interest in using the last interglacial in both polar regions as a constraint on the likely environmental impacts of a sustained polar temperature a few degrees warmer than present. The IPICS consortium continues to operate, and is in the process of expanding its NEEM priority project into a more general study of the last interglacial.

Improved observational facilities include a network of weather stations on the Greenland ice sheet and long-term monitoring systems of the fast-moving Greenland outlet glaciers. The example of cooperation and coordination between national space agencies established through the GIIPSY project, and the continuation of the Space Task Group beyond IPY (*Chapter 3.1*), will continue to provide high quality satellite data for polar operations, research and international monitoring activities such as the Global Cryosphere Watch (*Chapter 3.7*).

The GLACIODYN network continues through the IASC group, now restructured and renamed as the IASC Network of Glaciology. New projects have been established by the GLACIODYN network as follow-ups to the IPY efforts. Some examples include:

1) Six former partner groups in GLACIODYN are now working together in the EU-project ice2sea (2009–2013), which aims to reduce the uncertainty of sea level contribution from both ice sheets and glaciers and ice caps.
2) In the Nordic countries a new Nordic Center of Excellence in Climate and Cryosphere called SVALI (Stability and Variations of Arctic Land Ice) has been funded by the Nordic Ministry for the period 2011 to 2015. The 17 partners consist mainly of former GLACIODYN groups and the established network during IPY was the basis for the new center.
3) Seventeen former GLACIODYN groups from ten European countries have recently started a new project with focus on Svalbard glaciers (SvalGlac). This is under the umbrella of European Science Foundation (ESF) program PolarCLIMATE for the period 2009 to 2012 and was launched as a direct successor to IPY.
4) Steps have been taken to establish a new modeling initiative to include dynamics in predictive models as a contribution to the ice2sea project. This is a direct follow up of the aims of GLACIODYN which included development of robust, predictive models that include key dynamic processes. The inclusion of ice dynamics in predictive models of future glacier response would represent a significant advance from current mass balance models.

On the wider global stage, International Polar Year 2007–2008 provided a unique opportunity to develop polar observing systems and, by doing so, begin to close one of the most significant gaps in global observations. The Integrated Global Observing Strategy (IGOS) Cryosphere Theme and the Global Cryosphere Watch (GCW, *Chapter 3.7*) are major outcomes of IPY.

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Notes

[1] The titles and details of individual EoIs may be found at http://classic.ipy.org/development/eoi/

2.5 Antarctic Ice Sheet

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Historical Background

During the First Polar Year (1881-1884), scientists worked with incomplete knowledge of the horizontal extent of the polar ice. Ice sheets were empty voids on the scientists' maps. Seventy-five years later, during the International Geophysical Year (IGY), the horizontal extent of the ice sheets was reasonably well known, but the thickness and volume of the ice sheets remained unknown. Leveraging the technology and infrastructure developed during World War II, IGY traverse teams made measurements of the depth of the Antarctic Ice Sheet using seismic measurements revealing that the ice sheet was in places over 3 km thick (Bentley, 1964). This discovery of the tremendous volume of ice stored in the polar regions shifted forever the understanding of the ice sheet's role in the global climate system. The ice stored in Antarctica is capable of rising sea levels globally almost 60 m. During IGY, the common view was that ice sheets were generally static and could not change on human timescales. Fifty years later, during the planning for IPY 2007–2008, both the Greenland and Antarctic ice sheets had displayed surprisingly dynamic behavior. Accelerating large outlet glaciers (Joughin, 2003), ice shelves disintegrating within a month (Rignot, 2004) and rapidly thinning ice at the ice sheet margins (Zwally, 2005) were all observed; all astonished even the experts. Large polar ice masses changing at human timescales were unfamiliar and troubling given their potential effect on coastal areas around the world where much of the world population lives. A major focus for IPY 2007–2008 quickly emerged to understand the Antarctic Ice Sheet's current status, how it is changing and how it will change in the future. These larger IPY programs were elicited to attempt to reach beyond the ongoing vigorous research programs of many countries into some of the same areas of research. In many cases, these original programs were expanded through more ambitious goals or by combining similar national efforts. In other cases the IPY programs were new and the underlying research continued (Fig. 2.5-1, Table 2.5-1).

Framework for IPY 2007–2008 Antarctic Ice Sheet Studies

The IPY 'Framework' document outlined six major themes for IPY 2007–2008: Status, Change, Global Linkages, New Frontiers, Vantage Point and Human Dimensions at the Poles. The IPY studies of the Antarctic cryosphere spanned the first four of these six Framework document themes.

The New Frontiers theme targeted basic discovery and exploration of the unknown regions of the poles from the genomic scale to the continental scale. The New Frontiers title was used to avoid the sense of exploitation often associated with the term "exploration". The targeted cryospheric frontiers outlined in the framework documents included the study and exploration of subglacial lakes and the exploration of the Gamburtsev Mountains. Both of these targets became major IPY programs. The study of subglacial lakes is addressed in *Chapter 2.6* while the program targeting Antarctica Gamburtsev Province (AGAP) is discussed here and in the solid earth studies section. During the planning phases of IPY, the linkage between the exploratory aspects of subglacially focused programs and the relevance of their discoveries to understanding the changing cryosphere began to emerge as the awareness of the dynamic nature of subglacial hydrology become apparent. An ongoing and similar explor-

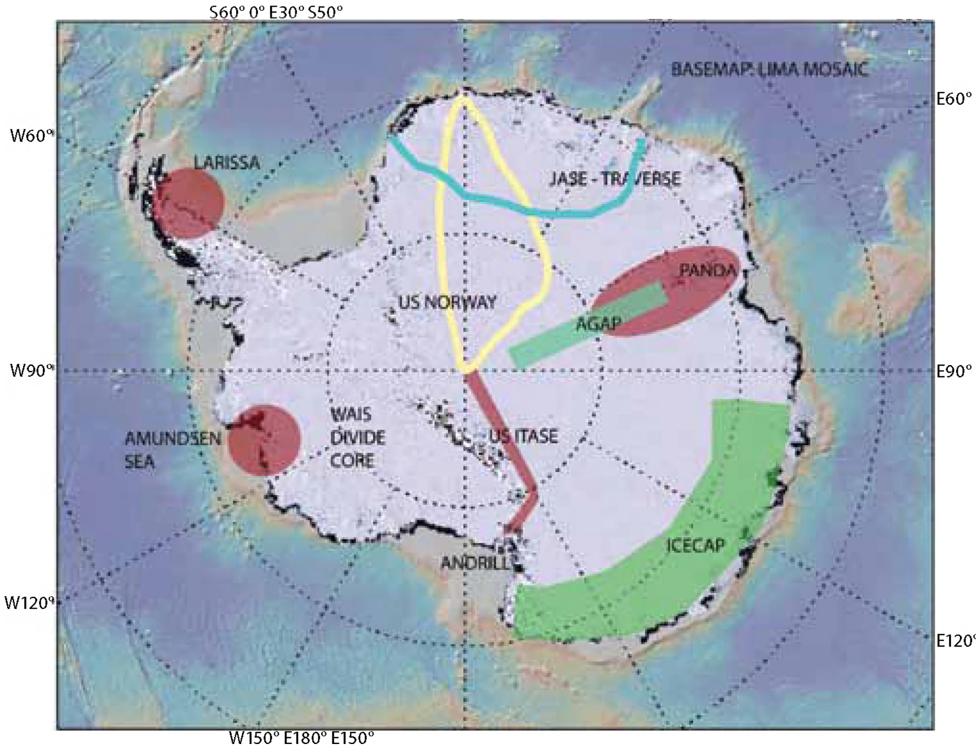

Fig. 2.5-1. Schematic illustration of Antarctic cryosphere activities in IPY 2007–2008 on the LIMA Mosaic. Projects that encompassed the entire ice sheet such as LEGOS are not identified on this map.
(Map: Robin Bell)

atory effort (ICECAP) into the interior of the Aurora and Wilkes basins in East Antarctica is also supporting improved understanding of both the structure of the East Antarctic continent while providing fundamental boundary conditions to ice sheet models. While the New Frontier programs are providing entirely new views of the Antarctic continent, the Global Linkages programs are revealing new aspects of the fundamental links between the dynamics of the Antarctic cryosphere and the global ocean and the northern hemisphere ice sheets. In Antarctica, much of IPY 2007–2008 Global Linkages efforts came from ice cores. Ice cores capture an accurate and invaluable record of ancient atmospheric composition. Insights into the record of greenhouse gases, such as methane and carbon dioxide, can only be measured from ice cores providing a cornerstone of climate change research. The IPY ice coring effort included shallow cores along the coast, a deep core in West Antarctica and site surveys searching for the oldest ice on the planet.

The framework's identification of documenting the Status of the Antarctic cryosphere as a key theme during IPY 2007–2008 carried with it the establishment of benchmarks for measuring future change. During IPY, important new measurements on the surface of the ice sheet, the mass of the ice sheet and velocities of the major outlet glaciers established these benchmarks. In addition to these well-established characteristics, other benchmarks are being or have been created, such as mapping the hydrostatic line (the critical interface where the ice sheet goes afloat and is in contact with the ocean), constructing a true color Landsat Image Mosaic of Antarctica (LIMA), and improving the estimate of discharge of ice through mapping previously unknown areas such as the Aurora and Wilkes basins as well as the Gamburtsev Mountains.

The framework theme of Change targeted quantifying and understanding past and present natural environmental change in the Antarctic cryosphere in order to improve projections of future change. Programs targeted at understanding the past stability of the Antarctic Ice Sheet recovered sediment cores such as those from the ANDRILL program in the Ross Sea achieved fruition during IPY 2007–2008. Satellite monitoring and use of satellite technology in establishing new geometric networks are providing heretofore impossibly precise insights into ongoing change. The interpretations of change observed from satel-

Title	IPY Project no.	Nations
AGAP-Antarctica's Gamburtsev Province	67	U.S.A., U.K., Germany, Australia, China, Japan, Canada
ICECAP-Investigating the Cryospheric Evolution of the Central Antarctic Plate	97	U.K., U.S.A., Australia, France
IPICS-International Partnerships in Ice Core Science-International Polar Year Initiative	117	Austria, Belgium, Brazil, Canada, Denmark, Estonia, France, Germany, India, Italy, Japan Netherlands, New Zealand, Norway, Russia, Sweden Switzerland, U.K., U.S.A.
LIMA-Landsat Image Mosaic of Antarctica	461	U.S.A., U.K.
ASAID-Antarctic Surface Accumulation and Ice Discharge	88	U.S.A., Australia, Germany, Italy, New Zealand, U.K., Norway, Russia
TASTE-IDEA-Trans-Antarctic Scientific Traverses Expeditions – Ice Divide of East Antarctica	152	Originated by Germany: implemented through the next two projects
JASE-Japanese-Swedish Antarctic Expedition	Contributed to objectives of 152	Sweden, Japan, Russia
US- Norway Traverse	Contributed to objectives of 152	Norway, U.S.A.
PANDA- The Prydz Bay, Amery Ice Shelf and Dome A Observatories	313	China, Australia, U.S.A., U.K., Japan, Germany
ITASE-International Trans-Antarctic Scientific Expedition	Linked to 88, 117, 152	Established prior to IPY with up to 20 national participants
WAIS Divide Core	-	U.S.A.
ACE-Antarctic Climate Evolution	54	China, Germany, Italy, New Zealand, Poland, Spain, U.K., U.S.A., Argentina, Australia, Belgium, Canada, France, Netherlands and Sweden
ANDRILL	256	U.S.A., New Zealand, Italy, U.K., France, Australia, Germany
Multidisciplinary Study of the Amundsen Sea Embayment	258	U.S.A., U.K.
LARISSA-Larsen Ice Shelf System, Antarctica	-	U.S.A., Belgium, Korea, U.K.
LEGOS	125	France, Australia, Germany, U.S.A.

Table 2.5-1. projects referred to in this Chapter.

lites, like ICESAT's measurements of elevation change and GRACE's measurements of mass change, emerged during IPY. Simultaneously, the SCAR supported ACE effort built a new community bridging between the paleooceanographic and modeling communities to interpret and support robust model development of past and future ice sheet change. Current change was also directly addressed through programs focused on ice shelves, the floating fringe of the ice sheet, where observations suggest strong interactions between the ice sheet and its surrounding waters on the continental shelf, ultimately connected to the deeper ocean. Thus IPY has enabled completely new means to measure change along with the research communities to interpret these changes just at the time when these changes are of most importance to societies across the globe. It is easy to view IPY as having arrived on the scene at the most critical time: the cryosphere is beginning to exhibit change previously not witnessed by humans, yet human behaviour will need to understand and accommodate these changes.

IPY Investigations of the Antarctic Ice Sheet

a. New Frontiers

The New Frontiers of IPY 2007–2008 were mostly hidden beneath the thick ice of the Antarctic Ice Sheet. During IPY the knowledge that subglacial hydrologic systems can change and influence ice sheet dynamics became evident and the groundwork was laid for upcoming exploration of several subglacial lakes (*Chapter 2.6*). The other efforts focused on understanding the last unknown tectonic systems on our planet: the deep basins beneath the ice sheet and the hidden mountain ranges.

The study of Antarctica's Gamburtsev Province (AGAP, no. 67) was a collaborative effort of seven nations (U.S., U.K., Germany, Australia, Germany, China and Canada) bringing together their resources and technologic knowledge to study the Gamburtsev Mountains hidden beneath Dome A in the center of East Antarctica. Using two research Twin Otters aircraft the team collected 130,000 km of data, equivalent to flying the aircraft around the globe three times. The team also installed 26 seismometers around Dome A that will record global seismic events. The seismic data will be used to determine the deep earth structure beneath Dome A. The aerogeophysical data has revealed a rugged mountain range incised by fluvial river valley in the south and truncated by the landward extension of the Lambert Rift to the North. Capturing measurements of some of the thickest ice (over 4600 m) and some of the thinnest ice in the center of the ice sheet (less than 400 m) this work is changing the view of the tectonics and the nature of the ice sheet. Evidence is emerging for complex interconnected system of subglacial water and extensive subglacial freezing at the base of the ice sheet. Well-resolved internal layers facilitate the identification of the oldest ice close to the Dome A.

East of the Gamburtsev Moutains, the collaborative ICECAP program began a multi-year program (U.K., U.S. and Australia) using an instrumented long-range aircraft to survey the portion of the East Antarctic Ice Sheet underlain by the Wilkes and Aurora subglacial basins. The ice drainage from these regions is dominated by the Byrd and Totten Glacier systems. This program is acquiring a combination of flow-line-oriented and gridded aerogeophysical observations over this portion of the East Antarctic Ice Sheet that is grounded on a bed below sea level, prompting questions of its regional stability. During IPY, the program flew over 30,000 km acquiring ice thickness and internal layers to support of ice sheet modeling to observe flow regime change and to study crustal geology and subglacial hydrological systems. These data will inform future studies on the processes controlling both past and future change of the East Antarctic Ice Sheet.

b. Global Linkages

The Global Linkages theme sought to advance the understanding of the links and interactions between polar regions and the rest of the globe. IPY 2007–2008 efforts in this aspect of the Antarctic cryosphere sought to use the climate record held within ice cores to link the climate record from Antarctica to global climate systems. The IPY ice coring efforts included shallow cores along the coast and ongoing deep cores in the interior. During IPY, the relatively new International Partnerships in Ice Core Sciences (IPICS) supported focused site surveys and beginning the West Antarctic Ice Sheet (WAIS) divide core. IPICS partnered in the major aerogeophysical programs (AGAP and ICECAP) that collected the data to be used to locate and identify the oldest ice available in Antarctica—hopefully at least one million years old—providing data that will be fundamental to understanding the orbital forcing of climate change.

The ice core recovered from the divide of the West Antarctic Ice Sheet will facilitate the development of climate records with an absolute, annual-layer-counted chronology for the most recent ~40,000 years. This ice core record will have a very small offset between the ages of the ice and the air (i.e. gases) trapped in the ice enabling a decadal-precision climate chronology relative to the Greenland ice cores. In addition to providing the most detailed record of greenhouse gases possible for the last 100,000 years and determining if the climate changes that occurred during the last 100,000 years were initiated by changes in the northern or southern hemisphere, the WAIS core project will investigate the past stability of the West Antarctic Ice Sheet and contribute to efforts to predict its future. During IPY 2007–2008 the deep drilling system was installed and drilling began.

c. Status

Determining the present environmental Status of the polar regions during IPY 2007–2008 was crucial to establishing benchmarks for documenting future change. In the Antarctic cryosphere key targets were the exact location of the edge of the ice sheet, the rate of accumulation of snow and the rate at which ice is being discharged. Several projects using techniques ranging from traverses crossing the continent with snow vehicles to detailed analysis of satellite images addressed these goals.

High resolution imagery is a commonly used data set to visualize a region and, in Antarctica, often replaces maps. Surprisingly, before IPY, the highest resolution data set of Antarctica used radar, not visible, imagery. As IPY approached, a joint U.S.-U.K. effort to produce the Landsat Image Mosaic of Antarctica (LIMA, http://lima.usgs.gov) began. During IPY, LIMA was released, capturing the status of the of the Antarctic Ice Sheet surface for the period 1999-2003. Extensive image processing was completed to rigorous scientific conditions to produce a scientifically valuable mosaic data set of surface reflectances. The outcome of this IPY project gives the public and educators a new, exciting and flexible tool to increase their familiarity with Antarctica (http://lima.nasa.gov). LIMA has been used extensively in the classroom and by media to add a real-look dimension to Antarctic activities. LIMA also serves the science research community with a new research tool of meaningful surface reflectances to facilitate not just field planning and exploration of the Antarctic surface, but also quantitative analyses that utilize surface reflectance data. LIMA offers parallel views of the surface with synthetic aperture radar from the co-registered Radarsat data set. The LIMA interface allows interested users to download either the mosaiced data or the individual scenes. Two biologists used the LIMA mosaic to map penguin rookeries over all of Antarctica, finding a number of previously unknown rookeries and identifying some abandoned rookeries based on the spectral (true color) signature of rookeries (Fretwell, 2009).

Following from the LIMA and during the LIMA period of 1999-2003 was the project ASAID defining the precise position of the Antarctic grounding line by including ICESat and SAR data at 15 meters resolution and, from it, the total ice discharge from the Antarctic continent. Scientists from Norway, the U.K., New Zealand, Italy, Germany, Australia and the U.S. produced a comprehensive estimate of the surface accumulation and ice discharge for the Antarctic cryosphere. Additional products were the first-ever mapping of the "hydrostatic line" where floating ice is in hydrostatic equilibrium, the first complete mapping of surface velocity across the grounding line. Previous estimates of the Antarctic discharge flux had been limited to the fast moving outlet glaciers. Some field data collected during IPY by the British Antarctic Survey was used for validation. Each of these new data products are benchmark data sets that will be used to measure change of the cryosphere in the future. New techniques were employed to derive surface elevations from Landsat imagery using ICESat altimetry as control while customized software was developed to provide analysts with tools for combining these data and drawing and editing the grounding line.

Russian research during IPY included Antarctic Ice Sheet and sea water interaction, geophysical investigations of ice stream-lines and subglacial lakes, and surface ice accumulation and discharge. During IGY, surface traverses across the Antarctic Ice Sheet were used to generate the first accurate estimates of the volume of ice stored on the continent.

During IPY 2007–2008, surface traverses were used to make key *in situ* measurements of the ice sheet in locations many of which had not been visited for decades. During the planning phases of IPY, one of the first concepts offered (by Heinz Miller of AWI under the title IDEA) was traverses along the divides of the ice sheets collecting shallow ice cores to capture the accumulation record and to provide the logistical infrastructure for other detailed work such as aerogeophysics. Much of this concept was implemented, although not always under the umbrella of IDEA. The long running ITASE program targeted where and how Antarctic physical and chemical climate has or has not changed over the last several hundred years with a view toward assessing future climate change over Antarctica. ITASE continued into IPY with traverses extended from McMurdo to the South Pole and from Dronning Maud Land to Dome F and on to the Japanese Base Syowa. Traverses were also completed by a joint Norwegian-U.S. team that covered one of the major ice divides and surveyed major sub-glacial lakes, as well as one component of the PANDA program that traveled from the coast to Dome A.

Making use of mobile platforms in the interior of Antarctica, the Japanese-Swedish Antarctic Expedition, JASE (November 2007 – February 2008), made continuous surveys of different parameters, including sampling and snow and ice radar surveys. The JASE traverse began in Dronning Maud Land, East Antarctica at the Swedish base Wasa and reached the Japanese base Syowa via the deep drilling sites at Kohnen and at Dome Fuji. Data collected included radar soundings for ice depth and snow layering, air sampling, snow sampling for chemical analyses, snow sampling for physical property measurements, snow pit studies for snow sampling, firn coring for various analyses and 10 m temperature, weather observations, GPS-measurements and ground truth surveys for satellite data. The traverse enabled extensive ground truth sampling of physical snow properties such as snow grain size. Snow grain size is determined by moisture content and air temperature, and shows decreasing size towards the center of Antarctica and larger grains in the coastal areas. The grain size and shape results are correlated with coincident and historical satellite data including SAR imagery from ENVISAT ASAR, QuikSCAT scatterometry and optical-thermal satellite data (MERIS & MODIS) over the study area. Preliminary results indicate that the black carbon content in air and snow over the Antarctic plateau is higher than expected. The concentration in air is higher than found near the coast, and the content in snow is about 10 times larger than used in published climate simulations, albeit with large spatial variations. Subglacial landforms that may be relicts from the initiation of the Antarctic glaciation about 30 million years ago were described and continuous measurements of aerosols, bed topography, ice layering, snow layering and surface topography were measured en route.

The Norwegian-U.S. Scientific Traverse of East Antarctica completed two seasons (2007 and 2008/2009) of overland traverses of East Antarctica beginning at the Norwegian Troll Station, following an ice divide to the South Pole and returning to Troll by a route over the Recovery Subglacial Lakes. The main research focus of the program was to examine climate variability in Dronning Maud Land, East Antarctica on time scales of years to a 1000 years by a series of shallow cores, firn studies and temperature profiles. The team has been able to establish spatial and temporal variability in snow accumulation over this area of Antarctic both through ice cores and linking the surface based studies to satellite measurements. Results from new ice cores are providing new constraints on the accumulation in East Antarctica for the past 2000 years. Analysis of the surface radar has enabled a robust relationship between the surface and space observations. Detailed snow pits enable new insights into the impact of atmospheric and oceanic variability on the chemical composition of firn and ice in the region. The physical properties of snow and firn, from crystal structure to mesoscale strata morphology, reveal a complicated East Antarctic climate history. Five 90 m-long *in situ* thermal profiles obtained from automated, satellite-uplinked stations provide an independent, new assessment of climate trends in the remotest parts of Antarctica.

d. Change

The planners of IPY envisioned that programs targeted at Change in the Polar Regions would seek to quantify, and understand, past and present natural environmental change in the polar regions, and to improve projections of future change. IPY 2007–2008 programs addressing change covered the spectrum of past change through present change to projections of future change.

The existing Antarctic Climate Evolution (ACE, www.ace.scar.org) activity, a Scientific Research Project (SRP) of the Scientific Committee on Antarctic Research (SCAR) emerged as a core IPY project and was an umbrella for many smaller projects fitting beneath. ACE's mission is to facilitate the study of Antarctic climate and glacial history through integration of numerical modeling with geophysical and geological data. The overall goal of ACE is to facilitate those model-data interactions for better understanding of Antarctic climate and ice sheet variability over the full range of Cenozoic (last ~65 million years) timescales. Over the last five years, ACE has made major contributions to the understanding of the early development of the Antarctic Ice Sheet in the Oligocene and its variability through the Miocene. Much of this work has led to a new appreciation for the importance of atmospheric greenhouse gas concentrations relative to other potential forcing mechanisms (e.g. orbital forcing, ocean circulation, etc.) in controlling the onset of glaciation and magnitude of subsequent ice volume variability.

A direct outcome of ACE was the ANDRILL project that included a major drilling field campaign integrated with a numerical modeling effort. During IPY, ANDRILL completed its first two seasons of sedimentary drilling in the Ross Sea. The drilling effort recovered over 2400 meters of high quality core in two locations: under the McMurdo Ice Shelf and in the Southern McMurdo Sound. The McMurdo Ice Shelf core ranges in age from recent to Pliocene, while the Southern McMurdo Sound core is mostly older, providing an expanded Miocene record. While the science associated with Southern McMurdo Sound is still evolving, important discoveries have already been made, including the recognition of exceptional Antarctic warmth in the middle Miocene (Sophie Warny, 2009). The McMurdo Ice Shelf effort and associated numerical modeling has made several important discoveries, including the recognition of a highly variable, orbitally paced West Antarctic Ice Sheet (WAIS) throughout the Pliocene and early Pleistocene (Naish et al., 2009). Based on a combination of sediment analysis and numerical ice sheet-shelf modeling, it is now clear that WAIS is capable of sudden retreats (collapses) within a few thousand years, mostly in response to relatively modest increases in ocean temperature and sub-ice shelf melt rates (Pollard and DeConto, 2009). The most recent WAIS collapse evident in the ANDRILL core occurred around 1 million years ago (Marine Isotope Stage - 31). At that time, WAIS appears to have retreated to the small sub-aerial islands of the West Antarctic archipelago, the Ross Sea was open water (with no ice shelf), mean annual sea surface temperatures were several degrees above freezing and there was little seasonal sea ice in the Ross Embayment.

Numerical modeling of Cenozoic ice sheets has been greatly improved in recent years by ACE-facilitated geophysical surveys (e.g. AGAP and ICECAP), providing improved subglacial boundary conditions. New working groups within ACE including Circum-Antarctic Stratigraphy and Paleobathymetry (CASP) and ANTscape have been particularly active over the IPY period, producing new paleotopographic and paleobathymetric reconstructions of the continent and offshore margins at key time slices in the past including the Eocene-Oligocene boundary (34 Ma), Last Glacial Maximum and Holocene.

Early in the planning stages of IPY, the Amundsen Sea Embayment was identified as a key location where rapid change was underway. The spatial pattern of change revealed the ocean as the driver of this change and, during IPY, a multi-national program (U.S. and U.K.) began targeting a sustained study of the impact of warm water circulating in the ice cavity adjacent to the Pine Island Glacier, a major WAIS outlet glacier. The targeted ice shelf turned out to be so heavily crevassed that it was unable to support landings by fixed wing aircraft. An alternative strategy using helicopters has introduced a delay; this multidisciplinary study, begun in early 2008, will continue through 2014. The Amundsen Sea program will be the first sustained sampling of sub-ice shelf circulation in a "warm-ice-shelf" cavity. The instruments lowered through borehole drilled in the floating ice shelf in 2011 will record the high basal melt rates thought to exceed 100m/yr in a region known to be changing rapidly. The Pine Island Glacier, feeding this floating ice shelf, is thinning, accelerating and retreating. Novel technology will be deployed enabling improved imaging systems and small-diameter ocean profiling instruments. The science outcomes are anticipated to be accurate measurements of the temperature, salinity and current changes in the incoming and outgoing water. These sub-ice shelf data will complement IPY data from ocean moorings placed on the continental shelf of the Amundsen Sea.

Other well-documented changes are continuing in the Antarctic Peninsula, particularly on the ice shelves and their feeding glaciers. A new interdisciplinary program to investigate environmental change in the LARsen Ice Shelf System, Antarctica (LARISSA) was initiated during IPY 2007–2008. Also delayed because of complex logistical requirements, it will provide a comprehensive approach to questions concerning the past, present and future of this rapidly changing region. Catastrophic ice shelf loss associated with rapid regional warming has resulted in large scale changes in the physical and biologic environment. The LARISSA Project represents an Earth Systems approach to describe and understand the basic physical and geological processes active in the Larsen embayment that contributed to the present phase of massive, rapid environmental change; are participating in the coupled climate-ocean-ice system; and are fundamentally altered by these changes. While observations of modern glacial, oceanic and biological dynamics will address the response of this polar system to global change, marine and terrestrial geologic data in combination with ice core data will provide the context of a paleo-perspective making it possible to address a suite of questions over a variety of time scales. Existing geologic data indicate the likely existence of a stratigraphic record from prior to the Last Glacial Maximum; this record will further our understanding of the Larsen System under climatic conditions of the penultimate interglacial, when globally, sea level was higher and average climate warmer than today. Sea floor mapping and strategic marine sediment coring combined with land-based geomorphologic work will be used to reconstruct the configuration of the northern Antarctic Peninsula Ice Sheet during the Last Glacial Maximum and the subsequent retreat. Sediment coring coupled to field observations and satellite imagery will be used to evaluate the controls on the dynamics of ice-shelf grounding-line systems.

On a much larger spatial scale, the present rate of ice and snow mass change continues to be estimated using multiple satellite approaches. GRACE accomplishes this monitoring role by measuring gravity variations created by regional mass redistributions within the ice sheets. The LEGOS project engaged scientists from four nations, namely France, Australia, Germany and U.S., to analyze GRACE data. The results of this work have documented an important mass loss from the ice sheets for recent year equivalent to an increase of global sea level at ~1mm/yr with recent increases in contributions from the southeast and northwestern coasts of Greenland. A major result is evidence of an increased contribution from the two ice sheets over the past five to seven years. The ice sheet contribution was estimated to be equivalent to about 15% of the total sea-level change for the 1993-2003 decade (IPCC AR4). These studies have shown that it increased to 30% since 2003. The total land ice contribution (ice sheets plus glaciers) amounts to 75% for the 2003-2009 time span (Cazenave, 2009). Post glacial rebound remains the major source of uncertainly in these studies with the modeling of the rebound in Antarctica being the least accurate. POLENET (Polar Earth Observing Network - *Chapter 2.8*) is another IPY project that includes as one of its geodetic products a much-improved measurement of the spatial pattern and magnitude of post-glacial rebound. This product will directly and significantly improve the correction of GRACE measurements of ice sheet mass loss.

Satellite laser altimetry is an independent means of monitoring ice sheet change and IPY fell within the 2003-2009 lifetime of ICESat-1, NASA's laser altimetry mission. ICESat data mapped Antarctic ice thinning and thickening rates with greater spatial acuity than GRACE, producing similar results. West Antarctica, especially the Amundsen Sea Embayment remains the region of greatest thinning, with thinning also apparent over the Antarctic Peninsula regions having recently lost ice shelves, allowing an acceleration and thinning of feeding glaciers. East Antarctica has experienced modest thickening over much of the interior during the ICESat period, but the area is so vast the mass balance of the East Antarctic Ice Sheet appears to be positive (+68 +/- 52 Gt/a) in contrast to the significantly negative mass balance (-51 +/- 4 Gt/a) of West Antarctica. The corresponding mass balance for the Antarctic Peninsula is (-25 Gt/a) brings the continental total to near balance.

Looking to The Future of the Antarctic Ice Sheet

As in earlier polar years, IPY enabled scientists to make advances that would have been impossible without the collaborative framework of the major international effort. Escalating fuel costs threatened many programs, but the strength of the IPY collaborations and the conviction of the diverse teams enabled remarkable efforts to be launched and completed. The polar environment proved to be a challenge in 2007-2009 as it has in earlier years and some of the work has yet to be finished. For example, the plans to instrument the water beneath the ice shelf in front of the Pine Island Glacier had to be reconfigured to minimize the dangers to field personnel. Similarly the high altitude and cold temperatures encountered by the Norwegian-U.S. traverse along the ice divides challenged the vehicles and threatened to end the program early. In the first traverse Antarctic field season the team had to leave their vehicles 300 km away from South Pole before the winter set. For the AGAP project, over four years of planning spanning all seven continents resulted in an effort requiring nine aircraft, dozens of traverse vehicles, four airdrops and two major high altitude field camps (Figs. 2.5-2 and 2.5-3). Again the compelling nature of the cryospheric science forged within the collaborative framework of IPY provided the neces-

Fig. 2.5-2. USAP Twin Otter aircraft lands at the AGAP North field camp during IPY. (Photo: Carl N. Robinson, BAS)

Fig. 2.5-3. Two scientists from the AGAP Project team, Beth Burton (USGS) and Adrienne Block (LDEO) and work on the new data sets collected under the AGAP field program. (Photo: Robin Bell, 2009)

sary environment to continue these programs even as daunting challenges were encountered.

New insights from IPY are just now emerging. Multiple projects have contributed various aspects of a much more dynamic ice sheet both in the past and at the present time. We can expect continued dynamic behavior in our future from the Antarctic Ice Sheet. Some of the cryospheric programs have produced terra bytes of data.

It is worth remembering that even though IGY insights were based on single data points or a few wiggly lines on a seismic record on paper in the field, these data still figure into new scientific insights. We should only expect vastly more expansive insights to follow from the manipulation and visualization of these large, complex digital data sets collected during IPY 2007–2008 and that these data will support scientific research for decades to come.

IPY 2007–2008 fostered collaboration between scientists, engineers, students and logistics operators. The entire fabric of the Antarctic community has been strengthened by the groups reaching beyond the easy "normal" collaborations to new, challenging collaborations.

Even as this document is being written, IPY programs are in the field and some will be continued for the next two years. The POLENET program is just installing the lion's share of their instruments and the LARISSA program, trying to reach the western side of the Antarctic Peninsula, is struggling against extreme ice conditions. The ICECAP program will continue to map the margins of the East Antarctic Ice Sheet for another field season and the IPY initiated effort in the Amundsen Sea area will finally deploy the instrument into the ocean below the Pine Island Ice Shelf in 2011.

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2.6 Subglacial Aquatic Environments

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Recognition as a Focus for Scientific Investigation

In 1996 an article, featured on the cover of *Nature*, reported that a massive subglacial lake containing liquid water was hidden beneath ~4 kilometers of ice in Antarctica (Kapitsa et al., 1996). While the data that suggested the presence of a lake dated to the 1960s and 1970s, this feature had gone largely unnoticed by the broader scientific community until a re-analysis of the data. The article sparked speculation that these environments might be habitats for exotic microbial life long isolated from the open atmosphere. It was speculated that if sediments were preserved at the bottom of the lake they would contain never before seen records of past climate change in the interior of Antarctica. The article demonstrated that the lake (Subglacial Lake Vostok, named after the Russian Antarctic Station famous for its 400,000 year ice core record of climate; Fig. 2.6-1) was an order of magnitude larger than other previously identified subglacial lakes, and was deep (510 m) making it a unique feature on Earth (Kapitsa et al., 1996). Conjecture was that the lake had been entombed for hundreds of thousands, if not millions of years, beneath the East Antarctic ice sheet. A small, but growing, international community of scientists became convinced, based as much on scientific vision as on actual data, that Lake Vostok and other subglacial lakes represented an important new frontier in Antarctic research. The group continued to examine what was already known as well as newly developed information about subglacial environments over the next decade developing the scientific rationale for the study of these environments. The emerging interest in Lake Vostok led to a series of international meetings to develop plans for its exploration. The first, in Cambridge in 1994, established the dimensions and setting of the lake and led to the first published inventory of subglacial lakes (of which 77 were recorded from analysis of radio-echo sounding records, Siegert et al., 1996). In the second half of the 1990s, three scientific workshops entitled "Lake Vostok Study: Scientific Objectives and Technological Requirements" (St. Petersburg, March 1998), "Lake Vostok: A Curiosity or a Focus for Scientific Research?" (Washington DC, U.S.A., November 1998; Bell and Karl, 1998), and "Subglacial Lake Exploration" (SCAR, Cambridge, September 1999) were held. It was recognized early on that that, in order to explore these remote habitats, a major, sustained investment in time, resources and scientific effort would be necessary. The Scientific Committee on Antarctic Research (SCAR) provided a forum for scientists and technologists to gather, exchange ideas and plan for the future; first as a Group of Specialists (2000-2004) and then as a Scientific Research Program (SCAR Subglacial Antarctic Lake Environments [SALE] 2004–2010). The timing of the SALE program conveniently paralleled the development and implementation of IPY, resulting in valuable mutual benefits for both of these iconic polar activities.

The Early Years

From 1998-2006 understanding of subglacial environments incrementally improved based on remote sensing studies and theoretical modeling. Slowly, the belief that the interface between the ice sheets and basement rock was frozen and devoid of environments of interest was changing. As knowledge of subglacial lakes increased, the potential importance

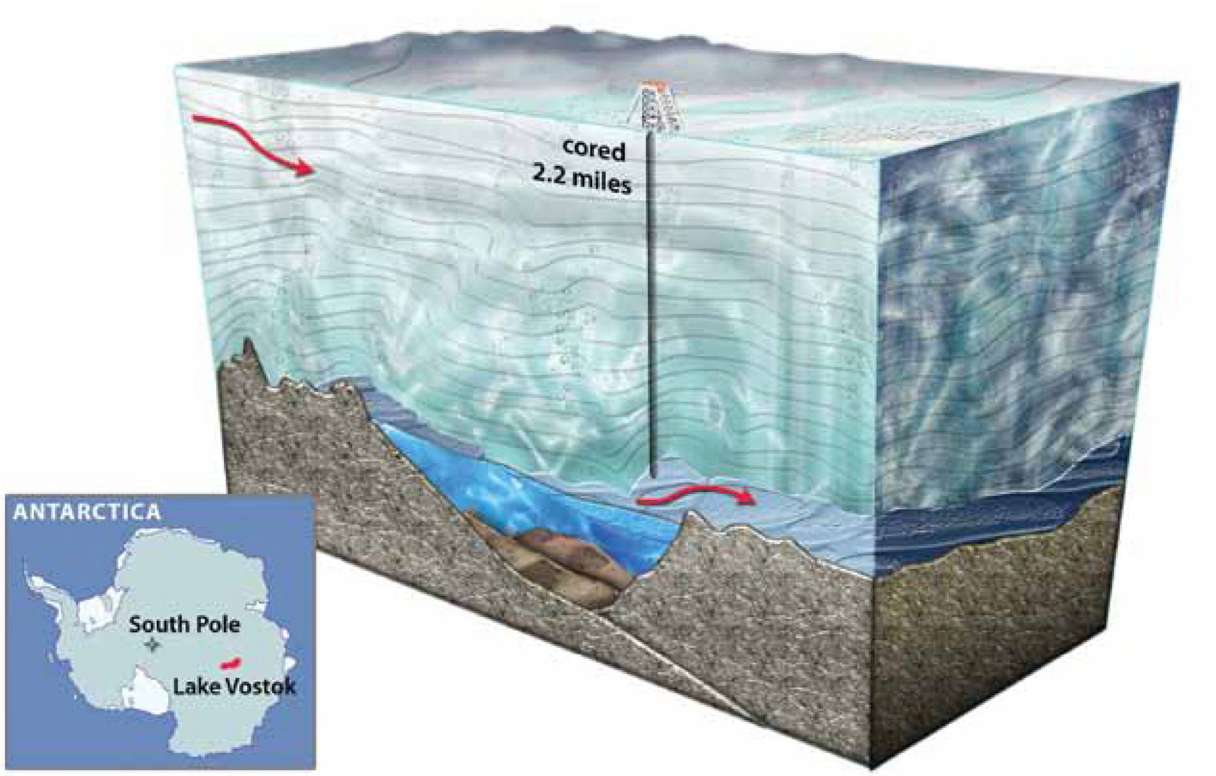

Fig. 2.6-1. An artist's cross-section of Lake Vostok, the largest known subglacial lake in Antarctica. Liquid water is thought to take thousands of years to pass through the lake, which is the size of North America's Lake Ontario
(Credit: Nicolle Rager-Fuller/NSF).

of these environments began to be recognized by a wider community. Early in the discussions, speculation about life existing in lakes beneath the ice dominated people's attention. This speculation was fueled by the detection of microbial cells in the so-called "accreted ice", which was interpreted as ice originating from lake water that had re-frozen on the underside of the ice sheet as it moved across the lake (Karl et al., 1999; Jouzel et al., 1999; Priscu et al., 1999; Bell et al., 2002). Accreted ice had been recovered from the deepest penetrations of the Vostok borehole.

The results of new geophysical surveys, in conjunction with previously collected data, led to the realization that subglacial lakes were not uncommon and in fact were to be expected beneath thick ice sheets (>2 km). Evidence for other lakes indicated that the number of features identified was a function of the coverage of surveys and that in all likelihood the inventory of features would increase as survey coverage increased. Therefore, subglacial lakes were likely to exist in many of the then un-surveyed regions of Antarctica. Lake Vostok continued to dominate discussions as it was the only lake whose shape and size were known. No other lakes had information on water depths or topography and Lake Vostok was the largest known subglacial lake (with an area of about 17,000 km^2 and water depth reaching up to 1200 m). Due to its size and the availability of accreted lake ice recovered by ice coring, it has remained a focus of exploration and research.

The expanding inventory of lakes revealed that subglacial features were not randomly distributed across Antarctica, but that lakes preferentially occurring in certain settings. The idea that different types of lakes might have differing histories, ages, origins and possibly biological residents led to classification systems for lakes. As the inventory of lakes grew, it was evident that some clusters of lakes occurred in regions defined by the dynamics of the overlying ice sheet and the morphology of the underlying basement. "Lake districts" were identified near Dome C (Concordia Station) and other clusters of lakes were located near ice-divides or at the heads of ice streams. Analysis of the distribution of lakes led to the suggestion that at least some lakes might be expected to have hydrological connections analogous to sub-aerial lakes, streams and wetlands. Ideas about hydrological connections between lakes and coupling

Fig. 2.6-2. An artist's representation of the aquatic systems scientists believe are buried beneath the Antarctic ice sheets (Credit: Zina Deretsky/ NSF).

of basal water with the overlying ice sheet dynamics fundamentally advanced our understanding of subglacial environments and how they may evolve and function (Fig. 2.6-2). Geophysical surveys also detected features that did not fit the definition of lakes, but nevertheless appeared to contain liquid water or water-saturated sediments. This led to a broadening of interests from lakes to subglacial aquatic environments in general.

Life under the Ice

As discussed above, in parallel with physical science discoveries, the debate over the existence of life in the lakes continued unabated. This debate engendered public interest in what might be living in the lakes and prompted extensive coverage in the popular press. This discussion proved valuable in maintaining a high profile for subglacial research and assisted in keeping the topic high on the agenda of funding agencies. While many of the physical attributes of subglacial environments (temperature, pressure, salinity, etc.) would not be considered "extreme", the general consensus is that the ultra-oligotrophic conditions (extremely low nutrient levels) that would most likely prevail in these environments would be very challenging, even for microbial life. Extreme nutrition, essential element and energy limitations were expected to be common in these environments due to their relative isolation.

Indirect evidence of biological residents and geochemical conditions in these environments came from the analysis of accreted lake ice (lake water frozen onto the base of the ice sheet) recovered from the Vostok borehole. These samples were not originally recovered for microbiological analyses raising questions about possible contamination of the samples. Partitioning of lake water constituents into ice under subglacial lake conditions is also poorly understood making extrapolation of accreted ice results to lake water compositions difficult at best (Gabrielli et al., 2009). These circumstances have resulted in conflicting and ambiguous evidence about life in the lake, the biogeochemistry of lake water and the possible influence of hydrothermal effluents in Lake Vostok. These discrepancies will not be resolved until water and sediments are collected *in situ* and returned to the laboratory for analysis under clean conditions. The general consensus is that all of these environments almost certainly contain life, based on the current knowledge of the settings, but that life more complex than microbes is highly unlikely. Early speculation that the water in these lakes has been isolated for millions of years is also considered far less likely given the degree of hydrological communication apparent among those lakes examined to date.

A New Frontier Continues to Advance during IPY

The early phases of subglacial aquatic environment research coincided with initial planning for IPY 2007–2008. As a consequence, a group successfully proposed to become an ICSU-WMO IPY project entitled Subglacial Antarctic Lake Environments Unified International Team for Exploration and Discovery (SALE UNITED). As Antarctic science is funded by National Programs, both SCAR SALE and SALE UNITED served primarily as fora to exchange information and network with others interested in subglacial aquatic environments. SALE UNITED participants included scientists and technologists from Belgium, Canada, China, France, Germany, Italy, Russia, the U.K. and the U.S.A. SCAR SALE (and during IPY, SALE UNITED) held meetings in Austria (2005), France (2006), the U.S. (2007), Russia (2008) and Belgium (2009) to further development of strategic plans and sharing of information on progress. In 2006, a large international workshop "Subglacial Antarctic Lake Environment in the IPY 2007–2008: Advanced Science and Technology Planning Workshop" for the broader community was convened in Grenoble, France by M.C. Kennicutt II and J.R. Petit. The workshop brought together 84 participants from 11 countries.

During IPY, significant advances in understanding subglacial environments were achieved. Wingham et al., (2006) detected changes in ice-sheet surface elevations in central East Antarctica using satellite remote sensing and demonstrated that a lake in the Adventure subglacial trench discharged approximately 1.8 km^3 of water over a period of 14 months. The water flowed along the axis of the trench and into at least two other lakes some 200 km away. The flux of water, at around 50 m^3 s^{-1}, was equivalent to the flow of the River Thames in London. This discovery was particularly significant as the observations were from the center of East Antarctica, which was considered to be a stable and ancient ice sheet. The conclusion was that the movement of subglacial water was likely everywhere in Antarctica and indeed the hydrological processes have subsequently been shown to be common-place. This work also suggested that subglacial systems were linked together by a network of hydrological channels defined by the basal topography and surface slopes. Siegert et al., (2007) showed the nature of these channels and suggested how groups of lakes may be associated within discrete systems. Later, Wright et al., (2008) revealed that the directions of several such channels were sensitive to the ice surface slope. They concluded that small changes in surface slope can result in a major alteration to the basal water flow, especially during periods of ice sheet changes such as after the last glacial maximum or even as a consequence of future global warming. These findings also suggested that water would flow along a hydrologic potential which in some instances might be up topographic slopes (up-hill).

Further analysis of satellite remote sensing showed that the process of subglacial discharge and water flow was indeed common-place in Antarctica (Smith et al., 2009). Additionally, many of the newly found lakes and discharge areas were located at the heads of ice streams (Siegert and Bamber, 2000; Bell et al., 2007). Smith et al., (2009) showed, that these lakes actively discharge water to ice stream beds altering basal flow. Satellite investigations of the Byrd Glacier by Stearns et al., (2008) revealed that this was the case and that subglacial lake discharges coincide with 10% anomalies in flow velocity in a major outlet glacier (Byrd) draining East Antarctica. Hence, subglacial lakes can and probably always have influenced the dynamics of overlying ice sheets. Additional satellite imagery analysis has confirmed the widespread existence of lakes and episodic water release events. Evidence has also been found of paleo-outbursts from subglacial lakes, most notably the dramatic outflow features present in the Labyrinth area of the McMurdo Dry Valleys. Vast amounts of lake water were released from large lakes and such events have been speculated to affect ocean thermohaline circulation due to the influx of fresh water possibly interacting with regional climate.

During these years, meetings and international workshops facilitated the development of research questions and plans to enter and sample subglacial environments. Critical issues that surfaced were the cleanliness of these experiments and the need for long-term stewardship of subglacial lakes as sites of scientific and public interest. A U.S. National Academies committee reviewed plans for subglacial lake exploration from the perspective of environmental protection and conservation. This review and subsequent international acceptance of major findings has set standards for conducting future subglacial aquatic environment study and exploration (U.S. National Research Council, 2007).

Studies of Lake Vostok during IPY

Russian exploration at Lake Vostok continued as part of the drilling program within the framework of the long-term Federal Targeted Program "World Ocean", subprogram "Antarctica." It was implemented by a consortium of eight Russian research institutions led by the Arctic and Antarctic Research Institute (AARI) of Roshydromet. In the framework of this program, the Polar Marine Geological Research Expedition (PMGRE) and Russian Antarctic Expedition (RAE) have performed extensive geophysical surveys of the Lake Vostok area and its vicinity by means of ground-based radio-echo sounding (RES) and reflection seismic measurements (Masolov et al., 2006; Popov et al., 2006, 2007; Popov and Masolov, 2007). The overall length of the geophysical traverses completed in February 2009 exceeded 6000 km and included 320 seismic measurements (Fig. 2.6-3). The main output of this large-scale field activity was a series of 1:1,000,000 maps of the Lake Vostok water table limits, the ice and water body thickness, the bedrock relief, its geomorphological zones and the spatial pattern of the internal layers in the overlying ice sheet. While a handful of geophysical transects, involving radio-echo sounding, were acquired over Lake Vostok between 1971-1972 and 1974-1975, it was more than twenty years before the first systematic survey of the lake by Italian geophysicists occurred in 1999. In the Austral season of 1999-2000, twelve new radio-echo sounding transects were collected over the lake, including one continuous flight across the long axis of the lake. From these data, the lake extent was better understood (to be ~260 km by 80 km) and the steady inclination of the ice-water interface was reconfirmed along the entire length of the lake (Kapitsa et al., 1996). The investigation also revealed the relatively high topography on either side of the lake showing that the lake occupies a deep trough.

A year later, U.S. geophysicists undertook what still remains the definitive survey of the lake by airborne measurements (Studinger et al., 2003). More than 20,000 line-km of aerogeophysical data were acquired over an area 160 by 330 km, augmented by 12 regional lines, extending outside of the main grid by between 180 and 440 km. The outcome was the first detailed assessment of the lake and its glaciological locale. Gravity modelling of the lake bathymetry established the existence of two basins (Studinger et al., 2004). The southern basin of the lake is more than 1 km deep. These geophysical investigations supplemented the long-standing geophysical campaigns by Russian scientists from 1995-2008 and resulted in 318 seismic reflection soundings and 5190 km of radio-echo soundings (Masolov et al., 2001, 2006).

During IPY, geophysical, geodetic and glaciological traverse programs carried out by RAE focused on investigating the two ice-flow lines starting at Ridge B, the Vostok flow line (VFL) passing through drilling site 5G at Vostok Station and the North-Vostok flow line (NVFL) crossing the northern part of Lake Vostok (Fig. 2.6-3). These ground traverses were planned and implemented under the IPY TASTE IDEA (Trans-Antarctic Scientific Traverses Expeditions – Ice Divide of East Antarctica) project, as part of the Italian/French/Russian traverse from Talos Dome, via Dome C, Vostok and Dome B to Dome A. The data collected in the field were used to constrain a thermo-mechanical ice-flow line model (Richter et al., 2008; Salamatin et al., 2009; Popov et al., submitted). Coordinated field and modeling efforts yielded an improved glaciological timescale for the 5G ice core and refined the isotope-temperature transfer functions for converting isotope and borehole temperature data from Vostok into a palaeo-temperature record (Salamatin et al., 2009). Other important outputs of the "Vostok ice flow lines" project were more accurate model estimates of the contemporary distribution of the accreted (lake) ice thickness and freezing rates along the Vostok flow line. In addition, ice age-depth and temperature profiles and the basal melt-rate were predicted for

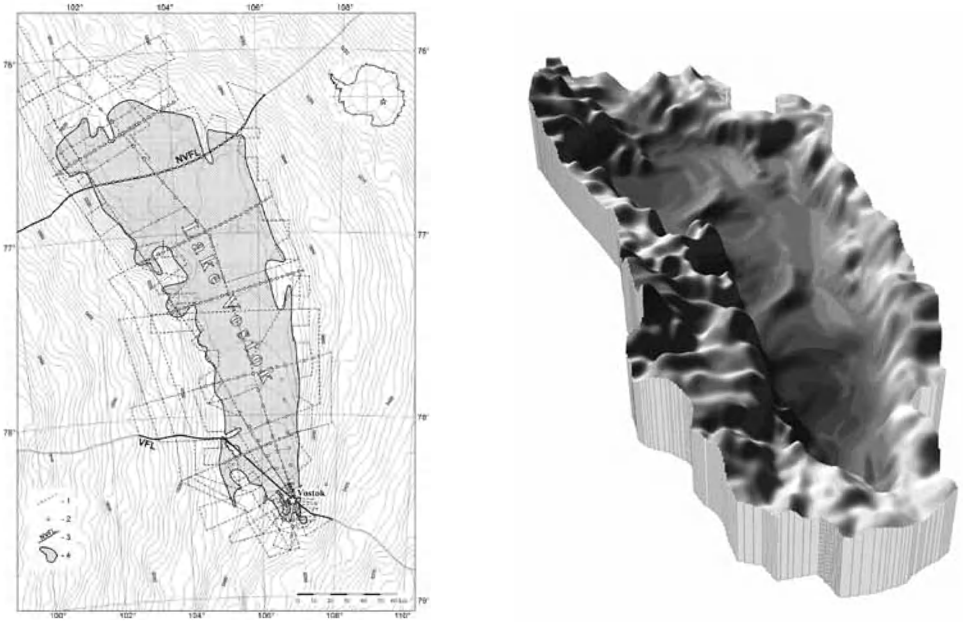

Fig. 2.6-3. Russian scientific traverses in the Lake Vostok area (left) and subglacial landscape of Lake Vostok depression as revealed by RES and seismic measurements (right), courtesy of Sergey Popov (PMGRE). Shown on the map: 1- radio-echo sounding profiles; 2- reflection seismic stations; 3- VFL and NVFL ice-flow lines (the studied segments of the flow lines are highlighted with thicker curves); 4 – the expansions of Lake Vostok water table.

the northern part of Lake Vostok (Fig. 2.6-3). The age and the location of lake accretion ice formation in the Vostok core, as inferred from the ice flow modeling, is illustrated in Fig. 2.6-4 (Salamatin et al., 2009). The upper stratum of lake ice bedded between 3539 and 3609 m beneath the surface comprises scarce mineral inclusions entrapped from the lake bottom sediments in the shallow strait and/or over the small island on the upstream side of Lake Vostok. The underlying clean ice is assumed to be refrozen from the deep water as the ice sheet moved between the "islet" and Vostok Station (Fig. 2.6-4).

Extensive study of mineral inclusions conducted at the Institute for Geology and Mineral Resources of the World Ocean (VNIIOkeangeologia) and at the All-Russian Geological Institute (VSEGEI) showed that in most cases they were soft aggregates composed of micro-particles of clay-mica minerals, quartz and a variety of accessory minerals (see inset in Fig. 2.6-4). The larger (up to 4-5 mm) rock clasts found in the inclusions were classified as quartzose siltstone comprised of zircon and monazite grains. The composition of the clasts confirms that the bedrock to the west of Lake Vostok (a potential source of terrigenous material in the ice core) is of sedimentary origin. The ages of zircon and monazite grains cluster between 0.8–1.2 Ga and 1.6–1.8 Ga, which suggests that the provenances of these sedimentary rocks, the Gamburtsev Mountains and Vostok Subglacial Highlands, are mainly Paleoproterozoic and Mesoproterozoic-Neoproterozoic crustal provinces (Leitchenkov et al., 2007).

Resumption of deep drilling at Vostok Station during IPY allowed an extension of the ice core isotopic ($\delta^{18}O$ and δD) profile of accreted ice to 3650 m depth. Analysis of the data set with the aid of an isotopic model of Lake Vostok revealed significant spatial and/or temporal variability in physical conditions during ice formation as well as variability in the isotopic content of freezing lake water (Ekaykin et al., 2010). The data suggested that there was a significant contribution of a hydrothermal source (2.8-5.5 mt of water per year) to the hydrological regime of the lake. Independent evidence (Jean-Baptiste et al., 2001; Bulat et al., 2004; de Angelis et al., 2004) including recent data on the distribution of helium isotopes (Jean-Baptiste, pers. comm., 2009) supports this inference. The extent to which Lake Vostok may be hydraulically connected with other components of the hydrological system beneath the Antarctic ice sheet cannot be assessed from such isotopic data. Precise geodetic GPS observations, from the southern part of Lake Vostok throughout IPY, have demonstrated that, at least on the time scale of five years, the lake and the ice sheet in the vicinity of Vostok Station are in steady-state (Richter et al., 2008) whereas other subglacial lakes show highly dynamic behaviours.

Biological and chemical analyses of the newly obtained accretion ice core and the development of clean procedures for biological sampling continued in collaboration with French scientists from Laboratoire de Glaciologie et Géophysique de l'Environnement, Laboratoire de Ecologie Microbienne and Laboratoire de Microbiologie des Environnements Extrêmes in the bilateral research network "Vostok," established just prior to IPY. A special effort was made by biologists from the Petersburg Nuclear Physics Institute (PNPI) of the Russian Academy of Sciences to accurately assess the cell concentration of microorganisms in the Antarctic ice sheet in the vicinity of Vostok Station. Segments of the Vostok ice core and 10 kg samples of snow collected from layers deposited before the beginning of human activity in the area were collected avoiding contamination (Figs. 2.6-5). The samples were then processed using state-of-the-art decontamination procedures (Bulat et al., 2004, 2007; Alekhina et al., 2007) and concentrated up to 3000-10,000 times. Among methods used for detection and counting of microbial cells (fluorescence, laser confocal and scanning electron microscopy, cytofluorimetry) only the flow cytofluorimetry was successful in assessing the very low quantities of cells typical in the samples studied. The results suggest extremely low biomass in ice strata, both of atmospheric and lake water origins, and emphasize the importance of ultra-clean procedures (and decontamination where necessary) if ice samples are to be used for microbiological analyses (Bulat et al., 2009). Similar pre-IPY studies were undertaken by U.S. and U.K. researchers, confirming low cell numbers and diversity in glacial and accreted ice, though their findings suggested higher cell numbers and diversity in the accreted ice (Christner et al., 2006).

The data obtained for contemporary snow and glacial (meteoric) ice suggest that the Antarctic ice sheet over Lake Vostok serves as a barrier preventing the contact of potential lake biota with the surface rather than being a conveyer of dormant microorganisms inoculating the lake water as assumed in the earliest studies. The purity of accreted lake ice suggest that Lake Vostok water may have a very low microbial content as PCR-based prokaryotic 16S ribosomal RNA gene sequencing has indicated that accretion ice is essentially free of bacterial and archaeal DNA (Bulat et al., 2009). The few bacterial phylotypes recovered from accreted ice cores have all been found in those

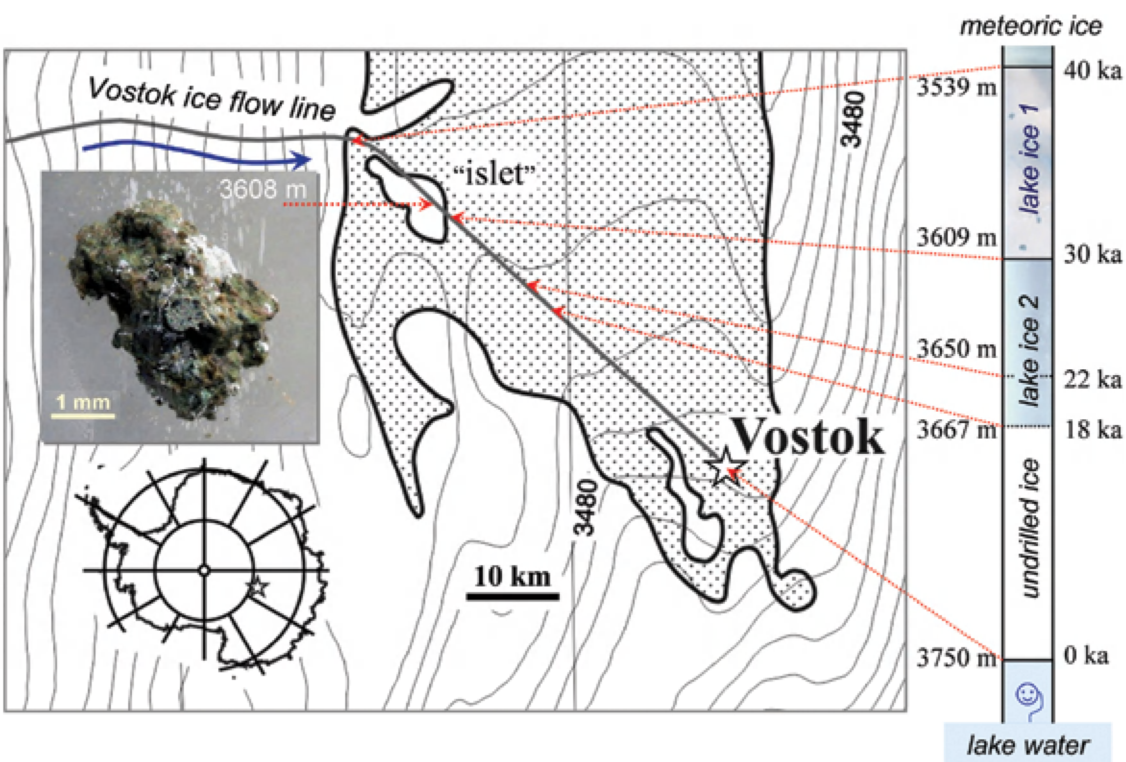

Fig. 2.6-4. Spatial and temporal coverage of the lake ice extracted as a core from the deep borehole at Vostok Station (adapted from Ekaykin et al., 2010). The Inset shows a relatively large inclusion of Lake Vostok bottom sedimentthat was trapped in lake ice 1 as the glacier was crossing the "islet" located 40 km upstream of the borehole.

Fig. 2.6-5a. Collecting snow samples for biological studies at the surface of the Antarctic ice sheet over the subglacial Lake Vostok (Jean Robert Petit from LGGE, France, January 2008), 3 km southwest of Vostok Station.
(Photo: Vladimir Lipenkov)

Fig. 2.6-5b. Russian scientist Sergey Bushmanov collects snow samples on the surface of the Antarctic ice sheet over the subglacial Lake Vostok (January 2010).
(Photo: Vladimir Lipenkov)

ice layers containing mineral inclusions.

Based on current knowledge of the lake conditions inferred from the accretion ice studies and from modeling, the lake may be inhabited by chemoautotrophic psychrophiles that are tolerant of high pressures (and possibly high oxygen concentrations) though no evidence of such microorganisms have yet been found in the accretion ice (Bulat et al., 2007a). Two independent laboratories have confirmed the presence of a thermophilic, chemoautotrophic bacterium *Hydrogenophilus thermoluteolus,* which may be associated with postulated hydrothermal activity in the lake (Bulat et al., 2004; Lavire et al., 2006). It has been speculated that the main water body of Lake Vostok is an extremely dilute, biological solution and this would suggest that life will likely be restricted to bottom sediments. If proven correct, Lake Vostok is an ideal location to develop methods for searching for life beyond our planet (Bulat et al., 2009).

Studies of Other Subglacial Lakes during IPY

The beginning of IPY marked the discovery of a major new set of subglacial lakes at the onset of the Recovery Ice Stream (Bell et al., 2007). Three or possibly four subglacial lakes, predicted by Johnson, are similar in scale to Lake Vostok and are coincident with the onset of rapid ice flow of a major East Antarctic ice stream that drains a surface equivalent to 8% of the ice sheet. These lakes were defined by the distinctive ice surface morphology of subglacial lakes, extensive, relatively flat, featureless regions bounded by upstream troughs and downstream ridges. The Recovery Subglacial Lakes appear to collect water from a large area, effectively concentrating the energy from basal melting and re-releasing it where it can have a significant impact on ice flow through either basal accretion or catastrophic drainage.

Two major programs targeted systematic studies of the Recovery Lakes as part of IPY, the U.S.-Norway traverse conducted surface geophysics and installed GPS stations to monitor ice sheet motions and the AGAP program targeted three flights at these major features. The IPY AGAP program (*Chapter 2.5*) collected gravity magnetics, laser and radar data over the southern two Recovery Lakes (Block et al., 2010). These data will be used to determine the distribution of subglacial water in the lakes and the upstream catchment and to evaluate the geologic setting of these features. The U.S.-Norway Traverse crossed all four of the Recovery Lakes during January 2009 on the return from South Pole Station to the Troll Station. Low frequency radar was used to map the morphology of the subglacial lakes and to image the ice sheet bed of the dynamic lakes identified by Smith et al., (2009). Together these two datasets will provide the first insights into the role subglacial lakes play at the onset of fast ice flow.

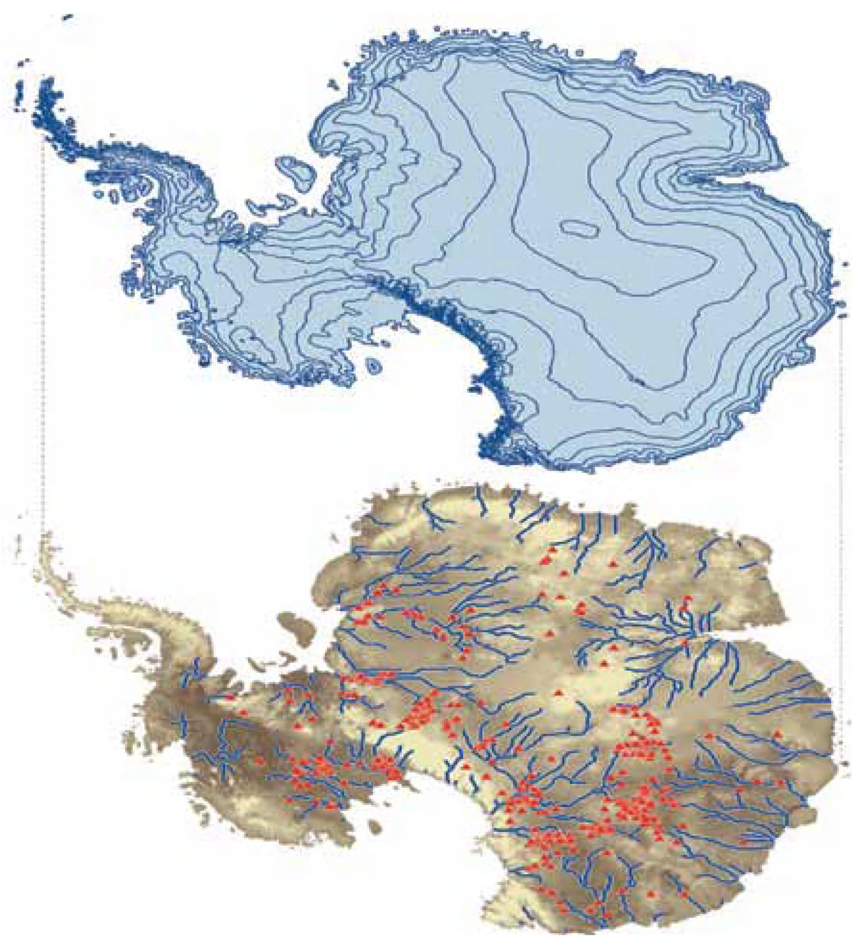

Fig. 2.6-6. The location (red triangles on the lower panel) of 387 subglacial lakes superimposed on the BEDMAP depiction of Antarctic sub-ice topography. The upper panel denotes the ice sheet surface topography.
(Courtesy: Andrew Wright and Martin Siegert)

Emerging Subglacial Exploration Programs

Significant progress has continued on subglacial lake exploration after the IPY period. Almost a decade of planning has led to the funding of major new programs to study various aspects of subglacial aquatic environments. These programs are in addition to continuing efforts at Lake Vostok. An ambitious U.K.-led program will survey and sample Subglacial Lake Ellsworth in West Antarctica in the next few years with lake entry predicted in 2011-2012. The geophysical studies of Lake Ellsworth have shown it to be 10 km long, 2-3 km wide and at least 160 m deep (under 3 km of ice). Surveys confirmed that sedimentary deposits can be expected on the floor of the lake. The surrounding topography revealed that the area is an ancient fjord developed at a time when an ice cap occupied the Ellsworth Mountains prior to the development of the West Antarctic ice sheet. Geophysical surveys confirmed that the lake has likely persisted through glacial cycles. The project will access the lake using clean hot-water drilling and deploy a probe to sample and measure both the water and sediment. Lake penetration and *in situ* sensing and sampling should take place in 2012. On a similar time scale, the U.S. has funded a further program (WISSARD) to enter, instrument and sample an 'actively discharging' subglacial aquatic system beneath Whillans Ice Stream, which is also in West Antarctica. Russian researchers had hoped to penetrate Lake Vostok during IPY, but were beset by technical problems so they are now developing a new strategy for lake penetration and sampling.

A New Frontier in Antarctic Science is Advanced by IPY

The IPY period saw the development of significant new insights into the importance of subglacial aquatic environments including:

- subglacial lakes were common features of ice sheets,
- a spectrum of subglacial environments exists,
- subglacial hydrologic systems and water movement beneath ice sheets on various spatial and temporal scales were common,
- subglacial lakes may be linked with the onset of ice streams influencing ice sheet movement, and
- outbursts of subglacial waters could have feasibly played a role in past climate change.

The exploration and study of subglacial aquatic environments is at its earliest stages and if the major advances realized during IPY are any indication of what is to come, the most exciting discoveries will unfold in the years ahead. In just a decade, findings regarding subglacial aquatic environments have revolutionized how Antarctica is perceived (Fig. 2.6-6). Ice sheets are now seen as exhibiting a highly dynamic behaviour and the environments beneath them may play critical roles in fundamental processes that affect the complex interplay of geology, glaciology, tectonics, ecology and climate over geologic time. On-going and planned projects will ultimately determine if subglacial environments house unique microbiological assemblages, but these programs would not have been possible without the momentum provided by the IPY.

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2.7 Permafrost

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Introduction and Overview

Hans-Wolfgang Hubberten, Jerry Brown, Hanne H. Christiansen and Hugues Lantuit

Permafrost is defined as ground (soil or rock and included ice or organic material) that remains at or below 0°C for at least two consecutive years (van Everdingen, 1998), and exists in approximately 25% of the terrestrial part of the Earth (Fig. 2.7-1). Since permafrost is present on most continents on Earth, in lowlands and in mountains, permafrost research is also undertaken beyond the traditional polar regions (north and south of 60°). During International Polar Year (IPY) 2007–2008, most permafrost research focused on land activities in polar regions. Several coordinated cluster projects had bipolar focus (Fig. 2.7-2). Permafrost research, forming an important part of the cryospheric research, is becoming increasingly multidisciplinary, bringing together geologists, geographers, engineers, biologists, ecologists, and soil and social scientists.

IPY 2007–2008 provided a unique opportunity for permafrost science to focus on regional, bipolar and multidisciplinary activities. Late 20th century observations and compilations of recent data indicated a warming of permafrost in many continental, marine-dominated and mountainous regions with resulting degradation of ice-rich and carbon-rich permafrost (Romanovsky et al., 2007). Major activities during IPY focused on the measurement of ground temperatures to assess the thermal state of permafrost and the thickness of the active layer, on the quantification of carbon pools in permafrost and their potential future remobilization, as well as the quantification of erosion and release of sediment along permafrost coasts, and periglacial process and landform quantification.

To address these and related bipolar questions, four permafrost cluster projects were approved by the IPY Joint Committee:

- The Permafrost Observatory Project: A Contribution to the Thermal State of Permafrost (TSP) [IPY Project 50]
- The Antarctic and sub-Antarctic Permafrost, Periglacial and Soil Environments Project (ANTPAS) [IPY Project 33]
- The Arctic Circum-Polar Coastal Observatory Network (ACCO-Net) [IPY Project 90]
- Carbon Pools in Permafrost (CAPP) [Project 373].

These four cluster projects focused on research and observations in the permafrost and periglacial environments of the Planet Earth. They together represented more than 50 individual IPY Expression of Intent (EoI) proposals with participants from more than 25 countries representing both polar regions, as well as mid- and low-latitude, permafrost-dominated mountainous regions. They were coordinated by the International Permafrost Association (IPA) and its Secretariat, then based at the University Centre in Svalbard (UNIS). An overall objective of these coordinated projects was to produce a "snapshot" of permafrost conditions during the IPY period, with emphasis on the thermal state of the permafrost (TSP). This includes active layer thickness measurements as part of the Circumpolar Active Layer Monitoring (CALM) program established in the 1990s (Nelson et al., 2008).

The history and accomplishments of the IPA and its related IPY activities are well-documented in semi-annual reports in the journal *Permafrost and Periglacial Processes* (Brown and Christiansen, 2006; Brown and Walker, 2007; Brown and Romanovsky, 2008; Brown et al., 2008 a,b; Christiansen et al., 2007; Kuhry et al., 2009). Permafrost research during the Fourth IPY was highlighted in the Ninth International Conference on Permafrost (NICOP). From 29 June to 3 July 2008, approximately 700 participants representing 31 countries convened at the University of Alaska Fairbanks for the NICOP. Early results of IPY activities were published in the two-volume NICOP proceedings (Kane and Hinkel, 2008), with papers related to borehole temperatures (46), active layer (50) and a number of reports on periglacial, coastal and carbon processes. NICOP also marked the 25th anniversary of the formation of the International Permafrost Association and the Fourth International Conference on Permafrost in 1983, also held in Fairbanks, Alaska. Permafrost activities were also well represented at the official IPY Conferences in St. Petersburg, Russia July 2008 and at the International Geological Congress, Oslo, August 2008.

Traditionally, permafrost research has been mostly undertaken in Northern Hemisphere polar regions by Canada, Russia (formerly the Soviet Union) and the U.S.A. (Alaska). These three countries contributed

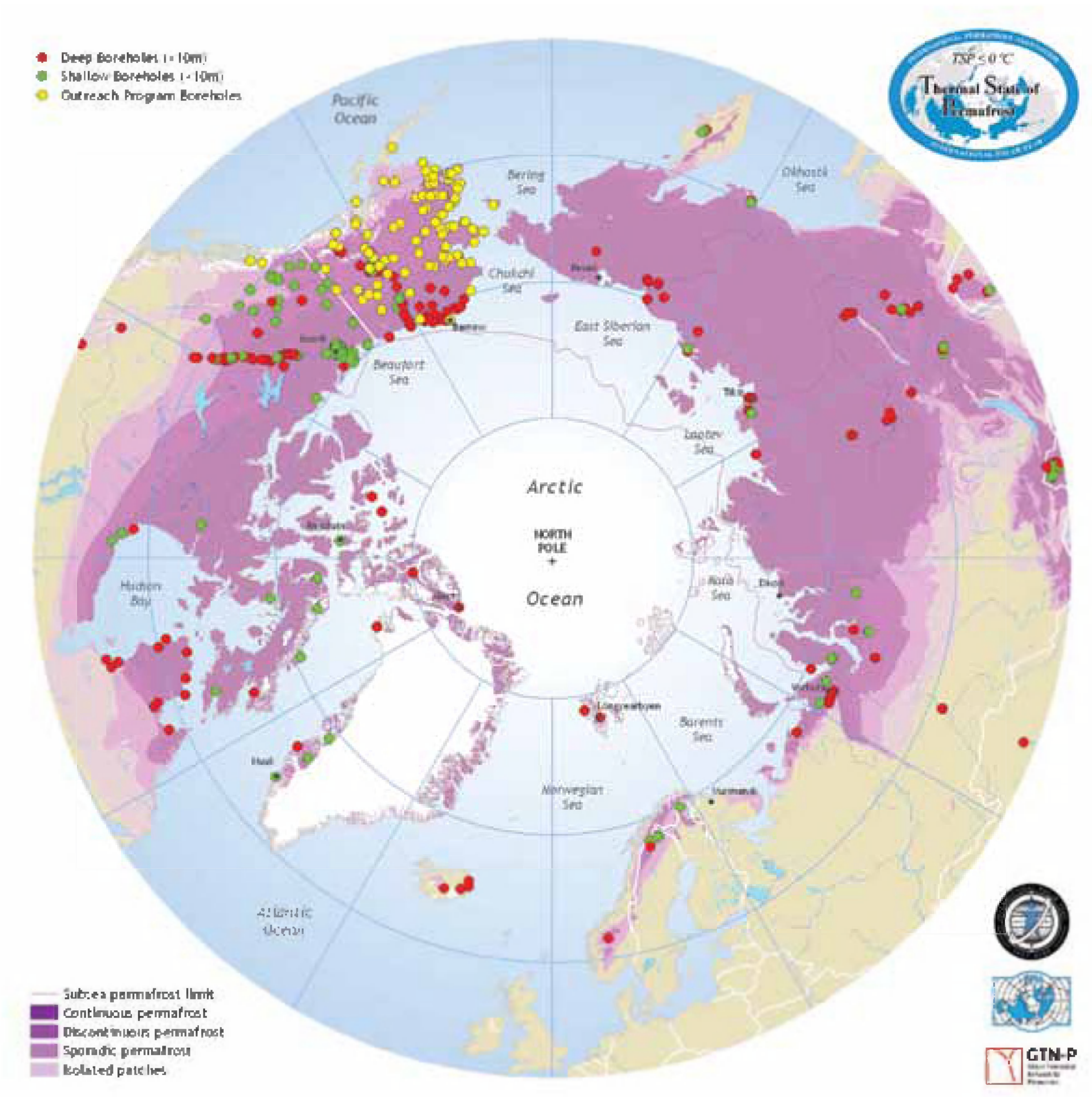

Fig. 2.7-1. Permafrost extent in the northern hemisphere and boreholes drilled during IPY.

(Map: H. Lantuit after Brown, 1998)

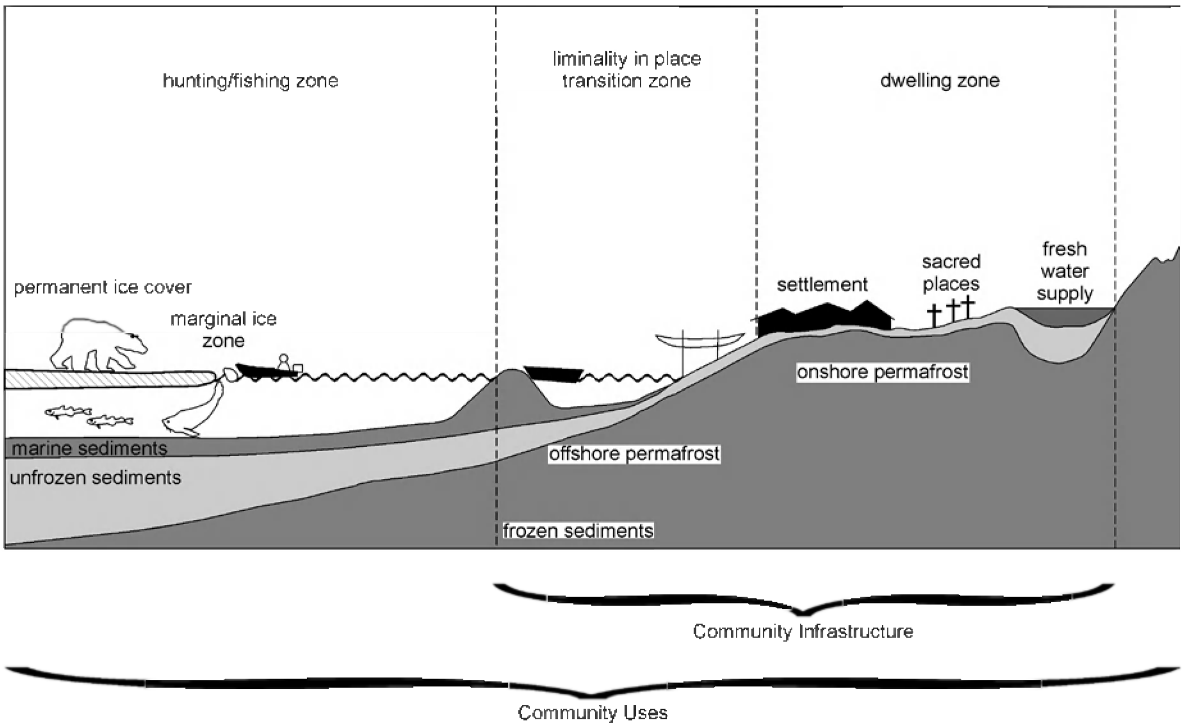

Fig. 2.7-2. The Arctic coastal zone depicted as the climate-sensitive region of the Arctic in which human activity and current rapid change intersect. Observatories in the coastal zone offer the potential for combined multidisciplinary work in a socio-economically relevant milieu.
(Graphic courtesy of the Arctic Centre, University of Groningen, Netherlands)

the majority of the observations performed during IPY. For the Northern Hemisphere, U.S.A., Canadian, Norwegian, Swedish, Russian and European agencies made substantial funding contributions. Several nations took on leadership in several of the IPY permafrost cluster projects. Norway took on a prominent role in temperature and periglacial observations and national database development in Norway, Svalbard and Iceland. Germany coordinated coastal permafrost observations and the drilling of several deep holes in Russia. Sweden played an important role in coordinating research on permafrost carbon pools. Portugal and Spain contributed with great enthusiasm to permafrost research with their projects in Antarctica and their outreach efforts strengthened the overall polar research of those two nations.

IPY provided a unique opportunity to build on existing permafrost and periglacial research in the Antarctic, with development of new sites and mapping efforts. Argentina, Brazil, Bulgaria, Italy, New Zealand, Portugal, Russia, South Africa, Spain, Sweden, U.K. and U.S.A. continued or expanded their activities. The 10-year European PACE project data were reviewed (Harris et al., 2009). In non-polar regions European countries continued the PERMOS (Vonder Mühll et al., 2008) network in Switzerland. In Asia, China, Mongolia, Kazakhstan and Japan continued on-going and developed new permafrost observations (see below). Most participating countries provided funding through national projects.

The establishment of the permafrost thermal snapshot in the TSP project primarily confirms large differences between marine and continental regions, and between bedrock and sedimentary sites, lowlands and mountains mainly in the Northern Hemisphere (Smith et al., 2010; Romanovsky et al., 2010 a,b; and Christiansen et al., 2010). Temperature trends from pre-IPY existing boreholes allow us to conclude that the evolution of the permafrost temperatures is spatially variable and that the warming of the upper permafrost differs in magnitude from region to region, as well as between bedrock and sedimentary regions according to the Northern Hemisphere TSP research. This highlights the need for continued acquisition of a baseline dataset such as the one developed by the TSP, but also for integration with climate monitoring and for sustained observations over many decades.

The Carbon Pools in Permafrost (CAPP) project contributed to our ability to better estimate the amount of carbon stored in permafrost soils, incorporating the upper three meters of the ground and deeper in some cases. Substantial numbers of new soil pedons from Russia were added to the database. This led to the publication of a revised estimate of the amount of carbon stored in the northern circumpolar permafrost region, amounting to approximately 50% of the estimated global below-ground organic carbon pool (Tarnocai et al., 2009). The increasing awareness that carbon pools in permafrost regions are much larger than previously estimated and the potential importance for the global carbon balance has prompted additional scientific questions.

A long-term framework aimed at maintaining both the new operational networks stemming from IPY, as well as the management and capacity-building efforts needed to sustain the level of observation are required. Our overriding goal has been the establishment of the International Networks of Permafrost Observatories including active layer, periglacial, coastal and carbon key study sites, and the development of a sustainable data management system and associated archives. The role of remote sensing in permafrost research has only been touched upon during the IPY and its specific role in detecting key processes relevant to permafrost dynamics as well as its input to modeling will be a future key permafrost technological development in both the Arctic and the Antarctic.

IPY made it clear that international research projects need strong coordinated management, data and information platforms. These needs and approaches were well-recognized by the IPA as early as 1988, when it held its first data session in Trondheim, Norway. This was followed by several workshops that led to the implementation of the Global Geocryological Database; a metadata based information service. Successful future integration with other international programs and compliance with data standards will maximize permafrost cross-disciplinary usability. Data management is often overlooked, but a fundamental component of modern research and often the most challenging for developing financial support. Yet, data management ensures the long-term viability and usability of the results of a large research effort such as IPY and for the IPA, this is of course especially so for permafrost observations and research.

An IPY permafrost initiative included also to continue the IPA support and patronage of the development of the Permafrost Young Researchers Network, PYRN (Bonnaventure et al., 2009). PYRN was started in 2005 to establish a network among students and young permafrost researchers in order to promote future generations of permafrost researchers. During IPY, PYRN grew to a web-connected organization of more than 720 students and researchers in 43 different countries. PYRN activities included training in permafrost methodology, development of the PYRN-TSP Nordic boreholes, participation in conferences, development of a database on dissertations and a list of 160 senior researchers in 16 countries to serve as mentors. Another outreach activity focused on education and was the compilation by the IPA Secretariat of a web-based map and associated searchable catalogue of International University Courses on Permafrost (IUCP) containing 136 courses in 17 countries during IPY. Both PYRN and IUCP are still active after IPY and thus are important IPA IPY legacies.

The four IPY permafrost cluster projects all were integrated into international research or observing programs. The TSP is part of the Global Terrestrial Network for Permafrost (GTN-P), which is a network of both the Global Climate Observing System (GCOS) and the Global Terrestrial Observing System (GTOS). Links to the Climate and Cryosphere (CliC) project of the WCRP, SCAR and IASC, and more broadly to the World Meteorological Organization (WMO) and the Global Carbon Project of the ESSP facilitated organizing and supporting the CAPP project. The long-term IPA connections with the Scientific Committee for Antarctic Research (SCAR) further facilitated the development of ANTPAS. The ACCONet activities, including new information on carbon fluxes from the erosion of permafrost coasts are a direct contribution to the Land-Ocean Interaction in the Coastal Zone (LOICZ) project, and its assessment of global coastal biogeochemical fluxes. It is also envisioned that the networks created and/or strengthened during IPY will form an integrated component of the upcoming observing networks of the Arctic (Sustaining Arctic Observing Networkds - SAON) and the Antarctic (Pan-Antarctic Observing System - PanTOS), thereby contributing to the overarching Global Earth Observation System of Systems (GEOSS). The international permafrost community also contributed during IPY to the Integrated Global Observing Strategy Theme on Cryosphere, which will serve as a strategic document for the elaboration of polar observing networks.

The June 2010 IPY Oslo Science Conference (*Chapter 5.6*), followed by the Third European Conference on Permafrost (EUCOP III) on Svalbard, provided opportunities for permafrost researchers and scientists from both hemispheres from related research fields to discuss IPY results in context with regional and global changes, and related environmental and social consequences. A special issue of the journal *Permafrost and Periglacial Processes* was presented at the June 2010 conferences, with regional papers for North America (Smith et al., 2010), the Nordic Region (Christiansen et al., 2010), Russia (Romanovsky et al., 2010a) and Antarctica (Vieira et al., 2010), and reports on Central Asia (Zhao et al., 2010), and carbon-rich permafrost (Kuhry et al., 2010), including a Northern Hemisphere synthesis paper on the snapshot of the permafrost thermal state during the IPY period (Romanovsky et al., 2010b; Fig. 2.7-1). The following sections provide more details on our four IPY permafrost cluster project accomplishments.

Permafrost Observatory Project: A Contribution to the Thermal State of Permafrost (TSP, IPY no. 50)

Jerry Brown and Hanne H. Christiansen

Formal planning of the IPY Project 50, Thermal State of Permafrost (TSP) commenced in late summer 2003 following the IPA Zürich Council recommendations on permafrost monitoring and data management. TSP is a focused extension of the Global Terrestrial Network for Permafrost (GTN-P) program (Smith et al., 2009). In 2003, the GTN-P involved 15 countries in both hemispheres and consisted of 287 candidate boreholes and an additional 125 sites in the Circumpolar Active Layer Network (CALM) network. Inventories of these sites and metadata are found on websites maintained by the Geological Survey of Canada (GTN-P) and the CALM project (Shiklomanov et al., 2008).

A TSP planning document, co-authored by Romanovsky et al., (unpubl. 2003), was prepared in fall 2003 with the goal to produce a data set as a standard against which to evaluate future changes and reanalyze past histories of permafrost development and degradation. Initial results of the TSP project were reported and published in the proceedings of the Ninth International Conference on Permafrost (NICOP) in Fairbanks, Alaska and presented at the 33rd International Geological Congress in Oslo, Norway, in summer 2008.

The TSP plans were submitted to the ICSU IPY Planning Group, which assigned TSP to its Theme *"To determine the present environmental status of the polar regions by quantifying their spatial and temporal variability".* A more formal TSP plan was prepared in July 2004 focusing on an intensive research campaign, with the overall goals:

- obtain standardized temperature measurements in all permafrost regions of Planet Earth (thermal snapshot);
- produce a global data set and make it available through the GTN-P;
- develop maps of contemporary permafrost temperatures;
- include periglacial process monitoring; and
- develop and verify models and reanalysis approaches for past, present and future permafrost and active layer temperatures and scenarios.

Detailed TSP planning took place at meetings and conferences leading up to the November 2005 Second International Conference on Arctic Research Planning (ICARP II) in Copenhagen where an IPA permafrost planning workshop was supported by the International Union of Geological Sciences (Brown, 2006). The TSP project was formally acknowledged by the IPY Joint Committee in November 2005 and subsequently was assigned as project no. 50. Formally, 26 individual Expression of Intent (EoI) proposals were assigned to Project 50. An international TSP meeting was held in October 2009 in Ottawa to summarize and coordinate the international synthesis of the TSP results including both the permafrost snapshot and analyzing permafrost temperature trends including the conditions during IPY. The TSP snapshot comprises measurements in over 850 boreholes and almost 200 current and pre-IPY CALM active layer sites in both hemispheres with over 25 participating and reporting countries (Table 2.7-1). Globally, nearly 350 new boreholes were drilled and instrumented during IPY. The total number of ground temperature sites

Table 2.7-1. Inventory of Northern Hemisphere TSP boreholes and CALM sites.

	Total # of boreholes	Established during IPY	Surface <10m	Shallow 10-<25m	Inter-mediate 25-<125m	Deep >125m	CALM sites*
Austria	3	-	-	3	-	-	-
Canada	192	119	39	122	20	6	28
China	39	6	5	14	15	1	11
Greenland	11	8	7	2	-	2	3
Finland	1	1	1			-	-
Germany (others in Russia/ Svalbard)	2	2	-	-	-	2	-
Iceland	4	-	-	4	-	-	-
Italy	8	0	-	4	4		
Japan (others in Svalbard/ Mongolia/Switzerland)*	10	9	9	1	-	-	-
Kazakhstan	4	2	3		1	-	3
Mongolia	75	27	31	33	8	3	44
Norway/Svalbard	61	48	14	29	13	4	3
Poland/Svalbard	-	-	-	-	-		4
Russia	151	12	39	82	25	4	45
Spain	2	0	1	-	1	-	-
Sweden	12	10	8	3	-	1	1
Switzerland (PERMOS)	30	8	1	15	14	-	2
U.S.A.	185	91	111	16	37	23	48
Total	**790**	**343**	**269**	**328**	**138**	**46**	**192**

** see CALM sites for details < www.udel.edu/Geography/>*

in the Antarctic and South America is 77, including 10 boreholes deeper than 10m in the Antarctic. Fifteen countries are participating in the Southern Hemisphere TSP projects.

Several protocols have been developed for obtaining and reporting data. These were based in part on the PACE project (Harris et al., 2009), the Permafrost in Switzerland (PERMOS) program (Vonder Mühll et al., 2008) and the NORPERM (Juliussen et al., in prep) and a joint U.S.-Russian manual (www.gi.alaska.edu/snowice/Permafrost-lab/literature/TSP_manual.pdf). An online, master borehole inventory containing selective site metadata and the 2007-2009 snapshot data of all boreholes sites was presented at the Oslo, June 2010 IPY Polar Science – Global Impact Conference. Detailed regional TSP results were presented at the Third European Conference on Permafrost (EUCOP III) focusing on the thermal state of frozen ground in a changing climate during IPY. Updates of annual CALM data are maintained on its website.

Early results of the TSP and related activities were published in the two-volume NICOP proceedings (Kane and Hinkel, 2008) with 46 papers related to borehole temperatures and 50 papers related to active layer observations. The establishment of the permafrost thermal snapshot in the TSP project primarily confirms large differences between marine and continental, between bedrock and sedimentary sites, and between lowlands and mountains mainly in the Northern Hemisphere. Temperature trends from pre-IPY existing boreholes allow us to see that the evolution of the permafrost temperatures is spatially variable and that the indications of warming of the upper permafrost differ in magnitude from region to region and between bedrock and sedimentary regions; these trends are mainly based on the Northern Hemisphere TSP research (Romanovsky et al., 2010b; Smith et al., 2010). Regional TSP results for North America (Smith et al., 2010), the Nordic Region (Christiansen et al., 2010), Russia (Romanovsky et al., 2010a), the Antarctic (Vieira et al., 2010), and Central Asia (Zhao et al., 2010) are presented in the June 2010 issue of *Permafrost and Periglacial Processes,* where the Northern Hemisphere polar permafrost thermal state synthesis was also presented (Romanovsky et al., 2010b).

Education and outreach is an important component of the present and future TSP. The Permafrost Young Researchers Network (PYRN) serves to involve students and early career researchers and to develop ownership of individual boreholes (Bonnaventure et al., 2009). The International University Courses on Permafrost (IUCP) was developed as an online searchable database for students when planning permafrost courses as part of their bachelor's, master's or Ph.D. degrees (Christiansen et al., 2007). Several field courses have enabled undergraduates, graduate student and teachers to become directly involved in permafrost measurements. At the pre-university level, a program to install boreholes and active layer measurement sites in the communities, primarily at schools, was expanded from Alaska to Canada and other countries (Yoshikawa, 2008). More than 100 such sites are included in the TSP.

To be successful, TSP required additional sites, instrumentation and funding to provide representative geographic coverage. Most participating countries provided funding to national projects. For the Northern Hemisphere, U.S.A., Canadian, Norwegian, Swedish, Russian and European agencies made substantial contributions. To further encourage broad participation of Russian institutions and sites, a U.S. bilateral project with Russia was funded. IPY provided a unique opportunity to coordinate and expand observations in both hemispheres with development of new boreholes and CALM sites. For the Antarctic, Argentina, Brazil, Bulgaria, Italy, New Zealand, Norway, Portugal, Russia, South Africa, Spain, Sweden, Switzerland, U.K. and U.S.A. started, continued or expanded their monitoring activities (see the following section). Specific national and multi-national projects were funded and these sponsors are identified in the June 2010 *Permafrost and Periglacial Processes* regional paper on the Antarctic (Vieira et al., 2010).

The ultimate legacy of TSP will be the establishment of a permanent international network of permafrost observatories including boreholes and periglacial process monitoring in addition to standard meteorological observations and as appropriate coastal and carbon observations. A sustainable data activity, building on the GTN-P, involvement of the PYRN researchers and outreach activities are critical components of the future TSP.

TSP related websites:

TSP Alaska-Russia: www.permafrostwatch.org
TSP Outreach: www.uaf.edu/permafrost
TSP Norway: www.tspnorway.com
NORPERM: www.ngu.no/norperm
Canada: canpfnetwork.com, GTN-P: www.gtnp.org
CALM: www.udel.edu/Geography/calm/
FGDC: nsidc.org/fgdc/
IPA: www.ipa-permafrost.org/
Pre-university outreach: ww.uaf.edu/permafrost/
PERMOS: www.permos.ch
International University Courses on Permafrost (IUCP): http://ipa.arcticportal.org/index.php/Courses-IUCP/
PYRN: http://pyrn.ways.org

Antarctic and sub-Antarctic Permafrost, Periglacial and Soil Environments (ANTPAS, IPY no. 33)

Gonçalo Vieira

Antarctic and sub-Antarctic Permafrost, Periglacial and Soil Environments (ANTPAS - no. 33) is an interdisciplinary IPY-core project of the IPA Working Group on Antarctic Permafrost and Periglacial Environments and of the SCAR Expert Group on Permafrost and Periglacial Environments. The project includes the Antarctic region as defined by the Antarctic Treaty, as well as South American permafrost regions. Significant advances in the framework of ANTPAS were obtained on: a) developing the Antarctic permafrost monitoring network; b) extending the Circumpolar Active Layer Monitoring Network – Southern Hemisphere (CALM-S); c) soil characterization and mapping, and d) mapping,

Table 2.7-2. Inventory of Antarctic and South American TSP boreholes and CALM sites.

Countries	Total # of boreholes	Established during IPY	<2m	Surface 2 - <10m	Shallow 10 - <25m	Inter-mediate 25 - <125m	Deep > 125m	CALM sites
South America (>1 m)								
Argentina	2	-	-	2	-	-	-	
Argentina (Spain)	2		2					
Antarctica								
Argentina / Japan	1	-	-	1	-	-	-	-
Brazil	15	15	15	-	-	-	-	-
Italy	5	-	1	3	-	1	-	4
Italy / Argentina / Japan	1	-	-	1	-	-	-	-
Italy / New Zealand	2	-	-	-	-	2	-	-
Italy / United Kingdom	2	1	-	1	-	1	-	1
New Zealand	1	-	1	-	-	-	-	1
New Zealand / United States	7	-	7	-	-	-	-	7
Portugal / Bulgaria / Spain	3	3	-	3	-	-	-	1
Portugal / Spain / Argentina	2	2	2	-	-	-	-	1
Russia	6	6	2	4	-	-	-	3
South Africa / Sweden	5	2	5	-	-	-	-	-
South Africa / Sweden / Norway	1	1	-	1	-	-	-	-
Spain / Portugal	11	9	8	1	1	1	-	3
Spain / Portugal / Russia	3	3	-	3	-	-	-	1
United States	6	5	2	1	1	1	1	
United States / Russia	2	-	1	-	1	-	-	2
Total (Antarctica)	**73**	**47**	**44**	**19**	**3**	**6**	**1**	**24**

monitoring and modelling periglacial environment processes and dynamics.

a) Antarctic permafrost monitoring network

(see Table 2.7-2)

The installation of a network of boreholes for monitoring permafrost temperatures in the Antarctic started in the late 1990s in the Transantarctic Mountains (McMurdo Dry Valleys and Victoria Land). It developed into other Antarctic regions in the early 2000s (i.e. South Shetlands – Ramos et al., 2007, 2008; Queen Maud Land), but it was only with ANTPAS that a systematic and coordinated approach took place in order to expand the network to the whole Antarctic region (e.g. Guglielmin, 2006; Adlam, 2009; Adlam et al., 2009; Ramos et al., 2009). Bockheim (2004) reported 21 permafrost boreholes in the Antarctic. Nine of the sites are located in the McMurdo Dry Valleys, five in North Victoria Land, four along the Antarctic Peninsula and three in Queen Maud Land. In late 2009, following ANTPAS activities, the network consists of 73 boreholes, including a more extensive coverage in the Antarctic Peninsula region, Transantarctic Mountains and Queen Maud Land, as well as important sites in Enderby Land, Marie Byrd Land, Vestfold Hills and Wilkes Land. This growth in the number of boreholes is highly significant since it will allow for the first time a continental-scale overview of permafrost temperatures in the Antarctic and an important increase on the knowledge of permafrost characteristics. A synthesis paper (Vieira et al., 2010) was prepared and contains initial data prior to the availability of data from the Antarctic season of 2009-2010.

b) Circumpolar Active Layer Monitoring Network – Southern Hemisphere (CALM-S)

The Antarctic monitoring network of CALM-S sites includes the active layer thickness and temperatures, as well as measurements of controlling environmental variables. Due to the coarse texture and rocky nature of the terrain in the Antarctic, it is generally impossible to measure active layer depth using mechanical probing thus the protocol focuses on ground temperatures. This also limits the application of the CALM grid concept and several sites consist essentially of a shallow borehole with data being collected at closely-spaced depths in the active layer. ANTPAS provided the framework for the application of a common CALM-S protocol to the Antarctic (Guglielmin, 2006) and the expansion of the network from 18 sites in 2004 to 24 sites in 2009. This will be extremely valuable for monitoring the influence of climate change on active layer temperatures and processes as these are central for understanding the ecology of the terrestrial environment.

c) Soil characterization and mapping

One of the main goals of ANTPAS is to produce a soil map of Antarctica. Because of the size of the continent and the low proportion of ice-free areas, activities concentrate on producing permafrost maps of the eight key ice-free regions: Queen Maud Land, Enderby Land, Vestfold Hills, Wilkes Land, Transantarctic Mountains, Marie Byrd Land, Ellsworth Mountains and Antarctic Peninsula. A soil description and sampling protocol manual and keys for classifying soils has been prepared and is available at http://erth.waikato.ac.nz/antpas/publications.shtml.

Field investigations have been conducted all over Antarctica. In Victoria Land reconnaissance and detailed soil maps, as well as soil studies have been produced (Bockheim, 2007, 2008, 2009; Bockheim et al., 2007, 2008a; McLeod et al., 2007, 2008a,b,c; Balks et al., 2008a; Bockheim and McLeod, 2008; O'Neill and Balks, 2008). In the Antarctic Peninsula region, Schaefer and others (Simas et al., 2006, 2007, 2008; Navas et al., 2008; Schaefer et al., 2008) conducted mapping and soil survey, while activities have also taken place in the vicinity of the Russian stations in Queen Maud Land, Enderby Land, Vestfold Hills, Wilkes Land, Marie Byrd Land, the Oakes Coast and King George Island.

d) Mapping, monitoring and modelling periglacial environments processes and dynamics.

Multi- and interdisciplinarity are one of the main characteristics of ANTPAS and that has become especially evident in the investigations on the dynamics of the periglacial environment. Several studies have taken place, especially in the Transantarctic Mountains, Queen Maud Land, Antarctic Peninsula, Marion Island and also in South America with a focus on a diversity of disciplines. Main themes were permafrost and geomorphological mapping (e.g. Vieira et al., 2007, 2008; Bockheim et al., 2008a,b; Guglielmin et al., 2008a; Serrano et al., 2008, Melo, 2009), dynamics (e.g. Hall et al., 2007a,b; Hauck et al., 2007; Raffi et al., 2007; Boelhouwers et al., 2008; De Ponte et al., 2008, 2009; Strini et al., 2008; Trombotto and Borzotta, 2008; Valcárcel-Díaz et al., 2008; Guglielmin et al., 2008b) and landscape evolution (e.g. Bockheim and Ackert, 2007; Bockheim and McLeod, 2008b; Bockheim et al., 2008c,d, 2009), climate analysis (e.g. Berg, 2009; Trindade, 2009; Nel et al., in press), ground-atmosphere modelling (e.g. Ramos and Vieira, 2009; Rocha, 2009), remote sensing of snow (e.g. Mora, 2009), interactions between vegetation, geomorphological dynamics and climate (e.g. Boelhouwers et al., 2007; Cannone and Guglielmin, 2008; Cannone et al., 2008, 2009; Guglielmin et al., 2008b; Haussmann et al., 2009) and microbial communities.

ANTPAS is an important project for Antarctic permafrost research. In its framework, international investigations have been fostered, funding was obtained in several countries and new regions of the Antarctic are now being monitored in the medium to long timescale, providing a legacy of field instrumentation and data. The main results of the project are still to come as the data is still to be collected. ANTPAS will have an impact on Antarctic permafrost research in the next decades. The activities and objectives will continue being promoted within IPA and SCAR, but it is vital that funding continues so that the monitoring sites can be maintained beyond the typical short-term periods of science project funding.

Arctic Circum-Polar Coastal Observatory Network (ACCO-Net, IPY no. 90)

Paul Overduin

Within the Arctic coastal dynamics community, the IPY was seen as a chance to act on the recommendations of the 3rd Working Group of the Second International Conference on Arctic Research Planning (ICARP II), which laid out a series of six key recommendations centered around the establishment of supersites for the interdisciplinary study of Arctic coastal science (Cogan et al., 2005) (Fig. 2.7-3). IPY Project no. 90, entitled Arctic Circumpolar Coastal Observatory Network (ACCONet), arose from the Arctic Coastal Dynamics Project (ACD) of the International Arctic Science Committee (IASC) and the International Permafrost Association (IPA). ACD also has been identified as an affiliated project of the Land-Oceans Interactions in the Coastal Zone (LOICZ) project of the IHDP/IGBP. In its second science plan, created at a workshop at the Arctic Centre in Groningen, Netherlands in November 2006, plans were laid for a template of observables and the creation and/or adoption of standard operating procedures for all sites (Overduin and Couture, 2008). The IPY JC tasked ACCONet to coordinate the group of IPY projects collectively identified with monitoring of the arctic coastal zone, grouping 21 IPY expressions of intent together with a further six projects that submitted national level IPY project proposals, but were not listed in the international IPY database.

IPY has generated sustained international interest in coordinated circumpolar arctic monitoring efforts. As a transitional environment, the Arctic coastal zone is an ideal location for monitoring change. Such systems generally show the greatest sensitivity to climatic or environmental shifts (Committee on Designing an Arctic Observing Network, National Research Council, 2006). The coastal zone is the site of human habitation, industry and transport in the Arctic. A monitoring network here is socio-economically relevant and provides a two-way opportunity to involve residents in monitoring activities and to inform local communities about science. ACCONet's goal is to provide the infrastructure and networking to establish an observatory network in the arctic coastal zone.

ACCONet sites were selected at the national level by national level coastal observatory IPY proposals and by adoption of ACD Key Sites with existing coastal monitoring records. Criteria for selection included site access and the existence of historical records. At the international level, major classifications of coastal typology were included and sites were selected to include the range of arctic coastal environments as described above. Some sites are solely coastal observatories, while others use permanent infrastructure associated with settlements or science stations.

Site selection was further coordinated at an ACCONet meeting in Tromsø, Norway in October 2007 (Flöser et al., 2008) and initial remote sensing data were distributed. Interim results from ACCONet projects were presented at the Ninth International Conference on Permafrost in Fairbanks, U.S.A. in 2008 in a session on subsea permafrost, sea level changes and coastal dynamics (Kane and Hinkel, 2008).

To provide a standardized basis for classification and change detection across all network sites, the European Space Agency granted ACCONet access to third party remote sensing data products for all sites currently being sampled. Both archived data and acquisitions of high spatial resolution optical data during and after IPY have been granted so that change detection up to, during and following IPY is possible for all sites. A critical baseline of remotely sensed data is the cornerstone of the network, permitting comparison of observatory sites in terms of many parameters relevant to coastal processes in the human, biological and physical sciences. Current coastline position is a key observable at each site and will be compared to archival data to provide a baseline for past decadal and current and future annual-scale coastal flux assessments based on two and three dimensional change detection.

In the absence of an international agency for coordinating and apportioning support for circumpolar projects, the IPY process depended on projects funded piece-wise by national-level funding agencies. Not all of the goals of the ACCONet IPY project were completed during IPY 2007–2008 highlighting the continuing need for international support for monitoring activities, analogous to activities around the Antarctic. Remaining major goals are the provision and expansion of observatory on-site infrastructure and resources for sustained networking between observatories. Two major initiatives are currently underway to address both gaps as a post-IPY activity. An initiative arising as a network of terrestrial stations originally based in Scandinavia, SCANNET has grown to include stations in North America and Siberia. This effort provides a basis for observatory coordination and networking, an overlap with ACCONet exists at two stations. The Sustaining Arctic Observatory Network (SAON), an initiative arising out of an Arctic Council directive, aims to create an Arctic network of networks. ACCONet is the coastal network identified in the AON report (Committee on Designing an Arctic Observing Network, 2006) and participates in the SAON process. SAON is working towards presentation of a science plan at the 2011 Arctic Council meeting.

Carbon Pools in Permafrost Regions (CAPP, IPY no. 373)

Peter Kuhry

The CAPP (Carbon Pools in Permafrost Regions) Project is an initiative of IPA and was a full cluster project under IPY. The IPA Project was launched in 2005 with endorsement of the Earth System Science Partnership (ESSP) Global Carbon Project and the WCRP Climate and Cryosphere Project. Its principal objective is to address the increased concern and awareness both within the international scientific community and the general public about the effects of global warming on frozen grounds in the Northern Circumpolar region. Thawing permafrost would result in remobilization of the previously frozen soil organic carbon pools and release large amounts of greenhouse gases. This is a so-called positive feedback within the Earth System as climate warming results in permafrost thawing, which causes a further increase of greenhouse gases in the Earth's atmosphere resulting in even more warming. This effect is not yet considered in climate model projections of future global warming.

Recent findings were discussed during the 2nd CAPP workshop held in Stockholm 3-5 June 2009, which was planned to summarize progress at the end of the IPY years. Research on 'permafrost carbon' has dramatically increased in the last few years. A cooperative effort of the Global Carbon Project and IPA CAPP and CWG (Cryosol Working Group) prepared an important update of the Northern Circumpolar Soil Carbon Database. The new estimate on soil carbon in permafrost regions provided by Tarnocai et al. (2009) more than doubles the previous value and indicates that total below-ground carbon pool in permafrost regions (ca. 1672 PgC) is two times larger than the present atmospheric pool (ca. 750 PgC) and three times larger than the total global forest biomass (ca. 450 PgC). This paper was selected to be included in *Nature* Research Highlights (Ciais, 2009). The new estimate was also mentioned by Nobel Laureate Al Gore in his speech at COP 15 in Copenhagen (December 2009).

Nevertheless, uncertainties remain with regard to the High Arctic, the Eurasian sector and the deeper cryoturbated soil organic matter (SOM) because of relatively few available pedon data. More CAPP-related field studies are, therefore, important and currently underway in Alaska, Canada, Greenland, Scandinavia and Russia. Another uncertainty is associated with the large polygon size (hundreds to ten of thousands of square kilometers) in the soil maps that are being used for upscaling pedon data. A future objective of CAPP, identified at the Stockholm meeting, is to assess if land cover classifications, which have much higher resolution, can be reliably used to estimate soil organic carbon pools.

Permafrost degradation has already been observed in parts of the northern circumpolar region and a significant portion of permafrost is expected to thaw in this century (ACIA, 2005). A unique aspect of permafrost degradation is that gradual thawing of the ground with depth over time will be accompanied by more dramatic events, such as ground subsidence due to melting of buried ice bodies and lateral erosion along the edges of thaw lakes and arctic coastlines, further accelerating the release of greenhouse gases. It is, therefore, of paramount importance to better understand and quantify the physical landscape processes which will lead to carbon remobilization, such as talik formation and thermokarst erosion.

The future permafrost carbon feedback not only depends on the rate at which the soil carbon pools will remobilize (thaw), but also on how quickly the material will start to decompose. Recent findings in Alaska and northern Sweden provide strong evidence that the deeper soil organic matter in permafrost terrain is starting to be released (Dorrepaal et al., 2009; Schuur et al., 2009). Nevertheless, no attempt has been made to define or map SOM lability at the

Northern Circumpolar scale.

CAPP aims for a constant dialogue with the climate and ecosystem modeling communities. Recent research has highlighted the role of SOM in the ground thermal regime of the Northern Circumpolar region, with implications for climate and atmospheric circulation at large (Rinke et al., 2008). An important objective is to define, in consultation with the modeling community, typical pedons appropriate for model setups, with vertical distribution of soil C quantity and quality (mean and range), for all of the land cover and/or soil classes differentiated according to permafrost zone. The thawing permafrost carbon feedback needs to be included in model projections of future climate change.

IPY provided an important incentive for coordination of permafrost carbon research. An important milestone was the new and much higher estimate for soil organic carbon in the northern circumpolar permafrost region (Tarnocai et al., 2009), which highlights the potential role of permafrost carbon in the Earth System. Evidence for remobilization of this deeper and older carbon has already been found. Nevertheless, significant gaps were also recognized at the 2nd CAPP workshop (Stockholm, 2009), which was held to summarize progress at the end of the IPY period and for which continued field research, data synthesis and modeling efforts are needed.

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2.8 Earth Structure and Geodynamics at the Poles

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The study of Earth structure and geodynamics in polar regions contributes to an improved understanding of processes of global relevance, due to the role of the Arctic and Antarctic in fields such as geology, oceanography and glaciology, among others. For a better understanding of how global tectonics and sedimentation interact with the Earth system and its changes, it is necessary to have information about the current and past state and relationships of tectonic plates located at high latitudes. Geodynamic, tectonic and sedimentary processes drive the topographic formation and the location of ocean basins and corridors between emergent masses of land. Currents in the polar oceans move along pathways – that have changed through Earth history – with a significant effect on global climate. Subglacial relief features and processes are also connected to the Earth's structure and geodynamics. Such elements may have impacts on the stability and evolution of the ice sheets and must be considered in climate models.

A series of IPY projects have been conducted on this topic, incorporating many research groups and forming examples of multi-national and multi-disciplinary efforts as promoted by IPY. The networks of polar Earth and geodynamics observatories have been significantly improved during IPY; technical advances have occurred and valuable experience of conducting research and collecting data in remote areas and in extreme conditions has been acquired. Scientific results are starting to emerge, as noted below, and more results will appear after processing the great quantity of new data collected during the IPY period of observations. The scope of scientific results will grow thanks to future continuity of measurements in the observing networks, data sharing and international cooperation. Following the IPY spirit, projects in this field have incorporated new and young researchers and have made a significant effort on education and outreach activities.

Geodynamic studies, subglacial environments and evolution of ice sheets

Geodynamic processes act at the base of polar ice sheets, in some cases affecting ice flow and subglacial drainage. The knowledge of such processes, jointly with features at the base of the polar ice sheets, is needed for a better understanding of the status and changes of the polar ice masses. Geodynamic observations using seismic, magnetic, gravity and ice-penetrating radar data, together with satellite imagery and geological observations, were conducted before and during IPY in several locations.

The West Antarctic Rift System was studied as an example of a tectonic system that may be connected to the subglacial drainage and especially to the fast-flowing glaciers that drain the West Antarctic Ice Sheet, with implications for ice sheet stability (Fricker et al., 2007).

The IPY project Antarctica's Gamburtsev Province (AGAP) explored the more than 1200 km long and 3000 m high subglacial Gamburtsev Mountains, located in East Antarctica and discovered by the Russians in 1957 during the International Geophysical Year. This project includes seven nations - U.S.A., U.K., Germany, China, Canada, Australia and Japan - and is a good example of the IPY spirit of promoting international cooperation to carry out multi-disciplinary research in a remote area needing very complex logistics (Fig. 2.8-1).

AGAP field work during the IPY observational period included the deployment of a network of seismometers at 26 different sites, operating instruments over the Antarctic winter at very low temperatures, and a series of survey flights, covering a total of 120,000 square kilometers, using two aircraft equipped with ice-penetrating radar, gravimeters and magnetic sensors (Fig. 2.8-2).

As part of the AGAP survey a seismic experiment was designed to image details of the crust and upper mantle structure across the subglacial range. It consists of the following elements: a) a 900 km linear array of 12 broadband seismic stations; b) an intersecting 550 km linear array of seven broadband seismic stations crossing the Gamburtsev Mountains at an angle of aproximately 115 degrees to the larger line; and c) 8 broadband stations deployed to improve 3-D resolution of the Gamburtsev Mountains survey.

More information about the Gamburtsev Antarctic Mountains Seismic Experiment (GAMSEIS) can be obtained on the Web site at Washington University in St. Louis: http://epsc.wustl.edu/seismology/GAMSEIS/index.html.

The new observations have confirmed the existence of a mountain range with a rugged landscape that it is suspected to have been essential in formation of the East Antarctic Ice Sheet. The data confirm earlier findings about the presence of subglacial peaks, valleys, lakes and rivers in a complex water system connected to the ice sheet flow (Bell et al., 2007).

AGAP research allows study of the lithosphere structure and uplift history of the Gamburtsev Mountains, located within an intraplate setting, and the role it played in the formation of the East Antarctic Ice Sheet. It has provided inputs into ice sheet, subglacial flow and climate models, and could help to locate the oldest ice core record in the Antarctic Ice Sheet which would be useful for future ice and bedrock drilling. Information about the AGAP project is available at www.ldeo.columbia.edu/agap.

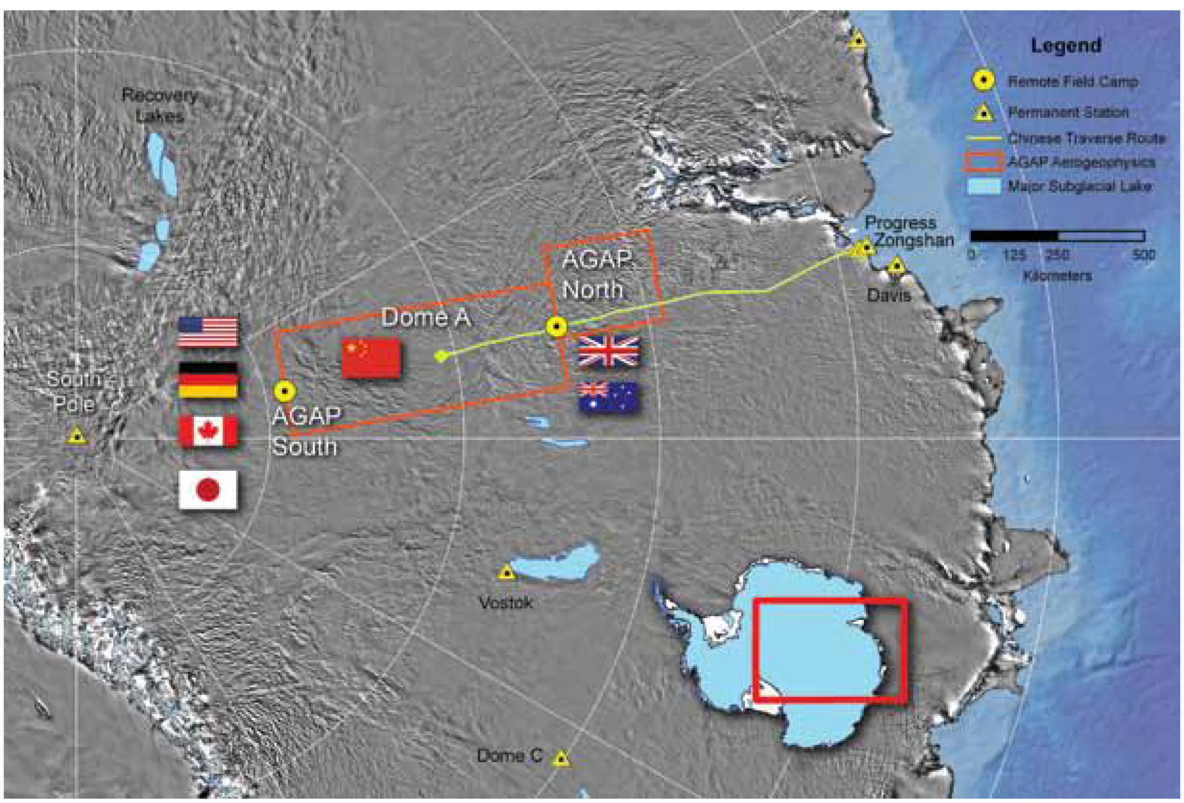

Fig. 2.8-1. Antarctica's Gamburtsev Province (AGAP) IPY project camp locations and aerophysical survey area in East Antarctica.
(Image: M. Studinger)

Plate tectonics and polar gateways in the Earth System

The thermohaline ocean circulation is an important component in the global climate system. The ocean currents transport heat and matter around the globe and are thus likely to cause global environmental changes. At large geological timescales, the global circulation is affected by geodynamic processes which control the motions of the lithospheric plates as well as crustal uplift and subsidence. Plate tectonic motions have constantly altered the shapes and geometries of the ocean basins and the distribution of land masses. In particular, the geometries of so-called oceanic gateways act as continental bottlenecks in the exchange of water masses between ocean basins and are, therefore, key parameters in simulating palaeo-ocean current systems and palaeoclimate scenarios. The reconstruction of the geometries of ocean gateways, basins and their continental margins feeds into numerical models studying the tectonic effect on climate changes. The IPY lead project PLATES & GATES (no. 77) focuses on tectonic reconstructions and sedimentary processes in Mesozoic and Cenozoic times and, in particular, on the transition from climatic greenhouse to icehouse conditions.

For the reconstruction of the oceanographic conditions at times of climate changes, tectonic-magmatic, geodynamic, sedimentary and biostratigraphic processes have been studied in the polar and sub-polar regions. Scientists of 16 nations have been involved in geophysical surveying techniques, tectonic measurements and sedimentary

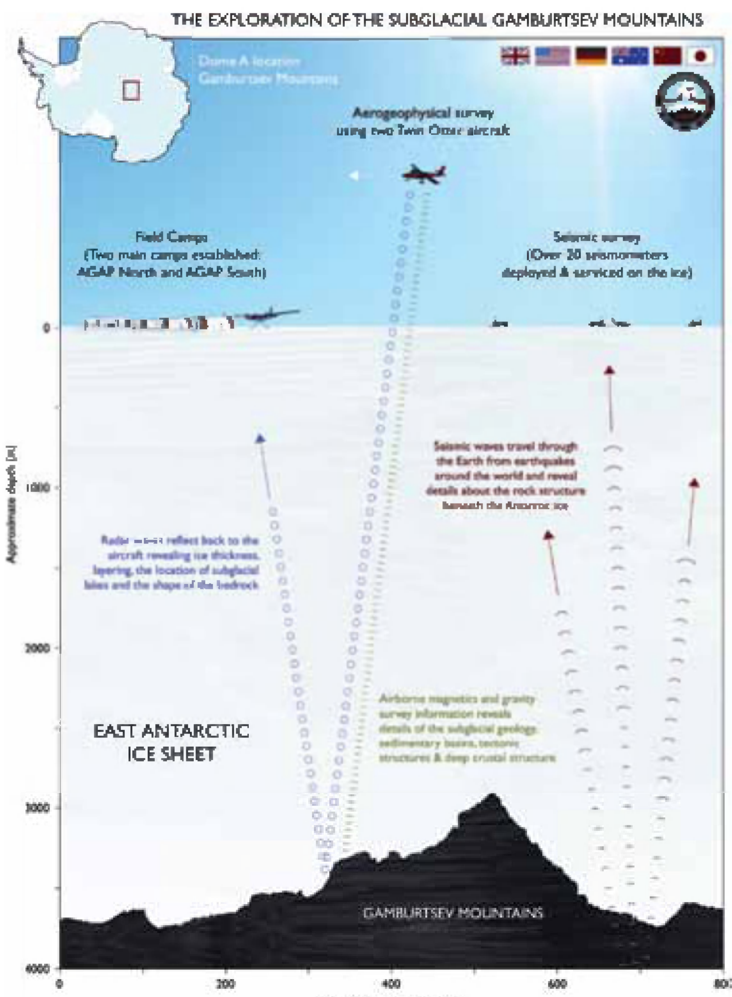

Fig. 2.8-2. Methods in the exploration of the subglacial Gamburtsev Mountains.
(Image: British Antarctic Survey)

sampling at relevant oceanic and terrestrial sites in the Arctic, sub-Arctic, Antarctic and the Southern Ocean in order to address specific objectives such as (1) seismic, magnetic and gravimetric surveying of crust and lithosphere of ocean basin, gateways and their continental margins for constraining past and present plate motions, mantle processes and vertical crustal motion, (2) reconstructing the distribution and variation of palaeo-current systems in the ocean basins by seismic imaging of sedimentary sequences in combination with analyses of palaeoceanographic proxies for decoding signals of past deep-water circulation patterns, (3) reconstructing the palaeobathymetric geometries of polar ocean gateways for shallow and deep water passages between basins at particular times, (4) reconstructing the long timescale palaeoclimatic evolution from the greenhouse conditions of the Mesozoic and Paleogene to icehouse conditions in the Neogene to Quaternary, and (5) numerical modelling of palaeo-current scenarios at varying gateway and basin geometries with regard to the global carbon cycle, the biological evolution and the development of ice sheets.

Studies in the Arctic

In the three Arctic field seasons of 2007, 2008 and 2009, palaeomagnetic, stratigraphic and petrological data from Franz Josef Land, Axel Heiberg Island, Ellesmere Island, the New Siberian Islands and Northern Greenland were collected and are being analyzed. Geoscientific studies including bathymetric mapping, seismic and magnetic surveying, sub-bottom profiling and sediment coring were carried out in the Amundsen Basin on transects across the Alpha-Mendeleev Ridge, over the Lomonosov Ridge and from the North Greenland Shelf. Geological and neotectonic studies were conducted for North and East Greenland, Svalbard, Bear Island, Mohns Ridge, Knipovich Ridge and the Barents Sea. The gateways between the Arctic Ocean and the other world oceans

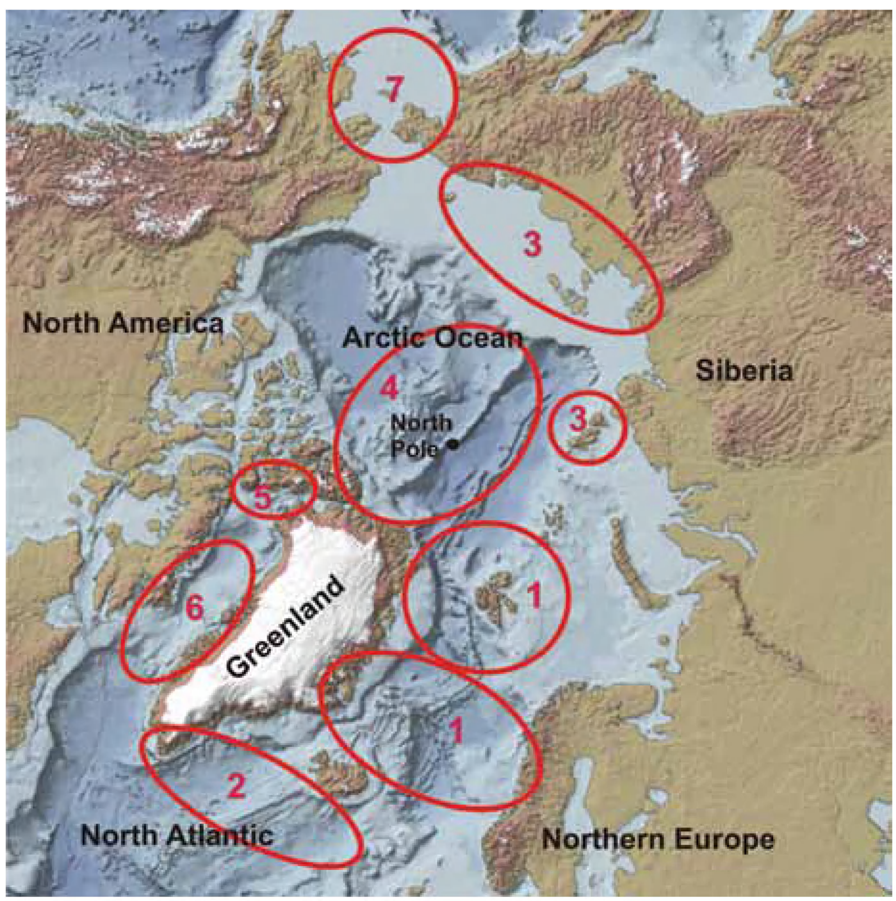

Fig. 2.8-3. PLATES & GATES research areas in the Arctic. 1, Fram Strait, Svalbard and Barents Sea. 2, Greenland Sea and North Atlantic. 3, Laptev Sea / E Siberian Sea. 4, Central Arctic and Alpha-Mendeleev Ridge. 5, Ellesmere Is., Axel Heiberg Is. and Nares Strait. 6, Davis Strait and Baffin Bay. 7, Bering Strait.

(Credit: ETOPO2 database, NOAA, National Geophysical Data Center, www.ngdc.noaa.gov/mgg/global/etopo2.html)

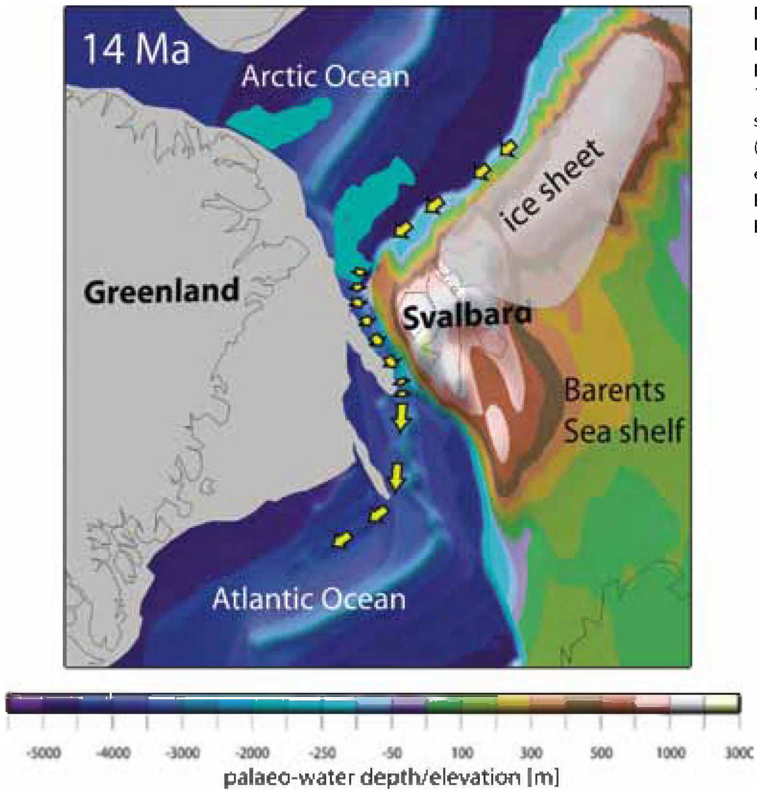

Fig. 2.8-4. Reconstructed palaeobathymetry and palaeotopography at about 14 million years ago with suggested path for icebergs (yellow arrows) and the extent of the northern Barents Sea ice sheet (after Knies and Gaina, 2008).

– the Fram Strait, Davis Strait/Baffin Bay with the Canadian archipelago as well as the Bering Strait – were investigated by a wide spectrum of geophysical and geological approaches to understand the timing and palaeoclimatic consequences of water mass exchange (e.g. Jakobsson et al., 2007) (Fig. 2.8-3). Recent work indicates that early Barents Shelf glaciation correlates with the initial deep water opening of the Fram Strait in the middle Miocene at about 15-14 million years ago (Knies and Gaina, 2008) (Fig. 2.8-4). A particular highlight was the multi-national, multi-expedition effort over several IPY seasons to obtain geophysical and geological data from the Barents Sea shelf, Svalbard and the adjacent Atlantic oceanic crust from the lithospheric mantle to shallow sediments (e.g. Wilde-Piórko et al., 2009) in order to improve understanding of the geodynamic, tectonic and sedimentary processes leading to and accompanying the initiation of major Arctic glaciation phases.

Antarctic studies

In the three Antarctic field seasons 2006/2007, 2007/2008 and 2008/2009, geophysical and bathymetric surveying as well as geological and biological sampling have been conducted in critical regions of the Southern Ocean that formed since the break-up of Gondwana (Fig. 2.8-5). A thorough revision of the break-up processes was performed in parallel with acquisition of new data, compilation and integration of existing data sets. The early stages of development of the Drake Passage/Scotia Sea gateway (e.g. Livermore et al., 2007; Maldonado et al., 2007) are now better constrained by studies of the tectonic and sedimentary evolution of the basins and the origin of bathymetric highs, the structure and history of relevant plate boundaries, and deformation of neighbouring land areas. In a multi-institutional effort, the areas of the southern to central Scotia Sea and northernmost Antarctic Peninsula have been surveyed and sampled thoroughly by a number of Spanish, Italian, U.K., Polish, Argentine, Chilean and U.S. led ship- and land-based expeditions during the IPY which will help solve the puzzle of plate kinematics and sedimentary basin evolution (e.g. Bohoyo et al., 2007; Maestro et al., 2008; Alfaro et al., 2010). From geophysical data of the Tasmanian Gateway, the

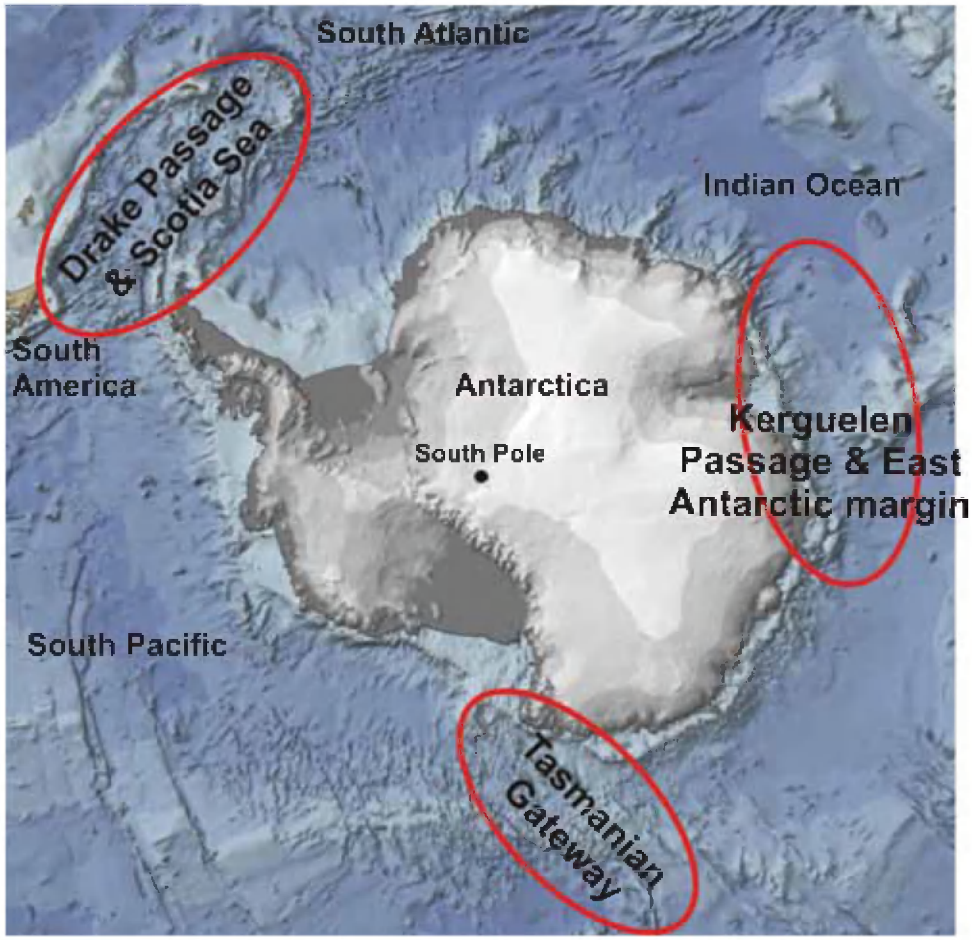

Fig. 2.8-5. PLATES & GATES research areas in Antarctica and the Southern Ocean.
(Credit: ETOPO2 database, NOAA, National Geophysical Data Center, www.ngdc.noaa.gov/mgg/global/etopo2.html)

timing of shallow- and deep-water opening between the Indian and Pacific Oceans as well as the motion between East and West Antarctica can be better constrained, which is critical to the determination of the timing of the uplift of the Transantarctic Mountains and the evolution of the West Antarctic Rift System. This large-scale continental rift may have played a role as an additional Pacific-Atlantic gateway at times when the submarine-based West Antarctic ice sheet did not exist or retreated entirely.

As global and regional bottom-water currents are strongly affected by seafloor morphology, the dynamics of outstanding oceanic plateaus, ridges and fracture zones as well as the varying morphology along continental margins and rises (e.g. development of sedimentary drift deposits) was an additional subject of the PLATES & GATES investigation. The Antarctic Circumpolar Current, for instance, is deviated by the elongated and up to three-kilometer-high basement ridges of the Udintsev and Eltanin Fracture Zone systems in the southern Pacific as well as the Kerguelen Plateau in the southern Indian Ocean. Investigating the crustal and sedimentary transition of the deep water Princess Elizabeth Trough between the shallower southern Kerguelen Plateau and the Antarctic continent was the aim of a specially designed Russian-German two-ship seismic experiment with RV *Polarstern* and RV *Akademic Karpinsky* in early 2007. This is just one example of several experiments in the true IPY spirit: a coordinated, multi-national, multi-ship effort with a large science added-value compared to individual experiments. The Russians conducted further extensive geophysical surveys along the continental margin of East Antarctica, which has already resulted in compiled stratigraphic models of the area from the Riiser-Larsen Sea to the eastern Wilkes Land margin (e.g. Leitchenkov et al., 2007). This mapping and interpretation effort contributes significantly to the *New Tectonic Map of Antarctica* (Grikurov and Leitchenkov, in press) as part of the IPY PLATES & GATES project. The information on this map, the characterisation of the Antarctic continent-ocean transitions (e.g. Gohl, 2008) and recent regional stratigraphic grids will be compiled in two follow-up, post-IPY projects *Circum-Antarctic Stratigraphy and Paleobathymetry* (CASP) and *Antarctic Paleotopographic Maps* (ANTScape). The generation of higher-resolution palaeobathymetric and palaeotopographic grids is a key condition for realistic simulations of palaeo-ocean currents.

Within the PLATES & GATES project, Cenozoic and Mesozoic climate reconstructions are performed using a variety of Earth system models designed to evaluate the effect of ocean gateways and basins on palaeo-circulation patterns, the global carbon cycle and nature of polar ice-sheet development. These experiments include sensitivity runs incorporating new palaeobathymetric reconstructions arising from the new data acquisition described above. The results from these experiments are compared with other model simulations, which include different forcing factors such as atmospheric greenhouse gases and mountain uplift to determine the relative importance of palaeogeography on the evolution of polar and global climates over long geological timescales.

An international effort

PLATES & GATES was set up as a closely knit network project, consisting of 33 individual projects with 46 expeditions, of which 26 expeditions were land-based, 27 were ship-based and 7 were conducted as combined marine-land expeditions. The split between Arctic/sub-Arctic and Antarctic/Southern Ocean expeditions is almost even. The following 16 nations with a total of about 60 scientists, technicians and students were active in funded polar expeditions for this project: Argentina, Chile, Denmark, Germany, Finland, Italy, Japan, New Zealand, Norway, Poland, Russia, Spain, Sweden, U.K., Ukraine and U.S.A.. At least two expeditions were conducted by Chile, Germany, Italy, Norway, Poland, Russia, Spain, Sweden and U.S.A. A summary of all funded PLATES & GATES projects and expeditions can be accessed at www.international-polar-year.de/Plates-and-Gates.28.0.html.

Although the tectonic evolution of the polar ocean basins and their continental margins has been investigated over the last 40 years in various individual projects, PLATES & GATES is the first coordinated effort to bring together the relevant geoscientific disciplines with the ultimate objective to understand the tectonic and sedimentary processes leading to ocean gateway developments. Also new is the approach to involve the numerical palaeoclimate modelling community, as they are the ones which translate the resulting basin and margin bathymetries and topographies into their dynamic model geometries. The challenge will be to compile this vast amount of data and results from the individual PLATES & GATES projects for more realistic dynamic palaeobathymetric and palaeotopographic grids of geological epochs which were relevant for major events in the Earth's climate history.

At this stage, most collected data and samples are still being analyzed, models are being built and first publications are being written. First initial results were presented at the IPY Open Science Conference 2010 in Oslo. With the abundance of the large variety of data and samples, it will take several years to unify models and describe the processes of polar gateway and basin formation and their effects on long-term climate change.

Polar Earth Observing Networks in International Polar Year

A dearth of geophysical observations in the polar regions has long been recognized, particularly from sites remote from permanent research stations or inhabited sites. Given the intensive global attention and accelerating research efforts focused on understanding ice sheet behaviour in response to climate change, the establishment of geophysical observing networks during IPY was particularly timely. Fundamental objectives of many of the projects involved in the IPY **Pol**ar **E**arth Observing **Net**work (POLENET) program are focused on measuring solid-earth phenomena that provide information on ice mass change and on controls on ice sheet evolution and dynamics. Predictions of the response of the ice sheets to changing global climate, including how ice mass will change, their modes of collapse and the rapidity of resultant sea-level rise, are crucial to planning for our changing environment. Robust predictions require systems-scale observations over the polar ice sheets. The new observational data from the POLENET deployments is providing such synoptic data for the first time.

Deployments of polar geophysical observatories in the IPY period

The label 'geophysical observatories' can be applied to large multi-instrument or single-sensor sites, consisting of a variety of instrumentation suites designed to probe the terrestrial and space environments. Here we focus on the IPY POLENET programme, which coordinated observations at permanent stations with remote site deployments of sensors at small stations designed to operate autonomously and record continuously (Fig. 2.8-6). GPS and seismic stations constitute the dominant sensor types in new deployments carried out as part of POLENET during the IPY period. Nevertheless, the POLENET umbrella also includes data acquired at magnetic observatories for earth applications (Cafarella et al., 2008), gravity and absolute gravity stations, tide-gauge sites and other types of geodetic observations.

Prior to IPY, continuously-recording GPS and seismic instruments were located at permanent research stations (Antarctica) or inhabited sites (Greenland) (Figs. 2.8-7a and 2.8-7c), relying on the local power grid for operation. Many did not have real-time communications and data were retrieved on a yearly basis. Several SCAR initiatives promoted deployment of remote geophysical observatories in Antarctica. In the time period immediately preceding IPY, many nations deployed GPS and/or seismic stations and arrays at seasonally-occupied stations and at remote sites away from permanent stations, experimenting with alternative energy sources (Fig. 2.8-6). Many of these stations operated continuously through the summer months and some succeeded with full-year recording. These pioneering efforts led the way for the IPY network deployments. IPY provided the opportunity to bring the Antarctic planning forward and forge international collaborative plans for network deployments. Similar IPY efforts were stimulated in the Arctic region, particularly in Greenland.

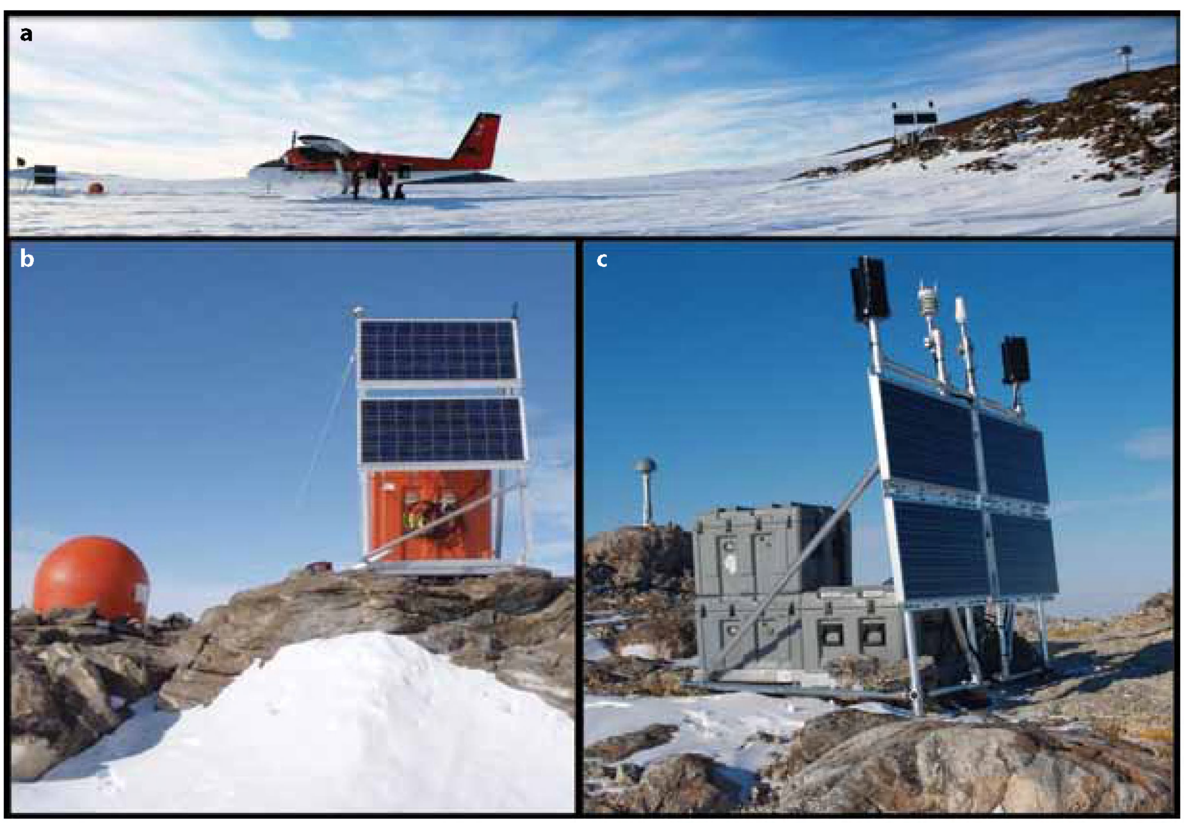

Fig. 2.8-6. POLENET autonomous, co-located continuously-recording seismic and GPS stations at Wilson Nunatak in Antarctica (a, upper panel). Seismic stations may be installed on snow, whereas GPS require bedrock, a major control on distribution of stations in polar regions. Remote sites are commonly hundreds of kilometers from logistic hubs, requiring long-range aircraft for deployment. Configurations of seismic (b, lower left panel) and GPS (c, lower right panel), show power system components (solar panels, wind turbines and extensive battery banks [in boxes]), Iridium antenna for remote communications with sensors. The GPS site has an ancillary meteorological package installed. (Photos: Antarctic POLENET field team)

Spatially extensive new observatory networks scientifically, targeted new local stations, and upgrades and ongoing maintenance of pre-IPY instrumentation all contributed to the data collection during IPY. The most spectacular advances in network coverage occurred in Greenland and in Antarctica (Fig. 2.8-7) where extensive deployments of autonomous stations at remote sites have been completed. In these regions alone, over 175 remote observatories were installed during the IPY years and 28 nations contributed to the Antarctic and Arctic POLENET effort. More detailed information on the range of activities and national contributions to the program is provided on the POLENET web site (www.polenet.org).

In Greenland (Fig. 2.8-7d), a U.S.-led effort carried out in collaboration with Denmark and Luxembourg installed 46 new continuous GPS sites in a network called GNET (***Gre****enland GPS* ***Net****work*) that completely surrounds the bedrock margins of Greenland (Bevis et al., 2009b). Seismic efforts, led by Denmark, continued in Greenland through the IPY and a new internationally-coordinated seismic network, called GLISN (**G***reen***l***and* I*ce* ***S****heet Monitoring Network*), will deploy new, co-located, autonomous seismic and GPS stations in the coming years (Anderson et al., 2009).

In Fennoscandia, the LAPNET (***Lap****land* ***Net****work*) project deployed ~35 broadband seismometers, complementing existing continuous GPS stations and permanent seismic stations, led by Finland in collaboration with several European nations and Russia (Kozlovskaya and Poutanen, 2006). The HuBLE (**Hu**dson **B**ay **L**ithospheric **E**xperiment) overlapped with IPY activities and seismic data from an array of 35 broadband seismometers is providing a data set across part of arctic Canada, with science objectives highly complementary to the POLENET IPY programme (www1.gly.bris.ac.uk/~jmk/HuBLE/home.html). Elsewhere across the Arctic, geodetic and seismic infrastructure maintained by Canada, Denmark, Finland, Norway, Sweden, Russia and the U.S.A. form an important backbone network providing data from regions surrounding the new, embedded network deployments.

In West Antarctica (Fig. 2.8-7c), the ANET (***A****ntarctic GPS and seismic* ***Net****work*) project led by the U.S. in collaboration with Canada, Chile, Germany, Italy, Ukraine and the U.K. has installed a network of 29 new continuous GPS and 34 new continuous seismic stations, 18 of which are co-located. Three additional co-located stations and five additional continuous GPS stations will be installed (Fig. 2.8-7c). Additional components of this network on the Antarctic Peninsula include nine new continuous GPS on bedrock from the U.K. CAPGIA (***C****onstraints on* ***A****ntarctic* ***P****eninsula* ***G****lacial* ***I****sostatic* ***A****djustment*) project, six new continuous GPS on bedrock from the U.S.-led LARISSA (***La****rsen* ***I****ce* ***S****helf* ***S****ystem,* ***A****ntarctica*) project and new seismic installations by LARISSA and Spain. Other new continuous GPS stations were installed by Germany/Russia and by Italy to expand the network (Fig. 2.8-7c).

In East Antarctica, the GAMSEIS network (***G****amburtsev* ***A****ntarctic* ***M****ountains* ***Seis****mic Experiment*), also a component of the AGAP (*Antarctica's Gamburtsev Province*) IPY program, led by the U.S. in collaboration with Australia, Canada, China, , Italy, Japan and U.K. (Kanao et al., 2007a,b; Heeszel et al., 2009; Leveque et al., 2010), installed a network of ~40 broadband seismometers on the East Antarctic Ice Sheet (Fig. 2.8-7c). Additional seismic and geodetic installations also took place at inland stations (Leveque et al., 2008; Lombardi et al., 2009).

In addition to these new installations, an essential component of the POLENET programme includes continuously-recording geodetic and seismic stations that existed prior to the IPY period (Figs. 2.8-7a and 2.8-7b). These stations contribute data in sectors of the Arctic and Antarctic that are essential to achieve systems-scale polar data coverage. Some stations, for example Japan's Syowa Station, maintain a critical infrastructure of geodetic measurement systems that supplement GPS. Repeat measurements at absolute gravity stations and related gravity studies are another important POLENET IPY effort in Antarctica (Makinen et al., 2007, 2008; Rogister et al., 2007; Doi et al., 2008). The network of tide gauges in the Antarctica and Arctic provides important data for global sea-level estimates (Craymer et al., 2006; Watson et al., 2008).

Research outcomes

Seismic and geodetic data must be acquired over a substantial time span for robust analysis to be possible. Data collected during the IPY years is currently undergoing initial analysis; results will be forthcoming over the next few years. Here, selected

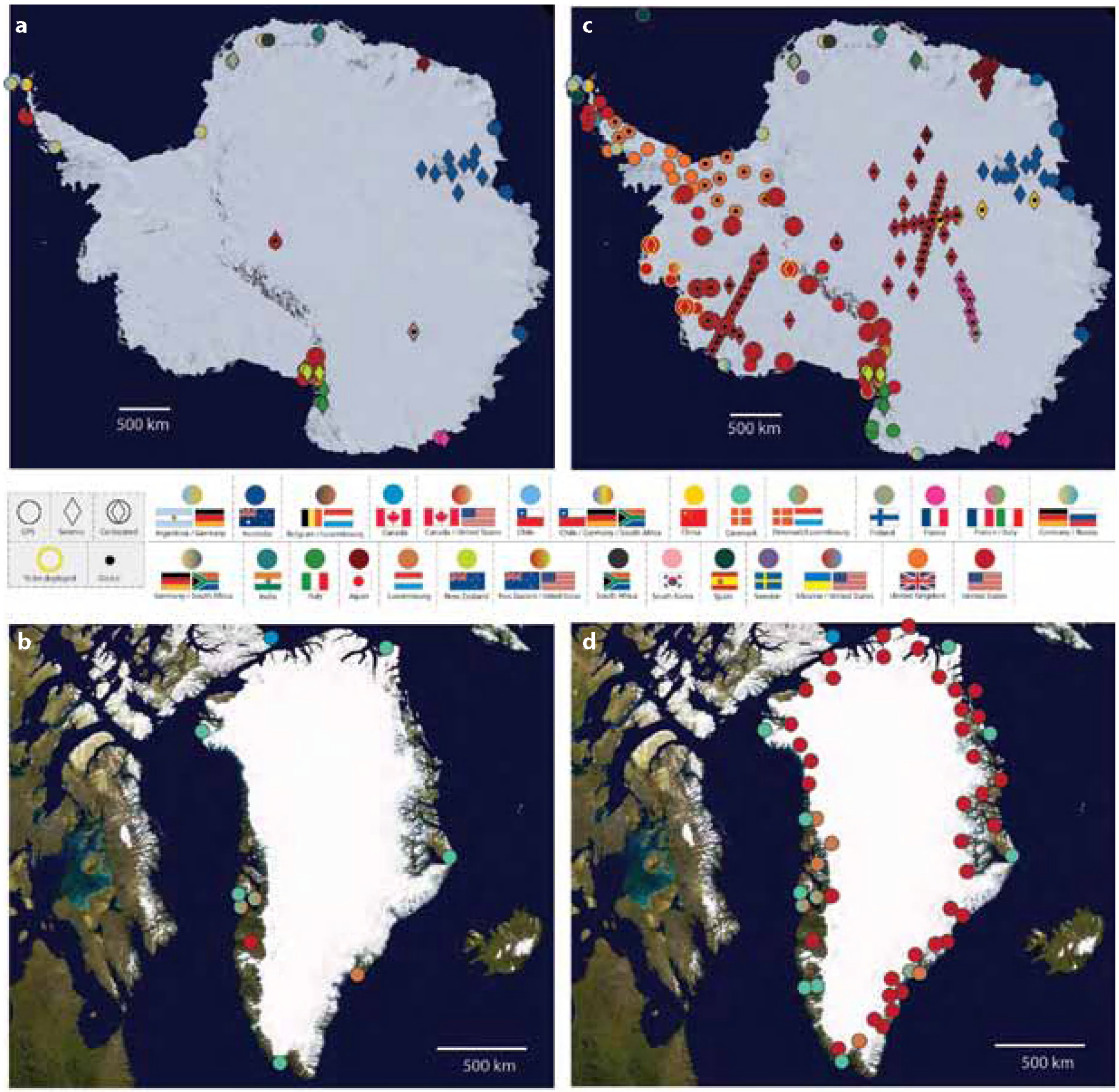

Fig. 2.8-7. Continuously-recording GPS and seismic stations prior to IPY (a, b) and deployed during the extended IPY period from 2006 to early 2010 (c, d).
(Credit: POLENET database, maintained by T.J. Wilson; maps drafted by M. Berg and S. Konfal)

science objectives of projects under the POLENET umbrella are highlighted to indicate the breadth of the scientific results that can be expected from the geophysical observations. Examples are provided of results from relevant studies incorporating pre-IPY and/or initial POLENET IPY data.

Glacial isostatic adjustment and ice mass balance

Measurements of vertical and horizontal solid-earth deformation at mm/yr accuracy are being attained by GPS measurements, providing the first comprehensive view of bedrock motions across polar regions. Viscoelastic rebound (referred to as post-glacial rebound – 'PGR', or glacial isostatic adjustment – 'GIA') is the time-dependent response of the solid Earth to glacial unloading over longer time scales, typically since the Last Glacial Maximum (LGM). Rebound-related crustal motions measured by GPS can provide a unique proxy record of ice mass change. Crustal motions predicted from GIA models depend on several factors, including the ice model (magnitude and position of ice loads, and the history of ice mass loss/gain) and the rheological structure of the Earth. The patterns of uplift documented by GPS measurements can document the positions of major ice loads (Sella et al., 2007). Mantle viscosity and the thickness and elastic rigidity of the lithosphere, control the magnitudes and time scales for isostatic response to glacial loading and unloading. These earth properties, and their variation, can be inferred from studies of seismic velocity and attenuation. Hence, by simultaneously measuring crustal motions using GPS and by gaining higher-resolution data on the thickness and rheology of the crust and mantle from seismological studies, the POLENET observational programme will make an unprecedented leap in our ability to model GIA in Antarctica and Greenland. The first tests of glacial isostatic adjustment models for Antarctica and Greenland based on GPS-derived vertical crustal motions mainly show that GIA model predictions do not match measured rates (Ohzono et al., 2006; Mancini et al., 2007; Khan et al., 2008; Willis et al., 2008c; Bevis et al., 2009a). This emphasizes the need for improved ice and earth models, and for 'GPS-tuned' GIA modeling.

Satellite-based monitoring provides one means of obtaining data on modern ice mass balance for entire ice sheets, and ongoing analyses of both altimetry and time-variable gravity data indicate mass loss from the Greenland and Antarctic ice sheets that appears to be accelerating (Rignot et al., 2008; Chen et al., 2009; Velicogna, 2009). Uncertainties in both types of measurements, however, are mainly due to 'contamination' by vertical displacement of the bedrock beneath the ice sheets due to 'rebound', and a poorly constrained 'correction' must be applied to remove this component in order to derive ice mass change (Alley et al., 2007). POLENET observing networks were designed to directly measure solid earth phenomena, including 'rebound', and provide the first synoptic ground-based observations across the Greenland and Antarctic ice sheets. The new observations will thus greatly reduce the sources of uncertainties in satellite-derived measurements. For example, GPS data from Enderby Land, Antarctica, has shown that an apparent region of positive ice mass change, which could be interpreted as increasing ice mass, cannot be ascribed to incorrectly modeled vertical crustal motion due to GIA (Tregoning et al., 2009). POLENET GPS measurements will thus complement the orbital data sets to measure ice mass change to an unprecedented level of detail and accuracy.

Earth's response to any very recent changes in ice mass, including rapidly accelerating ice loss over decades, will be largely elastic. Outlet glaciers in southeast Greenland showing accelerated flow speeds and rapid ice discharge in the current decade produced a detectable increase in uplift in the time series of a nearby continuous GPS station, recording a rapid elastic response of the crust (Khan et al., 2007). The new array of continuous GPS stations in both Greenland and Antarctica ensure that any such elastic signals will be recorded and, using seismological constraints on regional elastic structure and any independent data on ice mass change, we will be able to calibrate the relationship between ice mass change and crustal deflection. This geodetic measurement of earth's elastic response will provide a new way to recognize and measure periodic or accelerating ice mass loss.

Ice dynamics

An understanding of the 'solid Earth' processes that influence ice sheet dynamics is essential for predicting the future behavior and stability of the polar ice sheets. Coupled ice-sheet climate models require estimates of heat flow and sediment thickness at the base of the ice sheet, which can 'lubricate' the ice-rock interface. Since these parameters cannot be measured directly in Antarctica, seismic images provide a 'remote sensing' method to obtain information that is vital to understanding ice sheet stability. Scientists will use seismological investigations, integrated with results from the geodetic studies, to provide first-order constraints on geological/tectonic parameters important for understanding ice sheet dynamics.

New seismic data will be used to develop high-resolution seismic images that will constrain lithospheric viscosity and thermal structure as well as basal heat flow. High heat flow could produce sub-ice water, lowering bed friction, and may lead to the formation of subglacial lakes. Tomographic images of West Antarctica show the entire region is characterized by slow upper mantle velocities suggestive of high heat flow and thin lithosphere, but resolution is too poor for detailed correlation of low velocity regions with tectonic and glacial features.

Seismic imaging can also be used to map the presence of sedimentary substrate, bedrock topography and structure, all of which can significantly influence ice flow. A variety of evidence suggests that thick sedimentary deposits may be critical to the formation of fast-moving ice streams, yet the distribution and thickness of sediments beneath the ice sheets is poorly known.

Important constraints on ice sheet dynamics can be obtained from glacier seismicity, including insight into the flow of glaciers (e.g. Danesi et al., 2007). Glacial earthquakes of longer period provide critical information about processes associated with calving at ice margins and at the base of glacial systems (Wiens et al., 2008; Nettles and Ekstrom, 2010).

Deep Earth structure and evolution

The resolution of deep seismic structure using data from pre-IPY permanent seismic stations was on the order of 500-1000 km across most of Antarctica, but the new array of seismic sensors will improve this resolution by orders of magnitude, to produce seismic images at scales of interest to tectonic studies. For example, mantle structure associated with rifting, mountain uplift and with potential rising mantle plumes can now be resolved (e.g. Lawrence et al., 2006; Watson et al., 2006; Reusch et al., 2008; Gupta et al., 2009). In addition to improving detail of deep seismic structure beneath Antarctica, Greenland and other Arctic regions, the new seismic data will contribute significantly to global tomographic models of the Earth's interior, which suffer from undersampling around the poles, particularly in the southern hemisphere.

The polar regions provide a unique vantage point for studying the structure and improving understanding of the evolution of the Earth's inner core. Only seismic phases traveling along polar paths can map seismic anisotropy in the core, generally aligned parallel to Earth's rotation axis, which may be due to convection patterns in the core (Leykam et al., 2010). New studies will provide insights into core dynamics with implications for the earth's magnetic field.

Plate tectonics, intraplate deformation and magmatism, and tectonic evolution

GPS and seismology are primary tools for resolving neotectonic deformation between and within plates. The pattern of steady horizontal motion of the bedrock of the continents will be better resolved by the spatially distributed continuous GPS measurements and this information, combined with new knowledge of the location and magnitude of earthquakes from the deployment of seismic stations, will show any active deformation and elucidate the relationships between ice mass loads, GIA, crustal stresses and seismicity (e.g. Chung, 2002; Reading, 2007).

GPS studies using pre- and early-IPY continuous, quasi-continuous and campaign data have indicated rigid behaviour of the Antarctic plate (e.g. Ohzono et al., 2006; Casula et al., 2007; Capra et al., 2008; Jiang et al., 2009). In contrast, tectonic crustal motion is clearly resolved by GPS in the Bransfield Strait and Scotia Arc from GPS results (Dietrich et al., 2004; Smalley et al., 2007). Very small residual horizontal motions remain after rigid plate motion is removed in the Transantarctic Mountains region, suggesting rifting processes may be inactive (Casula et al., 2007; Capra et al., 2008) and/or that horizontal motions may be largely driven by glacial isostatic adjustment (Willis, 2008b).

Available data from long-term, continuously-recording seismic stations indicate that continental Greenland and Antarctica are characterized by a low level of seismicity (Gregersen, 1989; Kaminuma, 2000; Reading, 2007), with the exception of the tectonically active Scotia Arc region, (Fig. 2.8-8). Temporary seismic arrays have shown that regional seismicity is present in the continental interior and around the continental margins in Antarctica, and can be attributed to active structures and plates mobility (e.g. Reading, 2007). Earthquakes go undetected in Antarctica and improved seismic station distribution will reveal seismicity patterns in increasing detail. Deployment of hydroacoustic arrays on the ocean floor is improving monitoring of seismicity associated with Bransfield Strait and Scotia Arc neotectonics (Dziak et al., 2007, 2010). Seismic methods also provide a way to map ancient orogenic fabrics developed during assembly of supercontinents, including the Antarctic core of the Gondwana supercontinent (e.g. Reading, 2006b; Barklage et al., 2009) and the Laurentian and Fennoscandian shields (e.g. Eaton and Darbyshire, 2010), as well as active-margin crustal structure (Majdanski et al., 2008). Mapping of seismic anisotropy can reveal fabric associated with Precambrian and Paleozoic orogenic belts, with rifting processes and with mantle flow and plate motions (e.g. Müller et al., 2008; Reading and Heintz, 2008; Barklage et al., 2009; Salimbeni et al., 2009).

Interdisciplinary outcomes

In addition to the multidisciplinary science investigations and outcomes outlined in the preceding sections, GPS data from the POLENET network will be useful for other disciplines. Two prominent examples are GPS-derived observations of the ionospheric total electron content (TEC) and the amount of water vapor in the troposphere. Studies have shown that GPS data will provide unique and valuable constraints in the undersampled polar regions on TEC and electron density profiles (De Francheschi et al., 2006; Rashid et al., 2006; Yang et al., 2008) and on integrated water vapor estimates for weather and climate models (Sarti et al., 2008; Vey and Dietrich, 2008).

Many of the POLENET stations in West Antarctica have been augmented by simple meteorological instrument packages. Given the near-absence of *in situ* weather data from this region, these data will provide important new information for weather modeling and prediction as well as logistic operations. The new network of continuous GPS bedrock stations will both improve the global and continental reference frames for geodetic measurements (e.g. Dietrich and Rülke, 2008) and provide an important reference network for other experiments, including airborne surveys, meteorite sample locations and measuring glacier motions. The new data will significantly improve ocean tide loading models (King and Padman, 2005; King et al., 2005; Scheinert et al., 2007, 2008, 2010) and improve understanding of other global signals in the atmosphere and hydrosphere.

POLENET Programme – contributions and challenges

Observational data

The data provided by new arrays of sensors spatially distributed around Greenland, across the interior and along the margins of Antarctica, and in targeted regions of the Arctic represent an invaluable trove of new information, commensurate with the

Fig 2.8-8. Seismic station in the Wright Valley, McMurdo Dry Valleys, Antarctica.
(Photo: Jerónimo López-Martínez, 2009)

expectations of a 'step function in activity' during an IPY period. For the first time, geophysical observations of a much greater density and a much larger spatial scale are available across the polar regions. This increased observational capacity is the foremost achievement of the Polar Earth Observing Network during IPY.

Many of the new data are being provided to the global science community either in near-real-time via remote communication systems, or shortly after data is retrieved from remote sites, and is available through established archiving facilities. As some data sets remain sequestered, a challenge remains in meeting IPY data goals. A broader data-sharing agreement ,and compiling project metadata and data access, are continuing program goals.

Multidisciplinary and interdisciplinary scientific research

As outlined in previous sections, scientific investigations on a broad range of topics utilizing the new polar geophysical observations are underway. Initial results are beginning to emerge as evidenced by the large number of studies cited here. Results of particular societal relevance will include prediction of mass fluxes of polar ice sheets, improved models of glacial isostatic adjustment, and better modeling and prediction of sea-level change. Improved understanding of continental evolution, plate and intraplate deformation processes, and feedback processes between ice sheets and the solid earth, will provide fundamental new insights into the workings of the polar and global earth systems. Opportunities for interdisciplinary studies between communities studying geophysical, climate, atmospheric and space weather phenomena are provided by new data sets from sectors of the polar regions where few measurements have previously been made. The synoptic scale and scope of the new observational data will surely lead to serendipitous scientific discoveries that we have not yet imagined.

Essential to reaching the full potential for scientific outcomes of the new observational data are integrated, multidisciplinary analyses. Examples include integration of geodetic observations with complementary seismic imaging studies to place new and robust constraints on solid-earth 'rebound', ice mass change and the contribution of polar ice sheets to sea level change, and the integration of geodetic and seismic investigations of glacial earthquakes to understand what their signals tell us about ice dynamics and response of ice sheets to climate change. Geographical integration, combining results and insights obtained from both poles, is also vital. Enhanced modeling capabilities must be developed to integrate data sets, assimilate the improved data sets and boundary conditions effectively, and improve model predictions. Providing a framework for collaborative, interdisciplinary, international research is a key future challenge for the POLENET programme.

Technical advances

The major challenges of remote deployments in polar regions are to provide year-round power, including through the several months of darkness at polar latitudes, to minimize logistical requirements to reach and maintain stations at very remote locations, and to operate the instruments in extreme environmental conditions. Major advances have been made in these areas during the IPY period. The U.S. National Science Foundation invested in technical development for this type of instrumentation. Detailed information from this effort on engineering developments for GPS deployments are found in Willis (2008a,b), Johns (2008), and online from the UNAVCO facility (http://facility.unavco.org/project_support/polar/remote/remote.html). Detailed information on new seismic engineering developments are provided on line by the PASSCAL Instrument Center (www.passcal.nmt.edu/content/polar-programs). Best practices information for autonomous systems construction, power supplies and satellite communications are provided via these websites to the polar science community. Additional development efforts from many nations and disciplines are described in abstracts from sessions on instrumentation development in polar regions that have been held at international meetings, such as European Geosciences Union annual assemblies, throughout the IPY period.

Polar outreach and new polar scientists

The POLENET programme has convened a range of international workshops and thematic sessions at international geoscience meetings to encourage dissemination of science outcomes and promote international collaboration. A significant thematic volume entitled *Geodetic and Geophysical Observations in Antarctica – An Overview in the IPY Perspective,* edited by A. Capra and R. Dietrich (2008), stemmed from these thematic sessions. A section of the journal *Physics Education* featuring IPY (Volume 43, Number 4, July 2008) included a contribution by A. Reading entitled *Bouncing continents: insights into the physics of the polar regions of the Earth from the POLENET project in the International Polar Year.* A variety of education and outreach media have been produced and are under development, and blogs, podcasts and project information are provided on the website *www.polenet.org*. A unique game produced by UNAVCO (http://facility.unavco.org/project_support/polar/remote/POLENET-engineering-game/POLENET-engineering-game.html) is designed to introduce students of all ages to the technical challenges of deploying polar networks and will be a centerpiece of an interactive touch-screen kiosk on polar science. Undergraduate students have worked on polar geophysical research as POLENET interns and a large cohort of graduate students is participating in the program, gaining experience in polar and global collaborative science. These outreach efforts will continue to be developed, hopefully within a broader international framework.

Infrastructure for geophysical observations

The POLENET programme has established a framework for ongoing international geophysical observation networks. Given funding, a subset of the stations deployed during IPY can remain in place as a pan-polar monitoring network. Additional types of sensors can be installed at the same locations to maximize disciplinary and interdisciplinary science outcomes and to minimize logistic efforts that distributed networks in the polar regions demand. Realization of ongoing and expanded polar networks will require new planning and coordination by the polar science community.

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2.9 Polar Terrestrial Ecology and Biodiversity

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Introduction

The land masses beyond the polar circles are vast; they are often remote, uninhabited and experience harsh climatic and physical environments. Because of these characteristics, polar ecological and biological research and observation are generally under-represented compared with such research and observation in more populated and benign environments. Past international campaigns have sought to document the biodiversity and ecological processes of terrestrial ecosystems and the previous polar years together with the International Biological Programme of 1967–1974 (Bliss et al., 1981) provided major advances in our understanding and a significant legacy in new generations of researchers and international collaborations. However, the Polar Region research has remained rather esoteric and relatively unconnected with global issues.

Within the past 20 years, this has changed: the Polar Regions have attracted world-wide attention because impacts of UV-B radiation, contaminants and particularly climate change are profound there. The comprehensive Arctic Climate Impact Assessment (ACIA, 2005) documented the major ecological changes occurring in the Arctic and showed how some of these changes, the biospheric feedbacks, were likely to influence the global climate system. Since then, a similar assessment for the Antarctic has also provided compelling evidence of major climate impacts on the Antarctic terrestrial biota (Turner et al., 2009; *Chapter 5.2*).

It is now clear that the Arctic and the Antarctic Peninsula are warming at approximately twice the general planetary rate and that many impacts are already affecting biodiversity and ecosystem processes, some of which are likely to have global consequences. International Polar Year 2007–2008 was therefore, organised at a critical time. The international science community mobilised during this period to document changes, understand its causes, provide baselines against which future changes can be measured, predict future changes and assess prospective global influence of some of these changes.

Altogether, 30 international project consortia on polar biology and ecology were formally endorsed by the IPY Joint Committee. Each project is described in Table 2.9-1, which gives information on title, status, geographic area studied, number of nations, partners and participants involved. For this chapter we contacted all team leaders in order to receive updated information on their activities. Seven projects operated both in the Arctic and the Antarctic; 19 projects operated only in the Arctic and most of these had a circumpolar perspective; three projects operated only in the Antarctic (one project did not receive funding). All projects were international (ranging from three to 27 participating nations), which means that the activities involved several nations with a short history in polar research. Some of the larger consortia had up to 150 participants, but some projects used only a handful of scientists. Many IPY projects were multidisciplinary and engaged climatologists, molecular biologists, soil biologists, plant and animal ecologists, modellers and experts on GIS and remote sensing. Some of the projects had socio-economic aspects as well. A common denominator for most of the research under IPY terrestrial projects was the impact of climate change.

At this time, many of the projects are still processing their data following fieldwork, so that results and publications are likely to continue for the foreseeable

Table 2.9-1. Terrestrial Projects under the International Polar Year 2007–2008

Status: O=operational; U=unknown; Nf=not funded;
Type of output, as of June 2010: B=books; P=papers; W=web site

Short title or acronym	IPY no.	Full title	Status	Region	# nations	# partners and participants	Type of output
ABACUS	246	Arctic Biosphere-Atmosphere Coupling across multiple Scales	O	Arctic: Fennoscandia	3	40 participants	P W
ABC-net	300	Arctic Biodiversity of Chars	U	Arctic			
ACCO-Net	90	Arctic Circum-Polar Coastal Observatory Network	O	Arctic			
Aliens	170	Aliens in Antarctica	O	Antarctic	11	22 partners / 40 participants	P W
ARCDIV NET	72	Network for ARCtic Climate and Biological DIVersity Studies	U	Arctic			
Arctic Hydra	104	The Arctic Hydrological Cycle Monitoring, Modelling and Assessment Program	U	Arctic			
Arctic WOLVES	11	Arctic Wildlife Observatories Linking Vulnerable EcoSystems	O	Arctic: Canada; Norway; Sweden; Greenland; Svalbard; Russia	7	32 partners / 142 participants	P W
B-CILCAS	390	Biodiversity and Climate Induced Lifecycle Changes in Arctic Spiders	U	Arctic			
BIRDHEALTH	172	Health of Arctic and Antarctic bird populations	O	Arctic, Antarctic	3	7 partners / 24 participants	P W
BTF	214	Retrospective and prospective vegetation change in the polar regions: Back to the future	O	Arctic, Antarctic	6	40	P W
CARMA	162	CircumArctic Rangifer Monitoring and Assessment Network	O	Arctic	7	60+ participants	B F W
CARP	329	The Canadian Antarctic Research Program	U	Antarctic			
CBMP	133	Circumpolar Biodiversity Monitoring Program	O	Arctic: circumpolar	7	24 partners	B P W
Cold Land Processes	138	Cold land processes in the northern hemisphere: regional and global climate and societal-ecosystem linkages and interactions	O	Arctic: circumpolar			
Complex monitoring and elaboration of IAS on polar PAS	284	Development of a system of Complex monitoring and elaboration of information and analytical systems on Protected Areas of the Polar zone	U	Arctic			
EBA	137	Evolution and biodiversity in the Antarctic: the response of life to change	O	Antarctic	22	40+ partners	P W

EBESA	452	Internationally coordinated studies on Antarctic environmental status, biodiversity and ecosystems	U	Antarctic	3	6+ participants	P
ENVISNAR	213	Environmental baselines, processes, changes and impacts on people in the Nordic Arctic Regions	O	Arctic	20	100	P
Freshwater Biodiversity Network	202	Arctic Freshwater Biodiversity Monitoring and Research Network		Arctic			
Greening of the Arctic	139	Greening of the Arctic: circumpolar biomass	O	Arctic: circumpolar	5	35 participants	P W
ITEX	188	International Tundra Experiment:	O	Arctic; Subarctic; Antarctic	9	>150 participants	P W
MERGE	55	Microbial and ecological responses to global environmental changes in polar regions	O	Arctic: Canada, Greenland, Svalbard; Antarctic	24	150 participants	B P W
NOMAD	408	Social science migrating field station: monitoring the Human-Rangifer link by following herd migration	O	Arctic: Kola Peninsula	6	7 participants	P W
NORLAKES 4 future	169	Network for present and future circumpolar freshwater lake research and data management	Nf				
PHOENIX	432	Exploring Antarctic dry valleys in preparation for Mars landings	O	Antarctic	6	7 participants	P
PPS	151	Biotic, abiotic and socio-environmental conditions and resource components along and across the Arctic delimitation zone	O	Arctic: circumpolar	9	150 participants	P W
RASCHER	262	Response of Arctic and Subarctic soils in changing Earth: dynamic and frontier studies	O	Arctic; Subarctic	4	22	
TARANTELLA	59	Terrestrial ecosystems: effects of UV light, liquefying ice and ascending temperatures	O	Arctic, Antarctic	14	24	P W
USGS Integrated Research	86	U.S. Geological Survey Participation in the International Polar Year	U	Arctic, Antarctic			
USNP Environmental Change	21	USNP Environmental Change	U	Arctic: Alaska, Chukotka, Yukon			

future. For this reason, the present chapter serves to document activities and early results rather than attempting a full synthesis of the data collected. Further, we are aware that the recent recognition of the global significance of the Arctic biota and ecological processes has stimulated a surge in research and observation activities that are not affiliated with IPY; we do not attempt to review these studies, some of which have been recently summarized (Post et al., 2009).

As most of the IPY projects focus on a certain aspect of change in ecosystem structure and/or function, we structure our paper along a timeline, that is, establishing current baselines against which future changes can be measured, documenting past changes, recent changes, and assessing the likely future changes and the impacts they may have within and outside the polar regions. Finally, we address some critical gaps in our understanding and discuss how the legacy of IPY may help reduce these uncertainties.

Establishing current baselines

Several IPY terrestrial projects sought to monitor biodiversity in terrestrial, freshwater and marine ecosystems across the circumpolar Arctic. For example, the Circumpolar Biodiversity Monitoring Program (CBMP, IPY no. 133; *Chapter 3.9*) is a part of the Arctic Council's CAFF (Conservation of Arctic Flora and Fauna) Working Group. Its aim is to coordinate pan-Arctic biodiversity monitoring, data management and reporting through the development of integrated, ecosystem-based monitoring plans, coordinated, Web-based data management products and targeted reporting tools (e.g. development of biodiversity indicators and indices). CBMP activities within IPY have developed, in coordination with other partners, monitoring frameworks for marine mammals and seabirds and contributed to the development of ecosystem-based, pan-Arctic biodiversity monitoring plans (marine and freshwater) bringing together a multitude of monitoring networks into a coordinated, pan-arctic monitoring effort. It has also contributed to an application for funding by SCANNET (Circum-Arctic Network of Terrestrial Field Bases) to extend the biodiversity monitoring plans to terrestrial ecosystems. A distributed, interoperable Web-based system for accessing and displaying current arctic biodiversity information has already been developed and a range of products is available.

One aspect of biodiversity documentation that has been notoriously difficult is that of microbial diversity and our baseline information has been poor compared with other taxa. MERGE (Microbial and Ecological Responses to Global Environmental Changes in Polar Regions, no. 55) is a large IPY consortium that has used recently developed technology to make major advances in understanding microbial diversity and function in both Polar Regions. MERGE discovered Polar microorganisms with surprising diversity, essential ecological functions and environmental roles as global warming sentinels.

MERGE has resulted in a major leap forward in our understanding of the microbial diversity of polar ecosystems and has contributed fundamental insights into Arctic habitats, their communities and climate impacts. Some of the most striking microbial communities were found in the perennial cold springs in the Canadian High Arctic. Grey-coloured microbial streamers form during winter in snow-covered regions but disappear during the Arctic summer. The streamers were uniquely dominated by sulfur-oxidizing species of the genus *Thiomicrospira* (Fig. 2.9-1). This finding broadens our knowledge of the physico-chemical limits for life on Earth.

The IPY project "The Phoenix Mars Polar Lander and Antarctic Analog Studies" (no. 432) had a component focused on the Antarctic Dry Valley Soil/Ice History and Habitability. It investigated life in an extreme environment by deploying an interdisciplinary team and using recently developed technologies including those used on the Phoenix Mars Lander. This effort not only produced new findings about Antarctica, but also provided a unique opportunity to do comparative planetology. For the first time high- and low- elevation valleys (University Valley and Taylor Valley, respectively) were sampled in depth with samples acquired and analyzed for soil mineralogy, soil solution chemistry, soil pedogenic processes, and total and live biomass, with complementary analyses performed for soil water availability and local environmental conditions. Due to the discovery of perchlorate (ClO_4) on Mars by the Phoenix spacecraft, this chemical was searched for in the Dry Valley samples and unexpectedly high levels were found. These were correlated to nitrate,

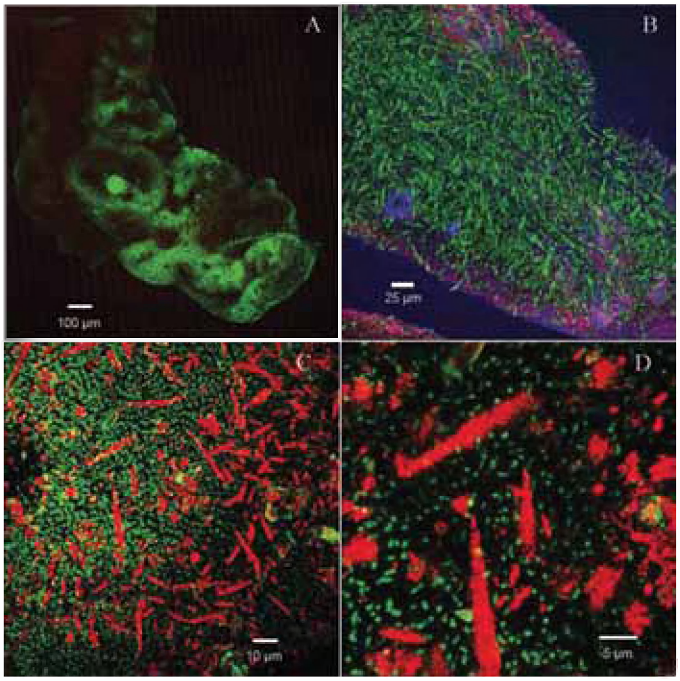

Fig. 2.9-1. Sulfur-oxidizing species of the genus *Thiomicrospira* (confocal micrographs of microbial consortia). (Photo courtesy Warwick Vincent)

supporting an atmospheric source and the hypothesis that ClO_4- is globally formed, but can accumulate only in hyper-arid environments. Also, a new ecosystem was found in the University Valley. The soil temperatures are below zero throughout the entire year, preventing free flowing bulk liquid water. Nonetheless, this valley, the best Mars analog location on Earth, shows soil pedogenesis, salt distribution, diurnal variations in dielectric permittivity, and living microbes, each requiring water, only available from surface snow and humidity or as vapor through sublimation of ground ice. The results from this study move us one step closer to understanding the potential habitats on Mars.

In contrast to the study in the Dry Valleys, IPY MERGE investigated Antarctic lakes and ponds that provided much information relevant to global warming and associated ecological responses. For example, Holocene climate changes were reconstructed from lake sediment cores and palaeo-nests of penguins. Viruses were shown to be responsible for controlling microbial food webs and community structures of the lake ecosystems. Catchment hydrogeology was shown to influence vegetation of terrestrial vascular plants and aquatic mosses. Unique aquatic "moss pillars" are maintained by synergetic biogeochemical processes of a microbial community, and its species diversity and functions have been dissected by metagenomic DNA analyses. In addition, human impacts, specifically the effect of trampling on soil characteristics and biota were first evaluated.

MERGE also compared the genetic characteristics of microbes from the Arctic and Antarctica, such as the 16S rRNA gene sequences of cold-dwelling cyanobacteria from lakes, streams and ice communities. Several High Arctic taxa were >99% similar to Antarctic and alpine sequences, including to the ones previously considered to be endemic to Antarctica. One High Arctic sequence was 99.8% similar to *Leptolyngbya antarctica* sequenced from the Larsemann Hills, Antarctica, and many of the Arctic taxa were highly dissimilar to those from warmer environments. These results imply the global distribution of low-temperature cyanobacterial ecotypes, or cold-adaptive *endemic* species, throughout the cold terrestrial biosphere.

In addition to "endemic" species, global-wide distribution of "cosmopolite" species, or cosmopolitans, has been strongly suggested. Eco-physiological and molecular characterizations of such cosmopolitans will compliment our understanding of distribution and colonization of cold-adaptive endemic species, and thus help prediction of microbial "sentinel" responses to Global Warming.

Fig. 2.9-2. A small moving drill was used to make holes to measure permafrost temperature for the BTF and PYRN-TSP projects near Abisko, northern Sweden. (Photo: Frida Keuper)

In the Arctic, two contrasting studies set up baselines of current biodiversity and population dynamics as well as ecosystem processes for organisms in higher taxa than microbes. ArcticWOLVES (Arctic Wildlife Observatories Linking Vulnerable EcoSystems, no. 11) project initiated comparable observations, mainly on animals, and experiments at a range of sites in Arctic Canada, Norway, including Svalbard, and Russia. The ENVISNAR (Environmental Baselines, Processes, Changes and Impacts on People in the Nordic Arctic Regions, no. 213) project focused national Swedish and international efforts, mainly on the physical environment and vegetation, in one geographic area, Swedish Lapland. ENVISNAR facilitated the analysis of unique long-term (up to 97 years) data on temperature trends, precipitation extremes, snow depth, snow pack structure, lake ice formation and melt timing, permafrost temperatures and active layer depth changes: most showed an accelerating change since the late 1980s (Callaghan et al., submitted: Johansson et al., 2008). ENVISNAR facilitated the research at Abisko by many projects and other IPY consortia such as ABACUS and BTF (see below). It provided logistics including helicopter support (courtesy of the Swedish Polar Secretariat – Fig. 2.9-2) and funding through the EU project ATANS for representatives of over 50 projects to set up baseline information.

To better understand small-scale changes in vegetation, and create a model baseline for future projections, one ENVISNAR sub-project has downscaled past and current climate to the 50 m scale (Yang et al., in press; Fig. 2.9-3). This model is currently being used to downscale regional climate model projections as a driver for ecosystems and permafrost models.

Past Decadal Changes

IPY Project "Greening of the Arctic: Circumpolar Biomass" (GOA, no. 139) used a hierarchical analysis of vegetation change based on a multi-scale set of GIS data bases, and ground information at several sites along two long, north-south transects across the full Arctic climate gradient.

GOA studied 1982-2008 trends in sea-ice concentrations, summer warmth index and the annual Maximum Normalized Difference Vegetation Index (MaxNDVI, an index of the photosynthetic capacity of the vegetation). Sea-ice concentrations have declined and summer land temperatures have increased in all Arctic coastal areas. The changes in MaxNDVI have been much greater in North America (+14%) than in Eurasia (+3%). The greatest increases of MaxNDVI occurred along the 50-km coastal strip of the Beaufort Sea (+17%), Canadian Archipelago (+17%), Laptev Sea (+8%) and Greenland Sea (+6%). Declines occurred in the Western Chukchi (-8%) and Eastern Bering (-4%) Seas. The changes in NDVI are strongly correlated to changes in early summer coastal sea-ice concentrations and summer ground temperatures (Bhatt et al., 2010 in revision; Goetz et al., 2010 in press).

Examples from north-south Arctic transects in Russia and North America studied within GOA, and examples from other locations from the sub-Arctic to high Arctic studied within the IPY "Back to the Future" (BTF, no. 214) project, provide insights to where the changes in productivity are occurring most rapidly. In polar desert landscapes near the Barnes Ice Cap, Baffin Island, Canada, recent repeat photographs 46 years after the initial studies and under the auspices of the IPY "Back to the Future" project show dramatic changes on most land surfaces. The vegetation is increasing

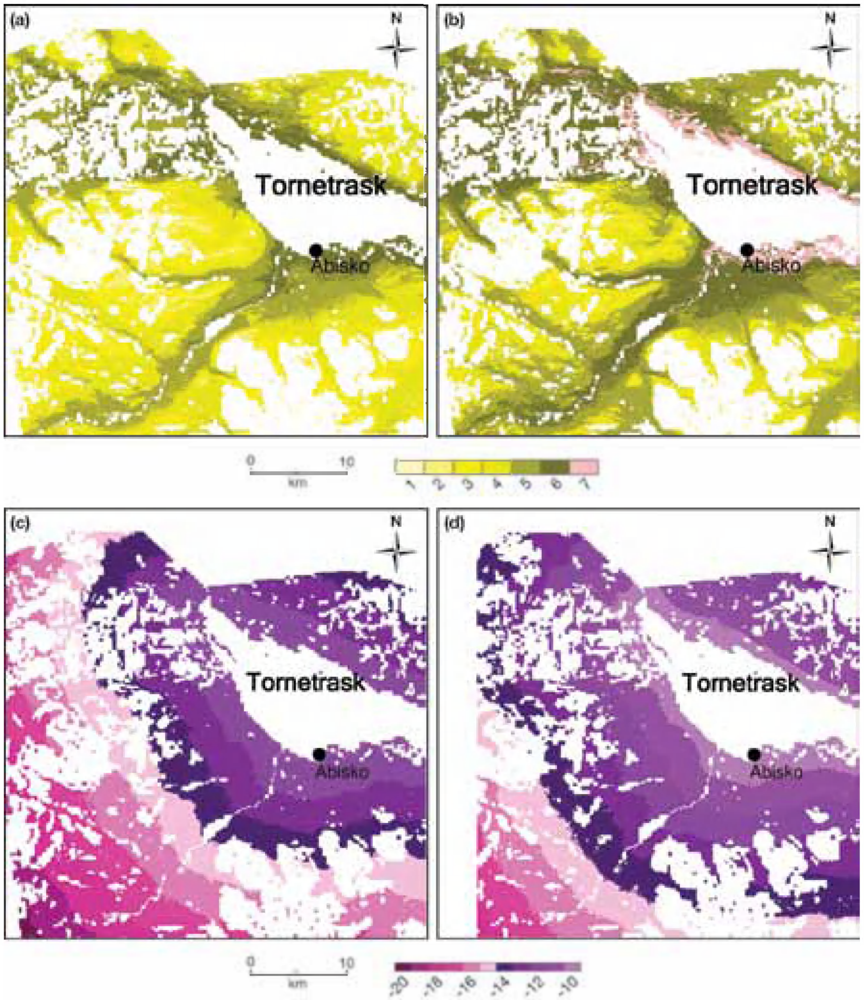

Fig. 2.9-3. Mean monthly surface-air-temperature pattern for the Abisko region for different periods: (a) August 1913-2008, (b) August 2000-2008, (c) January 1913-2008, (d) January 2000-2008. For the August data, growth days above 5°C (GDD5) are used because of their importance for climate-impacts research.
(From Yang et al., in press)

most strongly along ponds and streams and areas with abundant moisture and nutrients. Similar changes have been observed by the BTF researchers in wetland vegetation of East Greenland, but changes in productive habitats in West Greenland over the past 42 years were not so dramatic. Changes in more barren rocky landscapes are less obvious in Canada, although there is strong increase in lichen cover that cause increased NDVI on these surfaces as well. A new satellite-derived data set (AVHRR GIMMS NDVI data) has permitted IPY-GOA to make the first analysis of NDVI trends in the High Arctic (north of 72°). Dry, unproductive sites in West Greenland and Svalbard re-visited after 70 years (Prach, 2010; Fig. 2.9-5) were also much smaller than those in the more productive habitats.

In the Low Arctic, several GOA studies indicate that change is occurring most rapidly in areas where disturbance is most frequent. In the central Yamal Peninsula in West Siberia, Russia greening is concentrated in riparian areas and upland landslides associated with degrading massive ground ice, where low-willow shrublands replace the zonal sedge, dwarf-shrub tundra growing on nutrient-poor sands (Walker et al., 2009; Walker et al., 2010 in press). Analysis of annual growth rings in the Varendei tundra of the Nenets Autonomous Okrug, Russia shows that willow growth is closely linked to the temperature record and increasing NDVI, demonstrating a clear relationship between deciduous shrub growth and Arctic warming (Forbes et al., 2009).

In sub-Arctic Sweden, site re-visits under the BTF project over the past three decades showed dramatic changes in birch tree growth by a factor of six (Rundqvist et al., in press), recent invasion of

2.9-4. Field sites established in 1967 on Disko Island, West Greenland, were re-visited in 2009 as part of the BTF project to repeat measurements of plant performance and plant community composition in order to detect changes over four decades. (Photo: T.V. Callaghan)

aspen trees (Van Bogaett et al., 2010a; Rundqvist et al., in press) and increases in the growth of some shrub species. Repeated photography over 100 years has been used to document changes in tree line location, birch forest growth and aspen stand growth. Also, dendrochronology has been used to identify disturbances to the birch forest caused by periodic outbreaks of geometrid moths that are currently expanding their northern ranges (Post et al., 2009) and herbivory of aspen by moose. A picture emerges in which disturbance to birch caused by its invertebrate herbivore facilitates invasion by aspen that is subsequently controlled by moose browsing (Van Bogaert et al., 2010a, 2010b). Thus the effects of climate on vegetation growth in this region are complex and at least partly result form indirect effects via the population dynamics of herbivores. At tree line near Kharp in northwest Siberia, IPY-GOA studies have shown that alder shrubs are expanding vigorously in fire-disturbed areas and seedling establishment is occurring primarily in areas with disturbed mineral soils, particularly non-sorted circles. Analysis of NDVI trends using three Landsat images (1985, 1995 and 1999) near Toolik Lake in Alaska shows that the higher spatial-resolution Landsat-derived greenness trends match those derived from the AVHRR GIMMS data and that increased greenness is strongest in disturbed areas, such as road-side tracks, and sites with warmer soils and abundant moisture such as south-facing water tracks, wetlands and areas with warmer soils, such as moist non-acid tundras (Munger, 2007).

At the most detailed level of observation, the GOA team used methods developed for the International Tundra Experiment (ITEX) to monitor changes between 1990 and 2008 in the species composition and structure of the vegetation in 150 plots near Toolik Lake, Alaska (Gould and Mercado, 2008). Average plant canopy height at each point has increased by a factor of three; shrub cover and graminoid cover also increased, whereas moss cover has decreased. These observations are concomitant with direct warming manipulations carried out within ITEX. At the same level of detail, observations on the species composition of fellfield and herb slope sites in West Greenland under the PTF project over a period of 42 years showed general reductions in biodiversity although some new species were recorded. Phenology of flowering increased by up to six weeks (as recorded for Zackenberg, North-east Greenland; Høya et al., 2008) although the performance (size, reproductive capacity and population density) of the targeted grass species remained identical after 42 years (Callaghan et al., in prep). Detailed inventories of species over a 30-year period in sub-Arctic Sweden showed changes in floristic composition of some meadows (Hedenås et al., in prep). On Bylot Island, Nunavut, Canada, analysis of a long-term dataset of annual plant biomass by the ArcticWOLVES project revealed that primary production of graminoids doubled between 1990 and 2008 in wetlands (Cadieux et al., 2008).

The general trend at the landscape level across the Arctic is that the most rapid decadal changes have occurred where there are fine-grained soils, strong natural and anthropogenic disturbance regimes, and relatively high supply of water and nutrients. However, where changes have occurred, they were not necessarily caused by climate shifts. For example, some of the vegetation changes documented for Barrow, Alaska, could have been caused by local people changing the hydrology of the system and some of the changes in the wetlands could have been caused by increased goose populations and their effect on eutrophication (Madsen et al., 2010). Similarly, changes in shrub and tree abundance could be related to changes in herbivory in some areas (Olofsson et al., 2009). In general, changes in ecosystems are relatively easy to document but attribution to particular causes is often difficult.

Recent Changes

At the circum-Arctic scale, the latitudinal and northern alpine tree lines are expected to be sensitive indicators of climate change since their shifting locations have responded to changes in climate since the last de-glaciation. Further, changes in the location of tree lines and in the structure of the forest (tree density, growth, species) have many profound consequences, such as regulating biospheric feedbacks to the climate system, biodiversity and ecosystem services to people. Current vegetation models predict that warming will lead to the northward and upward range extension of tree lines but the controls on tree line location are in practice far more complex than temperature alone. Further, there is little evidence of recent tree line advances responding to recent warming and there are only few studies addressing the topic.

IPY PPS Arctic project (Present day processes, Past changes, and Spatiotemporal variability, no. 151) developed an international team to assess the tree line movement in a circum-arctic perspective. The project also seeks to identify the controls on the tree line and the consequences of changes in its position. Recent results show that the influence of climate is seen strongly at all sites even if this is complicated by differences in regional land use pattern. However, responses differ across different climate regions; between coastal and continental regions of the circumpolar north; and according to the dominant tree species. Further, rather than seeing the expected northward tree line shift, due to climate warming, examples of advancing, retreating and stationary tree

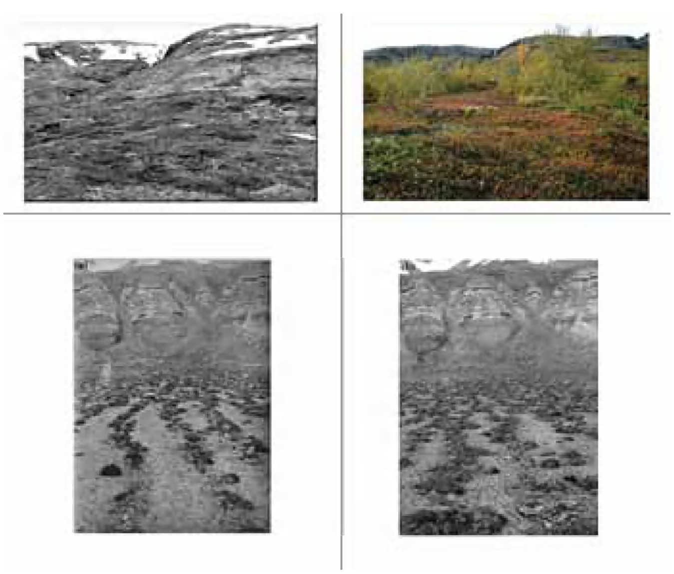

Fig. 2.9-5. Decadal vegetation change and lack of decadal vegetation change. Top left, dwarf shrub and birch woodland vegetation near treeline at Abisko, sub-Arctic Sweden, in 1977 (Photo: Nils Åke Andersson); top right, same location in 2009 (Photo: H. Hedenås). Trees and shrubs increased up to six-fold and a new species colonised the site (Rundqvist et al., submitted.). Bottom left: Vegetation on Svalbard dominated by *Dryas octopetala* in 1936 and bottom right, same location in 2008 (Prash et al., 2009). Note the vegetation and snow beds have not changed substantially in 70+ years.

line zones have been documented across the PPS study sites; still, the advancing zones are dominant.

Several IPY projects showed major changes in ecosystems within particular environments. In the Yukon North Slope, one of the northern regions of Canada where climate warming has been most rapid, ArcticWOLVES project studies detected changes in the abundance of many species. Abundance of savannah sparrows and peregrine falcons has increased, but abundance of Baird's sandpipers and gyrfalcons has decreased. Many rough-legged hawk and peregrine falcon nests are now failing as mud cliffs collapse due to increased rates of permafrost melt. The new northern occurrences of at least five species of butterflies were confirmed. Advancement in the onset of laying for many avian species was also detected. These observations add significantly to the recent review of species range and ecosystem process changes (Post et al., 2009). In sub-Arctic Sweden, the BTF team recorded changes in the location of the tree line and also changes in the structure of the tree line in that aspen trees had recently replaced mountain birch in many areas (Van Bogaert et al., 2010b).

Both ArcticWOLVES and "Back to the Future" projects found that climate change acted as a driver of change directly and indirectly through complex interactions among species. ArcticWOLVES studies demonstrated conclusively that predation played a dominant role in the structuring and function of arctic ecosystems and that many animal populations are strongly impacted, and sometimes driven, by predator-prey interactions. In parallel, "Back to the Future" studies showed that the interaction between two sub-Arctic tree species (mountain birch and aspen) was driven largely by an invertebrate herbivore of one that responded to climate, and the moose herbivore of the other species (Van Bogaert et al., 2010). Similar conclusions have been reached in a recent review of changes in arctic ecosystems (Post et al., 2009).

It has been known for some time that changes in ecosystems can be sudden, even catastrophic, in contrast to ongoing gradual changes. Examples are forest fires and rain on snow events that have decimated ungulate populations. During extreme winter warming events, temperatures increase rapidly to well above freezing (e.g. a change from -20°C to +5/+10°C in 24 hours) and may remain so for a week-long period. Such warming events can result in near complete snow thaw across large regions. Return of freezing temperatures can also be rapid, leaving ecosystems, unprotected due to a lack of snow cover, exposed to extreme cold. Exposure to extreme cold can damage vegetation either directly (through freezing or winter desiccation) or indirectly through ice encasement by re-freezing of melted snow. These events are of considerable concern for indigenous reindeer herders in the sub-Arctic as winter warming events may cause harsh grazing conditions, limit food supply and, consequently, incur large economic costs through the necessity for additional feeding. However, ecosystem response to extreme winter warming events has received little attention.

Simulation of such events within the IPY project ENVISNAR at the Abisko Scientific Research Station using infrared heating lamps and soil warming cables has revealed that (especially) evergreen dwarf shrubs show large delays in phenology, reproduction and even extensive shoot mortality in response to extreme winter warming (Bokhorst et al., 2008). Physiological measurements taken during the simulations have demonstrated that plants will initiate spring-like development after only three to four days of exposure to ~5°C. This breaks winter dormancy/winter hardening and leaves the plants vulnerable to the returning cold following the warming event. Such findings from the simulation study have recently been supported by consistent evidence from a naturally occurring extreme winter warming event that occurred in northwestern Scandinavia in December 2007 (Bokhorst et al., 2009). During the following summer extensive shrub mortality was observed. Vegetation "health", assessed through remote sensing, showed a 26% reduction in NDVI across 1400 km² compared to the previous year (Fig. 2.9-6). This reduction indicates a significant decline in either leaf area or photosynthetic capacity at the landscape scale (as illustrated by the IPY GOA and ABACUS projects). These impacts of extreme winter warming are in sharp contrast to the observed greening of the Arctic through shrub expansion considered to be caused by summer warming in other regions.

Overall, the full potential impacts of increased frequency of extreme winter warming events on Arctic ecosystems could be considerable in terms of ecosystem carbon sequestration and floristic composition together with herbivore and predator population numbers.

In the Canadian High Arctic, IPY 2007–2008 was a time of extreme warming at the northern coastline. MERGE researchers recorded that many of the ice-dependent microbial ecosystems in this region experienced substantial change, including extinction of some ecosystem types (Vincent et al., 2009).

Projecting future changes

In the Arctic, projections of changes in ecosystems can be made from the relationships between changes in the environment and changes in vegetation derived from the IPY GOA project. If the summer sea ice vanishes as predicted, the fastest changes will be seen in High Arctic areas that are presently surrounded by perennial sea ice (subzone A of the Circumpolar Arctic Vegetation Map; CAVM Team, 2003). Mean July temperature increase by 3-4°C degrees will cause these areas to change toward the vegetation of the Low Arctic with increased diversity of plants, greater ground cover of mosses, sedges, prostrate shrubs and dwarf shrubs — but also the elimination of the characteristic ecosystems that occur in these coldest regions of the Arctic. Measurements and models resulting from the IPY ABACUS project (Arctic Biosphere-Atmosphere Coupling across multiple Scales, no. 246) will also lead to projections of the future ecosystems and the consequences of the forthcoming changes. Already, it is projected that if global warming results in the tree line continuing to move north (see above sections), then the process of priming (release of organic compounds by plant roots that accelerate decomposition of dead matter in the soil) recorded by ABACUS may result in a loss of carbon from tundra soils.

Projections of impacts of future environmental changes on biota can also be deduced from manipulation experiments that simulate some aspect of a future climate or environment. Passive warming devices have been used extensively for the past ca. 20 years in the International Tundra Experiment (ITEX) (Henry and Molau, 1997; Arft et al., 1999; Walker et al., 2009) and before that in "pre-ITEX" experiments (Havström et al., 1993; Press et al., 1998; Robinson et al., 1998). The IPY project TARANTELLA deployed standard passive warming experiments in the Antarctic and on sub-Antarctic Islands that were comparable to the ITEX experiments in the Arctic. One outcome was the realisation that changes in temperature are more complex than changes in means as they operate through extremes and minima and maxima. Also, many other factors are important, such as the effect of the warming devices (open top chambers) on snow and moisture. Overall, it was concluded that the change in moisture availability brought about as a result of climate change is very likely to be more important for the Antarctic terrestrial ecosystem than change in temperature alone (Fig. 2.9-7).

In contrast to the projections above that imply continuous, gradual greening of the Arctic, the winter warming experiment under the ENVISNAR project suggests that, as temperatures continue to rise in colder regions of the Arctic, it may be that the damage events observed in warmer sub-Arctic communities are indicative of the impacts expected in a warmer higher Arctic. Given these winter events result in opposite effects to spring and summer warming, and

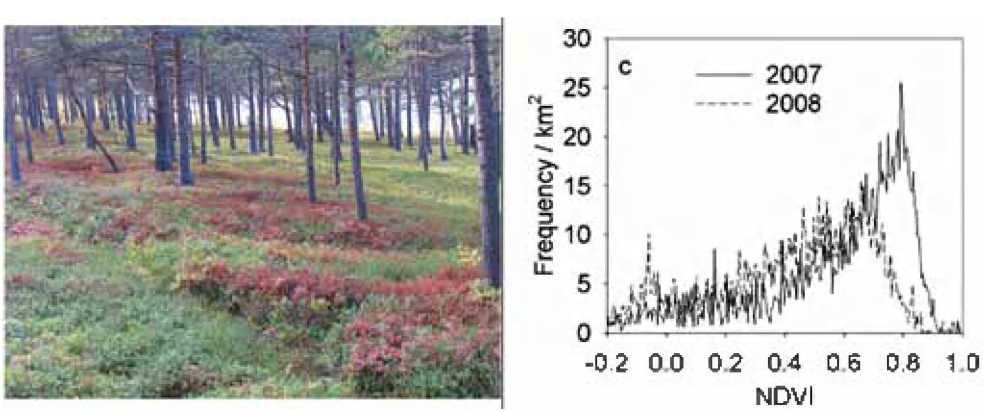

Fig. 2.9-6. Damaged vegetation after a natural extreme winter warming event in northern Scandinavia. During the winter 2007–2008, a week-long period of warm ambient air temperatures melted snow across > 1000 km^2. During the following summer extensive damage to dwarf shrub vegetation was observed. (a - Photo: Terry Callaghan) The extent of damage was validated by NDVI reduction across 1400 km^2 of the winter warming affected area (b): Bokhorst *et al.*, 2009.

that the Arctic is anticipated to warm more in winter than in summer, they provide a considerable challenge and uncertainty to predicting the future of Arctic and sub-Arctic ecosystems in a warmer world.

Projecting changes in animal population numbers and ranges is complex. A surprising projection emerging from the ArcticWOLVES project is that Arctic foxes are vulnerable to changes in sea ice projected in the Gore and Støre report (2009). Observations of predator behaviour and movement showed that Arctic foxes sometimes travelled vast distances over sea ice (Tarroux et al., in press). Satellite-tracking of snowy owls in North America, another predator of the tundra, revealed that many individuals overwinter on the sea ice, a new and unexpected result. This suggests that many top predators of the tundra may be threatened by the rapid melting of Arctic sea ice, and this may have far-reaching consequences to the tundra ecosystem.

Wider consequences of polar ecological processes and changes

Regulation of Climate

Arctic ecosystems have generally acted as a negative feedback to climate in the past by sequestering the greenhouse gas CO_2 and storing large quantities of organic carbon in cold soils as well as reflecting solar thermal radiation away from the Arctic land surface that is covered by snow in late winter-spring. A major reason for current concern about changes in Arctic ecosystems is that climate warming is expected to enhance positive feedbacks to the climate thereby stimulating further warming in the Arctic and further south.

The IPY project ABACUS (Arctic Biosphere Atmosphere Coupling at Multiple Scales. no. 246) has used multiple scales of observations, from leaf to satellite, and has significantly advanced the measurement and understanding of carbon stocks and fluxes in landscapes of sub-Arctic Sweden and Finland. It has used innovative research strategies including using small chambers, flux towers, and aircraft sensors and has developed methodology to enable small-scale processes to be identified from remote sensing. For example, although roots can constitute the majority of plant biomass in Arctic ecosystems, root length and carbon are difficult to quantify. Measurements of root carbon, root length and leaf area in a diversity of Arctic vegetation types has revealed a linear relationship of leaf area with root carbon and length up to a leaf area index of 1. This suggests quantification of root carbon and length measurements at landscape scales may be possible from remotely sensed leaf area data. ABACUS researchers also identified methods to reduce bias in multi-scale estimates of carbon fluxes in Arctic ecosystems by preserving the information content of high spatial and spectral resolution aircraft and satellite imagery.

Studies of carbon cycling in sub-Arctic Sweden and Finland indicated that soil organic matter content was highly variable on a range of scales, but there was a clear pattern of greater total organic matter in tundra (~6.5 kg C m^{-2}) compared to birch woodlands (~3.5 kg C m^{-2}). Plants can increase rates of decomposition (i.e. carbon release to the atmosphere) by supplying labile organic compounds below ground. This process is called 'priming.' Using $^{14}CO_2$ measurements we demonstrated that the decomposition of older soil organic matter was stimulated by plant activity during mid summer in a subarctic birch forest.

The partitioning of fixed carbon into biomass or autotrophic respiration is a critical determinant of ecosystem C balance, often assumed ~50% but rarely measured. ^{13}C pulse labelling in a range of moss communities provided a means to quantify the fate of fixed C. Measurements of $^{13}CO_2$ gaseous return from *Sphagnum* confirmed the expected 50% partitioning over a period of ~14 days. However, in *Polytrichum*, a more productive moss, autotrophic respiration was ~80% of fixed photosynthetic C. These results indicate very different patterns of C dynamics among moss species, with implications for total ecosystem budgets.

Chamber and eddy covariance measurements of CO_2 exchange recorded similar seasonal timing over a range of vegetation types, with a range of magnitudes that corresponded closely to differences in LAI (leaf area index). Chamber measurements of CO_2 exchange identified early-season environmental and physiological factors driving seasonality in branch level CO_2 fluxes while cold season data were successfully collected to facilitate calculation of source/sink status of the landscapes. Aircraft flux measurements during the peak growing season provided an estimate of landscape variability alongside the temporal sampling from fixed tower systems, and a means to constrain upscaling via models.

ABACUS researchers have built the first 3D models of a sub-arctic tree and shrub environment (Fig. 2.9-8) covering areas of many square km in Sweden and Finland. These models were developed based on detailed field measurements, and are now helping the understanding and use of satellite and aircraft data over these regions, to estimate biomass and to improve the use of such data in ecosystem models. Such a process-based mass balance model was parameterised from ABACUS data on tundra and birch woodland and tested against CO_2 eddy flux data and observed time series of stock changes. The initial results closely matched observed fluxes.

In addition to the research by ABACUS on the CO_2 fluxes, methane (a more potent greenhouse gas than CO_2) exchanges were measured with chambers over a range of vegetation types in Finland. These measurements indicated that mires were strong summer sources, while birch woodland was a weak sink. Eddy covariance measurements of mire exchanges were consistent with chamber estimates.

Carbon cycling in sub-Arctic Sweden is also a focus of the IPY projects BTF and ENVISNAR. Within BTF, comparisons are being made of former measurements of fluxes of methane and CO_2 (Christensen et al., 2004; 2008) and a particular focus is being placed on the interannual dynamics of C balance of the birch ecosystem that can be dramatic. Outbreaks of the insect pest of birch (the autumn moth) can result in defoliation of the birch forest and this can convert the birch forest from being a sink for carbon into being a source (Johansson et al., submitted). As birch woodland occupies a large area of the Torneträsk catchment in northern Sweden, such damage can affect the carbon balance of the entire ecosystem (Christensen et al., 2008). Current analyses are in progress to determine the duration of the insect outbreak impacts on the birch forest (Heliasz et al., 2011).

Socio-economic linkages of some of the IPY terrestrial projects

GOA project is presently assessing the relevance of climate and disturbance-related changes to people living in the Arctic — most notably the Nenets reindeer herders on the Yamal Peninsula, Russia, who are faced with rapid changes to their rangelands through both climate change and a rapidly developing infrastructure of roads and pipelines associated with gas and oil exploration and development. Similarly, IPY ENVISNAR is contributing to a multidisciplinary project that includes numerous stakeholders such as Sami reindeer herders to develop adaptation strategies to climate change. These strategies will be based on detailed, high resolution projections (50 m) of climate and snow, derived using the downscaled model to dive the ecosystem model LPJ GUESS (Sitch et al., 2003).

ENVISNAR also includes the sub-project "Snow and Ice" - Sami Traditional Ecological Knowledge and Science in Concert for Understanding Climate Change Effects on Reindeer Pasturing. This joint Nordic study sought an exchange of knowledge between Sami reindeer herders and a multidisciplinary team of scholars with a basis in the humanities, natural and social sciences and in Sami language. The collaboration between reindeer herders and experts in economics, snow physics, ecology, remote sensing, meteorology and linguistics aims to enrich the understanding of the past, present and future changes in snow and ice conditions across northern Sweden and Norway. Indigenous knowledge and its communication with science play a core role in the project, for example by developing better collaborative monitoring at a range of spatial scales. The study builds on the complementary skills and approaches of all participants. For example, scientific experiments and models were employed to predict future changes and are combined with the in-depth knowledge of the Sami on the landscape-scale patterns of past and present snow conditions and their relevance. To-date, workshops have been held and several expeditions to winter grazing lands have resulted in physical measurements of snow conditions and their correlation with Sami snow classifications. Further, Sami knowledge of extreme weather events in winter, and changes in wind patterns in the late 1980s has led to the deployment of a winter-warming experiment (Bokhorst et al., 2008) and observations of a natural event (Bokhorst et al., 2009; Fig. 2.9-6) as well as a re-analysis of long term climate data (Callaghan et al., submitted).

Legacies

Legacy of understanding. Some of the IPY terrestrial projects have contributed significantly to the

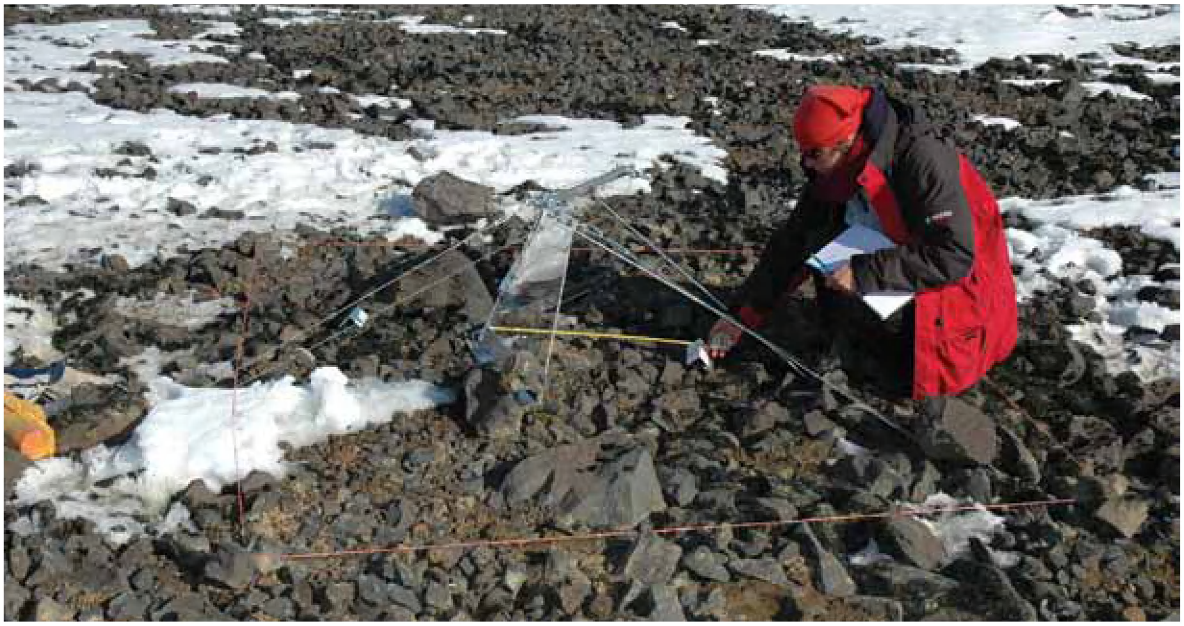

Fig. 2.9-7. Olga Bohuslavova, Ph.D. student from the Czech Republic, conducts site assessment for the IPY project "Multidisciplinary research of the Antarctic terrestrial vegetation". (Photo: Josef Elster)

development of ecological theory. For example, within IPY ArcticWOLVES, standardised observations along a latitudinal gradient together with an experimental approach have contributed significantly to ecological theory by explaining the reason for bird migration northwards to unproductive ecosystems: predation decreases towards the North (McKinnon et al., 2010). Further, the significant development of baseline information, for example on the biodiversity of polar microorganisms (MERGE), is an essential pre-requisite for future assessments of biological change. Also, the development of methodology such as spatial scaling to improve remote sensing analyses (e.g. GOA and ABACUS) will play significant roles in future research.

Legacy of infrastructures. The pulse of activity and funding in IPY 2007–2008 has led to the up-grading of Arctic infrastructures within ArcticNet in Canada and at the Zackenberg Station in Greenland. These improved facilities will continue to facilitate high quality observation and research into the future.

Legacy of collaboration. Many nations and hundreds of researchers in various disciplines have taken part in the terrestrial IPY activities together with some stakeholders. Many legacies of inter-disciplinary research, international research, inter-regional (e.g. bipolar) research and collaborations between scientists and stakeholders such as reindeer herders will endure.

Legacy through input to ongoing international organisations and programmes. Although the IPY projects led to a pulse of activities for a short time span, some of these activities, like CBMP, are planned to continue. Also, data, methods and researchers will play role in several new initiatives such as SAON (Sustained Arctic Observing Network; *Chapter 3.8*) and existing organisations such as AMAP and CAFF.

Conclusions

IPY 2007–2008 had six major, general themes or objectives. The terrestrial IPY activities outlined in this chapter have contributed significantly to all of them.

1. *Status.* Most projects, and particularly CBMP, ENVISNAR, MERGE, Antarctic Dry Valley Soil/Ice History and Habitability, ArcticWOLVES, GOA and ABACUS, have produced new baselines of polar environmental conditions, biodiversity and ecosystem processes.
2. *Change.* Two projects have explicitly addressed past decadal changes (GOA and BTF), while four other have explicitly focused on recent changes (PPS, ArcticWOLVES, ENVISNAR and MERGE). Two of these projects (GOA and ENVISNAR) are developing socially relevant activities such as facilitating the development of adaptation strategies. However, only one project explicitly seeks to project future

changes (TARANTELLA) by simulating future warming. Despite that, inferences can be made from almost all the projects while some have developed methodology such as models (e.g. ABACUS, ENVISNAR) and baselines (almost all the projects) that can be used to project changes or to measure them in the future.

3. *Global linkages.* Although a major incentive for several of the projects (particularly ABACUS and ENVISNAR) was to understand processes that could potentially have global consequences, i.e. biospheric feedbacks from Arctic landscapes to global climate, the link from the findings in the Arctic to the Global/Regional Climate Models remain to be made. However, the characterisation of carbon cycling at multiple scales in ABACUS and the interannual dynamics of carbon cycling measured in ENVISNAR and BTF potentially have global relevance and plans exist to incorporate processes measured in these projects in models of wider scale climate processes.
4. *New frontiers.* IPY terrestrial projects have investigated new frontiers in science by discovering new microbial diversity and polar and global connections between genetic lineages (MERGE); by describing new extreme environments and their biota (MERGE), some of which are analogous to environments on Mars (Antarctic Dry Valley Soil/Ice History and Habitability); contributing to ecological theory and answering long-standing persistent ecological questions (ArcticWOLVES); recording effects of hitherto unrecorded extreme events (MERGE, ENVISNAR); and by developing new methodologies/models (GOA, ABACUS, ENVISNAR).
5. *Vantage point.* Only one project, "The Phoenix Mars Polar Lander and Antarctic Analog Studies" through its focus on the Antarctic Dry Valley soil/ ice history and habitability, made the connection between the Earth and beyond. This project used the same technology that was used on the Mars Lander to measure environmental conditions in the Dry Valleys that are the habitat on Earth most similar to that on Mars.
6. *The human dimension.* While most of the projects have relevance to people through changes in ecosystem services, GOA and ENVISNAR are explicitly engaging the Indigenous peoples and other Arctic residents in a dialogue that it intended to help the development of adaptation strategies to alleviate – or opportunistically use – the expected changes in Arctic environments and ecosystem services.

Overall, the IPY projects have made major contributions to the spirit, knowledge generation and legacy of IPY 2007–2008.

Fig. 2.9-8. IPY-ABACUS researchers built the first 3D models of a sub-Arctic tree and shrub environment in sub-Arctic Sweden and Finland including part of the area in Sweden where ENVISNAR modelled the landscape temperature distribution.
(Image: Mathias Disney - Disney et al., 2011)

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2.10 Polar Societies and Social Processes

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Introduction

The introduction of the social sciences and humanities, as well as the inclusion of polar residents, particularly indigenous people in International Polar Year (IPY) 2007–2008, marked a radical shift from the earlier IPY/IGY template. It was a major experiment not only to its planners (*Chapter 1.3*), but also to the social scientists and polar residents themselves. Previous IPYs, especially IPY-2 in 1932–1933 and the International Geophysical Year (IGY) in 1957-1958 excluded research in the socio-economic and humanities field, though some medical and psychological studies were carried out, mostly in Antarctica and focused exclusively on the personnel of the IGY polar stations (*Chapter 1.1;* Krupnik et al., 2005; Aronova et al., 2010). Many advocates and key institutional supporters of IPY 2007–2008, such as the Arctic Council (IASC) and the International Arctic Social Sciences Association (IASSA) argued for the inclusion of social and human studies in the new IPY program, but their role expanded significantly only after a special theme focused on polar people was added to the IPY science plan in fall 2004 (*Chapters 1.3, 1.4;* Rapley et al., 2004; Krupnik, 2008, 2009).

The IPY organizers and institutions involved in the early planning viewed the prime mission of the social sciences in contributing what was then called 'The Human Dimension' to the new IPY program centered on geophysical and natural science research (*Chapter 1.3*). As welcoming as it sounds, the 'human dimension' paradigm assumed the leading role of the physical and natural processes, to which a certain 'human aspect' (or 'dimension') is to be added to produce a more integrative or societal-appropriate view. Nonetheless, the inclusion of a 'human dimension' as a special theme in 2004 is widely viewed among the major achievements of IPY 2007–2008 (Allison et al., 2007, 2009; Stirling, 2007; Elzinga, 2009; Carlson, 2010).

Joining IPY 2007–2008 was also a major challenge to polar social scientists. Never before had they participated in a multi-disciplinary research initiative of such magnitude. Coming late to the IPY planning, lacking the institutional memory and the expertise of physical and natural researchers in running complex big-budget projects, polar social scientists were pressed to experiment and to learn on the fly. Even more so, that applies to many indigenous organizations and institutions that joined IPY 2007–2008, either as partners in social science and humanities projects or by launching their independent research initiatives.

This chapter covers IPY activities in social science disciplines (anthropology, archaeology, economics, linguistics, political science) and the humanities (history, literature, arts) that are featured in the 'People' field of the IPY project chart (Fig. 2.10-1).[1] It includes 35 endorsed international research projects (Table 2.10-1), plus several initiatives in 'Education and Outreach' that are directly related to the social science and humanities themes (nos. 69, 82, 112, 135, 160, 299, 342, 410, 433), as well as a number of projects with a substantial social component in the 'Land' and 'Ocean' fields (nos. 21, 29, 151, 162, 164, 212, to name but a few). Some of these projects are partly covered in other sections (*Chapters 2.9, 5.4*). Activities related to human health and associated issues, such as pollution, contaminants and food security are reviewed in *Chapter 2.11*.

Table 2.10-1. List of active projects in Social Sciences and the Humanities, 2007–2009 (projects that sent reports for this chapter are marked with *).

Research

IPY No.	Full Title	Project Acronym	Participating Nations
6*	Dynamic Social Strategies		Denmark, Norway, Canada
10*	Historical Exploitation of Polar Areas	LASHIPA	The Netherlands, Sweden, Russia, Norway, U.K., U.S.
21	Understanding environmental change in national parks and protected areas of the Beringian Arctic		U.S., Russia, Canada
27*	History of International Polar Years		Germany, Russia
30	Representations of Sami in Nineteenth Century Polar Literature: The Arctic 'Other'		Sweden
46*	Traditional Indigenous Land Use Areas in the Nenets Autonomous Okrug, Northwest Russia	MODIL-NAO	Norway, Russia
82	Linguistic and Cultural Heritage Electronic Network	LICHEN	Finland, Norway, U.K.
100	Polar Field Stations and IPY History: Culture, Heritage, Governance (1882-Present)		U.K., Sweden, Norway Russia, U.S., Denmark
120*	Northern High Latitude Climate variability during the past 2000 years: implications for human settlement.	NORCLIM	The Netherlands, Canada, Greenland, Iceland, Norway, U.S.
123	Glocalization: Language, Literature, and Media		Greenland, Denmark, U.S., Canada
157*	Community Adaptation and Vulnerability in Arctic Regions	CAVIAR	Norway, Canada, U.S., Iceland, Finland, Russia, Greenland
162*	Circum-Arctic Rangifer Monitoring and Assessment	CARMA	Canada, U.S., Russia, Norway, Finland
164*	Inuit, Narwhal, and Tusks: Studies of Narwhal Teeth		U.S., Canada
166*	Sea Ice Knowledge and Use: Assessing Arctic Environmental and Social Change	SIKU	U.S., Canada, Russia, Greenland, France
183	Community Resiliency and Diversity		Canada, Greenland
186*	Engaging communities in the monitoring of zoonoses, country food safety and wildlife health		Canada, Denmark, Greenland, Norway, Poland
187*	Exchange for Local Observations and Knowledge of the Arctic	ELOKA	U.S., Canada, Finland
227	Political Economy of Northern Development		Denmark, Greenland, Finland, Russia
247*	Bering Sea Sub-Network: International Community-Based Observation Alliance for Arctic Observing Network	BSSN	U.S., Russia
276	Initial Human Colonization of Arctic in Changing Palaeoenvironments		Russia, Canada, Norway
310	Gas, Arctic Peoples, and Security	GAPS	Norway, Canada, Russia
335*	Land Rights and Resources	CLUE	Sweden, U.S., Russia
386*	Survey of Living Conditions in the Arctic, Remote Access Analysis System: Inuit, Saami, and the Indigenous Peoples of Chukotka	SliCA-RAAS	Greenland, U.S., Canada, Norway, Finland, Russia
399	Reindeer Herders Vulnerability Network Study	EALAT	Norway, Finland, Denmark, Russia, Sweden
408*	Social-science migrating field station: monitoring the Human-Rangifer link by following herd migration	NOMAD	Germany, Bulgaria, Finland, Norway, Russia
435	Cultural Heritage in Ice		Canada, U.S.
436*	Moved by the State: Perspectives on Relocation and Resettlement in the Circumpolar North	MOVE	U.S., Canada, Denmark, Finland Greenland, Russia
462*	Arctic Social Indicators	ASI	Iceland, Canada, Finland, Denmark, Greenland, Norway, Russia, Sweden, U.S.

Knowledge Exchange (Conferences, Publications, etc.)

69*	6th International Congress of Arctic Social Sciences	ICASS-6	Greenland, U.S., Canada, Denmark, Finland, Iceland, Norway, Russia, Sweden, U.K.
135*	Polar Heritage: Protection and preservation of scientific bases in polar regions – Polar Base Preservation workshop		Norway, U.S., Australia, U.K.
160	Arctic Change: An Interdisciplinary Dialog Between the Academy, Northern Peoples, and Policy Makers		U.S., Canada, Greenland, Iceland
299	Arctic Energy Summit		U.S., Canada, Russia
410*	Inuit Voices Exhibit: Observations of Environmental Change		U.S., Canada

For this overview, standard questionnaires were mailed in November 2009 to the leaders of all international projects in the 'People' field and of several projects in the 'Education and Outreach' field. Altogether, 23 responses were received by April 2010; information on nine other projects was assessed via participating in their meetings or tracking their publications and websites (Table 2.10-1). *Chapters 3.10* and *5.4* introduce additional data on eight projects with a strong community observation/monitoring component (nos. 46, 157, 162, 166, 187, 247, 399, 408).[2]

Basic Features of Social Science and Humanities Research in IPY 2007–2008

Polar research today is moving rapidly to address global and local urgencies and to seek strong societal justification, as requested by many key stakeholders—the Arctic Council, major science organizations (like ICSU, WMO, IASC and SCAR), local governments, funding agencies, environmental groups, indigenous organizations and polar communities, and the public at large. All of these constituencies have become increasingly vocal about social issues, thanks in part to the massive educational, outreach and communication efforts during IPY 2007–2008. As the public is introduced to and engaged in the issues of polar regions, the stakeholders' interest in societal justification continues to drive the growing portion of polar research and funding, and raises the role of social, economic and cultural issues in the science advancement and planning. We may expect more of these developments continue in the years to come.

The changing nature of polar research and its shift towards more societal-oriented and societal-justified scholarship has been in the making during the past two decades, but was greatly accelerated by IPY 2007–2008 (*Chapter 5.2*). It has been observed at various scales—from national to regional to global. The transition is particularly visible in the Arctic, in Canada, (Griffiths, 2009; www.northernstrategy.ca/index-eng.asp), Iceland, Greenland, but also in the U.S.A. (U.S. ARC, 2010) and other polar nations that are members of the Arctic Council.[3]

Arctic social scientists have previously participated in large interdisciplinary initiatives, starting with the International Biological Programme (IBP) in 1964–1974, although at smaller scale than today. Even the IBP, with its strong 'human component,' had a much narrower disciplinary focus than IPY 2007–2008, and its human studies were primarily in physical adaptation, nutrition, health and small-population demography (Sargent, 1965; Milan, 1980; Worthington, 1965), that is, in the 'human health' domain (*Chapter 2.11*). The social science and humanities field in IPY 2007–2008 was, by far, the largest and the most diverse program of its kind by all measurable criteria, including the number of projects, nations and scientists involved, and the level of funding.[4] In addition, dedicated efforts were made to encourage cross-disciplinary studies linking socio-cultural processes, ecological diversity, community and ecosystem health (*Chapters 5.1, 5.2*). For the first time, physical, biological, social and humanities researchers, and local community-based experts were encouraged to join forces under common multi-disciplinary framework.

To many polar social scientists, the experience of collaborating with a broad spectrum of other disciplinary experts—remote sensing specialists, oceanographers, climate modelers, cryosphere scientists, biologists, data managers—was also eye-opening. Several large multi-disciplinary IPY projects

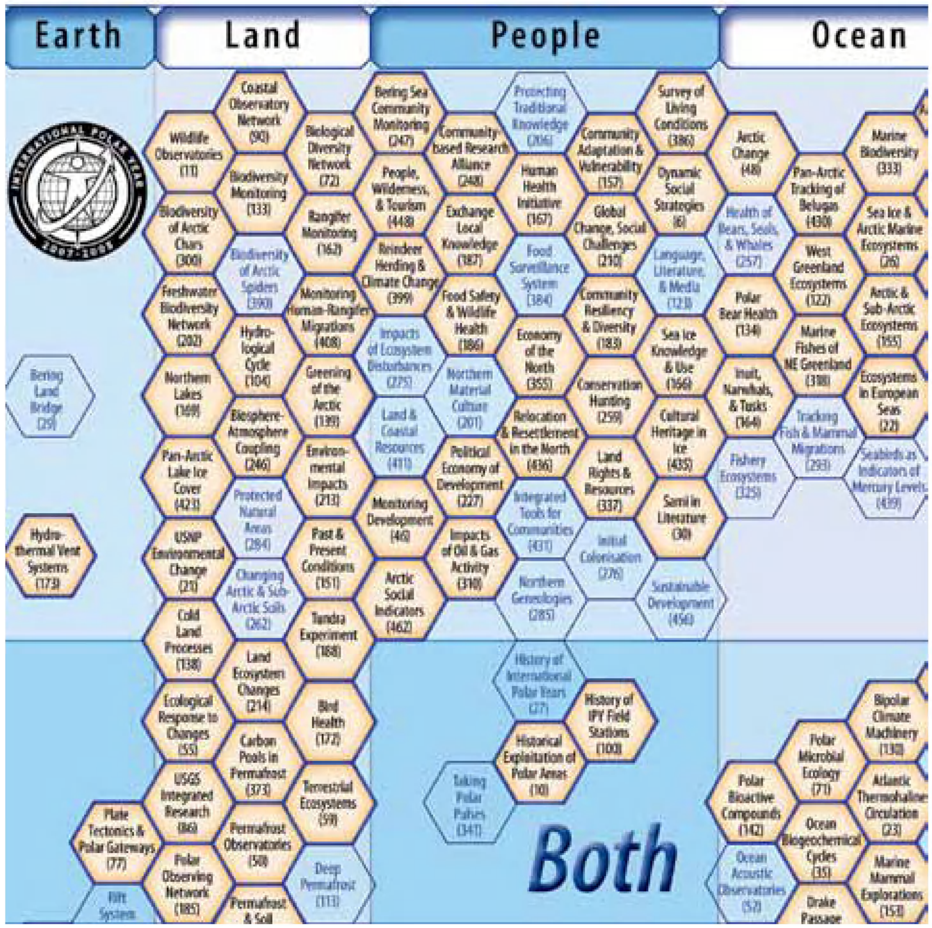

Fig. 2.10-1. IPY projects in the 'People's' field and adjacent themes as shown in the IPY projects chart (Version 7.3 – September 2008). Projects with limited or no funding are colored in blue (though some eventually contributed to the IPY program).

that included social scientists and Arctic indigenous experts, such as ArcticWOLVES (no. 11), Biodiversity of Arctic Chars (no. 300), the Canadian Circumpolar Flaw Lead System Study, PPS Arctic (no. 151), DAMOCLES (no. 40), Circumpolar Biodiversity Monitoring Programme (no. 133) and others helped expand interdisciplinary partnership beyond the pre-IPY range.

IPY also created the momentum for polar social science and humanities researchers to advance the international collaboration to a new level. All endorsed IPY projects included partners from several nations and/or from indigenous communities and polar residents' organizations. Many social science and humanities studies were, in fact, large, coordinated programs with teams of researchers from several nations working in different areas under a concerted agenda, though with the individual national funding (nos. 6, 10, 100, 120, 123, 157, 162, 166, 399, 436, 462). Such collaborative studies included researchers and agencies from at least 21 countries[5]; scientists from 14 nations acted as project leaders.[6] Several projects generated large international teams of 50-80 people from six to eight nations (nos. 10, 157, 166, 386, 399, 436, 462); the average size of an IPY social science project team, including local partners, was close to 30 people. This new level of institutional complexity achieved in IPY 2007–2008 helped move social studies structurally closer to large interdisciplinary programs that are currently the trademark activities in the polar regions.

For the first time, several initiatives in IPY 2007–2008 have been proposed by polar indigenous organizations (*Chapter 5.4*). All major organizations representing indigenous people in the Arctic—the Inuit Circumpolar Council, Aleut International Association, Arctic Athabaskan Council, Gwich'in Council International, Russian Association of Indigenous Peoples of the North, the Sámi Council—and many of their national and local chapters were actively involved in IPY activities (nos. 30, 46, 69, 162, 164, 166, 183, 187, 247, 399, 410, etc.) as local partners, logistical and public supporters, but also as initiators and lead institutions (nos. 46, 183, 247, 399; Fig. 2.10-2).

Altogether, IPY social science and humanities projects engaged at least 1500 researchers, students, indigenous experts and monitors, and representatives of polar indigenous people's organizations. Compared to an almost 'zero' presence in IPY-2 and in IGY 1957–1958, the social/human studies accounted for more than 20% of active research projects in this IPY (28 out of 136) and for 34% of all research projects in the northern polar regions (24 out of 71)[7].

As of 2010, 28 research projects in the 'People' field and at least seven related projects in other categories had been implemented (Table 2.10-1). The list is most likely incomplete. In addition, more than 20 national IPY projects have been supported by national funding agencies in Canada, U.S., Russia, Sweden and other countries besides the endorsed international initiatives. We may tentatively estimate that social sciences, humanities and community studies constituted the third-largest component of IPY activities, after 'Oceans' and 'Land,' though its share in terms of funding and personnel involved is significantly smaller. Social science project budgets until recently were dwarfed by the funding allocated to natural science research, and to geophysical projects in particular.

Highlights of IPY Social Science and Humanities Research

Principal research areas. Almost 30 implemented international research projects in the social science and humanities field addressed a broad variety of themes: the well-being of polar communities (nos. 157, 183, 386, 462); the use of natural resources and economic development, particularly, the impact of oil and gas industry (nos. 46, 227, 310); local ecological knowledge (nos. 164, 166, 183, 399); preservation of natural, historical and cultural heritage (nos. 27, 100, 135); history of exploration, peopling and the exploitation of polar regions, including Greenland, Svalbard and Antarctica (nos. 6, 10, 27, 276); and many

Fig. 2.10-2. EALÁT herders'meeting in Khralovo (Photo: Svein Mathiesen).

Box 1. The 'first-ever' achievements in the social and humanities field in IPY 2007–2008
(As reported by Project Lead Investigators, November–December 2009)

In Research

- Comparative study of local community vulnerabilities and adaptation strategy under the impact of modern climate change and non-physical (social, economic, etc.) factors across eight Arctic countries (Canada, Finland, Greenland, Iceland, Norway, Russia, Sweden and U.S./Alaska), with a snapshot of today's challenges and community responses from 30 studied communities (CAVIAR, no. 157)
- Pioneer study in constructing of Arctic 'social indicator' monitoring system of assessing community well-being and tracking human development in the Arctic (ASI, no. 462)
- Analysis of potentials and limitations (restrictions) of Arctic regional economies and their abilities to build a self-reliant (sustainable) development path (POENOR, no. 227)
- First contemporary 'snapshot' of the use and knowledge of sea ice in 30-some communities in four Arctic nations (Canada, Greenland, Russia and U.S.) during the IPY 2007–2008 era, with a new vision on polar sea ice as a critical subsistence area for indigenous people and a highly endangered 'cultural landscape' being sustained by the continuous use and shared community knowledge of ice environment and processes (SIKU, no. 166)
- Analysis of the political and ideological sphere created via conflicting interactions of the local drive for indigenous self-governance and self-determination with modern enlightened environmental discourse and commercial interests of local majority population, extractive industry and regional administrations (CLUE, no. 335)
- Correlation of social, cultural, economic and environmental factors in rapid economic transition (social change), which is commonly (mis)interpreted, often deliberately, as a consequence of catastrophic climate/environmental change (NOMAD, no. 408)
- First pan-Arctic perspective of governmental initiated relocations and resettlements of northern residents and indigenous communities (in Canada, Greenland, Russia/Soviet Union and U.S.) during the 20th century – with the lessons critical for prospective future decisions regarding community relocation due to climate change and resource development (MOVE, no. 436)
- Comparison of the early commercial exploitation of marine and terrestrial resources (whaling, sealing, etc.) in the Arctic and Antarctica over the past 400 years (LASHIPA, no. 10)
- New insights and comparative overviews of the history of the polar research, both in the Arctic and Antarctic, starting from the preparations for the First IPY in the 1870s and up until the IGY era (no. 27)
- Greater awareness of significance of historical/heritage resources in the polar regions, particularly in Antarctica, and of special activities related to polar heritage protection, site preservation, documentation and public use (tourism) (no. 135)
- Synchronous study of ancient Eskimo/Inuit adaptation patterns across Nunavut, Nunavik, Labrador and Northwest Greenland, in relation to sea ice conditions and climate change (GeoArk, no. 6)
- The most diverse international gathering of scholars from Arctic social sciences and the humanities and the largest venue during the IPY 2007–2008 era to present results on the ongoing activities and to get feedback from colleagues, community activists and insights from other disciplines (ICASS-6, no. 69).

In Data Collection, Observation, Monitoring and Data Management

- Building up of a GoogleEarth-based GIS atlas and database for the indigenous Nenets communities in northwestern Arctic Russia to help them deal with degradation of their land use areas through large-scale oil and gas development (MODIL-NAO, no. 46)
- Establishment of a comprehensive dataset (since 1998) containing comparative data on the living conditions among circumpolar indigenous people in six nations (Canada, Greenland, Norway, Russia, Sweden and U.S.) based upon local surveys and broad partnership among social scientists, local statistical services, polar indigenous residents and their organizations (SLICA, no. 386)
- Establishment of an international network of researchers, caribou hunters, co-management boards and government agencies to cooperate in monitoring and research; assessment of vulnerability and resilience to the environmental and human pressure of individual caribou herds across Alaska, Canada, Greenland, Norway and Russia (CARMA, no. 162)
- Engaging northern communities and local organizations in collection and preservation of cultural sensitive mate-

rials (including cultural objects and human remains) that become available through land and environmental change triggered by climate warming in the Arctic (no. 425)

- Engaging northern residents in communicating, monitoring and managing new food safety risks due to climate and economic change by using traditional and modern methods and techniques (no. 186)
- Collaboration of scientists and indigenous knowledge experts in combining data from various science fields (anatomy, genetics, physiology, morphology, acoustics) and traditional ecological knowledge for in-depth study of narwhal (NTR, no. 163)
- First experience of a community-driven regional observational network crossing international boundaries and run by indigenous organizations, with the purpose to document quantitative and qualitative observations by local experts in nomadic and/or remote indigenous communities (BSSN, no.247; EALAT, no. 399)
- First-ever data management and user support service established for local and traditional knowledge data and community based research/monitoring, with the prospect of emerging into a circumpolar network (ELOKA, no. 187)
- Visual, educational and public presentation of the experiences of Inuit communities facing impacts of climate change through the words and stories of the people who live there (Silavut, no. 410).

more.[8] Indigenous participants were particularly active in studies investigating community response and adaptation to rapid environmental and socio-economic changes (nos. 46, 157, 247, 335, 399). Many polar communities joined the IPY monitoring efforts to collect, exchange and document data on changes in sea ice, biota and climate (*Chapter 3.10*). All of these themes were new to the IPY program.

Major achievements (Box 1). As in the case of other IPY fields, the complete picture of research activities in the social science and humanities disciplines may not be available until 2011 or even 2012. Nonetheless, we were able to generate a list of 'first-ever' achievements—in research, observation, data collection, and management—based upon the responses from the leaders of 23 implemented projects. This is, of course, a preliminary inventory of major advances, since many IPY projects were cluster initiatives of several local and national efforts, and the results of several implemented projects are yet to be accounted.

The 'pulse' of social science and humanities research during the IPY years produced a steady stream of tangible products, such as scientific and popular papers and books, observational data, conference and project reports, maps, museum exhibits, websites and other online materials, as well as new explanatory models and research practices. Only a fraction of these results ('products') can be assessed at this early stage. No estimate exists yet of the total number of new papers in the social science and humanities fields, out of the overall number of some 3900 publications reported in the general IPY publication database as of May 2010 (http://nes.biblioline.com/scripts/login.dll - *Chapter 4.4*). A more 'user-friendly' Canadian IPY database (www.aina.ucalgary.ca/ipy/), which lists about 1900 entries related to Canadian IPY research *only*, counts more than 1100 social and human science entries, including 398 on 'indigenous people', 357 on 'government and socio-economic conditions', 141 on 'history', and 192 on 'human health'. The overall list of papers produced by IPY projects in the social sciences and humanities is certain to grow into many thousand. It is worth noting that IPY data were collected and disseminated in several indigenous languages of the Arctic, such as Sámi, Inuit (Inuktitut, Kalaallit, Inupiaq), Yupik/Yup'ik, Chukchi, Nenets, Sakha and others.

The field of the social sciences and humanities generated by far the largest share of the first books produced by the IPY 2007–2008 programs. As of this writing (summer 2010), at least twelve volumes based upon nine IPY projects in the social science and humanities field were already published or are in press (Barr and Chaplin, 2008 – no. 135; Barr and Lüedecke, 2010 – no. 27; Fienup-Riordan and Rearden, 2010 – no. 166; Hovelsrud and Smit, 2010 – no. 157; Krupnik et al., 2009, 2011 – no. 166; Launius et al., 2010 – no. 27; Larsen et al., 2010 – no. 462; Oskal et al., 2009 – no. 399; Shadian and Tennberg, 2009 – no. 100; Stuckenberger, 2007 – no. 160; Winther, 2010 – no. 227). Several more books are in submission and preparation. In addition, several reprints of the early IPY sources, collections on IPY history and polar research heritage were produced (Andreev et al., 2007; Arnestad Foote, 2009; Barr and Chaplin, 2008; Tromholt, 2007; Vairo et al., 2007a,b). By 2012, the publication 'imprint' of IPY social science and humanities research will be even more visible and will include several special journal issues and heritage materials produced for participating polar communities, now in preparation.

From 'local' to 'polar.' During IPY, seven projects (nos. 157, 162, 166, 227, 399, 436, 462) included new coordinated research and data collection in four or more Arctic nations. Four projects, CAVIAR (no. 157), CARMA (no. 162), EALÁT (no. 399) and MOVE (no. 436), aspired to produce pan-Arctic overviews of local community adaptation and vulnerability; subsistence caribou hunting; status of reindeer herders' knowledge; and the role of governmental policies in community resettlement and relocations, respectively. These projects, together with other large initiatives were critical in moving the social science and humanities field from local and regional to the 'circumpolar' level, as a result of IPY.

Two new 'pan-Arctic' IPY projects – Community Adaptation and Vulnerability in the Arctic Region (CAVIAR, no. 157) and Arctic Social Indicators (ASI, no. 462) – were particularly instrumental in this transformation. The CAVIAR project was aimed at testing a new research and modelling approach to assess Arctic populations' vulnerability and adaptability via studies in 26 communities in Canada, U.S. (Alaska), Greenland, Iceland, Norway, Sweden, Finland and Russia (*Chapter 3.10;* Hovelsrud and Smit, 2010). The main outcome was a new vision of the Arctic peoples' resilience to environmental stress as a 'two-way' process that depends as much (or more) on the strength of the community internal networks (social, cultural, institutional, economic, etc.) as on the intensity of the environmental signal (Fig. 2.10-3). As the CAVIAR case studies illustrate (and as social scientists have been arguing for years), the projected impact of change should be first assessed at the local community level rather than from the top-down, large-scale climate change scenarios that simulate certain temperature, ice, or seasonal shifts. In the pre-IPY impact assessment, including the IPCC Reports, the latter approach was viewed as a standard pathway to complex environmental impact modeling (Smit and Wandel, 2006; Krupnik, 2010). The ASI project aspired to develop a set of thoroughly calibrated indicators, via data mining and expert assessment, to evaluate the status of socio-cultural well-being of Arctic population at the community, local and regional level. Here, again, more general national indices used by UNESCO and other major international agencies, such as per capita gross domestic product or the overall level of literacy (http://unstats.un.org/unsd/demographic/products/socind/default.htm) have been successfully substituted by more locally-nuanced tools to assess community well-being, as a result of IPY research (Larsen et al., 2010; Table 2.10-2). It remains to be seen whether a community-based ('bottom-up') approach will become standard in the post-IPY studies.

The Power of Multiple Perspectives. This notion used by one of the IPY socio-cultural teams (Huntington et al., 2010) led to a new way of IPY data collection and will impact the future synthesis of IPY-generated materials. As has been long recognized by researchers, each process or phenomenon should be viewed from several perspectives, coming from different disciplines and/or groups of stakeholders. In physical and natural studies, bringing several disciplines to inter-disciplinary inquiry is most often aimed at grasping more elements and linkages in the complex natural systems. In social science research, this approach is rather associated with the use of radically different types of knowledge that have independent origins and basic principles, like those coming from the science and the

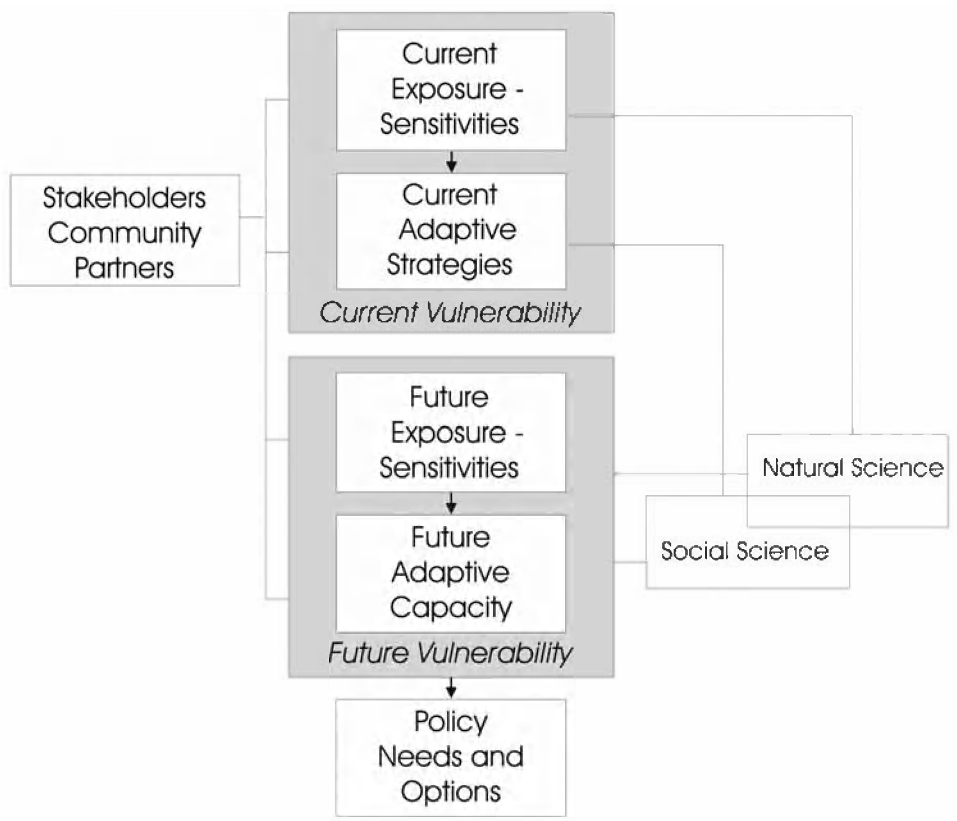

Fig. 2.10-3. CAVIAR interpretative framework for community vulnerability and resilience assessment (Smit et al., 2008).

humanities (arts, history, narratives) or from what is commonly called 'academic research' and indigenous knowledge. IPY 2007–2008 was a great experiment in demonstrating the power of multiple perspectives in many of its multi-disciplinary projects, but also specifically, thanks to the inclusion of social sciences, humanities, arts and indigenous knowledge with their very diverse vision, data collecting and roots.

Bringing together those diverse types of knowing, though not artificially merging ('integrating') them, increases the power of understanding; it also helps illuminate phenomena that are often beyond the radar of scientific research. For example, ice scientists, climate modelers, oceanographers, local subsistence users, anthropologists, mariners and science historians have remarkably different vision of polar sea ice. To various groups of scientists, sea ice is a multi-faceted physical and natural entity: an ocean-atmosphere heat fluxes regulator, a climate trigger and indicator, a habitat (platform) for ice-associated species and/or an ecosystem built around periodically frozen saltwater. To polar explorers and historians, sea ice was first and foremost a formidable obstacle to humanity's advance to the Poles (Bravo, 2010). Polar indigenous people view sea ice primarily as a cultural landscape; an interactive social environment that is created and recreated every year by the power of their cultural knowledge. It incorporates local ice terminologies and classifications, ice-built trails and routes with associated place names, stories, teachings, safety rules, historic narratives, as well as core empirical and spiritual connections that polar people maintain with the natural world (Krupnik et al., 2010). Cultural landscapes created around polar sea ice (icescapes) are remarkably long-term phenomena, often for several hundred years (Aporta, 2009 – Fig. 2.10-4). By adding a socio-cultural perspective and indigenous knowledge, ice scientists broadened the IPY agenda in sea ice research beyond its habitual focus on ice dynamics and coupled ocean-atmosphere-ice modeling (Druckenmiller et al., 2010; Eicken, 2010; Eicken et al., 2009).

The introduction of Arctic peoples' visions on weather, climate, snow and ice patterns is another

Table 2.10-2. Recommended 'Small' Set of Arctic Social Indicators for Tracking Human Development in the Arctic.
(Larsen et al., 2010)

Indicator	Domains
1. Infant Mortality	Health/Population
2. Net-migration	Health/Population and Material Well-being
3. Consumption/harvest of local foods	Closeness to Nature and Material Well-being
4. Per capita household income	Material Well-being
5. Ratio of students successfully completing post-secondary education	Education
6. Language retention	Cultural well-being
7. Fate Control Index	Fate control

example of how scientific understanding may be expanded by indigenous knowledge. The EALÁT project (no. 399, *Chapter 3.10*) was aimed at documenting indigenous herders' interpretations of weather and climate change they observe and at articulating the difference with the scientists' views dominated by the concepts, such as 'regime shift', 'tipping point', 'multiple feedbacks' and the like. As Sámi herders argue, "We have some knowledge about how to live in a changing environment. The term "stability" is a foreign word in our language. Our search for adaptation strategies is therefore not connected to "stability" in any form, but is instead focused on constant adaptation to changing conditions" (Johan Mathis Turi, in: Oskal et al., 2009). Whereas environmental scientists point to the increased vulnerability of polar ecosystems due to the warming climate, to the herders, the key factors in their response to rapid change are the overall range of their used territories and the freedom of movement across its constituent habitats. Therefore, the herders' prime concern continues to be about the diminishing size of Arctic pastures under the pressure of industrial development, government land rights and nature preservation policies, which are now increasingly coupling with the impact of climate change. Anthropologists and biologists working closely with communities had been long aware of this situation, but it took the momentum of IPY to bring this point across to a broader audience.

Field and Institutional growth

New Arctic-Antarctic Connection and the Emergence of Antarctic social sciences. IPY social science studies covered all eight Arctic nations (Canada, Denmark/Greenland, Finland, Iceland, Norway, Russia, Sweden and U.S.A.) and most of the IPY social and humanities projects focused on the Arctic region. No international proposals were originally submitted in 2004–2006 from the Southern hemisphere nations and only four proposals (nos. 10, 27, 100 and 135) were designed as 'bipolar' initiatives, with two (nos. 10 and 342) centered on Antarctica, albeit with strong participation by Arctic social science and policy experts. Nonetheless, IPY 2007–2008 has given rise to a number of social science and humanities studies in the southern polar regions: history of polar explorations, law and policy, governance and tourism. Eventually, 'Antarctic social sciences' emerged as a new and expanding field thanks to IPY 2007–2008.

A vocal and growing community of Antarctic social science and humanities researchers first anchored at the 'History of Science' Action Group established by the Scientific Committee of Antarctic Research (SCAR) in 2004 (no. 27, www.scar.org/about/history). The group held five workshops in 2005–2009 and produced numerous reports, publications and a summary edited volume (Barr and Lüdecke, 2010). This new level of awareness of societal issues in southern hemisphere research, with a growing number of interdisciplinary projects and system-based approaches stimulated SCAR to support the establishment of a new Social Sciences Action Group in 2009 (www.scar.org/researchgroups/via/). The new group focuses its activities on the topic of "Values in Antarctica: Human Connections to a Continent" and will use the *Social Sciences and Humanities Antarctic Research Exchange (SHARE)* network (www.share-antarctica.org/index.php/about-share) to improve the profile of Antarctic social studies. It also aspires to take on the role that the International Arctic Social Sciences Association (IASSA) plays for the Arctic social sciences. During the Oslo IPY conference, the new SCAR Social Sciences Action group/SHARE team held its first joint meeting with a large group of Arctic social science researchers, which was viewed as a key step in new bipolar cooperation in social science and humanities research. Thus IPY was instrumental in

Fig. 2.10-4 . Inuit polar ice trail network connecting communities across frozen land and water is being recreated every year, since time immemorial (Aporta, 2009).

raising interest to the social issues that are common to both polar regions, such as history of science, early economic exploration, sustainable economies, governance and political regimes, tourism, heritage preservation and engagement of local constituencies, to name but a few.

Funding. Twenty-one projects (out of 23) that reported their funding between 2006 and 2010 had a cumulative budget of $31.2M U.S.. This is, evidently, a low estimate of the level of funding for social science and humanities research in IPY, since it covers neither all endorsed international projects nor projects in other fields with a substantial human component. Also, it does not include national efforts supported by the national IPY programs in Canada, Russia, Sweden, the U.S.A. and other countries. For example, the total budget for 13 Canadian projects in social science and community studies, and human health was $21M (David Hik, pers. comm.); the NSF overall funding for social science research in 2006–2010 is estimated at $19M, of which only half was allocated to the internationally endorsed IPY projects. Other U.S. agencies, like NOAA, the National Park Service and the Smithsonian Institution, also contributed their resources to IPY social science research. In addition, many 'in-kind' expenses, such as researchers' salaries and travel costs, were often covered via their host institutions. It could be reasonably estimated that the overall amount of 'new' money for international IPY projects in the social science and humanities research was close to $40M, plus a yet unknown amount of funding (and in-kind contribution) for the 'national' IPY efforts, including conferences, websites, publications, travel and student support.

IPY highlighted the crucial role of funding for research in the polar social sciences and humanities, which produced additional tangible results. In summer 2005, the European Science Foundation (ESF) initiated a new 'EUROCORES (European Collaborative Research) Programme' called *Histories from the North – Environments, Movements, Narratives* (BOREAS – Vitebsky and Klein, 2005, 2006/2007). It was operational for five years, 2006–2010, with the overall budget of € 6M (about $8.5M) that eventually funded seven international project clusters (Klein et al., 2007; ESF, 2010), including several endorsed IPY projects (nos. 30, 100, 386, 436).[9] Though only a portion of the BOREAS budget was used for the IPY efforts, two corresponding initiatives resulted in an unprecedented rise in polar social science funding during the IPY years.

Technological innovations. IPY generated major advancements in new technologies used in polar social science research and facilitated the transfer of many of these technologies to polar residents and indigenous people. Several IPY social projects were focused on the creation of electronic maps and atlases (cybercartography – nos. 46, 166 – Fig. 2.10-5; Pulsifer et al., 2010) and new datasets and data management services for local communities (nos. 162, 164, 187, 247, 399). They used satellite imagery (nos. 166, 300, 399; Alfthan et al., 2010 – Fig. 2.10-6), Google Earth as a research and outreach tool (no. 436), and new GPS-based technologies (Druckenmiller et al., 2010; Gearheard et al., 2010) to assist in community-based monitoring and data collection. Many of these new technologies that were first tested in IPY will become core features of the research projects, services and legacy initiatives of the post-IPY era (*Chapters 3.8, 3.9, 5.2, 5.4*).

Major events. Four events (in chronological order) were critical in mobilizing the social science and humanities field in IPY. The first public discussion of some future IPY projects developed within the social science disciplines (nos. 6, 123, 157, 210, and 227) took place in April 2005 at the Nordic IPY seminar in Ilulissat, Greenland. It was organized by the Greenland National IPY Committee (Fig. 2.10-7) and included more than 100 researchers and students from the European (primarily Nordic) countries and also from North America, Russia and China. For indigenous participants, the key event was the symbolic launch ceremony for the 'Indigenous People's IPY' in the Norwegian town of Kautokeino/Guovdageaidnu, on 14 February 2007 organized jointly by the Sámi University College/Nordic Sámi Institute, International Centre for Reindeer Husbandry, the Association of World Reindeer Herders and the local municipality (Fig. 2.10-8). It brought together almost 300 representatives of indigenous peoples from all Arctic nations, climate researchers, reindeer herders, Sámi youth, as well as politicians and high-ranking officials from Norway, Russia and other countries. The largest IPY-related event was the 6th International Congress of Arctic Social Sciences (ICASS-VI) in Nuuk, Greenland in August 2008 (Figs. 2.10-9, 2.10-10) organized as an IPY project (no. 69, Poppel, 2009). It brought together 370 participants from 22 nations and featured plenary and thematic sessions on 12 IPY projects (nos. 100, 123, 157, 166, 167, 436, 462, etc.). Lastly, the IPY 'People Day' on 24 September 2008 (www.ipy.org/index.php?/ipy/detail/people/) (*Chapter 4.2*) was most instrumental in raising the profile of social science and human research in IPY and highlighted 41 projects, including associated efforts in education and outreach (Fig. 2.10-11).

Participatory research. IPY has advanced the participation of Arctic residents, including indigenous peoples, in polar research at all levels: project planning, data collection and management, analysis, and outreach. For the first time, Arctic residents and their organizations acted as partners and leaders in several international projects (nos. 30, 46, 157, 166, 183, 187, 247, 335, 399, 410, 425 – *Chapter 5.4*) that involved participants from many nations and disciplines. For the organizations and communities involved, it was an impressive contribution to local capacity building, training and introduction of modern research methods and technologies. The observations and knowledge of Arctic residents was the key factor to the success of IPY studies of sea ice (no. 166), wildlife habitat and distribution (nos. 162, 164), sustainability of local communities (nos. 157, 183) and economic development (nos. 46, 310, 335). Partnerships built

Fig. 2.10-5.
Cybercartographic atlas
(Credit: Peter Pulsifer).

Fig. 2.10-6. Poster "Polar View: Satellite-based monitoring to assist Arctic Indigenous Communities in Adapting to Climate Change" presented at the Oslo Science Conference (Alfthan et al., 2010) illustrates new links between satellite technologies and indigenous stakeholders.

during IPY enabled local communities to benefit from science projects in their home areas (Paci et al., 2008) and ensured that the implemented IPY projects were relevant to the communities and local policy development. That will certainly facilitate bridging research driven by academic institutions, agencies, and indigenous communities and organizations in the years ahead.

Several other footprints of the social science and humanities participation in IPY expand beyond the disciplinary field. Social scientists were the first to argue for the need for established 'ethical guidelines' in conducting IPY research and lobbied successfully for its approval by the Joint Committee in 2007 (www.ipy.org/ipy-blogs/item/796 - Appendix 8).[10] They initiated the collection of narratives, documents and memoirs related to the origination and early planning for IPY 2007–2008 (*Chapter 1.2*), and produced the first historical overviews of IPY 2007–2008 and compared it to the earlier IPY/IGY programs (Barr and Lüdecke, 2010; Elzinga, 2009; Korsmo, 2007, 2009; Launius et al., 2010). They argued for the preservation of IPY-related documentation and memorabilia that eventually helped establish the IPY archives at the Scott Polar Research Institute in Cambridge, U.K. (*Chapter 4.4*).

Social Science and Humanities Contributions to the IPY Science Themes

Snapshot (status). The fundamental goal of IPY 2007–2008 was to determine the baseline status of contemporary natural and human environments and processes in the polar regions (Theme 1 – Rapley et al., 2004). Almost every major IPY project in the social science and humanities field assessed the contemporary status of polar societies and social processes, and generated 'baseline' data on community development (nos. 157, 183, 462), industrial exploitation of polar resources (nos. 10, 46, 227, 310), status of indig-

Fig. 2.10-7. Participants of the 'Nordic IPY Seminar' boarding the ship in Ilulissat, Greenland, April 2005 (Photo: Birger Poppel).

Fig. 2.10-8. Opening of the Indigenous People International Polar Year, 15 February 2007. Left to right: former Sámi University College Rector, Mai-Britt Utsi, Mayor Klement Erland Heatta, former Norwegian Minister for the Environment Helen Bjønøy, and former President of the Norwegian Sámi Parliament, Aili Keskitalo (http://arcticportal.org/ipy/opening-of-the-indigenous-peoples-international-polar-year-guovdageaidnu-norway-feb-14-2007; www.polararet.no/artikler/2007/IP_IPY).

enous languages and knowledge systems (nos. 82, 123, 164, 166, 183), cultural heritage (nos. 100, 135), community use of local resources (nos. 162, 247, 399, 408) and other themes. Several IPY publications have already connected these data to earlier datasets, thus expanding the value of IPY records by several decades (Heleniak, 2008, 2009; Kruse, 2010; Winther, 2010). The comparative value of IPY datasets is certain to grow in the years to come; it is, nonetheless, contingent upon IPY researchers making their data available to a wider community in accordance with the IPY requirements.

Frontiers (Theme 4) is the code name for the most rapidly developing science areas that the IPY planners viewed as particularly relevant to IPY research. They included social transformation induced by large-scale resource exploitation, industrialization and infrastructure development in polar regions; relations between demographic, economic and social trends and their ultimate impact on the environment as the issues of particular importance (Rapley et al., 2004). Several IPY projects in the social science and humanities field addressed those issues (nos. 10, 46, 157, 227, 310, 335, 399, 462), but other themes emerged as the obvious research 'frontiers' in IPY.

By far, the most important is the inter-relationship between indigenous perspectives developed via generations of shared knowledge and observations, and the data and interpretations generated through thematic scholarly research. The field that compares such perspectives (on climate change, sea ice, sustainability, development, community well-being) did not even exist prior to the late 1990s (Huntington et al., 2004; Krupnik and Jolly, 2002; Oakes and Riewe, 2006; Roncoli et al., 2009). Many projects contributed to its rapid growth during IPY (nos. 27, 46, 157, 162, 164, 166, 186, 187, 247, 399, 408, 410, also nos. 133, 151, 300). A related, though independent, 'frontier' area centers on making polar research culturally and socially relevant by collaborating with the new groups of stakeholders (nos. 46, 157, 162, 164, 186,187, 247, 399; *Chapter 5.4*). As stakeholders become involved in research planning in their home areas, more attention is being paid to local concerns and community observations, so that research goals are set through dialogue with local communities, rather than among scientists and funding agencies.

Another frontier area pioneered in IPY is the comparative study of northern-southern hemisphere processes to understand the development of the so-called 'fringe environments.' In the social sciences and humanities field, it focuses on the history of polar explorations, commercial use of local resources, polar governance, tourism, heritage preservation and advances the 'bipolar' approach (nos. 10, 27, 100, 135 – Avango et al., accepted; Barr and Chaplin, 2008; Broadbent, 2009; Hacquebord, 2009; Hacquebord and Avango, 2009) typical for IPY.

Change in the polar regions (Theme 2 – Rapley et al., 2004). Perhaps the very addition of 'change' as the lead research theme was the hallmark of IPY 2007–2008 compared to its predecessors. It was also a projection of the new societal concerns about global warming, environmental diversity and the industrial exploitation of the lands and the ocean,

Fig. 2.10-9. 6th International Congress of Arctic Social Sciences (ICASS-VI) in Nuuk, Greenland (August 2008) was the largest gathering of IPY social sciences and humanities researchers (Photo: Birger Poppel).

Fig. 2.10-10. IPY Plenary session at the 6th International Congress of Arctic Social Sciences. Left to right: (unidentified technical assistant), Yvon Csonka, Aqqaluk Lynge, Kristjan Kristjanson, Lars Kullerud, Rüdiger Klein, Grete Hovelsrud, Igor Krupnik and Ludger Müller-Wille (Photo: Birger Poppel).

Fig. 2.10-11. IPY 'People Day' webpage, 24 September 2008. www.ipy.org/index.php?/ipy/detail/people

and of the growing focus on 'change' in modern interdisciplinary research. Change, both environmental and social, was addressed in many IPY social science and humanities projects, including the impact of oil and gas development, polar ice, community integration and well-being, and new threats to the continuity of indigenous economies, languages, and cultures (nos. 46, 82, 157, 166, 187, 227, 247, 335, 399, 408, 436, 462). Several IPY projects in history and archaeology explored past changes in the polar regions (nos. 6, 10, 100, 151, 276) and studied early forms of commercial exploitation of polar resources, such as whaling, seal-hunting and mining, as models to the present and future development (Hacquebord, 2009). Significant effort was put into researching Arctic social change via the creation of long-term comparative datasets (nos. 227, 386, 462).

Linkages and global connections (Theme 3). Two major outcomes of broad relevance emerged from the IPY social science and humanities research. The first relates to the multi-level and adaptive nature of governance of the 'international common spaces,' such as Antarctica, the Central Arctic Basin, High Seas and Outer Space (Antarctic Treaty Summit, 2009; Shadian and Tennberg, 2009; *Chapter 5.5*). Though few IPY projects ventured explicitly into the policy and governance field (nos. 27, 100, 342), the overall awareness of such issues has grown substantially during the IPY thanks, in large part, to the historical studies of IGY 1957-1958, the celebration of the 50th anniversary of the Antarctic Treaty in 2009 and the new role of the United Nations Convention on the Law of the Sea (UNCLOS) in the Arctic Policy debate. Significant effort was made to integrate law, economics and governance with more traditional research areas such as resource use, climate science and minority rights issues (nos. 46, 157, 310, 335, 436, 462), and more is to be expected by the Montreal IPY conference in 2012 (*Chapter 5.6*).

Another major input of social science research to IPY is the recognition of complex relationships among various drivers of change and the inclusion of local communities, their voices and perspectives in the interdisciplinary studies of climate change. Several IPY projects have demonstrated that, although climate warming and changing bio-physical conditions have direct consequences to the communities that depend upon local resources, more immediate challenges stem from the many social agents, such as local system of governance, economic development, break-up in community support networks and culture shifts (nos. 46, 157, 166, 247, 335, 399, 408). In certain areas in the Arctic, the purported 'threat' of climate change is being used to mask or distort the impact of more immediate factors, such as the alienation of property rights, appropriation of land, disempowerment of indigenous communities and more restricted resource management regimes (nos. 46, 335, 399, 408; Forbes et al., 2009; Konstantinov, 2010).

A broader implication of this perspective is that environmental change ('global warming') should be considered an *added* stressor to the already challenging local conditions that can be assessed by working with the communities on the ground rather than from general models. This is a very different process than the one used in physical and natural sciences to 'downscale' global or regional scenarios of change and our understanding of the complex interplay of many factors in this process has been markedly enhanced through IPY research. Again, the value and the impact of the new information collected during IPY depend upon the individual project teams making their data widely accessible via post-IPY publication, dissemination and cross-disciplinary teamwork.

Vantage Points. 'Theme 5' of the IPY science program promoted the unique vantage point of the polar regions and was originally tailored to feature geomagnetic, space and atmosphere studies, that is, geophysical research (Rapley et al., 2004). Nonetheless, the very idea of the polar regions offering unique insight in the broader global processes resonates with the current discussions among polar social science and humanities researchers. Polar regions indeed offer a special vantage point due to the long established tradition of community and human-environmental studies, and because of the 'amplification' of many societal phenomena at the local scale, much like in the case of climate and broader environmental change.

During IPY and particularly under the ESF BOREAS program, substantial efforts have been made to place the circumpolar regions into the wider global context, with the goal to 'de-provincialize' ('de-exoticize') Arctic social science studies and to demonstrate how social and environmental research at the poles can provide new insights of, and be linked up with other parts of the world (Heading North, 2008). Such broader insights explored in IPY included the development of policies in managing 'common spaces' (nos. 100, 342); commercial resource exploitation of the economic 'frontier' zones (no.10); population exchange between 'North' and 'South' (no. 436); search for the broadly applicable indicators of community well-being (no. 436); and gaps in our datasets to assess community vulnerability to environmental change.

An internal 'vantage point,' particularly in the Arctic, is the stock of knowledge about the polar environment accumulated by local residents and, especially, by indigenous people. That knowledge has been generated independently of the advancement of scholarly studies and is based upon different sets of data and observations. Many social scientists and indigenous experts believe that both vantage points offered by the two ways of knowing, the academic and the local/indigenous knowledge, are extremely beneficial to our common understanding of the polar regions and processes (nos. 162, 164, 166, 186, 187, 247, 399, etc.).

Conclusion: The Legacy of the Social Sciences and Humanities in IPY 2007–2008

Being true newcomers in IPY 2007–2008, polar social scientists and indigenous organizations mobilized quickly and made substantial contributions to its program. They also emerged much stronger—scientifically, institutionally, and financially—as a result of IPY (*Chapter 5.4*). This is evident from the growing acceptance of indigenous, social science and humanities issues by IPY sponsors, ICSU and WMO, many polar umbrella organizations, such IASC and SCAR, and from across-the-board expansion of funding for social science research during 2005–2010. The implementation of several IPY projects operated primarily by Arctic indigenous organizations, such as EALAT, BSSN and others is another success story (*Chapters 3.10, 5.4*). Overall, all parties should be pleased that they did not miss the IPY boat in 2004.

The IPY years also witnessed the growth of interest among physical and natural scientists in the issues related to polar residents, and in the methods of social and human research. This transition becomes especially apparent through the strong presence of human and social science themes at all major IPY-related events, like the two main IPY science conferences in 2008 and 2010 (Fig. 2.10-12).[11] Many national IPY committees, for the first time, added social scientists and representatives of polar indigenous organizations to their ranks (*Chapter 5.4*). Today, we have many more partners sympathetic to the indigenous, social and humanities topics than at the beginning of the IPY planning in 2002–2003. Several IPY 'legacy initiatives,' such as SAON (*Chapter 3.8*), CBMP (*Chapter 3.9*), SWIPA (*Chapter 5.2*) and the proposed International Polar Decade (*Chapter 5.6*) now view social science's inclusion and indigenous participation as a given. The lines of collaboration

Fig. 2.10-12. Ole Henrik Magga, former President of the Sámediggi (Sami parliament) and one of the leaders of the EALÁT project (no. 399) delivers plenary talk "Arctic peoples and Arctic research - success stories, contradictions and mutual expectations" at the Oslo Science Conference, June 10, 2010 (Photo: Igor Krupnik).

established during IPY produced new alignments with colleagues in the natural and physical sciences that will become instrumental in the years ahead. Last but not least, social science issues are taking much higher profile among the next generation of polar researchers represented by APECS (*Chapter 4.3*), which now has its Law and Policy working group and a social sciences disciplinary coordinator, not to mention that the last and the current APECS President (as of 2010) have been social scientists.

We believe that the IPY 2007–2008 also has broader repercussions beyond the field of polar research, namely as a successful attempt at 'remaking' science (or 're-thinking science – Gibbons et al., 1994; Nowotny et al., 2001) particularly, by building a grassroots trans-disciplinary program via bottom-up and open collaboration among academic scientists and many new stakeholders that had little or no voice in earlier research (*Chapter 5.4*). Another key IPY legacy is the legitimization of the 'two ways of knowing' (cf. Barber and Barber, 2007) or rather, of the many 'ways of knowing' of polar regions and processes, including those advanced by physical and biological scientists, polar residents, social and humanities researchers, but also increasingly by educators, artists and media. The door to those many 'ways of knowing' was, again, opened by the inclusion of the new 'others' to the PY, primarily by the inclusion of social sciences, humanities, and polar residents' agendas into its program, and also by the outstanding success of public and outreach activities in the fourth IPY.

This leads to other crucial legacies of the social sciences' and humanities' participation in IPY 2007–2008, namely, the more complex vision of the polar regions and processes, and the recognition that the 'human dimension' paradigm is too limiting. The latter term was originally coined in the wildlife and natural park management in the 1940s and was propelled to popularity during the 1980s (Manfredo, 1989; Stern et al., 1992). It has been applied broadly in the past two decades in the studies of environmental and climate change, resource management, ecosystem dynamics, wildlife monitoring and even broader areas, such as geoengineering, urban planning or adaptation to natural catastrophes.[12] In most of these applications, it has been viewed primarily as a tool in top-down 'impact assessment' (mitigation) approach, with little relation to local communities and actual socio-cultural development on the ground. The inclusion of social sciences and the humanities to the IPY program introduced the complexity of processes going at the local scale or, at the very least, demonstrated the limitation of the dominant top-down scenarios in complex environmental modelling. It strengthened the value of comparative perspectives, other ways of knowing, and new voices in what may eventually emerge as the new (post)-IPY 'inter-disciplinarity' (*Chapters 5.1, 5.2, 5.4*). The IPY momentum has been extremely helpful in putting it to work, bridging disciplines and fields as so often and long advocated. It will be for future generations to judge whether these approaches will have a lasting impact on polar science.

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We are grateful to the leaders of 23 social science and humanities projects in IPY 2007–2008 who shared information on their activities for this overview. Special thanks go to our colleagues in IPY, Björn Alfthan, Claudio Aporta, Birger Poppel and Svein Mathiesen for kindly supplying illustrations to this chapter, and to Hugh Beach and Piers Vitebsky, who offered valuable comments as external reviewers.

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Notes

1 The field of the social science and humanities research in IPY has been covered in earlier overviews (Hoveslrud and Krupnik, 2006; Krupnik, 2008, 2009; Hovelsrud and Helgeson, 2006) and at several meetings, particularly at the 6th International Congress of Arctic Social Sciences (ICASS-6) in Nuuk in 2008.

2 Additional information can be found on the websites and in publications generated by individual projects.

3 For example, the newly released U.S. Arctic Research agenda (2010) features 'Indigenous Languages, Cultures, and Identities' (also 'Arctic Human Health') among its five central themes.

4 Unlike their colleagues in physical and natural sciences, polar social researchers and indigenous organizations had little experience in running major international projects that crossed the boundaries of several Arctic nations and covered large sections of the circumpolar zone. The Study of the Living Conditions in the Arctic (SLICA), started in 1998 and completed as IPY project (no. 386), was the only coordinated international social survey in six Arctic nations (Canada, Greenland, Norway, Russia, Sweden and the U.S.) prior to IPY 2007–2008.

5 The nations most active in IPY social research, both in terms of internationally coordinated projects and their participants, were Canada, Norway, U.S.A., Denmark/Greenland, Iceland, Russia and Sweden, with the substantial participation by scientists from Germany, U.K., Finland and the Netherlands. Individual researchers from Bulgaria, Estonia, France, Poland, Australia, Argentina and New Zealand were active in certain projects. Little or no social research was, reportedly, conducted during IPY 2007–2008 in China, Korea, Japan, India, Chile, Belgium, Portugal, Spain, Switzerland and other nations with substantial IPY activities in other fields.

6 Bulgaria, Canada, Denmark/Greenland, Finland, Germany, Iceland, the Netherlands, Norway, Sweden, Russia, United Kingdom, and U.S.A.

7 The overall number of endorsed international projects associated with the social sciences and the humanities at the onset of IPY was around 60 (Hovelsrud and Krupnik, 2006), including 16 projects in 'Education and Outreach.' Overall, those 60 proposals made an amazingly high score of about 28% of the total IPY effort. The 'full proposal' database (http://classic.ipy.org) featured a total of 83 proposals under the listing of 'People,' of which 54 can be reasonably attributed to the social and humanities field.

8 See earlier analysis of a larger sample of endorsed IPY projects in Hovelsrud and Krupnik (2006), Hovelsrud and Helgeson (2006) and Krupnik (2006, 2008, 2009).

9 Funding for BOREAS was coordinated by the European Science Foundation and came as contributions from Canada, Denmark, Estonia, Finland, Iceland, Norway, Poland, Sweden and the U.S.A. Associated project partners were based in Belgium, France, Germany, Russia, Switzerland and the U.K. Though the overall amount of funding may look modest to the natural scientists, it was the biggest program ever funded for humanities research in the Arctic.

10 The discussion about a special statement on 'ethical guidelines' for IPY research to be issued by the Joint Committee was started at the JC-3 meeting in Cambridge in April 2006 and continued at the JC-4 and JC-5 meetings (in September 2006 and 2007, respectively). A draft of the 'Ethical guidelines' for IPY research was prepared by Igor Krupnik in November 2006; it was finally approved by the JC and posted on the main IPY website in May 2007 (Appendix 8).

11 The IPY Conference in St. Petersburg (2008) featured a special theme, "People and Resources at the Poles," with eight sessions on social/human projects in IPY 2007–2008 that included more than 100 oral and poster presentations (www.scar-iasc-ipy2008.org/). The Oslo Science Conference in June 2010, similarly had a special theme titled "Human Dimensions of Change: Health, Society and Resources" with six thematic areas featuring more than 350 presentations (http://ipy-osc.no/theme/4).

12 Recent Google search for 'Human dimensions' generates about 5.5 M references (May 2010)

2.11 Human Health

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Introduction and Overview

While health research is not new to international collaborations, International Polar Year (IPY) 2007–2008 was the first IPY to include human dimensions as a thematic area of study. The theme for the human dimension was established to "investigate the cultural, historical, and social processes that shape the sustainability of circumpolar human societies, and to identify their unique contributions to global cultural diversity and citizenship" (Rapley et al., 2004).

This chapter will introduce the circumpolar health context, and then provide an overview of the history which informed health research activities during IPY 2007–2008 and highlight the activities which arose as a result of this initiative.

The IPY activities related to human health primarily focused on polar regions with permanent human inhabitants (Fig. 2.11-1). Nevertheless, it should be recognized that locations such as Svalbard and Antarctica are inhabited by transient populations, and have rich histories in science and exploration. The legacy lives on as these populations continue to be primarily made up of scientists, explorers and occupational workers (including passing shipping traffic in Antarctica and coal miners in Svalbard). Both Antarctica and Svalbard have international treaties which support an environment for international activity. Despite the high level of scientific activity in these regions, scientific programs that explore the human health of these populations were underdeveloped during IPY. Human health needs in these populations tend to focus on emergency medicine, telehealth, rescue and expedition medicine and human response to isolation, cold and remote environments. Populations are small, so studies tend to be descriptive or qualitative. In some instances, human health research at the remote polar stations has been used to inform and better understand elements of human behavior in space (http://humanresearch.jsc.nasa.gov/analogs/analog_antarctica.asp). Communities such as Argentinean Esperanza Base in Antarctica and Longyearbyen in Svalbard have family residents, and medical services tend to be based on standards of the nation state: Argentina for the base in Antarctica and Norway in Svalbard. Each of these locations focuses on acute care and utilizes a medivac system to relocate individuals who are no longer able to work for any medical reason. Individuals with chronic conditions tend to self select and do not relocate to these remote locations.

Although substantial progress has occurred in the health of circumpolar peoples over the past 50 years, considerable disparities still exist across different regions and populations; these disparities tend to predominate in Indigenous populations (Young and Bjerregaard, 2008). Indicators such as life expectancy at birth (LE_0) and infant mortality capture these regional differences. In North America, LE_0 for the State of Alaska is the same as that of the rest of the United States. For Alaska Natives, however, there is a gap of about 5 years. In the three northern territories of Canada, the values decline as the proportion of Indigenous people increases, such that there is a difference of 11 years between the territory of Nunavut and the Canadian national value. In Scandinavia, there is essentially no difference between the northern and the national LE_0. Russia as a country is suffering

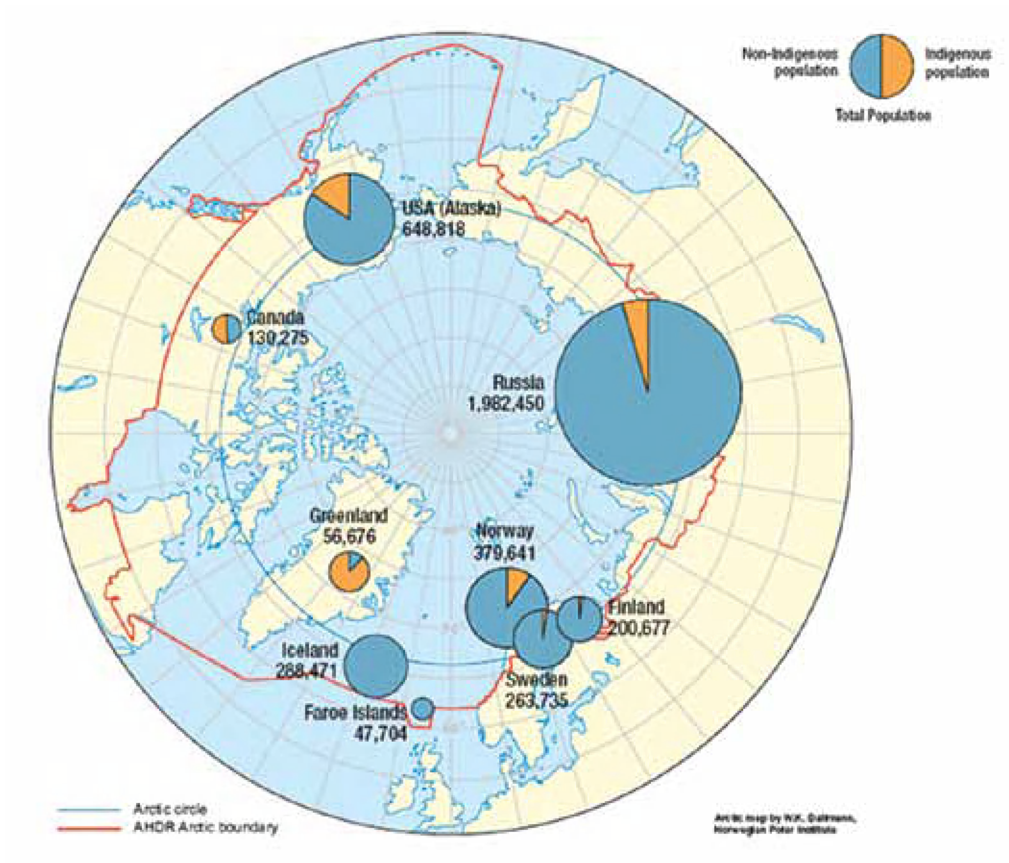


Fig. 2.11-1. The circumpolar Arctic region, showing total population and proportion of indigenous and non-indigenous populations.
(Map: K.W. Dahlmann, Norwegian Polar Institute)

from an unprecedented health crisis, with the male LE_0 less than 60 years. Among the northern regions, the difference in LE_0 between Iceland and Koryakia, Russia, is 29 years in men and 21 years in women.

A similar pattern is observed for infant mortality rate. The lowest rates (below 5 per 1000 livebirths) are observed in the Nordic countries (with little difference between North and South). There is an intermediate group consisting of northern Canada, Alaska and Greenland, with the Russian regions having the highest rates of infant mortality. There are substantial disparities between the Alaska Native and Alaska all-state rates, and Nunavut rate is almost three times the Canadian national rate. The highest Arctic infant mortality reported from the Evenki Autonomous Region in Russia, is 13 times that of the Faroe Islands (Fig. 2.11-2).

In general, substantial health disparities exist across different circumpolar regions. In terms of disparities between the Indigenous populations and the nation-states to which they belong, two extremes can be identified. In Scandinavia, the northern regions are almost indistinguishable from the country-at-large in terms of most health indicators. At the other extreme are Greenland and the northern territories of Canada, especially Nunavut, where the disparities with Denmark and Canada, respectively, are substantial. Alaska, as a state, tends not to differ much from the all-race U.S.A. rates, but Alaska Natives generally fare much worse than the State average. The health and demographic crisis in Russia is evident – in certain indicators, e.g. tuberculosis incidence, certain northern regions are at particularly high risk, within a country that is itself also at substantially elevated risk relative to other circumpolar countries. Selected health and demographic indicators have been compiled and available as a Circumpolar Health Supplement (Young, 2008) or online at the Circumpolar Health Observatory (www.circhob.circumpolarhealth.org).

History of Circumpolar Health Research

The scientific program of International Geophysical Year (IGY) 1957–1958 did not have a human health component. However, it did provide the catalyst for the beginning of the "Circumpolar Health Movement", a collaborative international effort to focus on human health in the Arctic. In 1957, the Nordic Council appointed a committee for Arctic Medical Research that resulted in the publication of the Nordic Council for Arctic Medical Research Report. Also in 1958, the idea for an International Biological Program (IBP) was conceived and it was implemented in 1967 as a biological analog for IGY, which had served as a successful catalyst for Arctic and Antarctic research in the physical sciences (Milan, 1980).

Although human health is new to IPY activities, there is well established history of cooperation and collaboration in health research between polar nations. The first exploratory conference on Medicine and Public Health in the Arctic and Antarctic, sponsored by the World Health Organization (WHO), was held in Geneva 28 August - 1 September 1962. It concluded that there was a need to stimulate high latitude research especially on health problems (WHO, 1963). As a result of these combined events, the first international circumpolar health symposium was held in Fairbanks, Alaska in 1967, and it was agreed to hold similar symposia every three years (Harvald, 1986). Twenty years later, these meetings resulted in the formation of the International Union for Circumpolar Health (IUCH). The IUCH is a non-governmental organization comprising an association of five circumpolar health organizations: American Society for Circumpolar Health, the Canadian Society for Circumpolar Health, the Nordic Society for Arctic Medicine, the Siberian Branch of the Russian Academy of Medical Sciences

Fig. 2.11-2. Map of perinatal mortality rate (number of late fetal deaths and early neonatal deaths per 1000 total births) in circumpolar regions. (Map: W.K.Dahlman, Norwegian Polar Institute)

and the Danish Greenlandic Society for Circumpolar Health. The IUCH promotes circumpolar collaboration and cooperation through the activities of its working groups in various fields of health and medicine (www.iuch.net). Outreach and communication are provided through the publication of the *International Journal of Circumpolar Health* and the hosting of the triennial International Congress on Circumpolar Health http://icch2009.circumpolarhealth.org/ .

The success of the IPY health activities can be attributed to the development of mechanisms for communication, contributions of existing polar organizations engaged in health research and the dedication of individuals through the circumpolar regions.

IPY and the Arctic Human Health Initiative

Within the Arctic Council, it was recognized that IPY 2007–2008 represented a unique opportunity to further stimulate cooperation and coordination on Arctic health research and increase the awareness and visibility of Arctic regions, and an opportunity to expand cooperation on human health. The Arctic Human Health Initiative (AHHI, IPY no. 167) was a U.S.-led Arctic Council IPY coordinating project that aimed to build and expand on existing Arctic Council and International Union for Circumpolar Health's human health research activities. The project aimed to link researchers with potential international collaborators and to serve as a focal point for human health research, education, outreach, and communication activities during IPY. The overall goal of the AHHI was to increase awareness and visibility of human health concerns of Arctic peoples, foster human health research, and promote health strategies that will improve health and well being of all Arctic residents. Proposed activities to be recognized through the initiative included:

- Expanding research networks that will enhance surveillance and monitoring of health issues of concern to Arctic peoples, and increase collaboration and coordination of human health research;
- Fostering research that will examine the health impact of anthropogenic pollution, rapid modernization and economic development, climate variability, infectious and chronic diseases, intentional and unintentional injuries;
- Promoting education, outreach and communication that will focus public and political attention on Arctic health issues, using a variety of publications, printed and electronic reports from scientific conferences, symposia and workshops targeting researchers, students, communities and policy makers;
- Promoting the translation of research into health policy and community action including implementation of prevention strategies and health promotion; and
- Promoting synergy and strategic direction of Arctic human health research and health promotion.

As of 31 March 2009, the official end of IPY, AHHI represented a total of 38 proposals, including 21 individual Expressions of Intent (EoI), nine full proposals (FP) and ten national initiatives (NI), submitted from lead investigators from the U.S., Canada, Greenland, Norway Finland, Sweden and the Russian Federation (Table 2.11-1).

The AHHI currently monitors the progress of 28 individual active human health projects in the following thematic areas: Health Network expansion (5), Infectious Disease Research (6); Environmental Health Research (7); Behavioral and Mental Health Research (3); and Outreach Education and Communication (5). While some projects have been completed in 2008–2009, others will continue beyond IPY. Individual project details can be viewed at: www.arctichealth.org. The AHHI proved to be an effective exercise in identifying and featuring health research activities during IPY. The information was shared via websites, circumpolar health supplements, congress presentations and within peer reviewed journals. The positioning of the project within the Arctic Council also allowed for information to be shared at the level of the Sustainable Development Working Group. The sharing of activities and projects raised the profile of health research and highlighted the need within Arctic Council for there to be ongoing access to research findings and experts engaged in circumpolar health research. To this end, strengths of the AHHI were identified and formalized through the development of the Arctic Human Health Expert Group, a government appointed advisory to the Sustainable Development Working Group (Parkinson, 2010a,b).

Project Title	Lead Country(s)	EoI/FP no.
Expansion of Networks		
International Circumpolar Surveillance	U.S.A.	1150
International Network for Circumpolar Health Researchers www.inchr.com/	Canada	516
Arctic Health Research Network. www.arctichealth.ca/	Canada	NI
Survey of Living Conditions in the Arctic: Remote Access	Denmark	**386**
The Inuit Diet and Health Study: Inuit Health in Transition	Canada	NI
Integrated Research on Arctic Marine Fat and Lipids	Canada	NI
Inuit Health Survey: Inuit Health in Transition and Resiliency (www.inuithealthsurvey.ca/?nav=home)	Canada	NI
Genetics and Environmental Risk Factors for Complex Diseases: A study of the Saami population	Sweden	1274
Center for Alaska Native Health Research	U.S.A.	NI
Does Exposure to Persistent Organic Pollutants (POPs) increase the risk of breast cancer?	Denmark	1257
An Epidemiological Study of the Cumulative Health Effects of Persistent Organic Pollutants and Mercury in Subsistence Dependent Rural Alaska Natives	U.S.A.	NI
The burden of Infectious Diseases in Greenland-means of evaluation and reduction	Denmark	1107
Hepatitis B in aboriginal Populations in the Arctic: Alaska Natives, Canadian Inuit, First Nations Peoples, Greenland Inuit and Russian Native Populations.	U.S.A.	1109
Addressing Viral Hepatitis in the Canadian North	Canada	NI
Sexual Health and Sexually Transmitted Infections in Northern Frontier Populations.	Canada	1147
Engaging Communities in the Monitoring of Zoonoses, Country Food Safety and Wildlife Health	Canada	**186**
Evaluation of the impact of an immunization program combining pneumococcal conjugated vaccine and inactivated influenza vaccine in Nunavik children, Province of Quebec, Canada	Canada	1119
Prevalence of Human Papillomavirus Infection and Cervical Dysplasia in the North West Territories	Canada	1121
Health and social condition of adoptees in Greenland - a comparative register and population based field study. Creation of an "adoptees-database"	Denmark	1201
Healthy Lifestyle Projects	U.S.A.	1271
Negotiating Pathways to Adulthood: Social Change and Indigenous Culture in Four Circumpolar Communities	U.S.A.	1266
Mental and Behavioral Health Issues in the U.S.A. Arctic	U.S.A.	NI
Outreach, Education, Communication:		
The Circumpolar Health and Wellbeing: Research program for Circumpolar Health and Wellbeing, Graduate School of Circumpolar Wellbeing, Health and Adaptation, and International Joint Master's Program in Circumpolar Health and Wellbeing	Finland	1045
Scientific and professional supplements on human health in polar regions-the International Journal of Circumpolar Health	Finland	1046
Development of a Women's Health and Well-Being Track at the 14th International Congress on Circumpolar Health in Yellowknife, NWT July 2009	U.S.A.	1223
Telemedicine Cooperation Project	U.S.A.	1270
Arctic Monitoring and Assessment Program Human Health Assessment Group Conference.	Canada	**145**
Climate Change and Impacts on Human Health in the Arctic: An International Workshop on Emerging Threats and Response of Arctic Communities to Climate Change	U.S.A.	NI

Table 2.11-1. Major Research, Outreach and Training Proposals in Human Health during IPY 2007–2008. IPY Full Proposals (FP) are denoted in bold.

Canadian training, communications and outreach projects

The Inuit Cohort: A Community of Research Practice Across Canada www.ciet.org/en/documents/projects_cycles/2007102165919.asp	Canada	NI
Healthy Foods North NWT www.hlthss.gov.nt.ca/sites/healthy_foods_north/default.htm	Canada	NI
Pan-Arctic Interactive Communications Health Project www.naho.ca/inuit/wellnessTV/index.php	Canada	NI

Research Infrastructure and the Expansion of Networks

While various networks exist to coordinate circumpolar health researchers, how circumpolar health research is organized varies from country to country. Some countries have established polar institutes and support special polar research programs focused on population health, whereas other regions do not have a central health program and health researchers have to compete with other specialists for program funds (Hanne, 2009). Over the IPY years, as a result of increases in research activities, both networks supporting individual researchers and infrastructure to support circumpolar research programs have been enhanced and developed.

During the preparation and implementation of IPY 2007–2008, circumpolar countries have made substantial progress in expanding health research institutes. In Greenland, the Greenland Institute for Circumpolar Health Research was established in Nuuk in 2008. In Canada, the Institute for Circumpolar Health Research in Yellowknife, NWT and the Arctic Health Research Network – Yukon and Qaujigiartiit/ Arctic Health Research Network NU, in Iqaluit, Nunavut were established. Health research capacity was also built at the Labrador Institute via infrastructure enhancements and the establishment of a faculty position in community health and humanities in partnership with the Memorial University in Newfoundland and Labrador.

The Centre for Arctic Medicine's Thule Institute, University of Oulu, Finland (http://arctichealth.oulu.fi) has a developed research program related to Circumpolar Health and Wellbeing. Activities are focused on environmental health and adaptation; population health and health care; societal and individual wellbeing, and cultural aspects of health and wellbeing. Research projects are supported by the Finnish Academy and the European Union.

In the U.S.A., circumpolar health research infrastructure has been expanded at the University of Alaska, Anchorage through development and support of a new graduate program in public health (MPH) focused on northern and circumpolar health issues (http://health.uaa.alaska.edu/mph/index.htm) and in the re-organization of Alaska's existing Institute for Circumpolar Health Studies (www.ichs.uaa.alaska.edu).

The establishment and development of institutes can be facilitated by northern-based leadership, a vision for health research and the engagement of key partners and stakeholders (Chatwood and Young, 2010). Proximity of these institutes to the peoples and governments allow for efficiencies in public health research including access to policy-makers, partnerships with community-based organizations and opportunities to design research projects of relevance to their regions while considering the circumpolar context.

Connecting people in circumpolar regions

During IPY 2007–2008, the core participants were self-organizing groups of researchers, their parent organizations, existing bodies with a role in polar regions research and monitoring, and consortia of such bodies. Increased activities created synergies and the development of new networks.

The International Union for Circumpolar Health (www.iuch.net) has served as an ongoing network where the numerous circumpolar societies can meet and work on initiatives that support research development, networking and dissemination of health information. To this end the main activity of the IUCH has been the International Congress on Circumpolar Health, which is held in circumpolar regions every three years (see below). The IUCH also has working groups which provide a mechanism for networking in specific thematic areas.

IPY saw the establishment of the International Network for Circumpolar Research (INCHR) (EoI no. 516). This is a voluntary network of individual researchers, research trainees, and supporters of research based in academic research centres, Indigenous people's organizations, regional health authorities, scientific and professional associations and government agencies, who share the goal of improving the health of the residents of the circumpolar regions through international cooperation in scientific research (www.inchr.com).

Another network that facilitated connections among more than 145 researchers in natural, health and social sciences from universities and institutions (or agencies) in Canada, Denmark-Greenland, France, Japan, Norway, Poland, Russia, Spain, Sweden, United Kingdom and U.S.A. was ArcticNet. Through this network, scientists connected with partners from Inuit organizations, communities, federal and territorial agencies to study the impacts of climate change in coastal regions (www.arcticnet.ulaval.ca).

The Arctic Health Research Network (AHRN) was launched as a Canadian contribution to IPY 2007–2008 (EoI no. 449 - www.arctichealth.ca/aboutahrn.html). The AHRN is based in the three northern territories and a provincial region of Canada and has four sites in Yukon, Northwest Territories, Nunavut and Labrador. Each site is independent and is registered under territorial societies act and are governed by a board of directors. The AHRN supports activities which build sustainable health research infrastructure in the north as well as engage northern partners in health research projects.

Data Resources

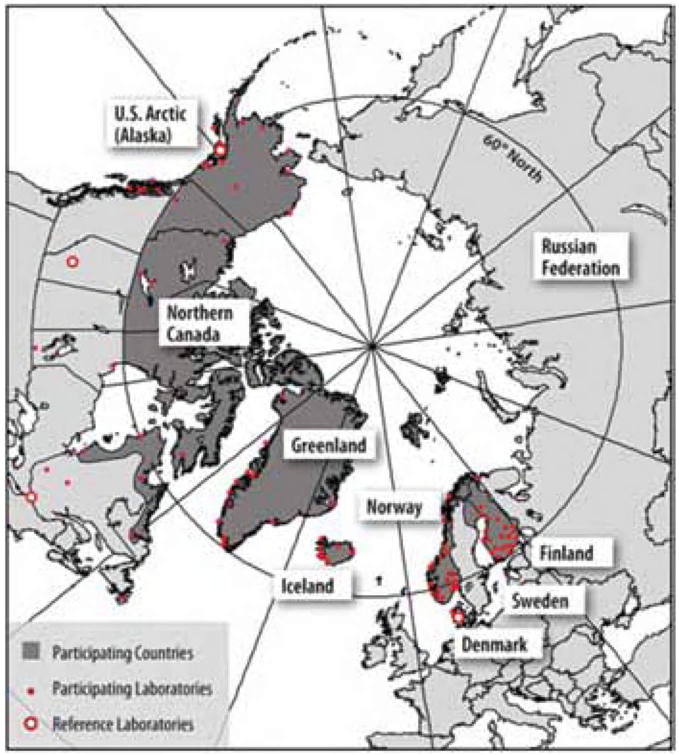
A key focus of International Polar Year was to create a legacy of data resources; thus it was not surprising to see the enhancement and development of networks that focus on data sharing among circumpolar countries. These health data initiatives were featured and contributed to discussions around the establishment of well coordinated and Sustaining Arctic Observing Networks (SAON) (www.arcticobserving.org - *Chapter 3.8*).

It is recognized that several human health monitoring networks already exist and could form the basis for the components of SAON related to human health. The following section highlights health data initiatives which could contribute to the SAON Human Health component. Established in 1999, the International Circumpolar Surveillance (ICS) system is an integrated population-based infectious disease surveillance network system, linking hospital and public health laboratories in the Arctic Circumpolar countries (U.S.A./Alaska, Canada, Iceland, Greenland, Norway and Finland) (Parkinson, 2008, Parkinson et al., 2008) (Fig. 2.11-3). Accomplishments during IPY included an expansion of surveillance to include tuberculosis, an effort to include northern regions of the Russian Federation in this system, and the establishment circumpolar working groups to focus on research aspects of viral hepatitis, diseases caused by *Helicobacter pylori* and sexually transmitted infections (EoI no. 1150). While the International Circumpolar Surveillance network is currently focused on prevention and control of infectious diseases, the network can be adapted to monitor and respond to other non-infectious Arctic human health priorities and, therefore, serves as a model as an Arctic Observing Network for human health (www.arcticobserving.org).

The Arctic Monitoring and Assessment Program (AMAP) of the Arctic Council has been coordinating circumpolar monitoring and assessment of atmospheric pathways, biota impacts, food chain dynamics and human health issues for environmental contaminants since 1991 (www.amap.no/). The contaminants have included persistent organic pollutants (POP's-both historic and emerging compounds), metals and radionuclides of concern in the circumpolar world (Fig. 2.11-4). The AMAP Human Health Assessment Group (HHAG) has members in all eight circumpolar countries and has completed three assessments on the human health impacts of arctic environmental contaminants (AMAP, 1996, 2002, 2009). These assessments include human monitoring data, dietary studies, health effects studies and risk management strategies to mitigate the effects of contaminants.

The Survey of Living Conditions in the Arctic (SliCA, IPY no. 386) itself is an interdisciplinary and international research project, which was founded in 1998 (Kruse et al., 2008; Poppel and Kruse, in press). The project is developed in partnership with the indigenous peoples organizations (*Chapter 2.10*). SLiCA has collected data in Canada, Alaska, Chukotka, Greenland and Sweden (Poppel et al., 2007) and, by the end of

Fig. 2.11-3. The International Circumpolar Surveillance (ICS) network of public health laboratories and institutes linked together for the purpose of sharing standardized information on infectious diseases of concern to Arctic peoples
(Source: Arctic Investigations Program).



2008, interviewing among the Sámi in Norway and the Kola Peninsula was concluded. The data material consists of approximately 8000 personal interviews.

During IPY, SLiCA intended to expand the understanding of Arctic change by extending the concepts of remote access analysis to the SLiCA international database (Hamilton et al., 2009), allowing other researchers to remotely conduct analysis without access to raw data. All interview data (except the Canadian SLiCA data) have been included in a SPSS database and almost 600 tables including survey results based on the interviewing among the Inuit (www.arcticlivingconditions.org).

During IPY, the concept of a Circumpolar Health Observatory (CircHOB) was developed (www.circhob.circumpolarhealth.org). Circumpolar regions have much in common beyond climate and geography. While health priorities are generally similar, health and social policies, service delivery systems, available resources and population characteristics vary considerably across regions. As a consequence, substantial disparities in health outcomes exist among circumpolar countries and regions. Monitoring, documenting and disseminating statistical health data will contribute to improvements in the design of policies, planning of services and evaluation of programs by government agencies, non-governmental organizations, academic institutions and communities across the circumpolar world. The objective of the CircHOB is an international collaborative health information system, involved in systematic, standardized and consistent data collection and analysis. It is population-based and covers all northern regions in all circumpolar countries. CircHOB's purpose is to monitor trends and patterns in health status, health determinants and health care, and provide an on-going knowledge base and analytical support for decision-makers, service providers, academic researchers and consumers.

Several other human health and social indicator networks are operational and will increase our research capacity and to address social realities of the Arctic. They all aim to encourage data sharing and use.

The Arctic Social Indicators (ASI - *Chapter 2.10*) is a follow-up project to the Arctic Human Development Report (Young and Einarsson, 2004). This project, which is currently on-going, will take advantage of existing data to create relevant indicators and will recommend a set of new and relevant indicators (*Chapter 2.10*). ASI developed indicators in six domains: ability to guide one's destiny, cultural integrity, contact with nature, education, health and demography, and material well-being. The Arctic Observation Network Social Indicators Project (AON-SIP, no. 462 - *Chapter 2.10*) is compiling data using a common framework, geography, time and variables. There are five clusters of indicators: community living conditions (organized within the six ASI domains), tourism, fisheries, oil gas and mining, marine transportation and marine mammal hunting (www.search-hd.net). ArcticStat is a portal database that allows the user to select and reach existing tables that cover Arctic countries and regions, some ten socio-economic indicators and more sub-indicators, and years (www.arcticstat.org). Thousands of tables mainly from national agencies are linked to ArcticStat.

Research

IPY human health research focused on some of the issues of most concern to Arctic residents. These concerns include: the health impacts of environmental contaminants, climate change, rapidly changing social and economic parameters within communities, the changing patterns of chronic diseases and the continuing health disparities that exist between indigenous and non-indigenous segments of the Arctic populations. Other issues of importance, such as injuries and maternal and child health, are not captured within the endorsed IPY projects and are thus not commented on in this chapter. Nevertheless, dissemination initiatives during IPY captured the broader spectrum of health research outputs outside of the IPY programs (Young and Bjerregaard, 2008).

The intensity of research activities and networks during IPY has served as a catalyst to integrated programs, which promote communities and researchers working collaboratively. It is hoped research, informed by community perspectives, will enhance the relevancy of findings and improve health policies and programs.

Environmental Contaminants

While socio-economic conditions and lifestyle choices are major determinants of health, contaminants may also have a contributing effect. Toxico-

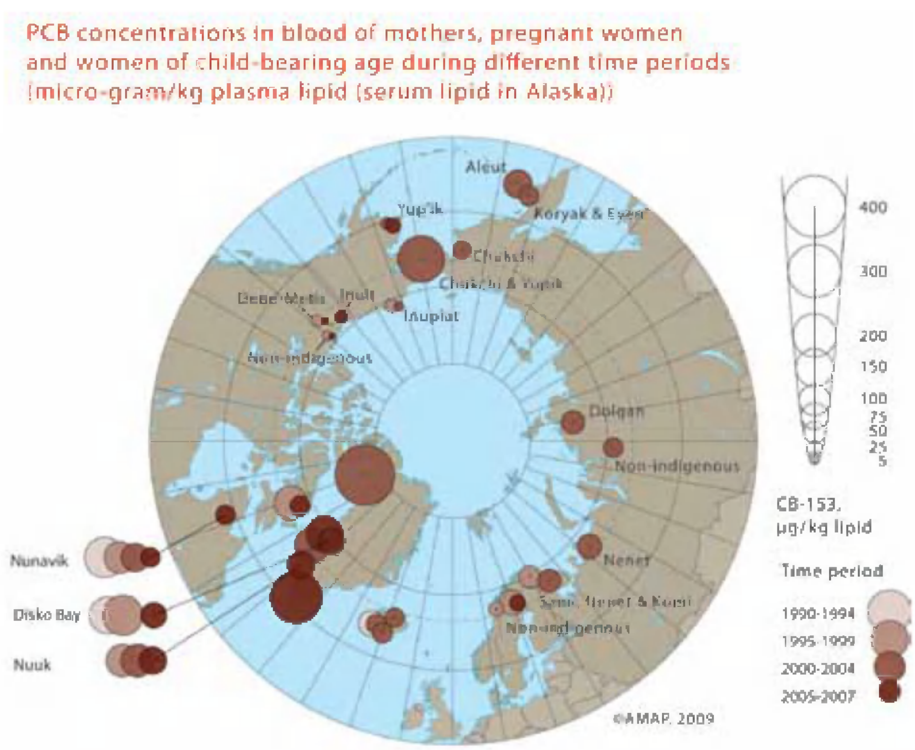


Fig. 2.11-4. PCB (CB 153) concentration in blood (serum/plasma) of mothers, pregnant women and women of child bearing age during different time periods
(Source: AMAP, 2009).

logical studies show that contaminant levels found in some parts of the Arctic have the potential for adverse health effects in people. Epidemiological studies looking at Arctic residents directly provide evidence for subtle immunological cardiovascular and reproductive effects due to contaminants in some Arctic populations (AMAP, 2009). If climate change is associated with rising salmon and human levels of POPs and mercury it would provide data to further support reduction of POPs and mercury production and release, and efforts to reduce global warming. Another study led by researchers at the Center for Arctic Environmental Medicine, School of Public Health, University of Aarhus, Denmark examined the risk of the development of breast cancer in Greenlandic Inuit women following exposure to persistent organic pollutants (EoI no. 1257). Blood levels of POPs in women with breast cancer will be compared to controls with respect to age and lifestyle. The bio-effects of POP levels on hormone receptor function will also be examined (Bonefeld-Jorgensen, 2010).

Infectious Diseases

A continuing major health disparity is the increased morbidity and mortality due to infectious diseases seen among indigenous populations when compared to the non-indigenous populations of the Arctic. These disparities can be resolved with greater understanding of their causes through research, focused efforts at treatment and prevention.

Hepatitis B infection occurs at high and endemic rates in Arctic populations. For example research has shown that 3-5% of individuals residing in the Canadian North, 5-14% of Inuit in Greenland and 3-10% of Alaska Native people in Western Alaska are infected with hepatitis B virus (HBV) and likely, if left untreated, 10-25% will develop liver cancer or die of cirrhosis. Researchers from the U.S., Canada, Greenland, Denmark and the Russian Federation have formed a Circumpolar Viral Hepatitis Working Group and are conducting studies to determine the epidemiology of chronic HBV in Aboriginal populations (EoI no. 1109). The study monitors patients to determine disease progression, examine demographic characteristics associated with disease outcome, examine environmental factors associated with disease outcome, including contaminants in the environment and subsistence foods, examine co-factors such as alcohol intake, obesity and metabolic syndrome, and examine viral characteristics, such as genotype and viral loads and mutations that could affect disease outcome. This study allows the identification of barriers to vaccination, the development of registries for research and clinical management, the development of criteria to identify potential treatment candidates, monitoring of treatment outcome, and the examination of the role of factors, such as demographics, viral genotype, and environmental factors in treatment outcome. Already, this research group has identified a new HBV sub-genotype (B6), which is only found in indigenous populations of Alaska, Canada, and Greenland (Sakamoto et al., 2007) and assisted Greenland in the investigation of an outbreak of hepatitis D superinfection in adolescents with chronic HBV in a community in Greenland (Borresen et al., 2010). In addition this working group has been instrumental in encouraging the Greenland government to adopt universal childhood hepatitis B vaccination in Greenland.

Similarly reported rates of sexually transmitted infections (STIs) are disparately high among indigenous populations of the Arctic (Gesink-Law et al., 2008). Research in Canada, U.S.A. and Greenland (EoI no. 1147), aimed at building capacity to examine individual, social and environmental factors that influence perceptions of sexual health and sexually transmitted infections, is being conducted by researchers and communities using participatory methods (Gesink et al., 2010; Rink et al., 2009). The aims include a description of the basic epidemiology of sexual health and STIs and to identify communities at risk and targets for capacity-building and interventions. Preliminary results indicate that *Mycoplasma genitalium* is as prevalent as *Chlamydia trachomatis* in Greenland, and that social and cultural norms around sexual health communication, trust, drinking and sex appear to influence individual sexual behaviours and risk for STIs. Based on this research, the National Science Foundation has granted U.S., Canadian, Greenlandic and Danish researchers new funds to explore community based participatory methods in Greenland and develop a social intervention focusing on sexual health communication with families and relationships.

Canadian researchers are examining the potential for incorporating Human Papillomavirus (HPV) DNA testing into the present screening program (EoI no. 1121). This project examined HPV infection and cervical dysplasia (precancerous cells) in women of the Northwest Territories, Yukon, Nunavut and Labrador to determine general prevalence rates, types of HPV and risks associated with the development of HPV. The aim is to provide scientific evidence for policy-makers and local public health workers to assist in the planning and implementation of cancer control programs.

With their strong hunting traditions and subsistence based on wild game, Arctic indigenous peoples are at increased risk of zoonoses and parasitic infections acquired from infected meat. Zoonoses refer to a group of diseases caused by organisms that are usually present in animals, but are transmitted to and cause disease in humans. As temperatures warm and habitats change, diseases and parasites will move northward with the migration of their wildlife hosts, others will increase their density due to optimal temperatures for replication. These factors together with other environmental changes (water availability, ice and snow cover, ocean currents, extreme weather events, forest fires, etc.) will favor a shift in the distribution of hosts and zoonotic disease threats to the safety of country foods. Food-borne parasites, such as Trichinella, Toxoplasma and Anisakidae nematododes, are significant Arctic zoonoses endemic in some regions and directly related to consumption of country food (Figs. 2.11-5; 2.11-6). In addition, the prevalence of some diseases, such as those caused by *Salmonella sp.* and *E. coli 0157:H7* may increase in warmer weather. A study in Canada has resulted in the development of simplified diagnostic tests for these pathogens (IPY no. 186). The study provided equipment and training for the evaluation of these tests in several northern communities (Gauthier et al., 2010). The prevalence and distribution of each disease studied in Canadian wildlife will be documented and entered into a Canadian web-based data base on wildlife diseases of the Canadian Cooperative Wildlife Health Centre.

Streptococcus pneumoniae is one of the leading causes of pneumonia, meningitis, bacteremia, septic shock and otitis media in Arctic indigenous populations, particularly among children and the elderly (Bruce et al., 2008). For example, the incidence rates of invasive pneumococcal disease in Inuit are approximately four times that of non Inuit. A Canadian study is analyzing medical records of more than 3000 children born in Nunavik between 1994 and 2005 to verify whether vaccination reduces the number of respiratory infections, prescriptions for antibiotics, hospitalizations and hearing disorders (EoI no. 1119). The results of this study could be used to inform vaccine programs for all populations living in the Arctic.

IPY provided the opportunity to strengthen surveillance and research on infectious diseases in Greenland (EoI no. 1107). This project, a cooperation between Greenland and Denmark, addressed the burden of infectious diseases in Greenland by establishing research programs to evaluate long-term consequences of certain infectious diseases, to evaluate the use of routine surveillance data, to initiate intervention trials in order to prevent infectious diseases, to seek implementation of results in the Greenland health system and to establish cooperation with public health and research organizations in other countries. Specific studies under this project included a validation of the Greenlandic inpatient register, the initiation of tuberculosis studies (Nielsen et al., 2009; Soborg et al., 2009), an evaluation of the distribution of bacterial pathogens causing invasive disease (Madsen et al., 2009; Meyer et al., 2008; Bruce et al., 2008), a study of the long-term consequences of hepatitis B (Sakamoto et al., 2007; Borresen et al., 2010), a study of the association between Epstein Barr virus and various cancers (Friborg et al., 2009; Boysen et al., 2009), a study of HIV drug resistance (Madsen et al., 2008; Lohse et al., 2008), and a study of the etiology of viral respiratory pathogens among Greenlandic children. In collaboration with Canadian researchers a nationwide study of viral pathogens in children hospitalized with lower respiratory tract infections in Greenland is on-going. With researchers in Canada and the U.S., the network organization is involved in studies of epidemiological, microbiological, and social aspects of sexually transmitted infections (Gesink et al., 2010).

Life-style, Diet and Nutrition

Considerable life-style changes have occurred over the past decades among the indigenous peoples in the circumpolar region. Parallel to this has been a change

Fig. 2.11-5. Salmon drying on the Yukon River. Indigenious peoples of the Arctic rely on nutrient dense traditional foods such as fish, marine mammals, wild game and plants to provide them with food security and nutrition. (Photo: David Hik)

Fig. 2.11-6. Walrus meat may be infected with *Trichinella nativa* which causes Trichinellosis, a disease caused by a roundworm whose larvae encapsulate in the muscle tissue. Illness can occur in humans, who ingest infected undercooked or raw meat, and it can range from mild or inapparent to a fulminating fatal disease depending on the number of larvae ingested. *Trichinella nativa* (shown right, x 100 magnification) can survive in frozen muscle tissue for many years. (Photos: Manon Simard, Makivik Corporation, Canada)

Fig. 2.11-7. The Inuit Health Survey, an IPY-Canada project, involved measuring the health status of Inuit across the Canadian Arctic onboard the science research ship/icebreaker Amundsen. A barge from the ship leaves for shore to pick up survey participants. (Photo: Kue Young)

in disease patterns, with an increase for example in cardiovascular diseases, obesity and diabetes. Among the main causes are alterations to the diet and levels of physical activity as the population changes from their traditional hunting and fishing economy to more Westernized living conditions. Several large IPY activities were initiated to address some of these issues.

A large international study entitled "The Inuit Health in Transition" was proposed to cover a cohort of over 7,000 Inuit adults in Alaska, Canada and Greenland during IPY. The Canadian federal IPY program funded a major component of this international study during 2007–2008 in Nunavut, Northwest Territories and Labrador. Known as the Inuit Health Survey, it covered 1900 households in 33 communities across the Canadian Arctic, which were visited by the Coast Guard icebreaker–science research vessel CCGS Amundsen (Fig. 2.11-7). The study was focused on diet and other lifestyle factors such as smoking, contaminant exposure and physical activity. Baseline data collection was completed in all participating regions during IPY. Cross-sectional analyses are currently underway to investigate the associations between environment, living conditions, lifestyle risk factors and existing chronic and other diseases among these populations. A total of 2600 adults participated. Information was collected by personal interviews, physical examination and laboratory tests. In addition, 388 children aged 3-5 from 16 Nunavut communities took part in a child health survey. The Inuit health survey contained question on household crowding and food security, nutrition, country food and eating habits, mental health and community wellness, and medical history. The survey also contained a number of medical tests including measures for heart health, diabetes risk, body measures, exposure to infection, bone health, nutrient status and exposure to environmental contaminants (Chan, 2009; Dewailly, 2009). Preliminary descriptive findings from the study have been compiled and distributed via community reports. Early studies have found there is a high prevalence of household food insecurity among Inuit households (Egeland et al., 2010) and overweight prevalence is increasing (Galloway et al., 2010).

A Swedish IPY project evaluated a northern Swedish population with known demographic and environmental exposures to identify genetic and environmental factors that contribute to health status (EoI no. 1274). In this study, cross-population comparisons are used to study genetic and environmental risk factors among populations with widely differing origins and environments. The study measures a broad spectrum of environmental (e.g. diet, physical activity and daylight exposure) and genetic (e.g. single-nucleotide polymorphisms) factors with potential relevance for health risk. A comprehensive set of health indicators and diagnoses of cardiovascular, orthopedic and metabolic diseases has been collected. In particular, the state-of-the-art laboratory analysis of blood lipids comprising several hundreds of lipid species will give unique insights into the human metabolism under extreme living conditions. Studies of rural populations can make substantial contributions to basic research to understand environmental and genetic determinants of disease. The European Special Population Network (EUROSPAN) provides a platform combining studies of rural populations from different parts of Europe to leverage these for collaboration with large international consortia (Igl et al., 2010).

In the U.S., the Center for Alaska Native Health Research (CANHR) at the University of Alaska, Fairbanks used the IPY momentum to build a collaborative research presence in Alaska Native communities, focusing on prevention and reduction of health disparities by seeking new knowledge through basic and applied research that can ultimately be applied to understand, prevent and reduce health disparities in indigenous communities (Mohatt et al., 2007) (http://canhr.uaf.edu/). The Center studies behavioral, dietary and genetic risk and protective factors related to obesity diabetes and cardiovascular disease risk in Alaska Natives of Southwestern Alaska. CANHR includes studies related to substance abuse and suicide prevention, the development of novel dietary biomarkers, contaminants and the safety of substance foods, stress and gene by environment interactions, and nutrition research. All CANHR studies employ community-based participatory research approaches.

Behavioural and Mental Health

Behavioural and mental health disorders are common worldwide and circumpolar regions are not exempt from this burden. Contemporary dynamics of rapid social change have dramatically affected the political, cultural and economic systems of circumpolar indigenous people. Depression and suicide have been highlighted as significant issues in northern regions. (Levintova et al., 2010). During IPY, there were a number of research projects which explored behavioral and mental health, and the relationships between outcomes and environmental factors.

The Inuit Health Survey collected information on mental and community wellness. Findings provide information on the burden of mental illness and also evaluate social support and other determinants of resiliency and self-reported health (Egeland, 2009). In Nunavik a cohort study was carried out that focused on exposure to environmental contaminants and child behaviour. The study also explored the impact of lifestyle factors, such as smoking, alcohol and drug abuse during pregnancy, on multiple domains of child development and behaviour (Muckle, 2009).

Two CANHR affiliated studies focus on behavioural health research. This U.S.-led study examined social change and indigenous culture in five circumpolar communities by exploring responses to rapid social transition through the life experiences of circumpolar youth (EoI no. 1266). This study is completing over 100 youth life history interviews from Alaska Inupiat, Alaska Yup'ik, Canadian Inuit and Sámi and Siberian Eveny communities. The project team identified shared and divergent stressors and patterns of resilience in the transition to adulthood across these different circumpolar settings (Fig. 2.11-8).

Elluam Tungiinun -"Toward wellness"- is a culturally-based preventive intervention to reduce suicide risk and co-morbid underage drinking among Alaska Native Yup'ik Eskimo youth. This five-year community based participatory research prevention trial will enroll 239 youth ages 12 through18 in five rural remote Yup'ik communities and test effectiveness post-intervention using a randomized dynamic wait list control design. This study represents the next stage in a 15-year community-based participatory research process with Alaska Native people (Allen et al., 2009).

A Danish study examined the health and social condition of adoptees in Greenland. Greenland has a significant number of adoptees and the number of children placed at institution is large (EoI no. 1201). The study explored how adoption and collective

Fig. 2.11-8. Even, Inupiaq, Inuit, Sámi and Yup'ik youth co-researchers with elders and university co-researchers at the Circumpolar Indigenous Pathways to Adulthood Workshop Meeting, Scott Polar Institute, Cambridge University, England, May 2009. (Photo: CANHR, 2009)

care have an impact on well being, family health and social conditions. Adoption is closely linked to social organization, identity, cultural openness and collective consciousness. This study identified settings in which adoption was linked to child neglect and lack of care. The study also examined parents' and care givers' control and coping strategies. The study concluded that, contrary to findings related to adoptees in Western societies, being an adoptee in Greenland does not increase the risk for psychiatric admission (Laubjerg and Petersson, 2009).

Health Services Delivery

The circumpolar regions experience unique challenges in the delivery of health services because of widely dispersed populations and geographic obstacles. During IPY 2007–2008, opportunities were created for cross-border partnerships to explore needs related to service delivery. The Northern Forum (NF), a forum of northern regional governments (www.northernforum.org), cooperated with the Alaska Federal Health Care Access Network (AFHCAN) to implement a strategic and innovative solution to address health care needs of two regions in the Arctic. Together, the NF and AFHCAN facilitated cooperation in telemedicine technology expertise between Alaska, the Republic of Sakha and Khanty-Mansyisk region in Russia (EoI no. 1270). The goal of the project was to promote the establishment of a mutually beneficial collaboration in telemedicine, tele-health, mobile medicine and distance learning in remote areas of the Russian north. This project is an important first step in both improving technologies to enhance access to care and utilization of existing forums to promote cross-border partnerships and activities.

Mental health services are also of importance in the north and efforts are required to enhance service delivery. The Northern Forum developed and promoted The Healthy Lifestyle Projects (EoI no. 1271), which provided information exchange and training opportunities to advance care and treatment of Arctic residents with mental health issues.

While the health service delivery research field is underdeveloped in the north, these projects identify key areas of importance and play an important role as we begin to understand and develop best practices to improve services and programs in northern regions.

Outreach Education and Communication

An important aspect of IPY was, and will continue to be, the promotion of education, outreach and communication, which will focus public and political attention on Arctic health issues; increase dialogue between researchers, policy-makers and communities; increase distribution of scientific information to scientists and the public through conferences, symposia, workshops and a variety of electronic and printed media; increase community involvement in research activities; and foster a "new" generation of Arctic health scientists.

Symposia and Workshops

IPY was highlighted by the occurrence of the 13th International Congress on Circumpolar Health held in Novosibirsk, Russian Federation, 12-16 June 2006, the *"Gateway to the International Polar Year"* for the circumpolar health community. This congress was put on by IUCH and brought together circumpolar health care professionals, workers, researchers, policy-makers and indigenous community members. The meeting presented a forum for discussion on their respective visions and priorities for human health activities for IPY and beyond. These discussions resulted in recommendations that emphasized the role of communities in research planning, research activities and the translation of research findings into actions that would benefit the health and wellbeing of Arctic communities (ICCH13, 2007). The Women's Health Working Group of the IUCH was reactivated at that congress in June 2006 (EoI no. 1223). Participants identified at least four areas of mutual interest, including, but not limited to: 1) perinatal health systems and challenges, 2) infectious disease, particularly HPV and new vaccine; 3) interpersonal violence prevention and 4) health communication and health literacy.

At the end of IPY, the 14th International Congress on Circumpolar Health was held in Yellowknife, Northwest Territories, Canada, 12-16 July 2009. The theme of the congress recognized the end of the Polar Year and spoke to *Securing the IPY Legacy: From Research to Action.* While results from much of the research conducted over IPY are still pending, the congress program contained a broad cross section of presenters, sessions and preliminary results from IPY. The sessions allowed for complementary perspectives of researchers, clinicians, community representatives and governments on numerous topics that impact public health, health services delivery, the research process and Indigenous wellness in our circumpolar regions. Presentations demonstrated instances where research findings are applied in numerous settings, with uptake by clinicians, community organizations and governments. Presentations also recognized the contributions of numerous stakeholders through the research process with a particular focus on community engagement and participatory methods (ICCH14, 2010).

IPY also provided the opportunity to conduct a number of workshops that brought together researchers from circumpolar countries on topics such as the human health impacts of climate change, environmental contaminants and developing a prevention research strategy for behavioral and mental health.

The Arctic, like most other parts of the world, has warmed substantially over the last few decades. The impacts of climate change on the health of Arctic residents will vary depending on such factors as age, socioeconomic status, life-style, culture, location and capacity of the local health care infrastructures to adapt. It is likely that the most vulnerable will be those living close to the land in remote communities and those already facing health related challenges (Berner and Furgal, 2005).

Climate change workshops were convened in Anchorage, Alaska as part of the 2008 Alaska Forum on the Environment (www.akforum.com), in Moscow, May 2008 and in Arkhangelsk, June 2009, all organized by UNDP, WHP and UNEP. These meetings recommended that action be taken on the human health recommendations put forward by Chapter 15 of the ACIA Report, and in the report by the United Nations and the Russian Federation "Impact of Global Climate Change on Human Health in the Russian Arctic" (Parkinson and Berner, 2008; Parkinson, 2010c; Revich, 2008, 2010).

A joint AMAP and Northern Contaminants Program (NCP) symposium was held in Iqaluit, Nunavut, Canada 10-12 June 2009 (IPY no. 145). At this meeting, the third NCP and AMAP Human Health Assessments reports on environmental contaminants were released and the results were discussed (AMAP, 2009; CACHAR, 2009). The symposium demonstrated that the overall management of contaminants issue in the Arctic by all partners has been effective in reducing the health risks to northern populations from environmental contaminants. While the results indicate that there are declines in many contaminants in several Arctic Regions, there are still indications that there may be subtle health effects (cardiovascular, immunological) due to contaminants in some Arctic populations. The symposium reemphasized the importance of biomonitoring of persistent organic pollutants and metals to track international protocols, biomonitoring of emerging contaminants, quality control of laboratory methods, health effects research and dietary choice, risk perception and risk communication.

The Fogarty International Center at the National Institutes of Health (NIH), together with the U.S. Arctic Research Commission (USARC) and other NIH institutes and CDC, organized a strategy setting conference on the *Behavioral and Mental Health Research in the Arctic* in Anchorage, AK on 2-3 June 2009. The purpose of this meeting was to develop a U.S. Arctic Human Health Research Strategy that will advise the Interagency Arctic Research Policy Committee (IARPC) on the development of a Arctic Human Health Research Plan. This meeting engaged Arctic health stakeholders including U.S. government, scientific and tribal community leaders and international scientists in behavioural and mental health with discussions of current knowledge and gaps in research, with a particular focus on improving our understanding of the risk factors for and barriers to reduce suicide and other behavioral and mental health ailments among Arctic populations. The conference outcome will be a strategy plan that will include specific goals and methods, as well as discussion of potential future research and research training activities on behavioral and mental health in the Arctic (Levintova et al., 2010).

Electronic and Print Media

Dissemination in Scientific Community

While the activities of the polar years focused on study implementation and data collection, analysis and dissemination of findings will be ongoing for years to come. During IPY, a number of summary and synthesis documents were created. The International Journal of Circumpolar Health (www.ijch.fi) produced a series of Circumpolar Health Supplements on topics of general interest and related to IPY themes (EoI no. 1046). To date, seven supplements have been published as contributions to the IPY: (1) Anthropology and Health of Indigenous Peoples of Northern Russia (Kozlov et al., 2007); (2) Diet and Contaminants in Greenland (Hansen et al., 2008); (3) Circumpolar Health Indicators (Young, 2008); (4) International Circumpolar Surveillance: Prevention and Control of Infectious Diseases (Zulz et al., 2009); (5) Behavioral and Mental Health Research in the Arctic: Strategy Setting Meeting (Levintova et al., 2010); and (6) The Arctic Human health Initiative (Parkinson, 2010b); (7) Proceedings of the 14th International Congress on Circumpolar Health (ICCH14 2010).

The International Network for Circumpolar Health Research produced a book, *Health Transitions in Arctic Populations* (Young and Bjerregaard, 2008) with contributions from 23 scientists and health care practitioners from all the Arctic countries. It synthesized existing knowledge on the health status of all the circumpolar regions and populations, with specific focus on the indigenous Sámi, Dene and Inuit people, their determinants, and strategies for improving their health.

Multi-media and knowledge sharing

The Arctic Human Health Initiative facilitated the development of the Arctic Health website www.arctichealth.org as a central source for information on diverse aspects of the Arctic environment and the health of northern peoples. The site gives access to health information from hundreds of local, state, national and international agencies, as well as from professional societies and universities. In addition, the Arctic Health Publications Database, (currently more than 96,000 records), provides access to Arctic-specific articles, out of print publications and information from special collections held in the Alaska Medical Library.

During IPY, a concept for a circumpolar health portal was developed (www.circumpolarhealth.org). This project is exploring the feasibility of a coordinated venue to capture and promote the activities of circumpolar health organizations and initiatives. The website also incorporates Facebook and Twitter, and has dedicated channels for You Tube iPod casts and Flickr. These mechanisms allow for storage and access of photos, audio files and video. These tools are especially valuable to share information and outputs related to youth driven and participatory research projects.

In addition to web-based media, radio and TV still play an important role in the sharing of information with circumpolar residents. A series of three live TV call-in shows on Inuit wellness was developed under the umbrella of the Pan-Arctic Interactive Communications Health Project. TV programs were produced and focused on the current health issues of importance to Inuit, including: (1) Inuit men's health and wellness, (2) Inuit maternal care, and (3) Inuit youth and coping. Each show was moderated and featured panel discussions about programs and research with community representatives and physicians, video vignettes and interactions with the studio audience, Skype, phone and e-mail participants. The television broadcasts reached a wide audience by airing on networks in Canada and Alaska. This project was an innovative, multi-dimensional, collaborative health communication project that raised both interest and awareness about complex health conditions in the North, and stimulated community dialogue and potential for both local and regional collaborative action. On-going evidence-based resources for health education and community action developed through this program were assembled and archived in digital format (www.naho.ca/inuit/e/TVseries) to increase accessibility for otherwise isolated individuals and remote communities.

Education and Training Initiatives

Education and training in the "discipline" of circumpolar health is as varied and broad as the number of topics related to human health, which are explored in circumpolar regions. Thus education and training activities through the polar years have tended to be cross-cutting and integrated in research programs. Activities have included the support of graduate students and training of community partners. Many health research initiatives now employ community-based participatory methods in which training in research methods, data collection and dissemination practices are integral components of the methodology. Examples of community participation have been demonstrated in programs, such as the Inuit Health Survey, Healthy Foods North project and the Inuit Cohort, an education initiative to promote graduate education for Inuit. All of these initiatives are important as research methods are improved to incorporate academic and community perspectives. The evaluation of the The Pan-Arctic Inuit Wellness TV Series project provides specific lessons to build a strong foundation of community-professional-academic partnership (Johnson et al., 2009).

In addition, the Centre for Arctic Medicine, Thule Institute, University of Oulu, Finland (http://arctichealth.oulu.fi) has a program dedicated to circumpolar health (EoI no. 1045). It is delivered in close collaboration with the University of the Arctic (www.uarctic.org). The program offers both PhD and Master's programs in the field of health and well being in the circumpolar regions. The International Master's program started in autumn 2008 with 14 students from Canada, United Kingdom, Finland, Russia and Australia. Other partners involved in providing courses towards the degree program include, the Center for Health Education (Nuuk, Greenland), Luleå University of Technology (Luleå, Sweden), Northern Medical State University (Arkhangeslsk, Russia), Pomor State University (Arkhangelsk, Russia), NORUT Social Science Research Ltd (Tromso, Norway), University of Lapland (Rovaniemi, Finland), University of Manitoba (Winnipeg, Canada) and University of Southern Denmark, (Esbjerg, Denmark) as well as the Cross Border University of Barents area. The Centre for Arctic Medicine is collaborating with the University of Alaska Anchorage MPH program and others to off the first Summer Institute in Circumpolar Health Research in Copenhagen in May 2010 (http://sichr.circumpolarhealth.org).

Securing the Legacy of IPY 2007-2009

The aim of IPY activities was to harness the resources and intellect across the circumpolar regions and leave a legacy of data, observing sites, facilities and systems to support on-going polar research and monitoring, and to provide value to future generations. (Rapley et al., 2004). During IPY, it was evident that health research productivity increased and many collaborative research projects were started because of national interest and the availability of new funding programs dedicated to human health research. Other projects were possible because agencies and organizations redirected resources and in-kind support to ensure the success of this human health initiative. Through these activities networks grew, infrastructure was built, health research institutes were established, training opportunities were provided, data projects were initiated and mechanisms to improve knowledge dissemination were supported and developed. Unique features of health research included the engagement of community and end user stakeholders in the research process to optimize relevancy and uptake of findings. A number of networks, policies and best practices to enhance research impacts have been developed and leave elements of frameworks for best practices in circumpolar health research.

The legacy for health research lies in the mechanisms and framework, which support the interconnectivity from polar communities to the international forums of decision-makers. It is through these initiatives from community-based networks, to SAON-coordinated projects, to Arctic Council advisories, circumpolar institutes and their affiliated networks of stakeholders and partners that value for future generations will be secured. On-going critical development of and support for these initiatives must be secured throughout the circumpolar regions. A broad informed base will ensure ongoing uptake and analysis of data to the highest standard as well as ensuring dissemination of findings so best practices may inform the development of government policies and clinical guidelines which influence health and well being. It is the networks and institutes, which support these connections, that will combine perspectives and knowledge bases required to address the complexities of the polar environments, the multifaceted nature of health determinants, and will ultimately inform solutions to promote health across the polar regions.

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PART THREE

IPY Observing Systems, Their Legacy and Data Management

Coordinating Editors: Eduard Sarukhanian and Colin Summerhayes
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Introduction

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Tillmann Mohr, Eduard Sarukhanian and Colin Summerhayes

IPY "Expressions of Intent" collected by the IPY Programme Office (IPO) in January 2005 (*Chapter 1.5*) contained specific sections that listed observing facilities to be established within each IPY project to ensure its implementation and meet its scientific requirements and objectives. The JC at its first meeting (JC-1, March 2005) after reviewing the submissions for future IPY projects agreed that it would be useful to have a special Subcommittee on Observations (SCOBS) similar to the Subcommittees on Data Management, and on Education, Outreach and Communications, to help ensure that appropriate links were made between the various projects and the space-based and *in situ* observations communities. An Observing Systems ad hoc group (T. Mohr, E. Sarukhanian, K. Alverson and C. Summerhayes) was formed within the JC to develop a draft Terms of Reference (ToR) and propose a preliminary composition for this subcommittee. At the second session of the JC (JC-2, November, 2005) the SCOBS was established as a special body under the JC supervision, and its ToR and composition were approved by the JC (the composition of SCOBS is given in *Appendix 5*).

According to the ToR, the main tasks of the SCOBS were to evaluate the observational requirements contained in the full proposals for IPY, assess which requirements could be met by existing observing systems, and, after a gap analysis, identify special observing systems and special data and products that needed to be established to meet the requirements of IPY projects. The JC asked the SCOBS to ensure that space-based and *in situ* observing systems, including those set by polar residents and based upon indigenous monitoring systems, would be optimized for IPY purposes. At the first SCOBS session (Potsdam, March 2006) the members submitted assessments of the observing systems requirements contained in 166 IPY-endorsed scientific projects within the domains Atmosphere, Ocean, Ice, Land, People, and Earth and Space (the latter assessment was done after the session in Potsdam).

The assessment results were informative, in particular with respect to observational data requirements, data sources, technological/institutional gaps, data management requirements, and the potential legacy of observing systems planned to be established during IPY 2007–2008. For example, in the case of requirements for satellite data, products and services, the assessment showed that it was crucial to establish an immediate dialog between IPY scientists and the Space Agencies to define the concrete requirements to be met by satellite operators. The appropriate actions were taken by ICSU and WMO, and a special IPY Space Task Group was formed at the end of 2006, as part of the SCOBS under the Joint Committee supervision (*Chapter 3.1*).

Another important task of SCOBS was to establish through the JC and the IPO a dialog with the Arctic Council, Antarctic Treaty Parties, IASC, SCAR and other international organizations and/or programmes, so as to secure the provision for the legacy of observing systems developed during IPY 2007–2008. The results of the SCOBS assessment, in particular those related to a legacy of IPY observing systems, were of potential use by the international organisations responsible for implementing and managing global and regional observing systems. In view of the importance of this issue, the JC at its sixth session (JC-6, October 2007) asked the SCOBS to develop a roadmap to provide a consolidated vision of the IPY observing systems legacy, and to identify a mechanism for early assessment of benefits acquired from IPY 2007–2008 observations, in order to prepare for obtaining support for the long-term reinforcement and maintenance of the observational networks in polar regions.

The SCOBS presented the roadmap to the IPY observing systems legacy to the seventh meeting of the JC (JC-7, July 2008) as a discussion paper. The roadmap was developed to provide a way forward to creating a basic vision of an IPY observing systems legacy that could then be used by decision-makers to identify funding in support of IPY observing networks in the post-IPY era. Some of the emerging initiatives listed below were described in the document. The SCOBS submitted a review of the results of the latest developments of these initiatives to the eighth session of the JC (JC-8, February 2009). That overview paper, *IPY Observing System Emerging Legacy* (JC8/Doc.3), covered the progress in five major observational initiatives established during the IPY 2007–2008 years:

- Sustaining Arctic Observing Networks (SAON) with an Integrated Arctic Ocean Observing System (iAOOS);
- Pan-Antarctic Observing System (PAntOS) with a Southern Ocean Observing System (SOOS);
- The Global Cryosphere Watch (GCW),
- Polar Satellites Constellation (PSC),
- Polar Climate Outlook Forum (PCOF).

The chapters in this section of the IPY Summary provide far more detailed and updated information on most of the listed initiatives, in addition covering several other observational networks developed during IPY 2007–2008. They include:

- Satellite Observations Program *(Chapter 3.1)*,
- Towards an integrated Arctic Ocean Observing System *(Chapter 3.2),*
- Southern Ocean Observing System (SOOS) *(Chapter 3.3),*
- International Arctic System for Observing of Atmosphere (IASOA) *(Chapter 3.4)*
- Meteorological Observations in the Antarctic

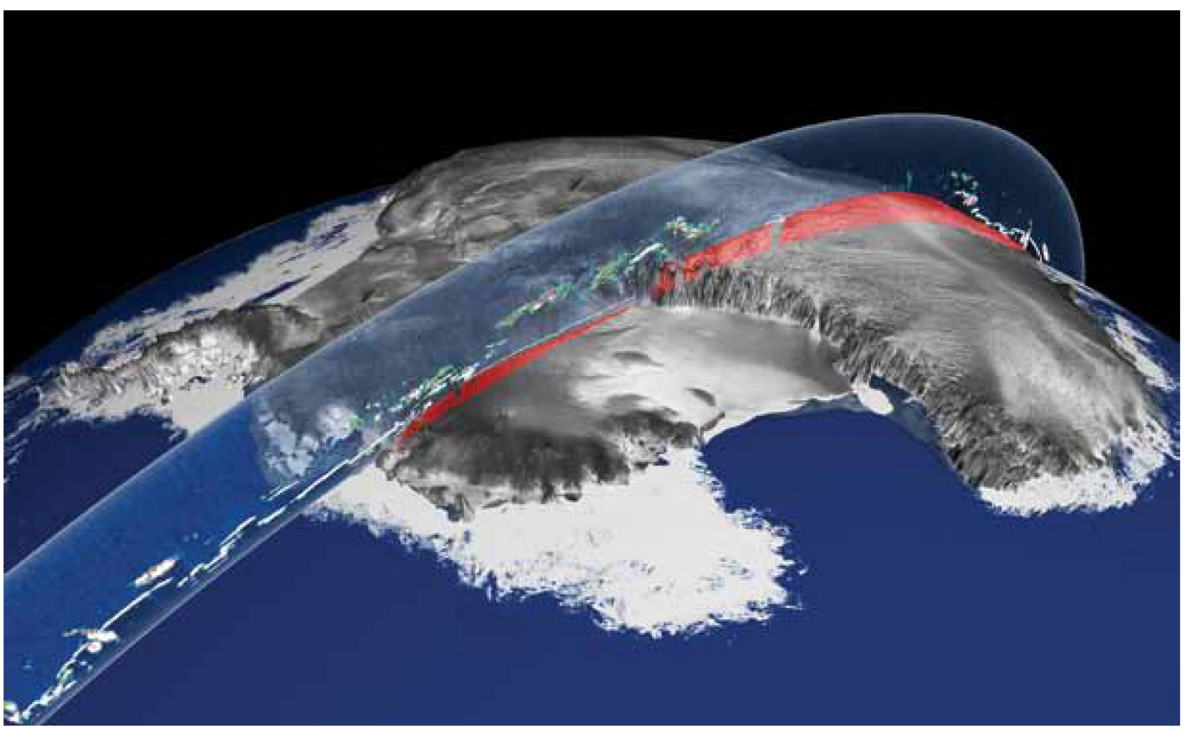

Fig. 3.0-1. NASA Ice, Cloud and Land Elevation Satellite (ICESat) data collection over the Antarctic. ICESat laser altimeters measured ice sheet mass balance, cloud, and aerosol heights during IPY.

(NASA/Goddard Space Flight Center Scientific Visualization Studio, RADARSAT mosaic of Antarctica. Canadian Space Agency)

during IPY *(Chapter 3.5)*
- Arctic Sea Ice Outlook *(Chapter 3.6)*
- Global Cryosphere Watch (GCW) *(Chapter 3.7)*
- Sustaining Arctic Observing Networks (SAON) *(Chapter 3.8)*
- Circumpolar Biodiversity Monitoring Program *(Chapter 3.9)*
- Human-based observational activities and indigenous monitoring *(Chapter 3.10)*

In most cases the description covers the process of initial establishment of each of the above-mentioned IPY 2007–2008 observational programmes and their implementation during the IPY period, and offers perspectives of their development as IPY 'legacy initiatives' (e.g. *Chapters 3.1, 3.4, 3.5* and *3.6*). Other chapters provide a scientific guidance and/or recommendations to determine a transition to a sustainable observing system in the post-IPY era (e.g. *Chapters 3.2, 3.3, 3.7, 3.8* and *3.10*).

The last chapter in this section (*Chapter 3.11*) addresses the issues of the IPY 2007–2008 data management. From the very beginning of IPY 2007–2008, the IPY planners saw data as a vital legacy of the process, notably stating in *"A Framework for the International Polar Year 2007–2008"* that *"In fifty years time the data resulting from IPY 2007–2008 may be seen as the most important single outcome of the programme."* (Rapley et al., 2004). On behalf of the JC, the Subcommittee on Data Management developed a Data Policy and Data Strategy and worked closely with the various IPY project leaders to ensure *to the extent possible* that data gathered during IPY was appropriately archived and readily available. *Chapter 3.11* reviews the success of the data strategy and policy, and makes a number of key recommendations for the way forward that - if implemented by national programmes - will greatly aid the dissemination, sharing and wider use of IPY 2007–2008 data.

Recommendations offered in *Chapter 3.11* could form the basis for a more strategic approach to data and information management in the polar regions, especially in the Arctic. The Scientific Committee on Antarctic Research (SCAR) used the opportunity of IPY 2007–2008 to develop its own comprehensive data and information management strategy for the Antarctic, (see http://scadm.scar.org/scadm/scar_dis.html). ICSU has followed up the recommendations of the IPY Data Subcommittee by creating its own committee to develop the notion of a 'Polar Information Commons' to enable widespread access to data and information in the polar regions. Successful development and application of these various aspects of the IPY data legacy will bring widespread benefits to scientists, national operators, indigenous peoples, and intergovernmental groups (such as Arctic Council and Antarctic Treaty Parties).

In concluding this introductory section to eleven thematic chapters to follow, we note that it deliberately focuses rather on the processes used during the IPY 2007–2008 period to upgrade, expand or establish observing and/or data management systems that could be expected to form the basis for an IPY legacy of improved observing networks and data management. The chapters thus do not stand alone, but should be read in conjunction with complementary chapters describing the science and the outcomes of project work. Publications produced during the IPY period, or about to be produced as a result of IPY, provide detailed descriptions of design plans, like those for SOOS (see www.scar.org/soos), and CryOS (see www.scar.org/researchgroups/physicalscience/ for The Cryosphere Observing Plan), and readers seeking that level of detail are encouraged to search elsewhere. It was not our intention to duplicate those descriptions. Instead we thought it important for those planning future IPYs to set down here the process by which the present constellation of observing systems and data management plans was designed.

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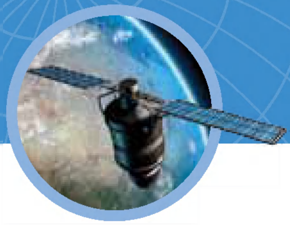


3.1 IPY Satellite Observation Program

Lead Authors:
Mark Drinkwater, Kenneth Jezek, Tillmann Mohr and Eduard Sarukhanian
Reviewers:
Yves Crevier, Jeffrey Key and Chris Rapley

The importance of satellite observations to IPY scientific objectives was recognized by the Joint Committee (JC) and its Scientific Committee on Observations (SCOBS) during early IPY planning and preparations. In 2006 SCOBS evaluated all IPY scientific projects that emphasized requirements for satellite data, products and services. The evaluation showed that these requirements were not consistent among projects and not always sufficiently detailed to establish immediate dialog between IPY projects and Space Agencies. Bearing this in mind, the SCOBS approached the Global Interagency IPY Polar Snapshot Year (GIIPSY) project (number 91, co-leaders K. Jezek, Byrd Polar Research Center and M. Drinkwater, European Space Agency) which was selected by JC in November 2005 as an IPY flagship project in order to realize the benefit of the growing constellation of international satellites to the scientific objectives of the IPY. The goal of GIIPSY was to develop consensus polar science requirements and objectives that could best, and perhaps only, be met using the international constellation of Earth observing satellites (Jezek and Drinkwater, 2006; 2008). Requirements focused mainly on all aspects of the cryosphere and ranged from sea ice and permafrost to snow cover and ice sheets. Individual topics included the development of high resolution digital elevation models of outlet glaciers using stereo optical systems, measurements of ice surface velocity using interferometric synthetic aperture radar (SAR/InSAR) and frequently repeated measurements of sea ice motion using medium resolution optical and microwave imaging instruments. Later, the requirements for satellite data, products and services were extended to cover composition, dynamics and chemistry of the polar atmosphere.

The functional link between the GIIPSY science community and the international space agencies was established through the IPY Space Task Group (STG) as part of SCOBS. International space agency participation in the STG was solicited through a letter sent in November 2006 on behalf of the WMO Secretary-General and the Executive Director of ICSU to the heads of space agencies. As result, STG membership consisted of representatives from the national space agencies of Brazil (INPE – A. Setzer), Canada (CSA – Y. Crevier), China (CMA – L. Zhao), France (CNES – E. Thouvenot), Germany (DLR – M. Gottwald), Italy (ASI – F. Battazza), Japan (JAXA – M. Shimada), Russian Federation (ROSHYDROMET – V. Asmus), U.K. (BSNC– D. Williams), U.S.A. (NASA – C. Dobson, NOAA– J. Key and P. Clemente-Colon, USGS – J. Mullins), the European Space Agency (ESA – M. Drinkwater, ESA/ESRIN – H. Laur) and the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT – K. Holmlund). To provide a link between the STG and IPY data management activities, the JC nominated IPY operational data coordinator O. Godoy (Norwegian Meteorological Institute) as STG member.

The IPY STG was established for the purpose of space agency planning, processing and archiving of the IPY Earth Observation legacy dataset. STG, chaired by M. Drinkwater, reported to SCOBS whose responsibility was to ensure that space-based and *in situ* observing systems were optimized for IPY purposes. SCOBS provided the guidelines for a scientific framework and consolidated science and data requirements to the STG, through the coordination of scientific groups such as the GIIPSY IPY project, the WCRP Climate and Cryosphere (CliC) project and the IGOS-P Cryosphere Theme team. STG recommendations were approved by the WMO Consultative Meetings on High-level Policy on Satellite Matters on an annual basis. The operating strategy for STG was to satisfy IPY science requirements in a fashion that distributes the acquisition burden across the space agencies while recognizing the operational mandates that guide the activities of each agency. Thus far, the space agencies have worked to develop IPY data 'portfolios' that, in total, aim to satisfy a significant number of scientific requirements. The primary objectives of STG meetings have been to review science requirements, to provide agency reports on progress in support of developing the IPY data legacy, and to identify and solicit new members. GIIPSY science requirements were presented at the first STG meeting.

STG has met in full session six times. Along with representatives of the space agencies mentioned above, members of GIIPSY (K. Jezek and others), the IPY Joint Committee (T. Mohr and E. Sarukhanian), WCRP (G. Asrar, V. Ryabinin, B. Goodison) and the WMO Secretariat, which provided administrative support, also attended STG meetings. The first meeting was held in January 2007 at the WMO headquarters in Geneva. Since then, the STG has met at EUMETSAT in Darmstadt, Germany in November 2007, at the ESA/ESRIN located in Frascati, Italy in May 2008, WMO Headquarters in Geneva in February and in December 2009 and in Oslo in June 2010. The STG also convened a SAR Working Group chaired by Y. Crevier (Canadian Space Agency). The purpose of the SAR-WG was to address fulfillment, on a best effort basis, of GIIPSY science requirements uniquely related to SAR/InSAR. The SAR-WG first met in March 2008 at the Canadian Space Agency in Montreal. Subsequent meetings were held in October 2008 at the German Aerospace Center in Oberpfaffenhofen and in June 2009 at ESA in Frascati. A full description of GIIPSY science requirements, agency data portfolios and meeting summaries can be found on the GIIPSY web page: http://bprc.osu.edu/rsl/GIIPSY (Drinkwater et al., 2008).

Based on GIIPSY recommendations, the STG adopted four primary data acquisition objectives for its contribution to IPY. The fifth objective was added at STG3. These are:

- Pole-to-coast multi-frequency InSAR measurements of ice-sheet surface velocity.
- Repeat fine-resolution SAR mapping of the entire Southern Ocean sea ice cover for sea ice motion.
- One complete high resolution visible and thermal

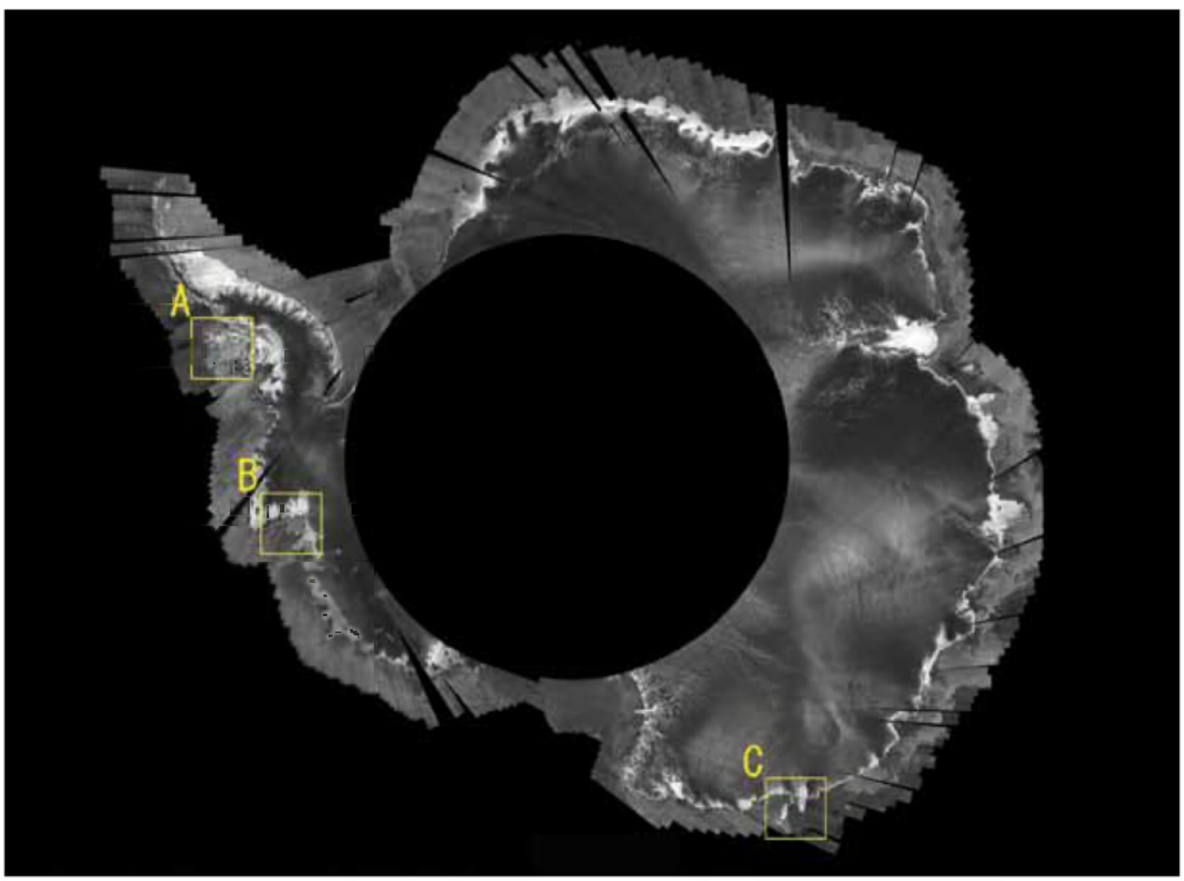


Fig. 3.1-1. Antarctica mosaic image covers the time between 8 December 2007 and 22 January 2008. Yellow square areas show fast glaciers and the location of retreating ice shelves in the Antarctic Peninsula.
(Courtesy: JAXA)

infrared snapshot of circumpolar permafrost.

- Pan-Arctic high and moderate resolution Vis/IR snapshots of freshwater (lake and river) freeze-up and break-up.
- Atmospheric dynamics and composition.

The STG has made substantial progress towards these acquisition objectives (IPY-STG, 2010). Fig. 3.1-1 shows a JAXA ALOS SAR mosaic image which covers the time between 8 December 2007 and 22 January 2008. Yellow square areas show the location of several fast glaciers and also the location of important ice shelf retreat in the Antarctic Peninsula. Fig. 3.1-2 shows the first measurements of surface velocity along a 250 km long tributary draining into Recovery Glacier, Coates Land, Antarctica (Floricioiu and Jezek, 2009). The tributary was discovered during the Radarsat-1 Antarctic Mapping mission. TerraSAR-X was used to acquire interferometric data along the length of the glacier resulting in the first velocity map of this unusual feature. ASI, CSA, DLR, ESA and JAXA have worked together to acquire the first pole to coast InSAR data sets for measuring surface velocity on both ice sheets. Surface velocity from these campaigns will be used to study the ice flux from the ice sheets into the oceans and to better understand controls on the motion of ice streams and the break-up of ice shelves. Ice shelf studies included an intense, routine-monitoring campaign following the Wilkins Ice Shelf break up, which demonstrated the importance of SAR for satellite daily monitoring of the polar regions (Fig. 3.1-3). COSMO-SkyMed, the Italian X-band SAR constellation, contributed to observations of the Wilkins ice shelf by monitoring the disintegration events and ice movement over large and medium areas (Battazza et. al, 2009a). COSMO-SkyMed data were also used to measure the glacier velocity field of Patagonian glaciers using spotlight high resolution images with time intervals of 8 and 16 days (Fig. 3.1-4), (Battazza et al., 2009b). ESA and CSA have coordinated SAR campaigns to fill gaps in Arctic and Antarctic sea ice cover where either station masks or on-board recorder time have usually precluded routine coverage.

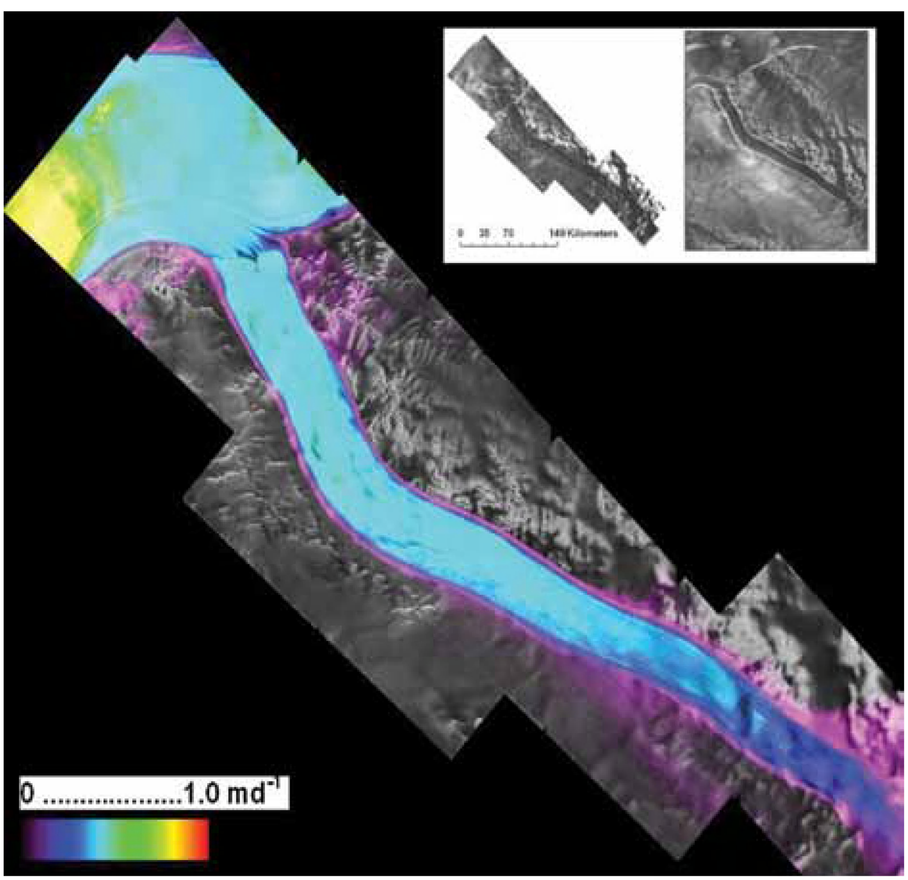


Fig. 3.1-2. 2008-09 TerraSAR-X mosaic (left inset) and 1997 RAMP mosaic (right inset) of Recovery Glacier tributary (Antarctica) The main trunk of Recovery Glacier is located in the upper part of the RAMP and TerraSAR-X mosaics. Scenes are centered on 82.5°S 19°W. Central figure shows surface velocity along the entire 250 km length of the tributary measured using TerraSAR-X data.
(Image: DLR)

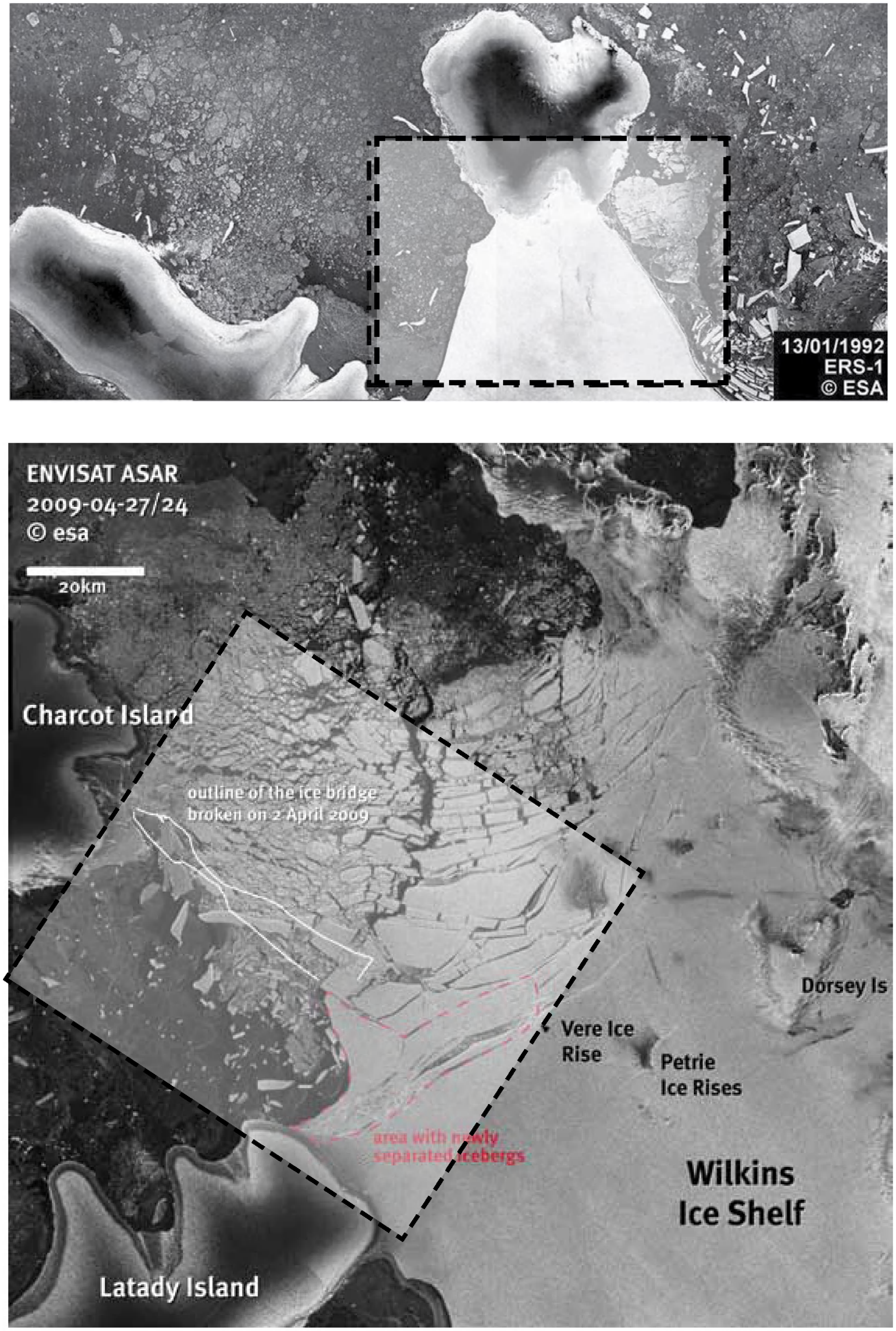
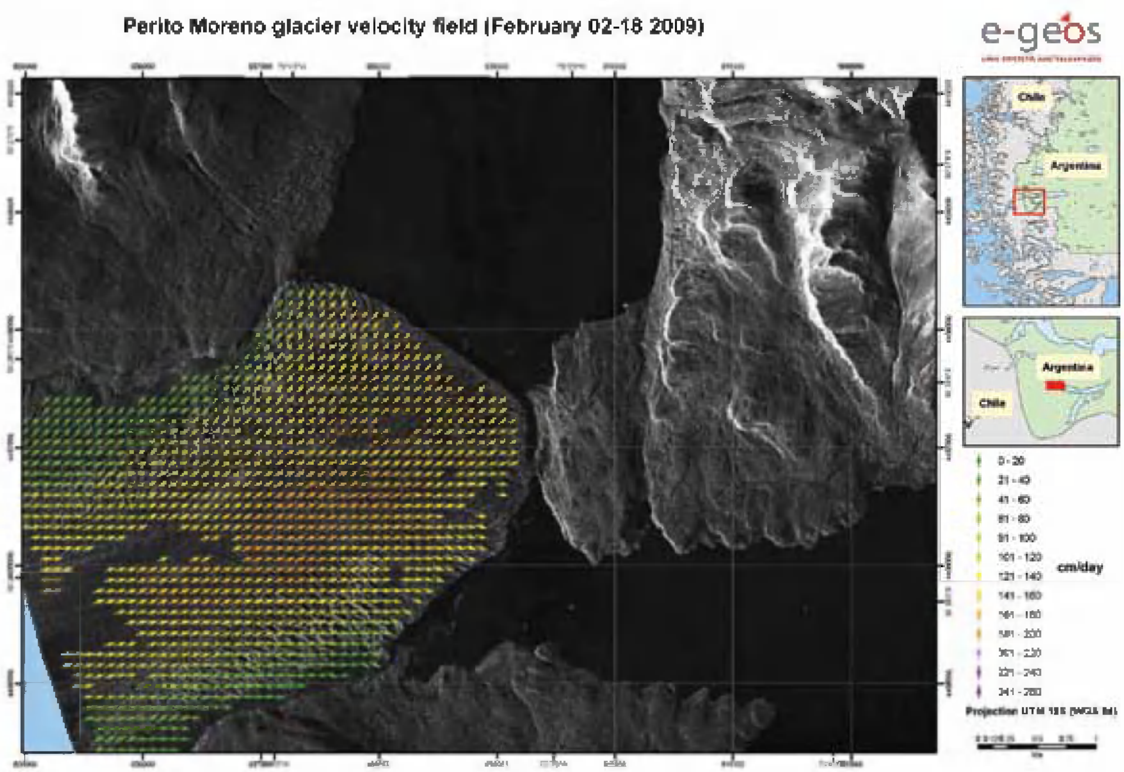


Fig. 3.1-3. Evolution of the Wilkins Ice Shelf in the past 18 years. Top: SAR image captured by ERS-1, showing the extent of the ice shelf. Bottom: Envisat ASAR following with daily imagery the break-up of the ice shelf giving scientists worldwide the opportunity to understand the dynamics of this event. This intense acquisition campaign has been one of the Envisat contributions to IPY. (Image: ESA)



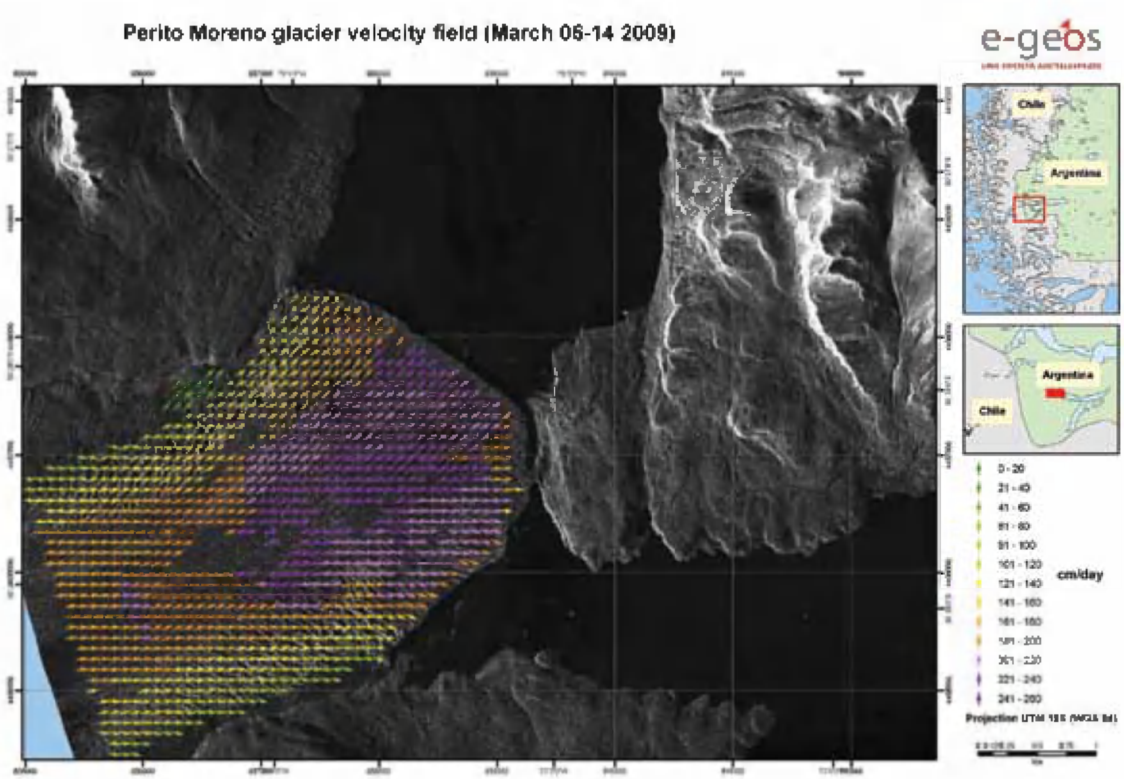


Fig. 3.1-4. Maps of Perito Moreno glacier (Argentina) velocity field using ASI COSMO-SkyMed constellation spotlight images (prepared by Luca Pietranera and Achille Ciappa, e-GEOS). The velocity field has been extracted from spotlight images pairs acquired on 2 and 18 February, 2009 (detected by COSMO-1 with a time interval of 16 days and pixel resolution of 1 meter) (upper) and on 6 and 14 March, 2009 (detected by COSMO-1 and COSMO-2 with a time interval of 8 days, 1 m, resolution) (lower). High speeds occur along the centre slope of the glacier tip while slow speeds are located along the lateral sides. End-of-summer speeds are higher than mid-summer speeds.

(Courtesy: Agenzia Spaziale Italiana, 2009)

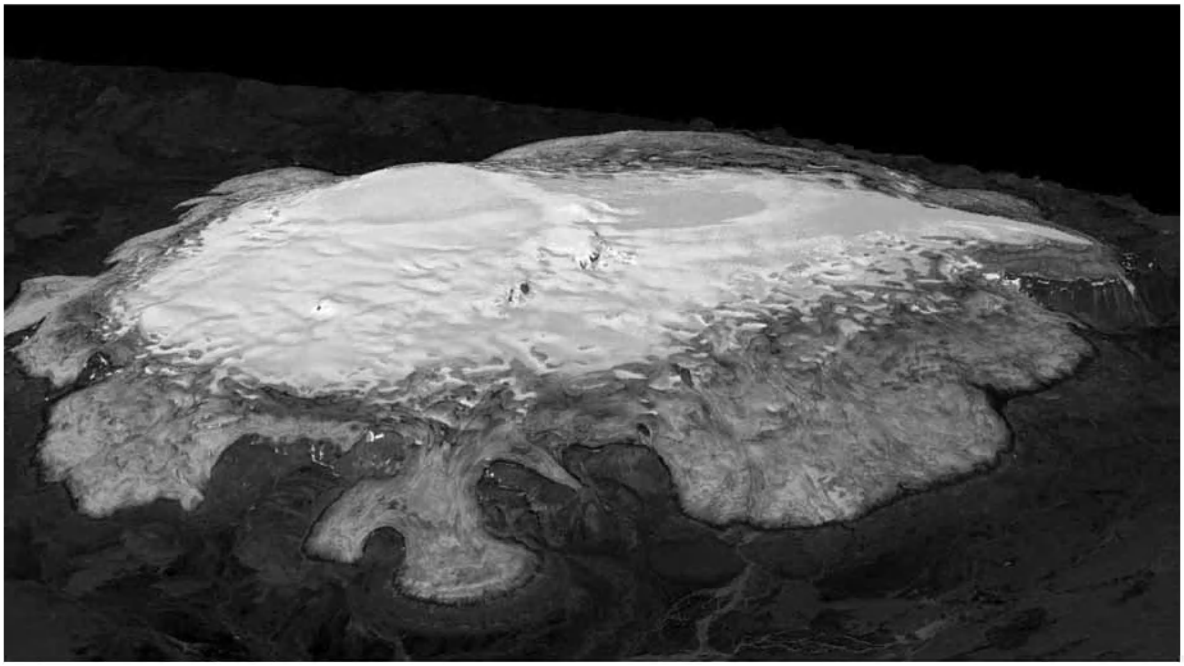


Fig. 3.1-5. Three-dimensional mapping of Hoffsjökull Ice Cap, Iceland completed as part of the CNES SPIRIT project. SPOT optical stereo data were acquired over substantial areas of Arctic ice caps and the Antarctic Ice Sheet (Korona and others, 2008a,b). (Image: CNES)

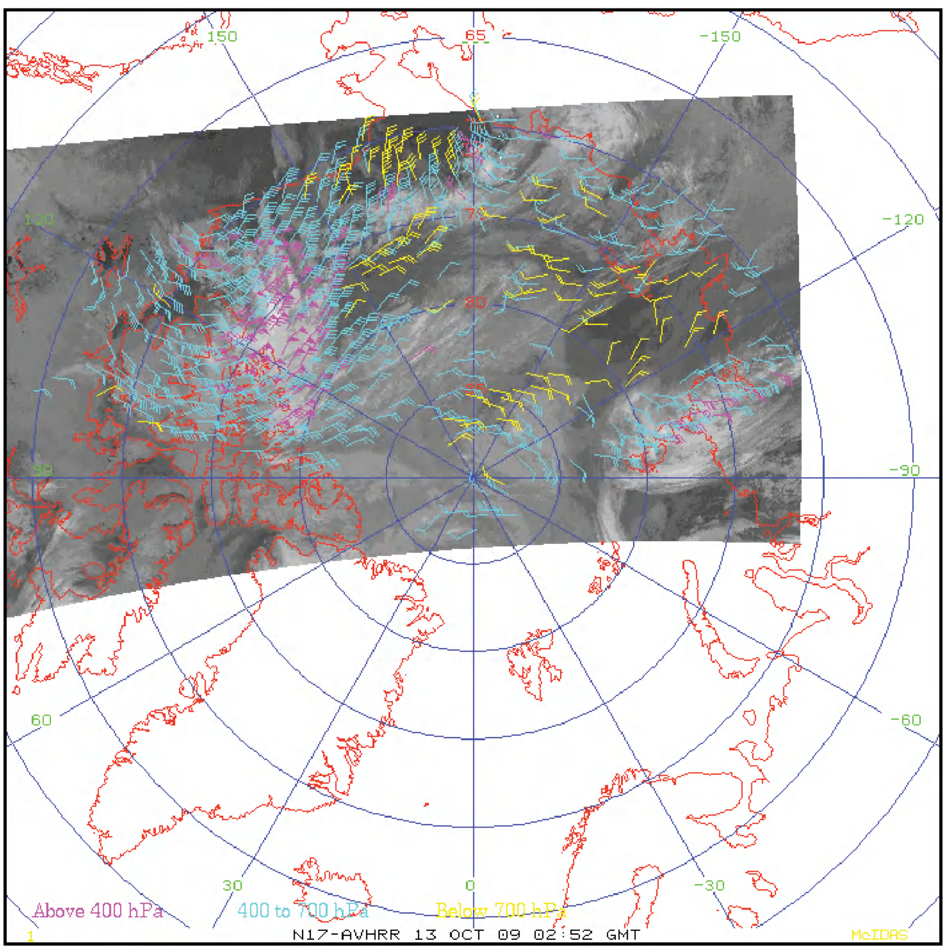


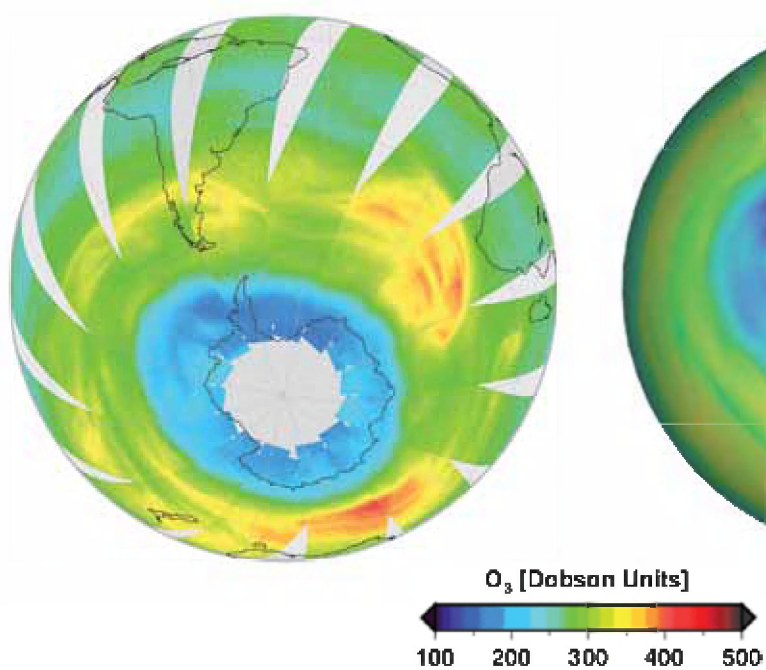
Fig. 3.1-6. Winds are now being generated from Advanced Very High Resolution Radiometer (AVHRR) data collected at the NESDIS High Resolution Picture Transmission (HRPT) receiving station in Barrow, Alaska. The first winds were generated on February 16, 2008. All processing is done at the NESDIS Fairbanks Command and Data Acquisition Station in Fairbanks. Data from NOAA-16, -17, -18, and -19 are processed. The HRPT wind information is an improvement over the AVHRR Global Area Coverage (GAC) winds in that it is available much sooner (e.g., 25 minutes after acquisition rather than 2-3 hours) and at a higher spatial resolution.

Using SPOT Stereo data, the CNES IPY SPIRIT project (Korona et al., 2008a; 2008b) is creating optically derived, high resolution digital elevation models (DEMs) of the perimeter regions of ice caps and ice sheets (Fig. 3.1-5). These highly detailed DEMs are the most extensive, high precision DEMs of polar ice caps and the margins of the polar ice sheets yet acquired. Using routine acquisitions by the NASA Moderate Resolution Imaging Spectroradiometer (MODIS) sensor and the ESA Medium Resolution Imaging Spectrometer (MERIS) instrument, as well as the JAXA Advanced Visible and Near Infrared Radiometer (AVNIR-2) and Panchromatic Remote-sensing Instrument for Stereo Mapping (PRISM) instruments, there have been extensive acquisitions of optical imagery of permafrost terrain.

Operational satellite data have been used to study, on a continuous basis, the polar atmosphere during the IPY. The acquired data permit retrieving information from all layers of the Earth's atmosphere, from the troposphere up to the mesosphere. For example, real-time systems for polar winds have been implemented at direct readout sites in both polar regions to meet numerical weather prediction needs for timeliness (Fig. 3.1-6). It is, however, equally important to generate long-term (relative to the satellite record) products for studies of recent climate change. In this regard, historical Advanced Very High Resolution Radiometer (AVHRR) data have been reprocessed to generate 25-year wind, cloud and surface properties, and radiation (Dworak and Key, 2009; Liu et al., 2008).

IPY satellite data are also being used to study atmospheric chemistry (Fig. 3.1-7 and Fig. 3.1-8). The polar atmosphere is considered to be highly sensitive to anthropogenic impacts on the earth system and thus to climate change. The acquired data permit retrieving atmospheric information, from the troposphere to the mesosphere. For example, reactive halogens are known to be responsible for ozone depletion (Fig. 3.1-7) and mercury deposition in polar regions during springtime. Bromine monoxide (BrO) is a key indicator of reactive halogen chemistry and is a highly efficient catalyst in ozone destruction. Meanwhile, the seasonal to interannual variability in BrO has been documented using high-latitude polar orbiting satellite data, both in the troposphere and stratosphere, where enhanced tropospheric BrO related to a tropospheric 'bromine explosion' is observed over the Arctic sea-ice area in springtime. Using SCIAMACHY limb-viewing observation mode data, a detailed timeseries of polar stratospheric BrO has been acquired spanning the entire IPY period.

The initial goal of the STG was to identify key IPY era science objectives addressable with satellite instruments and then to acquire the necessary data sets. Because a major international campaign of coordinated



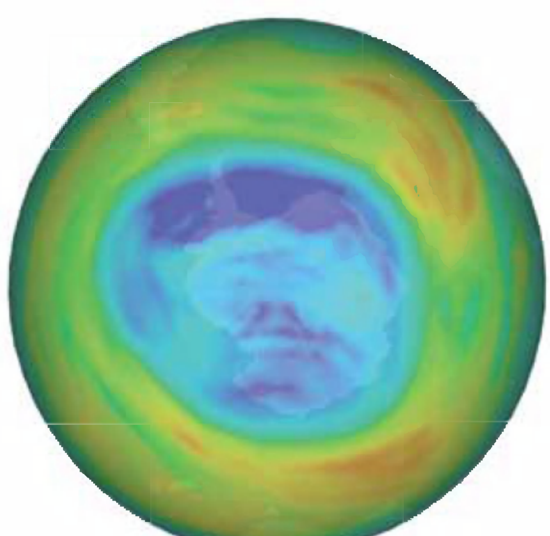
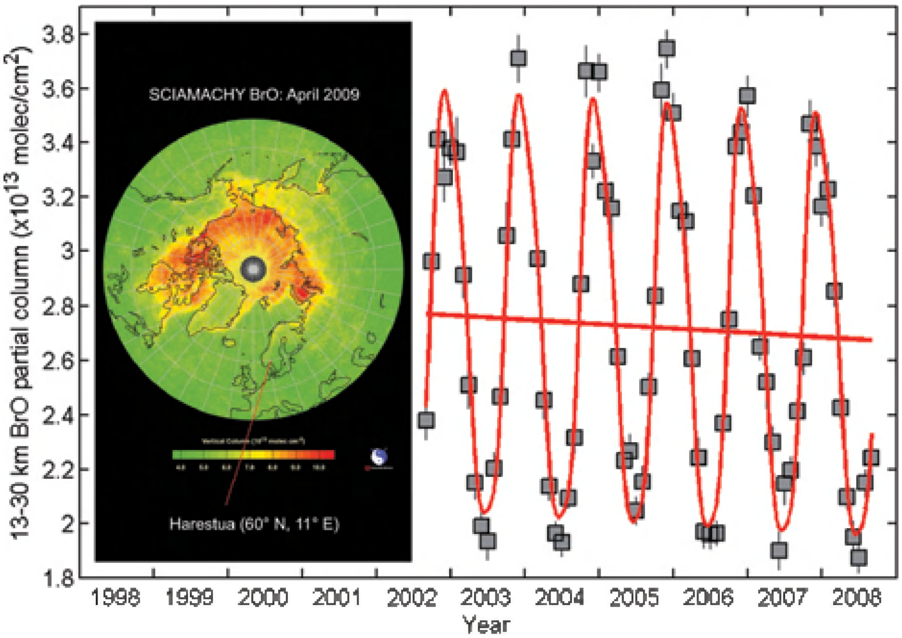


Fig. 3.1-7. Two independent views of the southern hemisphere ozone (O_3) hole on 8th September 2008, characterized using a) measurements of the GOME-2 instrument on-board the MetOp-A satellite (courtesy DLR/EUMETSAT/O3MSAF, available from http://wdc.dlr.de/); and b) total ozone columns from the TEMIS ozone and UV forecast, based on measurements from the SCIAMACHY sensor on-board ENVISAT.
(Courtesy KNMI/ESA, available from www.temis.nl)

Fig. 3.1-8. Time series of monthly averaged stratospheric inorganic bromine (BrO) partial column abundances measured over the Harestua upper air monitoring site by the SCIAMACHY instrument on-board ENVISAT (courtesy Hendrick et al, 2009. The inset shows a monthly composite BrO image over the Arctic in April 2009, again as seen by SCIAMACHY (courtesy IUP-IFE, University of Bremen) together with the location of the Harestua station in Norway. Analysing SCIAMACHY limb measurements over the 2002-2008 period, a trend analysis indicates a decline of -0.6+/-0.3% per year, which is in good agreement with ground-based UV-visible measurements (-0.7+/-0.3%/year). (Image: F. Hendrick (BIRA/IASB) and A. Rozanov (IUP/IFE-Bremen), 2009)



Earth observations from space had not been attempted previously, participants agreed that developing the mechanisms for coordinated acquisitions and then executing those plans was a substantial challenge. As a result, enhanced international coordination and cooperation among space agencies have produced an extraordinary quantity and quality of satellite observations of Polar regions (Jezek and Drinkwater, 2010). These and many other broad-ranging and easily accessible reference data on the status of the Polar regions that IPY provides will be crucial for comparisons with the future and the past (Allison et al., 2009). In fact, the STG participants have succeeded in meeting this challenge beyond initial expectations, as evidenced by the range of data types presented and illustrated here. Consequently in February 2009, the STG chose to take a step beyond data acquisition and to investigate coordinated product development (IPY-STG, 2010). These efforts, which will likely continue beyond the final year of GIIPSY and the IPY STG, are devoted to producing SAR polarization image mosaics of Antarctica, SAR image mosaics of Greenland, X-, C- and L-band interferometrically derived velocity fields for Greenland and Antarctica, and the distribution of high resolutions SPOT DEMs. The approach will be similar to the acquisition phase wherein geophysical product development loads will be distributed amongst the partners. CSA and NASA have already made progress in identifying resources to repatriate interferometric Radarsat-1 data that are needed to complete the most recent measurement of Greenland Ice Sheet surface velocity. ASI, CSA, DLR, ESA and JAXA have also begun the process of generating ice sheet wide SAR image mosaics and measurements of surface velocity (IPY-STG, 2010). In the atmospheric domain, polar science benefits from the progress in expanding our capabilities in retrieving atmospheric parameters from spaceborne data. This is a common effort of ESA, EUMETSAT, NOAA, NASA, DLR and various scientific institutes. To date, significant progress has been made during the IPY in acquiring new scientifically valuable datasets as well as ensuring access to the more routine datasets required for routine operational meteorological applications and numerical weather prediction.

IPY has provided a unique opportunity to demonstrate the value of inter-satellite operations between SAR satellites in a polar constellation as well as opportunity to illustrate the benefits of coordinated observations by a range of polar observing systems ranging from *in situ*, to airborne and to satellite-borne measurement capabilities. The STG and GIIPSY project are actively harnessing the technical capabilities of the world's space agencies and the specialized knowledge of their science communities to obtain a suite of 'polar snapshot' data, which comprise a unique IPY legacy. Through these efforts, the space

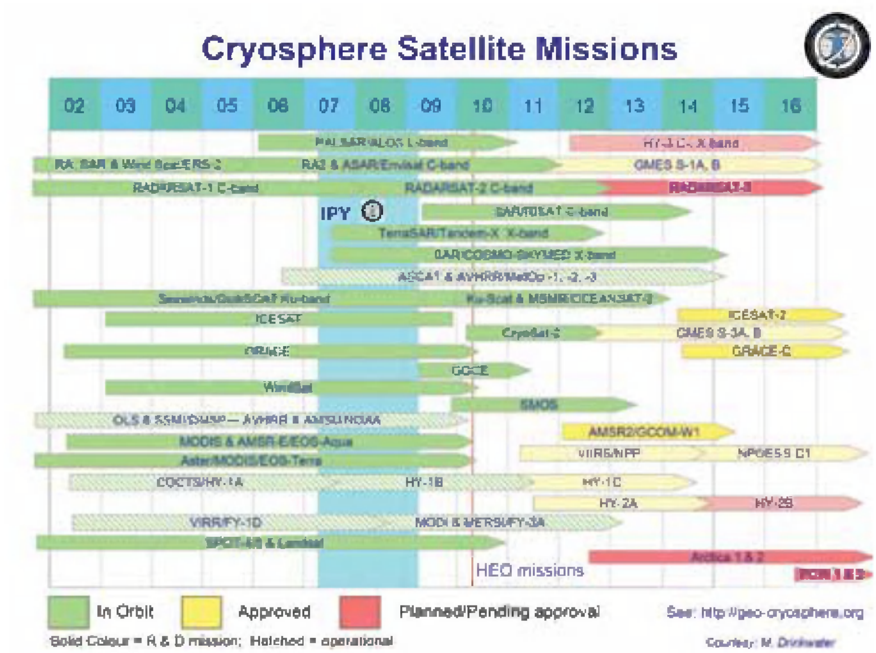


Fig. 3.1-9. Timelines of cryosphere satellite missions
(Image: M. Drinkwater, 2009)

and scientific communities involved will leave a legacy dataset compiled from multiple space agency satellite data portfolios comprising a broad range of snapshot products (Jezek and Drinkwater, 2010).

Looking toward the proposed International Polar Decade (*Chapter 5.6*), there are a number of issues that could be addressed by a follow-up to the IPY-era STG by expanding the acquisition and product suite beyond the polar regions to cover all sectors of the cryosphere (Fig. 3.1-9). More specifically and along the lines of the SAR-WG, there is consensus that an optical/IR working group could profitably address an updated list of measurements and derived products. There should be further integration of the atmospheric chemistry and polar meteorological science communities into the STG activity suite, as well as potential incorporation of gravity and magnetic geopotential missions into the STG discussion. It is also possible to envision discussion and collaboration on emerging technologies and capabilities, such as the Russian "Arktika" Project and Canadian Polar Communications and Weather (PCW) Project (Asmus et al., 2007; Garand and Kroupnik, 2009) and advanced subsurface imaging radars.

The STG has been a unique mechanism for informing the space agencies about GIIPSY science requirements. In turn the STG has been an important venue for coordinating acquisition and processing of important amounts of satellite data while distributing the data acquisition load amongst the participating agencies. Continuing a GIIPSY/STG IPY legacy activity, perhaps reconstituted with a new mission statement that addresses some of the additional points mentioned above, can be of future service by providing a direct link between both the recently formed WMO Panel of Experts on Polar Observations, Research and Services (see www.wmo.ch/pages/governance/ec/tor_en.html#antarctic), the IASC/SCAR Bipolar Action Group and the broader cryospheric science community to those offices of the space agencies responsible for mission planning, data acquisition and product development. A natural vehicle for adopting lessons learned from GIIPSY/STG into a more encompassing international effort could be the Global Cryosphere Watch (Goodison et al., 2007), recently proposed by WMO to be in support of the of the cryospheric science goals specified for the Integrated Global Observing Strategy Cryosphere Theme (IGOS, 2007). The main goal of a future effort would be continued STG coordination of international efforts in securing collections of space-borne "snapshots" of the Polar regions through the further development of a virtual Polar Satellite Constellation (Drinkwater et al., 2008) as part of the IPY legacy.

This section has been prepared on behalf of the IPY Space Task Group. Without the contributions of the participating space agencies and other supporting organizations, this effort would not have been possible.

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3.2 Towards an Integrated Arctic Ocean Observing System (iAOOS)

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The following chapter presents selected examples of new ideas that have emerged from the enhanced ocean-observing effort of IPY 2007–2008 on the role of the Northern Seas in climate. This is an incomplete sampling of the questions that must be asked to determine a sustainable observing system in the legacy phase following the completion of IPY.

Inputs to the Arctic Ocean: what questions should we be testing?

Q: *What is the relative importance of the two main Atlantic inflow branches in carrying ocean climate 'signals' from the Nordic Seas into, around and through the Arctic deep basins?*

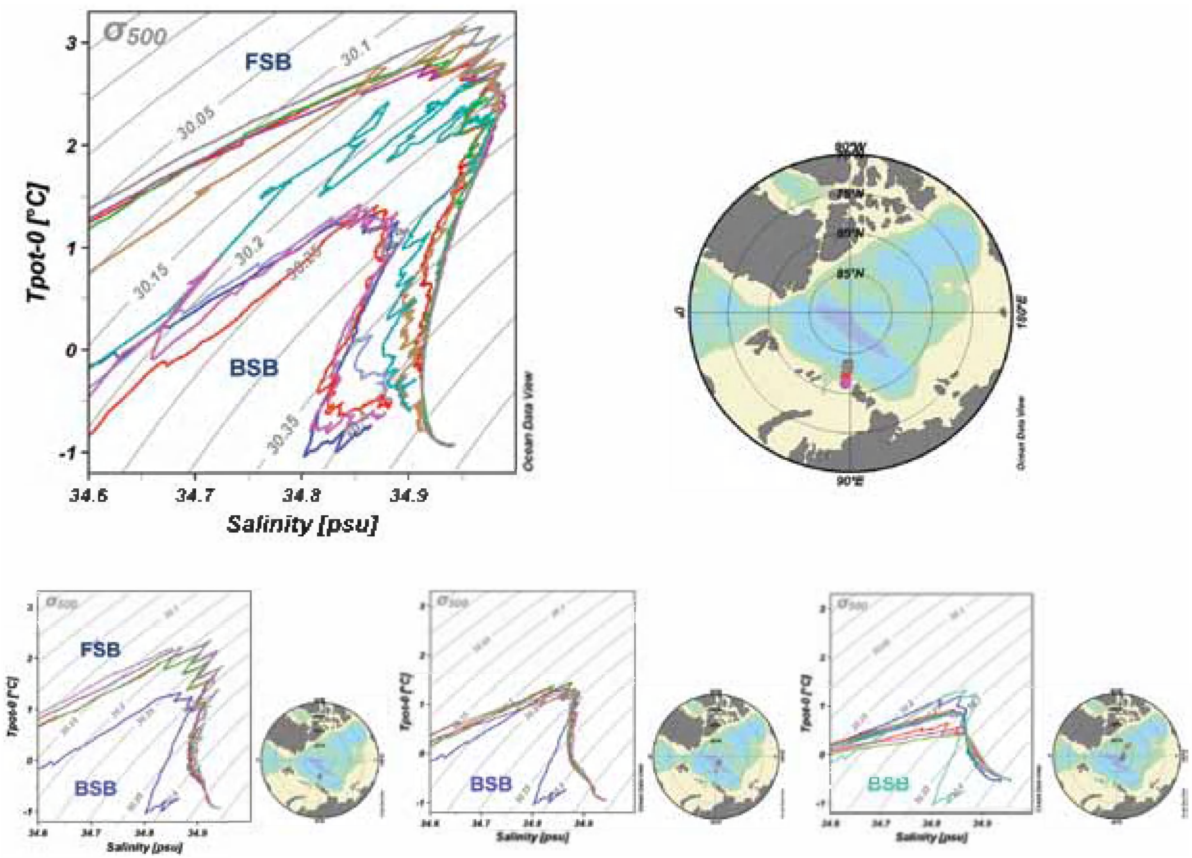
A: The basis for this as a focus question is the suggestion put forward by Bert Rudels (Univ. Helsinki) at the Arctic Science Summit Week, Bergen 2009, that the colder fresher Barents Sea inflow branch may dominate the Arctic Ocean beyond the Nansen Basin, with the Fram Strait branch seldom penetrating beyond the Lomonosov Ridge. Dmitrenko et al., (in press) would seem to agree. If so, the source of the recent warming — so graphically described along the boundary of the Laptev Sea and Canada basin by Polyakov et al., (2005; 2007), Dmitrenko et al., (2008a,b), Carmack (pers. comm.) and others — will effectively have been reassigned. As illustrated in the various panels of Fig. 3.2-1, the essence of Rudels' argument is that beyond the Gakkel Ridge the Θ-S characteristics of the Atlantic-derived sublayer are closer to those of the Barents Sea Branch (BSB in Fig. 3.2-1) than the Fram Strait Branch (FSB). Testing Rudels' idea will be an important task for the legacy phase to resolve, but the tools to do so are well proven: detailed ship-borne hydrography, sustained flux measurements through the northeast Barents Sea, and continued or intensified coverage of the boundary currents along the Eurasian margin of the Nansen basin from the point where both branches first flow together to their supposed points of separation at the Lomonosov ridge. This lends further support to the continuation of a modified NABOS (Nansen and Amundsen Basins Observational System) array across this boundary. The research team is likely to include Bert Rudels (Univ. Helsinki), Ursula Schauer (AWI), Øystein Skagseth (IMR Bergen), and Igor Polyakov (IARC).

Q: *Where can we expect the recent extreme warmth of the Atlantic–derived sublayer of the Arctic Ocean to have its main climatic impact?*

A: Very recently, the temperature and salinity of the waters flowing into the Norwegian Sea along the Scottish shelf and Slope have been at their highest values for >100 years. At the 'other end' of the inflow path, the ICES Report on Ocean Climate for 2006 showed that temperatures along the Russian Kola Section of the Barents Sea (33°30'E) had equally never been greater in >100 years (Holliday et al., 2007). As already noted, Polyakov et al., (2005; 2007), Dmitrenko et al., (2008a, b) and others have documented the onward spread of the most recent pulses of warmth along the Eurasian boundary of the Arctic Ocean.

When the IPY began in March 2007, the consensus view would likely have been that a 100-year maximum in the warmth of the inflow to the Arctic must in some way be bound up with an increased melting of Arctic sea ice. Since then our ideas have altered in response to new simulations by a group from the Alfred Wegener Institute (M. Karcher, pers. comm., also Karcher et al., 2007; 2008), which suggest that, as the warm Atlantic-

Fig. 3.2-1. Potential temperature/salinity relations at the depth of the Atlantic-derived sublayer between the continental slope of the Kara Sea and the Alpha Ridge.
(Image: Bert Rudels U Helsinki pers comm. 2009)



derived layer spread at subsurface depths through the Arctic deep basins (see Fig. 3.2-2), it did so at a significantly greater depth and with a significantly lower density than normal. Though the increased warmth may thus be too deep to have much effect on the sea ice, the intriguing suggestion is made that, as this layer circuits the Arctic and drains south again into the Nordic seas, its changed depth and density now seem capable of altering the two factors, the density contrast across the sill and the interface height above the sill, that together determine the strength of the Denmark Strait Overflow (Whitehead, 1998), hitherto regarded as largely unchanging (Dickson et al., 2008). When Karcher re-ran his simulations by applying two periods of past NCEP forcing after 2008, both runs appeared to confirm that the anomalies will progress from the Chukchi to the Denmark Strait as hypothesised, will slow the overflow as expected from hydraulic theory, but will do so a few years earlier (in 2016-18) than had been suggested by his initial prediction, which had been based on simple statistics relating interface height anomalies north of Denmark Strait to interface heights passing through the Arctic.

Thus in the Atlantic sector, the climatic impact of the recent inflow of warmth to the Arctic may have less to do with local effects on sea ice than on the Atlantic's thermohaline 'conveyor', years later and far to the south. As a candidate for the IPY legacy phase, the importance of this result seems clear: Maintaining surveillance on these changes taking place throughout the length and breadth of our Arctic and subarctic seas over decades is likely to prove highly instructive to our understanding of the role of our northern seas in climate. However, detecting and following such decadal transient signals is likely to impose a need for new tools in observational network design. Michael Karcher (AWI) will lead the testing of this focus question by both observation and simulation.

Q: *What is the ecosystem response to sea ice retreat and what observational system do we put in place to observe it?*
A: Although recent major changes in the physical

domain of the Arctic are well documented, such as extreme retreats of summer sea ice since 2007, large uncertainties remain regarding potential responses in the biological domain. In the Pacific Arctic north of Bering Strait, reduction in sea ice extent has been seasonally asymmetric, with minimal changes until the end of June, rapid summer retreat, and then delayed sea ice formation in late autumn. The effect of this seasonal asymmetry in sea ice loss on ocean primary production is still in question. Satellite images show variable chlorophyll concentrations with sea ice retreat in recent years, although model predictions indicate the potential for enhanced productivity with increased summer/fall sea ice retreat (Arrigo et al., 2008). However, clear changes have occurred at higher trophic levels, including shifts in species ranges for zooplankton, benthos and fish, as well as loss of sea ice as habitat and platform for marine mammal species. For example, Pacific zooplankton intrusions have been documented northward into the Beaufort Sea (Nelson et al., 2009) that are coincident with observations of Pacific clam subarctic species north of the Bering Strait into the Chukchi Sea (Sirenko and Gagaev, 2007). In the Bering Sea, fish and invertebrates showed a community wide northward distribution shift (Mueter and Litzow, 2008). Commercially fished species including walleye pollock, Pacific cod and Bering flounder now occur in the Beaufort Sea together with commercial-sized snow crab. For seabirds, declines in dominant clam populations critical as prey in the northern Bering Sea are concomitant with dramatic declines in numbers of spectacled eiders (Lovvorn et al., 2009). In the western Beaufort Sea, black guillemots have lost access to ice-associated arctic cod due to the extreme ice retreats and more frequently suffer predation by land-based polar bears. Polar bears have switched denning habitat from sea ice to land (Fischbach et al., 2007), have drowned at sea, and have been seen more regularly on beaches. There was a 17-fold drop in gray whale relative abundance in the northern

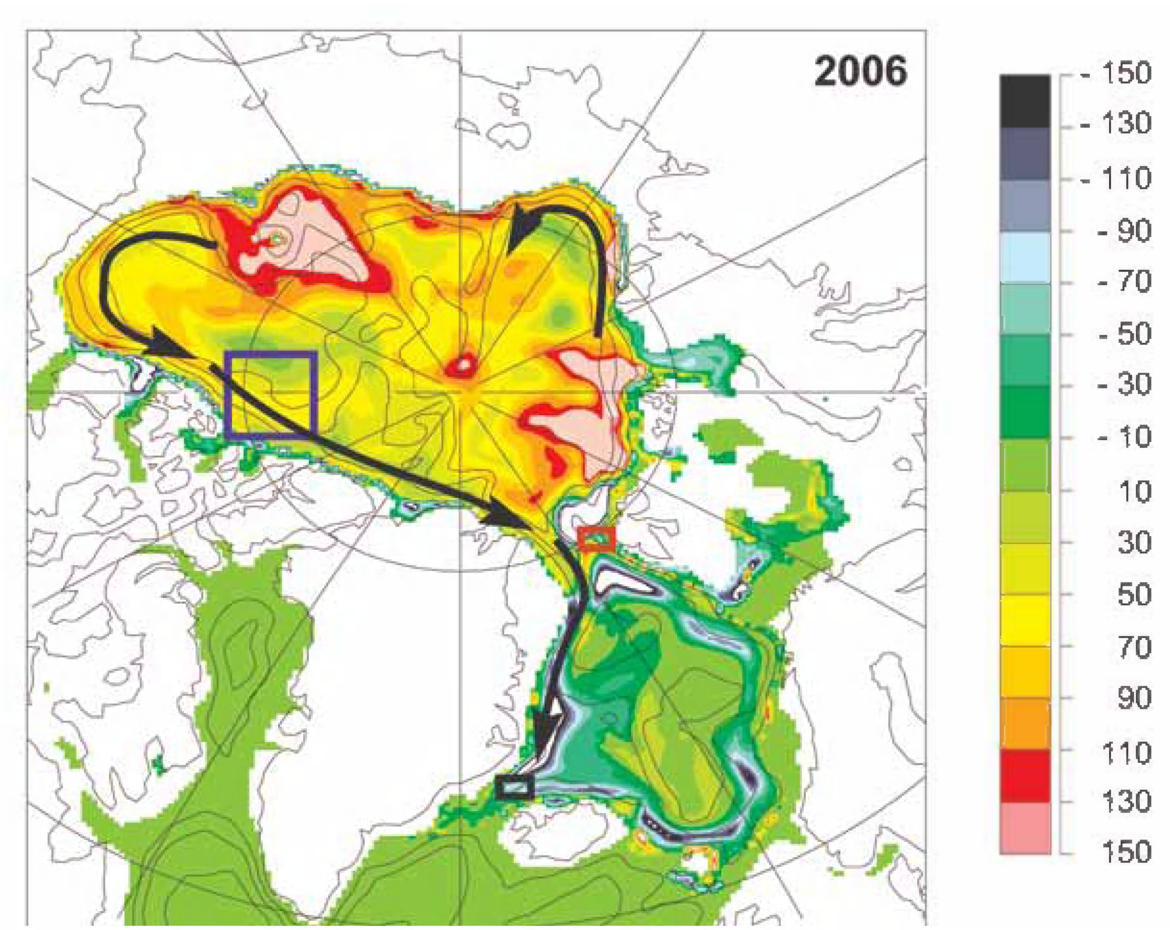


Fig. 3.2-2. Modelled location of the two deepening / low-density centres in the AW sublayer of the Arctic Ocean in 2006. The depth anomaly of the Atlantic-derived sublayer location is given in meters.
(Image: Unpublished, Karcher pers. comm.)

Bering Sea coincident with the decline in amphipod prey biomass and the nearly coincident extension of their feeding range to include over-wintering in the western Beaufort Sea (Moore, 2008). This combination of range expansions and/or changes to community composition and the timing of life history events are all clear indicators of an ecosystem in transition.

In order to evaluate ecosystem shifts, members of the scientific community are developing the concept of a 'Distributed Biological Observatory (DBO)' in the Pacific Arctic around known regional "hotspot" locations along a latitudinal gradient from the northern Bering to the western Beaufort Seas (Grebmeier et al., in press; Fig. 3.2-3). The DBO is envisioned as a change detection

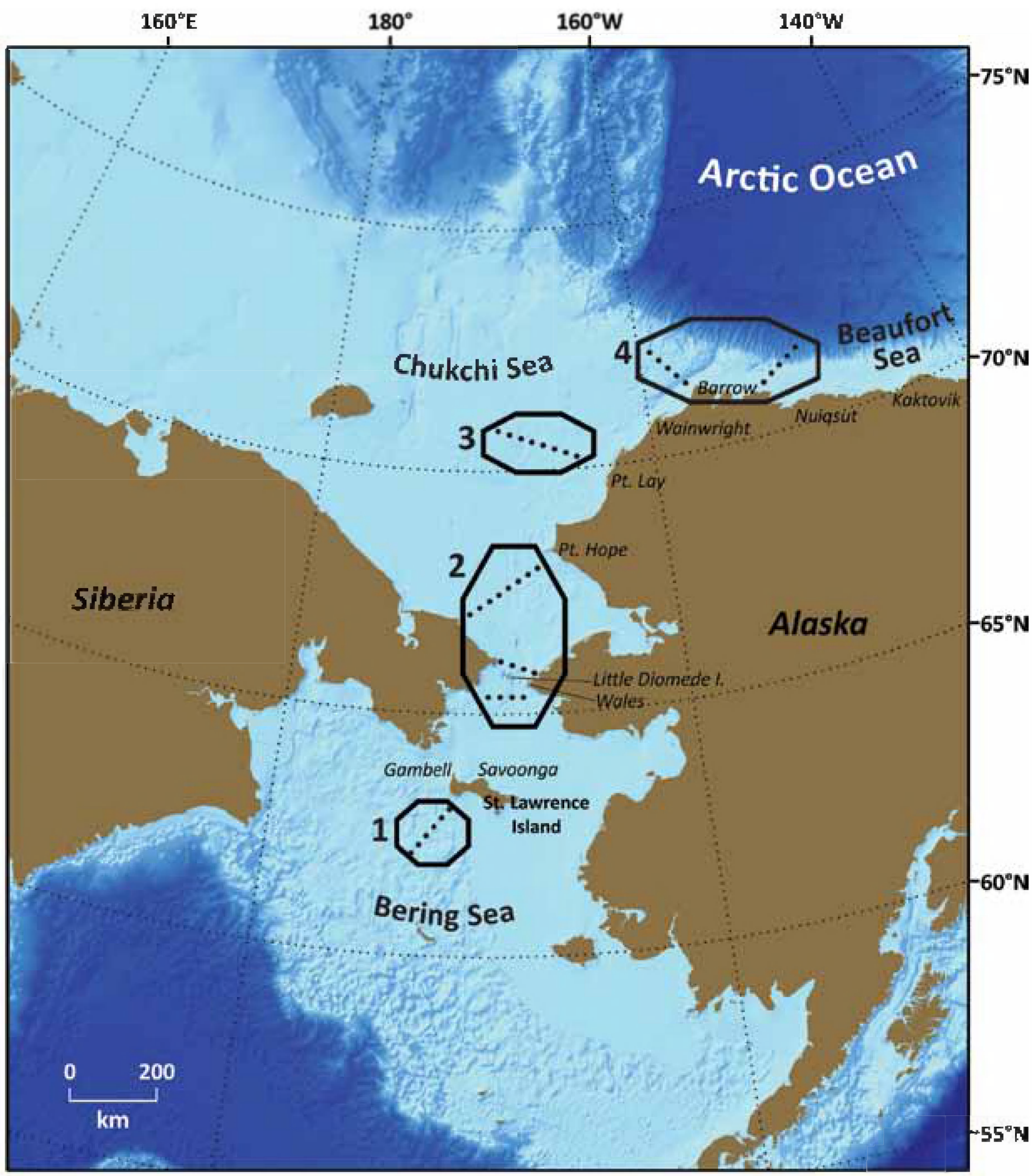


Fig. 3.2-3. A Distributed Biological Observatory concept for the Pacific sector of the Arctic as a "change detection array" to track biological response to ecosystem change in the region.
(Image: Grebmeier et al., 2010)

array for the identification and consistent monitoring of biophysical responses in pivotal geographic areas that exhibit high productivity, biodiversity and rates of change. The proposed regions are the: 1) northern Bering Sea, 2) Bering Strait/SE Chukchi Sea, 3) Central Chukchi Sea and 4) Barrow Arc. Stations in these regions can be visited through an international network of ship operations, both ongoing and planned. These include Canadian, Chinese, Japanese, Korean, Russian and U.S.A. research vessels coordinated through the international Pacific Arctic Group (PAG), and land based research from coastal communities using helicopter and small ships. A suite of primary standard station measurements are proposed for each of the DBO stations to be occupied by multiple international ships and dedicated national programs. Core hydrographic (T, S, chlorophyll, nutrients) and biological measurements (faunal diversity, abundance and biomass) of lower trophic level prey (zooplankton and benthic fauna) coincident with high trophic predators (seabirds, fish and marine mammals) would be the foci measurements. A second tier of sampling would include fishery acoustics and bottom trawling surveys on a more limited basis. Multidisciplinary moorings and satellite observations at focused regional locations would also be encouraged. The DBO would leverage ongoing and planned programs, both domestic and international. Incorporation of the DBO concept within the development of the international Sustaining Arctic Observing Networks (SAON) process (*Chapter 3.8*) will provide a foundation for investing system-level biological response to Arctic climate change and for improving the linkage between community-based monitoring and science-based measurement. An international community-developed plan of time series transects and stations for biodiversity studies of lower to higher trophic levels is being proposed in a pan-Arctic mode as part of the Arctic Council's Circumpolar Biodiversity Monitoring Program (CBMP; http://cbmp.arcticportal.org/).

The Arctic Deep Basins: what questions should we be testing?

Until relatively recently, the Arctic Deep Basins were among the least-measured places in the World Ocean. All that has now changed. The WHOI Beaufort Gyre Exploration Project [later Beaufort Gyre Observing System (BGOS)], led by Andrey Proshutinsky and employing a suite of new observing techniques has, since 2003, gradually transformed the data desert of the Beaufort Gyre into what is now one of the best-covered regions of our northern seas. The elaboration of that effort into a BGOS/C3O/JOIS collaboration and the intensive survey of its borderlands by other collaborative ventures such as JWACS (Joint Western Arctic Climate Studies between JAMSTEC and Canada DFO/IOS since 2002) and CHINARE (the Chinese National Arctic Research Expedition with EC-DAMOCLES aboard icebreaker "Xue Long" in 2008) have continued to intensify the scientific focus on the Beaufort Gyre, Canada Basin and Chukchi Sea so that our ideas of what drives change throughout this region and the significance of these changes for climate have developed rapidly. As a result, we now regard the Beaufort Gyre-Canada Basin as 'The Flywheel of the Arctic Climate' (the subtitle of the WHOI BGOS project) and as one of the key sites in the World Ocean from the viewpoint of the Ocean's role in climate.

Q: *What is the role of the Beaufort Gyre as a variable freshwater source/ reservoir?*

A: As the world warms, the expectation is that the freshwater outflows from the Arctic Ocean to the North Atlantic will strengthen and may suppress the rate of the climatically important Atlantic meridional overturning circulation. For some time, we have been aware in general terms of the link between retention/ release of freshwater from the Gyre and the state of the Arctic Oscillation. But it was relatively recently that the Beaufort Gyre has been identified as the largest marine reservoir of freshwater on Earth (Carmack et al., 2008) and the WHOI BGOS data have elaborated the details of the state, variability and controls on its freshwater content (FWC). The major cause of the large FWC in the Canada Basin is now recognised to be the process of Ekman pumping generated by the climatological anticyclonic atmospheric circulation centered on the Beaufort Gyre (Proshutinsky et al., 2008), confirming the hypothesis of Proshutinsky et al., (2002). Mechanically, the seasonal variability of FWC follows wind curl changes with a maximum in November-January and a minimum in June-August depending on changes in atmospheric circulation. The atmospheric and oceanic thermal regimes regulate seasonal transformations of liquid FWC due to the seasonal cycle of sea ice melt and growth. A first peak (June-July) is observed when the sea ice thickness reaches its minimum (maximum fresh water release from sea ice to the ocean) when Ekman pumping is very close to its minimum (maximum wind curl). The second maximum is observed in November-January when wind curl reaches its minimum (maximum Ekman pumping) and the salt flux from the growing sea ice has not reached its maximum.

The most important BGOS finding however, is the fact that the Beaufort Gyre freshwater content is a field in rapid transition with strongly increasing trends in FWC between 2003-2008 at mooring locations (Fig. 3.2-4) along Ice-Tethered Profiler trajectories and at the standard BGOS summer CTD sites. According to Proshutinsky et al., (2009), the spatially integrated FWC of the gyre increased by >1000 km^3 post-1990 relative to climatology.

Q: *What is the effect on climate of the recent transition from stable multi-year land-fast ice to free ice along the Canadian Arctic Margin?*

A: Warm Pacific Summer Water (PSW) inflow through the Bering Strait plus the creation of a Near Surface Temperature Maximum (NSTM) in the Canada Basin through the albedo feedback mechanism (Jackson et al., 2009) thins the ice against the Canadian Arctic coast. Once the multi-year ice breaks free of the coast, intensive Japanese investigations by Koji Shimada (Univ. Tokyo) suggest that the clockwise gyre circulation is able to rotate the ice out over what might now be termed the 'hotplate' of the Chukchi Borderland. The melting ice joins the transpolar drift and exits through Fram Strait. The now ice-free ocean stimulates the development of anomalously low pressure and the resulting formation of an atmospheric dipole further speeds the clockwise circulation of the Beaufort Gyre. Satellite remote sensing of sea-surface height appears to support a recent rapid intensification of the Gyre

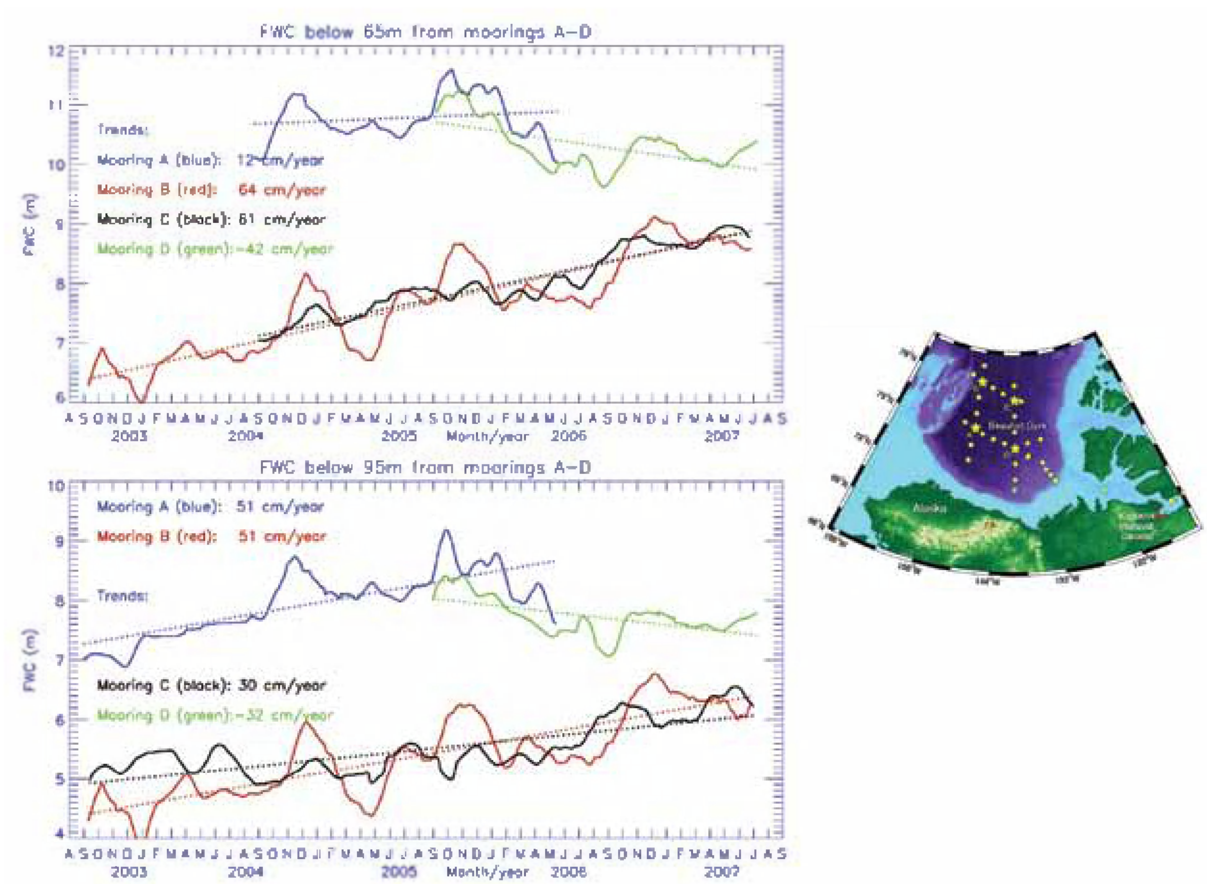


Fig. 3.2-4. Fresh water content (FWC, meters) variability and trends for moorings A-D (locations in inset map). FWC is calculated relative to 34.8 salinity at depths below 65m and 95m down to depth where salinity is less or equal to 34.8.

(Image: Andrey Proshutinsky, WHOI pers. comm.)

(Katharine Giles UCLCPOM pers. comm. and in prep) and Shimada's novel idea also gains weight from the analysis of change in the freshwater content of the Arctic Ocean by Rabe et al., (in press). As these authors point out, although there has been a fairly general increase in freshwater content of the Arctic Deep Basins between 1992-99 and 2006-08, amounting to > 3000 km3 between the surface and the 34 isohaline, the largest increase in FWC was observed in the western Canada Basin-Chukchi Cap, the area of increased ice-melt anticipated in Shimada's theory. Building on the intensive survey work during IPY by R/V Mirai (MR08-04) in summer 2008, the Japanese team intends to develop an understanding of the actual exchange of momentum, heat and salt at the interfaces between ice, ocean and atmosphere. A primary focus will be on studying the effects of sea-ice motion at a range of scales, from developing an understanding of the links between large scale sea ice motion and ocean circulation (including effects of large scale transitory events such as ENSO) to investigating the oceanic fluxes into surface mixed layer that arise through small scale sea ice motion/ocean turbulence. The Japanese team will be led by Koji Shimada (Tokyo University of Marine Science and Technology) and Kazutaka Tateyama (Kitami Institute of Technology).

Q: *What is the potential climatic impact of accessing the warm Pacific Summer Water (PSW) sublayer in the Canada Basin through an increased depth and intensity of turbulent mixing as the sea-ice retracts?*

A: The component parts of this problem are set out by Toole et al., (in press). The analysis of 5800 ITP profiles of temperature and salinity from the central Canada basin in 2004–2009 reveals a very strong and intensifying stratification that greatly impedes surface layer deepening by vertical convection and shear mixing, and limits the flux of deep ocean heat from the PSW sublayer to the surface that could influence sea ice growth/decay. At present, the intense pycnocline sets an upper bound on mixed layer depth of 30-40 m in winter and 10 m or less in summer, consistent with the analyses of Maykut and McPhee (1995) and Shaw et al., (2009). Toole et al., find these stratification barriers effectively isolate the surface waters and sea ice in the central Canada Basin from the influences of deeper waters. Although PSW heat appears not to be currently influencing the central Canada Basin mixed layer and sea ice on seasonal timescales, it is conceivable that over longer periods that heat-source could become significant. After all, as Toole et al., point out, the PSW heat now entering the central Canada Basin can't simply disappear; it is presently being stored in the ocean as intrusions in the 40-100 m depth range of sufficient magnitude to melt about 1 m of ice if its heat were somehow to be introduced into the mixed layer (Fig. 3.2-5). It is not yet obvious what physical mechanisms might allow the mixed layer to rapidly tap that heat. Winter 1-D model runs initialized with profiles in which the low-salinity cap in the upper 50 m was artificially removed failed to entrain significant PSW heat, even when more than

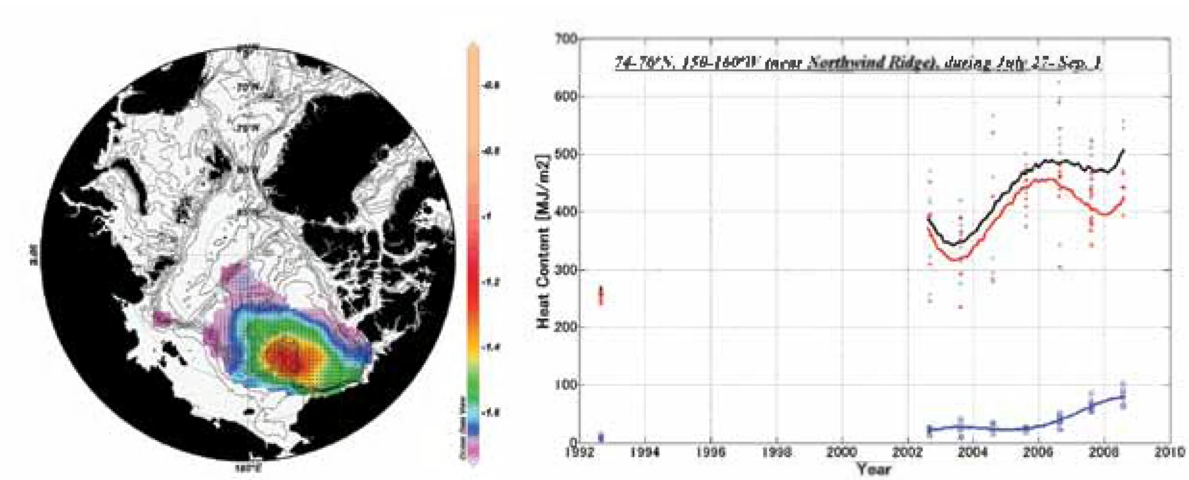


Fig. 3.2-5. (left) The extent of the warm Pacific Summer Water (PSW) sublayer in the western Arctic as shown by the subsurface ocean temperature distribution on the S=31.5 salinity surface, and (right) the temporal change in oceanic heat (MJm2) in selected upper layers of the western Canada Basin (74-76N, 150-160W), where blue: 0-20m, red: 20-150m, black: 5-150m.

(Images: unpublished by Koji Shimada, U. Tokyo)

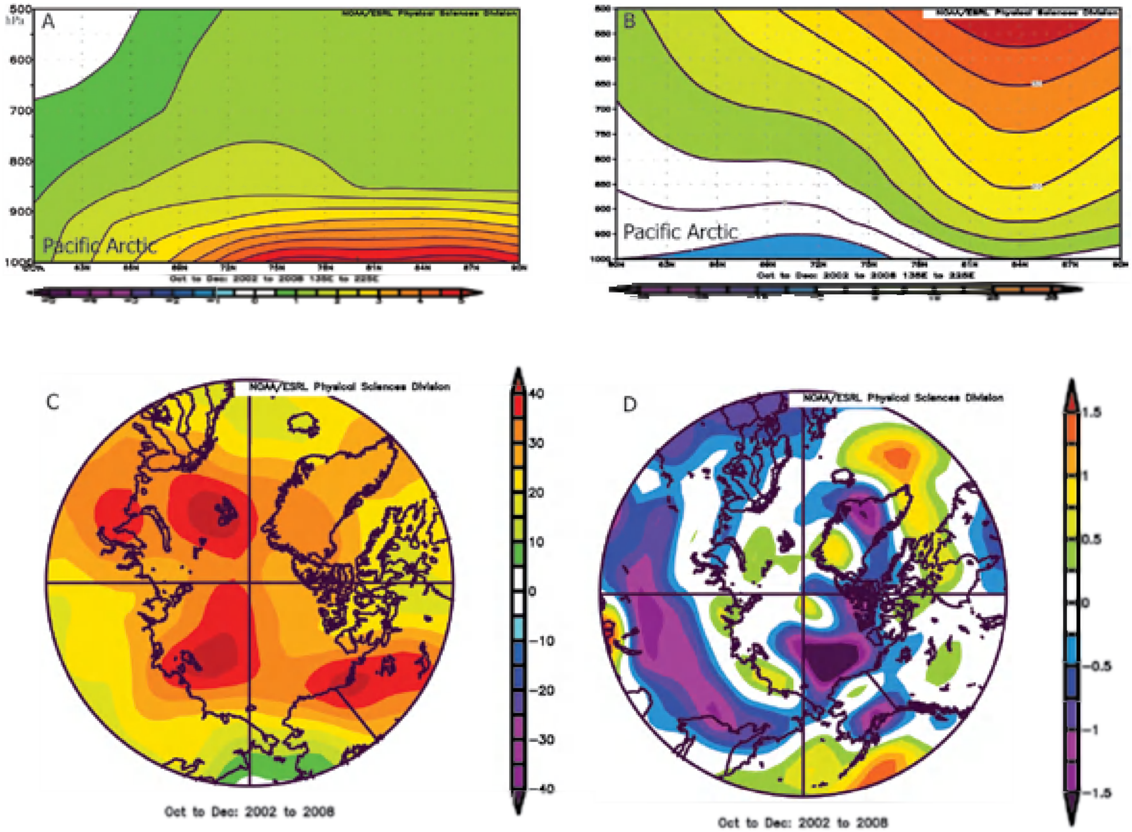


Fig. 3.2-6. Composite changes in the polar troposphere in October-December 2002-8 as the ice retracted from the western Arctic. Top left: vertical section of air temperature anomalies (°C) from the Bering Strait to the Pole. Top right: corresponding plot of geopotential height anomalies (dynamic metres). Lower left: the 500-1000 hPa thickness field anomaly showing, in particular, the band of greater thickness from the E. Siberian Sea to N Alaska, the main region of diminished sea-ice cover. Gradients in this field are the baroclinic contribution to the flow field. Lower right: the zonal wind anomaly field (ms-1) at 700 hPa showing the reduction in zonal wind component north of Alaska and western Canada.

(Images: Overland and Wang (2010)

three times the ocean cooling rate and 10 times the mechanical work of the standard winter model runs were applied to the mixed layer. It thus seems most likely to Toole et al., that if PSW heat is vented upwards in the central Canada Basin in the near future, that flux will be accomplished by a relatively weak, small-scale turbulent diffusive process. John Toole (WHOI) will lead on the two main questions that underlie this issue: What are the intensities and the physical mechanisms supporting turbulent diapycnal heat and fresh water fluxes between the Arctic surface mixed layer and the waters immediately underlying, and how might those fluxes change in future if we transition to a seasonal ice pack?

Q: *How might the ice-free polar ocean alter the regional atmospheric circulation?*

A: As the ice in the Pacific sector of the Arctic melted back to its record minimum in summer 2007 and the heat storage of the underlying ocean increased, the release of this heat in autumn eroded the stratification of the atmosphere to progressively higher levels leading to a clear change in the regional atmospheric circulation.

As Fig. 3.2-6 reveals, the retraction of sea-ice cover from the western Arctic in summer 2002-08 was accompanied by a warming throughout the Arctic troposphere and an increase in geopotential height anomaly in fall leading to a weakening of the poleward geopotential gradient. It is this weakening of the thermal wind that reduces the jet stream winds, according to Overland and Wang (2010). ["The consequences of increased September open water in the western Arctic and increased 1000–500 hPa thickness is an anomalous late autumn easterly zonal wind component, especially north of Alaska and Canada on the order of 40%". (op cit, P8)]. If so, this will be a highly significant result for the IPY. It therefore makes sense to inquire, in planning an observational legacy phase for the IPY, what continued coverage of the upper watercolumn would be needed to keep track of ocean-atmosphere heat exchange as the sea-ice dwindles away. It precisely this is the question that will be addressed by Jim Overland and Muyin Wang (NOAA-PMEL).

Q: *What ocean observing effort is needed to optimize the use of satellite altimetry and time-variable gravity in understanding change in Arctic Ocean hydrography and circulation?*

A: New developments in our observational capabilities present an unprecedented opportunity to make significant progress towards an integrated ability to address scientific issues of both the ocean and ice components of the Arctic Ocean system. In the coming decade, data from gravity satellites (GRACE and GOCE) and polar-orbiting altimeters (e.g., Envisat, ICESat, CryoSat-2, and upcoming ICESat-2 and SWOT) will provide basin-scale fields of gravity and surface elevation. Together with an optimally designed *in-situ* hydrographic observation network, these data sets will have the potential to significantly advance our understanding of the ice-ocean interactions, circulation and mass variations of the Arctic Ocean. Observations of Arctic Ocean hydrography have historically been sparse, consequently the circulation of the Arctic Ocean is poorly understood relative to that of lower latitude oceans. However, integrated analyses of new data from in-situ hydrographic observations, gravity satellites (GRACE and the upcoming GOCE) and polar-orbiting altimeters (e.g., Envisat, ICESat, CryoSat-2 and upcoming ICESat-2) show promise of redressing our poor understanding of the Arctic Ocean circulation and mass variations. Satellite altimeters observe the total sea level variation, including the signal caused by temperature and salinity fluctuations (the steric effect) and non-steric barotropic and mass variations. Separately, gravity satellites, like GRACE, measure temporal changes in the Earth's gravity field caused by the movement of water masses. A well-designed in-situ hydrographic sampling network – with judiciously deployed ocean instrument technologies – would ensure the most accurate quantification of the sea level, circulation and mass changes of the Arctic Ocean. Together with an optimally designed bottom pressure array for resolving shorter time scale processes, the steric (halosteric and thermosteric) and non-steric effects can be separated for quantifying changes in circulation and variability in Arctic sea level (Fig. 3.2-7). Furthermore, sea surface heights from altimetry when differenced with the mean Arctic satellite geopotential constrain the geostrophic circulation. As a first element under test, we recommend an investigation, assisted by detailed instrumented arrays, of the basis for the correlations that have been achieved to date between GRACE bottom pressure series (or ENVISAT SSH series) and time-series from Arctic bottom pressure recorders (ABPR). Second, Observing System Simulation Experiments (OSSE) will be necessary to optimize the cost and benefit of an expanded and sustained in-situ bottom pressure array, providing guidance on mooring locations and defining the measurement accuracy and frequency needed to provide acceptable levels of uncertainty. The research team will include Ron Kwok (JPL), Katharine Giles and Seymour Laxon (CPOM), Jamie Morison and Mike Steele (APL), Andrey Proshutinsky (WHOI).

Outputs from the Arctic Ocean: what questions should we be testing?

The focus of this 'outputs' subhead has largely to do with one topic – our projections of change in the efflux of ice and freshwater from the Arctic. As already mentioned, the expectation is that the freshwater outflows from the Arctic Ocean to the North Atlantic will strengthen and may suppress the rate of the climatically-important Atlantic Meridional Overturning Circulation (MOC).

Q: *Will any future increase in freshwater efflux from the Arctic pass west or east of Greenland?*

A: The climatic point of this question stems from the analysis of 200 decades of HadCM3 runs by Michael Vellinga (U.K. Met Office) who found that if the same freshwater anomaly (0.1 Sv*yr or 3000 km^3) is spread to depth, it has much less effect on any consequent weakening of the Atlantic MOC (Vellinga et al., 2008). If so, it matters whether any future increase in the freshwater outflow from the Arctic is likely to be incorporated into the dense water overflow system or is likely to pass to the west or east of Greenland. Two model studies currently make that prediction. In one, the results of coupled climate model experiments by Königk et al., (2007) using ECHAM 5 and the MPI-OM suggest that although the freshwater flux is expected to increase both east and west of Greenland, the loss of the dominant sea-ice component through Fram Strait suggests we should expect a much greater total increase in the efflux through the CAA (+48%)

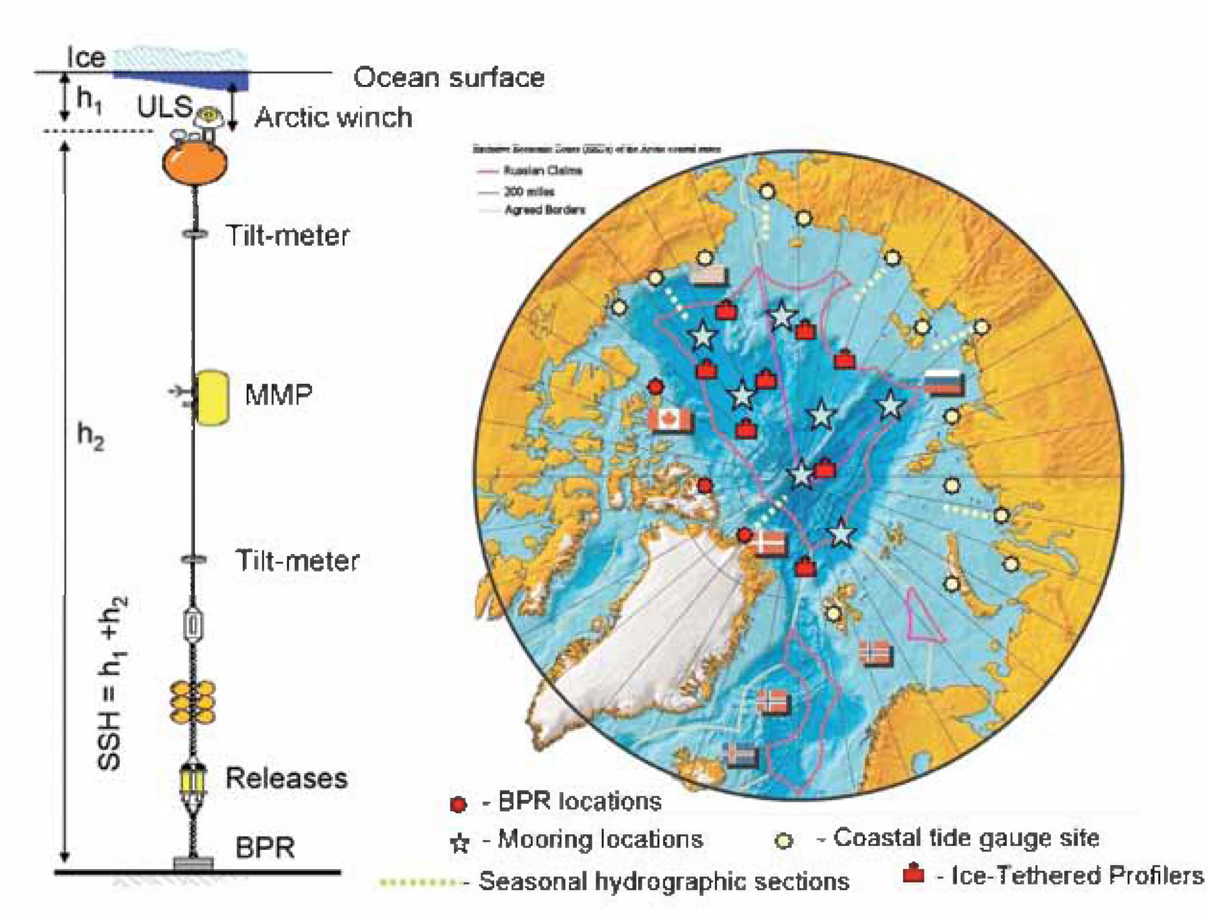


Fig. 3.2-7. Mooring components (left) and mooring, tide gauge and bottom pressure recorder (BPR) approximate locations to provide in-situ sustained observations in the Arctic Ocean to complement and validate space-borne measurements of ice thickness and sea surface heights in the Arctic.

(Image: Kwok et al., (2009)

by 2070-99 than through Fram Strait (+3% only). These results were based on IPCC AR4 experiments carried out in 2003/2004. Although the models have improved greatly in resolution and physics since these experiments were made in support of IPCC AR 4, these authors do not expect a fundamentally different result in AR5. The NCAR CCSM, which also has sufficient spatial resolution around Greenland to make the prediction, comes to the opposite conclusion, showing a much enhanced exchange between the Nordic Seas and the Arctic Ocean over the 21st Century. Rüdiger Gerdes (AWI) with Alexandra Jahn (McGill) and Laura de Steur (NPI) plan to address this important question with much higher resolved ocean-sea ice models and focusing on the ocean-observing aspects of that study.

Q: *What present and likely future factors control the freshwater outflow west of Greenland?*

A: The establishment of a simple statistical model (Ingrid Peterson, BIO) in which the surface wind anomaly outside the CAA is used to link the sea level set-up in the Beaufort Sea Shelf with the sea-level gradient along the NW Passage provides a basis for maintaining Prinsenberg's (BIO) transport series through Lancaster Sound at modest cost using a reduced moored array with modelling in support (for explanation see Dickson (2009), section 8.1.2). Humfrey Melling (DFO) has achieved, during 2009, the recovery of a full moored transport array from Nares Strait after two years. Further south, the monitoring of ocean fluxes through Davis Strait using SeaGliders to collect and return ocean profiles autonomously even in the presence of ice has become a proven technique (Craig Lee, UW pers. comm.). Thus the means of measuring the important oceanic freshwater fluxes west of Greenland in the longer term have become a reality. Our attention has now started to shift towards the actual and theoretical constraints on these transports and, most recently, towards the role of Greenland as a potential driver of change in this freshwater delivery

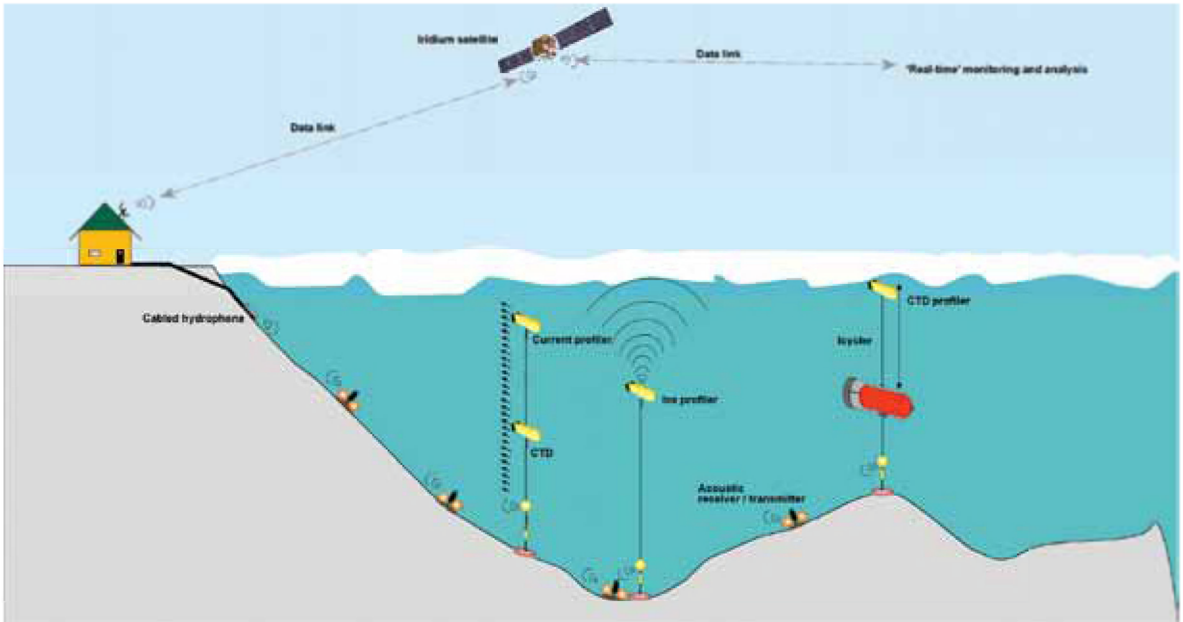


Fig. 3.2-8. A potential means of achieving a difficult but climatically-important measurement at modest cost. Through cooperation with the Canadian Defense Research Development Corporation (DRDC), it is planned to use an acoustic/cable/satellite link to provide oceanographic data from Barrow Strait in real time.
(Image: Simon Princenberg BIO)

system. Some of these constraints are reasonably well-known. In general terms, we know that when the Arctic Oscillation is in its negative phase, the atmospheric circulation tends to accumulate freshwater in the Amerasian Basin and decrease it in the Eurasian Basin (vice versa during the positive phase). This tends to increase the freshwater export by creating larger upper-layer thicknesses in the passages of the CAA compared with Fram Strait. Although the freshwater outflow leaving the CAA is normally sufficiently distinct in density to pass south along the west side of Baffin Bay or over-ride the fresh tongue passing north in the opposite sense along the W Greenland Margin, this is not necessarily an unvarying situation.

As Rudels (2009) has recently proposed on the basis of the present Θ-S structure to the west of Greenland, the freshwater transport in the W Greenland Current may well modulate or control that outflow. By this novel theoretical idea, an increased melting of the Greenland ice-cap may, in the outlook period, lower the density at large in E Baffin Bay sufficiently to alter the path or slow the southward flow of the CAA freshwater outflow. An increased freshwater production from Greenland also does not appear unlikely. On the contrary, it now appears demonstrable that warming of the seas around Greenland has been a cause of a recent acceleration in the four main outlet glaciers that drain the interior. Thus in addition to the main task of establishing an optimal observing system capable of capturing the changing character of the freshwater outflow through the CAA and Baffin Bay/Davis Strait at modest cost over years to decades (Fig. 3.2-8), a second task of establishing a sound theoretical footing for the disruptive effects of an increasing ice-melt from Greenland has arisen. Craig Lee (UW), Simon Prinsenberg and Humfrey Melling (DFO) and Bert Rudels (Univ. Helsinki) will investigate. Fiamma Straneo (WHOI) and Kelly Faulkner (OSU) will continue their fjord-scale assessment of the role of the warming ocean in accelerating the ice-flux from Greenland.

Designing an optimal ocean observing system for the IPY legacy phase

If we are to achieve more for (presumably) less funding in the post-IPY phase, it will be by close coordination and focus. This is not a new realization. The thrust of this Report is no different to the primary conclusion of the AON Design and Implementation (ADI) Project Plan following its task force meeting in November 2009, that '…there is now an urgent need for coordination, consolidation and optimization of the existing observing system elements as well as for development of a broader strategy that includes more detailed design studies to enhance and sustain the observing system'.

As Carl Wunsch made clear in his talk to the OceanObs09 meeting in Venice in September 2009, achieving a focused, coordinated and scientifically appropriate observing system will, initially at any rate, have less to do with Observing System Simulation Experiments (OSSE) than with asking and re-asking ourselves 'what is the question?'. Other studies agree. The ICSU 'Visioning' exercise in summer 2009 was one such attempt to define the observing task in hand by consulting widely on the subject of 'What is the most important research question in Earth system research that needs answering in the next decade; and why?' (See also Commentary by Reid et al., 2009). The ADI Task Force also named its first design consideration for an Arctic Observing System to be 'Guidance by science questions'. The testing of what we now believe to be the driving questions on the role of our northern seas in climate is the method we use here to bring the available effort to maximum focus. Naturally, the several lists of questions emerging from these approaches have varied. In the ICSU exercise, the questions were comprehensive, but rather broad-brush (e.g. 'How will polar climate respond to continued global warming? How and why is the cryosphere changing?'). The questions driving the science of the U.S. Study of Environmental Arctic Change (SEARCH) and of the present Arctic Observing Network are also of a rather 'large scale' nature (e.g. 'What is happening with Arctic sea-ice? Are carbon pathways in the Arctic marine system undergoing changes that are consequential, locally and globally' etc.).

The AOSB approach (this Report) is intentionally the most specific as regards the questions under test, but is different in that it covers both the pan-Arctic and the subarctic seas. This reflects the primary conclusion of the 2008 iAOOS Report for AOSB (Dickson, 2009) that we cannot understand Arctic change just by studying the Arctic; that change may certainly be imposed on the Arctic Ocean from subarctic seas, including a changing poleward ocean heat flux that would appear influential in determining the present state and future fate of the perennial sea-ice. The signal of Arctic change is expected to have its major climatic impact by reaching south through subarctic seas, either side of Greenland, to modulate the Atlantic thermohaline 'conveyor'. The changes and exchanges of both Arctic and subarctic seas thus seem necessary to understanding the full subtlety of the role of our Northern Seas in climate.

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3.3 Southern Ocean Observing System

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Historically, the Southern Ocean has been one of the least well-observed parts of the ocean. The Southern Ocean is remote from population centers and shipping lanes. Strong winds, large waves and sea ice provide additional reasons for vessels to avoid the region. Oceanography is also a young field. At the time of IGY, studies of the open ocean were rare, particularly in the Southern Ocean. Systematic circumpolar exploration of the region was conducted by George Deacon on the Discovery II in the 1930s, by Arnold Gordon and colleagues on the Eltanin in the late 1960s and early 1970s, within the framework of the International Southern Ocean Studies (ISOS) and Polar Experiment-South (POLEX-South) programs in 1970s-1980s, and during the World Ocean Circulation Experiment (WOCE) and Joint Global Ocean Flux Study (JGOFS) programs in the 1990s. Each of these expeditions was a major step forward in the exploration and understanding of the Southern Ocean. However, each survey suffered from similar weaknesses: each circumpolar survey took on the order of a decade to complete, was based on ship transects widely separated in space and time, and was heavily biased towards the summer months. A number of important Southern Ocean biological studies were conducted, including Biological Investigations of Marine Antarctic Systems and Stocks (BIOMASS) in the 1980s and Global Ecosystem Dynamics (GLOBEC) in recent years, but these efforts tended to focus on particular regions since a comprehensive circumpolar survey of the shallow and deep waters around Antarctica was not technically feasible. Many valuable studies were conducted as stand-alone investigations, but from these alone it was difficult to synthesise a circumpolar view of the status of the Southern Ocean. Satellite data were however proving increasingly useful for synoptic studies, and the advent of the Argo profiling float programme around 2003 began to provide useful data from just below the surface down to 2000m, though not from areas extensively covered by winter sea ice.

Against this background, IPY was a major leap forward. The unprecedented level of cooperation and coordination during IPY – between nations, disciplines, scientists, logistic providers and communicators – allowed a synoptic "snapshot" of the state of the Southern Ocean to be obtained for the first time. Advances in technology played a huge role as well, and IPY was well-timed to take advantage of revolutions in ocean observations and genetic techniques. New tools like autonomous profiling floats and miniaturised oceanographic sensors suitable for deployment on marine mammals have allowed year-round, broad-scale sampling of the Southern Ocean for the first time, including the ocean beneath the sea ice. DNA barcoding and environmental genomics are providing completely new ways to investigate evolution and biodiversity, ecosystem function and biological processes. New cryospheric satellites provided encouragement that variables of essential relevance to climate, such as sea ice volume and other characteristics relevant to air-sea-ice interaction, might be derived from space-based observations. New trace-metal clean techniques were developed, allowing many elements and isotopes to be measured for the first time throughout the full ocean depth.

IPY was also well-timed because at least some regions of the Southern Ocean have experienced rapid change in recent decades. The western Antarctic Peninsula has warmed dramatically; the duration of the sea ice cover has decreased near the peninsula at rates comparable to those observed in the Arctic, and increased in the Ross Sea; the collapse of ice shelves has opened up new areas of ocean where the process of seabed colonisation can be observed; and large but regionally-varying changes in temperature and ocean circulation have taken place in the Antarctic Circumpolar Current. The IPY therefore provided both a unique near-synoptic assessment of the physical, biogeochemical and biological state of the Southern Ocean and insight into the extent, drivers and impacts of Southern Ocean change.

Many aspects of the Southern Ocean were measured for the first time during IPY. Examples include measurements of trace metals like iron and mercury; patterns of pelagic and benthic biodiversity from near-shore Antarctic waters to the deep sea; and the circulation and water mass properties beneath the winter sea ice. A summary of the observations completed in the Southern Ocean during IPY and research highlights from this work are presented in *Chapter 2.3*.

The IPY Science Plan called for development of ocean observing systems in both the Arctic and the Southern Ocean. In 2006, at a meeting in the margins of the SCAR Open Science Conference in Hobart, an international consortium of scientists spanning all disciplines of Southern Ocean research started to develop a strategy for sustained observations of the Southern Ocean. One of the greatest achievements of Southern Ocean science during IPY was the demonstration that sustained observations of the Southern Ocean were feasible, cost-effective and urgently needed. IPY in this sense served as a demonstration or pilot project for the Southern Ocean Observing System (SOOS). Commitment to resource and implement the SOOS will leave a significant and long-lasting legacy of Southern Ocean IPY.

The scientific rationale and implementation strategy for the SOOS is summarised in Rintoul et al., (2010) and described in detail in Rintoul et al., (2010). As discussed there, sustained observations of the region are needed to address key research questions of direct relevance to climate and society, including the global heat and freshwater balance, the stability of the overturning circulation, the future of the Antarctic ice sheet and its contribution to sea-level rise, the ocean uptake of carbon dioxide, the future of Antarctic sea ice, and the impacts of global change on Southern Ocean ecosystems.

The limited available observations suggest the Southern Ocean is changing: the region is warming more rapidly, and to greater depth, than the global ocean average; salinity changes driven by changes in precipitation and ice melt have been observed in both the upper and abyssal ocean; the uptake of carbon by the Southern Ocean has slowed the rate of climate change but increased the acidity of the Southern

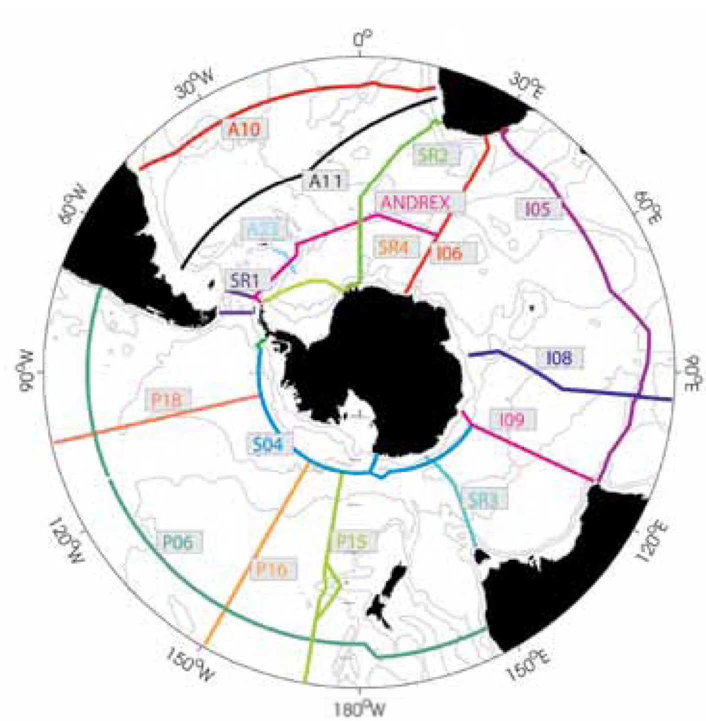

Fig. 3.3-1. Repeat hydrographic sections proposed for SOOS. Each of these lines has been occupied previously during the World Ocean Circulation Experiment and the Climate Variability and Predictability Program.

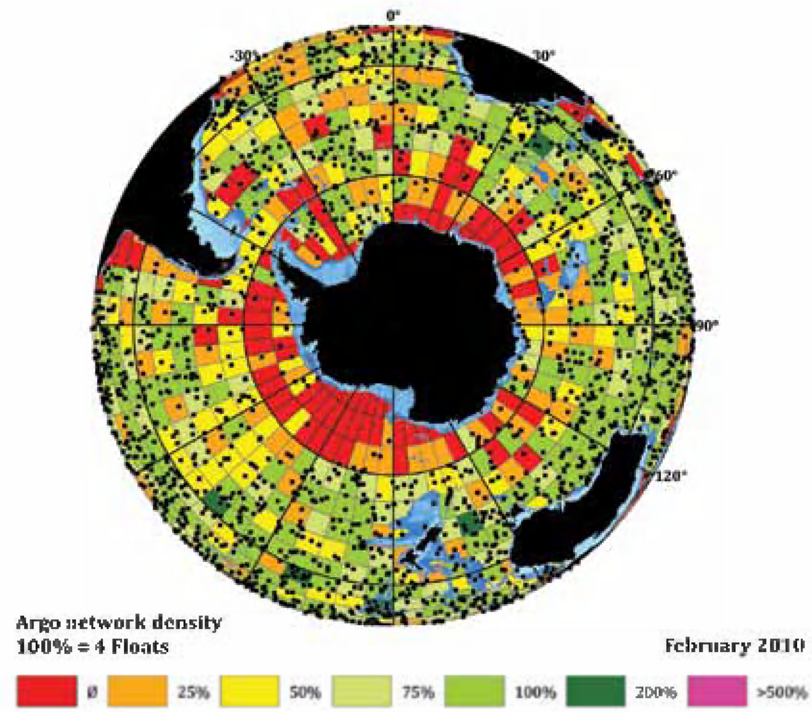

Fig. 3.3-2. Present status of Argo float array in the Southern Ocean. Note that coverage decreases with increasing latitude, with few observations in the sea ice zone.

Provided by Mathieu Belbeoch of JCOMMOPS

Ocean; and there are indications of ecosystem changes. However, the short and incomplete nature of existing time series means that the causes and consequences of observed changes are difficult to assess. Sustained, multi-disciplinary observations are required to detect, interpret and respond to change. The SOOS will provide the long-term measurements required to improve understanding of climate change and variability, biogeochemical cycles and the coupling between climate and marine ecosystems.

The SOOS includes the following elements:

- **Repeat hydrography:** Hydrographic sections from research vessels are the only means of sampling the full ocean depth. Repeat hydrography provides water samples for analysis of those properties for which in situ sensors do not exist, the highest precision measurements for analysis of change and for calibration of other sensors, accurate transport estimates and a platform for a wide range of ancillary measurements. The location of the recommended repeat sections is shown in Fig. 3.3-1. On each transect, measurements will be made of temperature, salinity, velocity, oxygen and oxygen-18, nutrients, components of the carbon system, tracers and a wide range of biological measurements (eg bio-optics, primary production, phytoplankton pigments, net tows and acoustics). Trace elements and isotopes will be measured on some sections.
- **Underway sampling from ships:** The full hydrographic sections need to be complemented by more frequent underway sampling transects, to reduce aliasing of signals with time-scales shorter than the 5-7 year repeat cycle of the repeat hydrography. Measurements will be made of temperature and salinity (both at the surface and below the surface using expendable profilers), nutrients, carbon, phytoplankton and, on some vessels, velocity.
- **Enhanced Southern Ocean Argo:** Year-round, broad-scale measurements of the ocean are needed to address many of the key science challenges in the Southern Ocean. These measurements can only be obtained using autonomous platforms like profiling floats. A sustained commitment to maintain and enhance a profiling float array in the Southern Ocean is critical. Argo has made a particularly significant contribution in remote areas like the Southern Ocean, where few ship observations exist (Fig. 3.3-2). Modified Argo floats are needed to obtain data from beneath the winter sea ice.
- **Time-series stations and monitoring of key passages:** Several key passages and boundary currents in the Southern Ocean are high priorities

for sustained observations because of their role in the global-scale ocean circulation and because they offer the best opportunities to measure water mass transport. High priority sites include Drake Passage and other chokepoint sections across the Antarctic Circumpolar Current and the dense water overflows and boundary currents carrying Antarctic Bottom Water to lower latitudes as part of the deep branch of the global overturning circulation (Fig. 3.3-4).

- **Phytoplankton and primary production:** Sustained observations of phytoplankton biomass, species distributions and primary production are needed to relate biological variability to environmental change. Ocean colour satellites are critical as they provide the only circumpolar view of biological activity in the Southern Ocean. In situ measurements are needed to refine algorithms used to interpret the satellite data, to relate surface chlorophyll to column-integrated production, for analysis of additional pigments and phytoplankton community composition, and to relate biological variables to simultaneous measurements of the physical and chemical environment. The repeat hydrographic sections (Fig. 3.3-1) provide the primary means of sampling the subsurface ocean for biological parameters; underway observations from ships of opportunity (Fig. 3.3-3) provide more frequent sampling of the surface ocean. Measurements needed include fluorometry and fast repetition rate fluorometry, phytoplankton pigments and size distribution, transmissometry and microscopy.
- **Zooplankton and micro-nekton:** Antarctic plankton may be particularly sensitive and vulnerable to climate change. Global warming will affect sea ice patterns and plankton distributions (e.g. a decrease in the geographical extent of sea ice has been linked to a decline in krill numbers). Increased UV levels, ocean acidification, invasive plankton species, pollution and harvesting impacts are also potential threats. Underway sampling by continuous plankton recorders provides the backbone of the zooplankton observing system, but needs to be supplemented by targeted net tows and acoustic sampling.
- **Ecological monitoring:** Observations of the distribution and abundance of top predators (fish, penguins, sea birds, seals and whales) can provide indications of changes in the ecosystem as a whole. Long-term monitoring programs have been established at a few sites around Antarctica and must be continued. The comprehensive sampling of physical

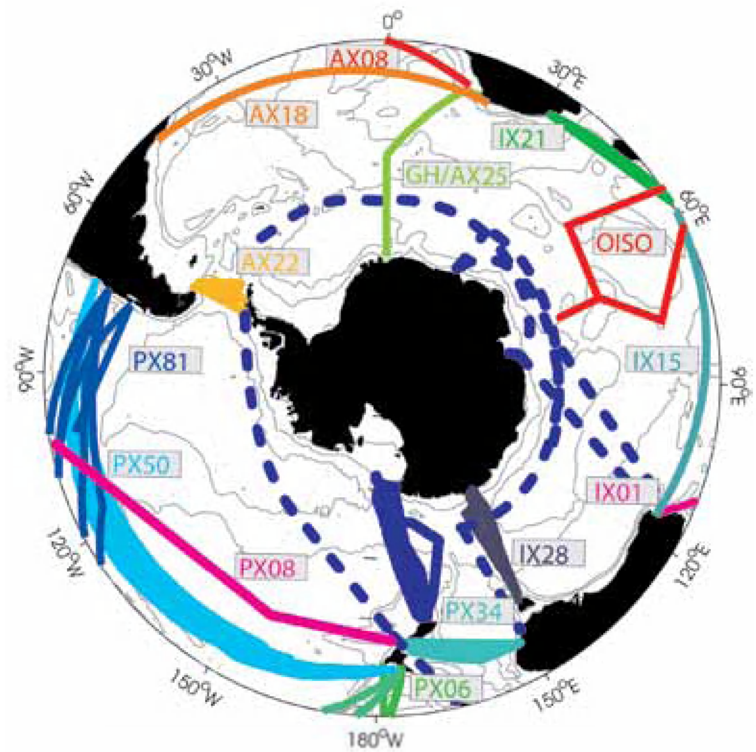

Fig. 3.3-3. Routes of ships-of-opportunity conducting underway observations in the Southern Ocean.

biogeochemical and biological variables carried out in the Palmer Long Term Ecosystem Research program, for example, has provided important insights into the dynamics of the ecosystem of the western Antarctic Peninsula and its sensitivity to change. Monitoring of predators has been carried out at a number of locations as part of the Ecosystem Monitoring Program of the Commission for the Conservation of Antarctic Marine Living Resources. However, in many cases there is a lack of simultaneous physical and biogeochemical data, and information on lower trophic levels, to allow the causes of changes observed in higher trophic levels to be determined. The SOOS aims to provide the integrated multi-disciplinary observations needed to understand the interactions between physics, chemistry and biology in the Southern Ocean. Continued long-term and large-scale observations of functional and structural changes in ecosystems are essential to assess the sensitivity of ecological key species and to ground-truth predictive models. The establishment of a series of core long-term biological monitoring sites would be extremely beneficial both in documenting biological responses and trends, and allowing explicit tests of predictive hypotheses. In addition there is a need to develop new sensors to rapidly measure biological and chemical variables.

- **Animal-borne sensors:** Oceanographic sensors deployed on birds and mammals can make a significant contribution to SOOS in two ways: by relating predator movements, behavior and body condition to fine-scale ocean structure, and by providing profiles of temperature and salinity from regions of the Southern Ocean that are difficult to sample by other means (e.g. beneath the winter sea ice). SOOS should maintain and enhance the program of seal tag deployments established during IPY (Fig. 3.3-5) and develop a multi-species tagging approach along the lines of the Tagging of Pacific Pelagics (TOPP) program.
- **Sea ice observations:** Measurements of both the extent and thickness of sea ice are needed to monitor changes in sea ice production and any related impacts on the climate system and/or Southern Ocean ecosystem processes. A variety of satellite instruments provide continuous, circumpolar observations of sea ice extent, with varying spatial resolution. Measuring sea ice volume, however, remains a significant challenge and requires in situ sampling to provide ground-truth data for the satellite sensors. These measurements need to include a combination of

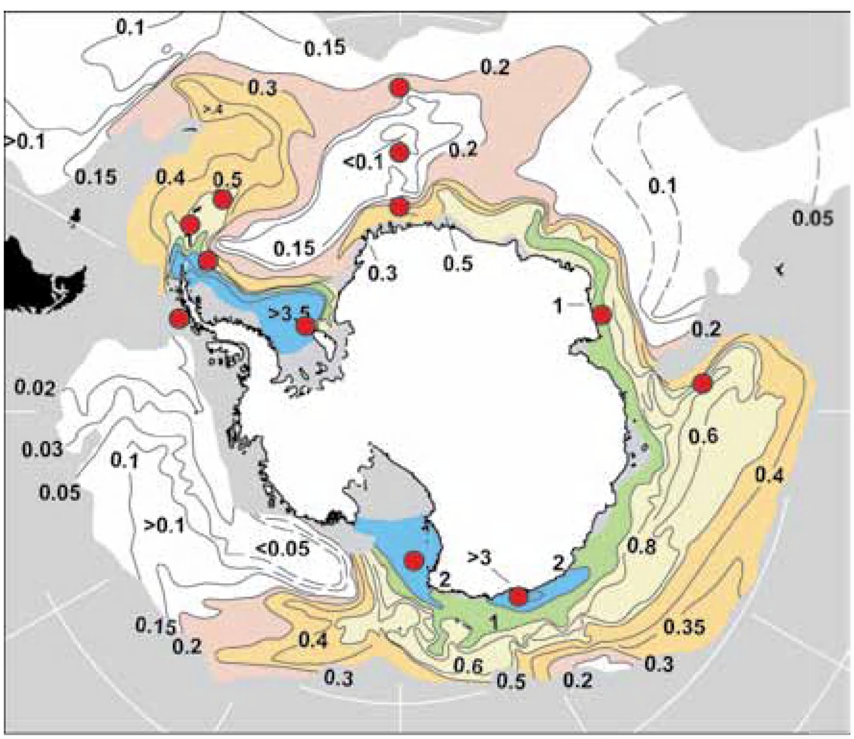

Fig. 3.3-4. Map of proposed moored arrays to sample the primary Antarctic Bottom Water (AABW) formation and export sites, as part of a coordinated global array to measure the deep limb of the global overturning circulation. The map shows the inventory of chlorofluorocarbon 11 (CFC-11) in the density layer corresponding to AABW, and thus the pathway of AABW from its source regions (blue) down the concentration gradient through green to orange.
Source: Orsi et al., 1999

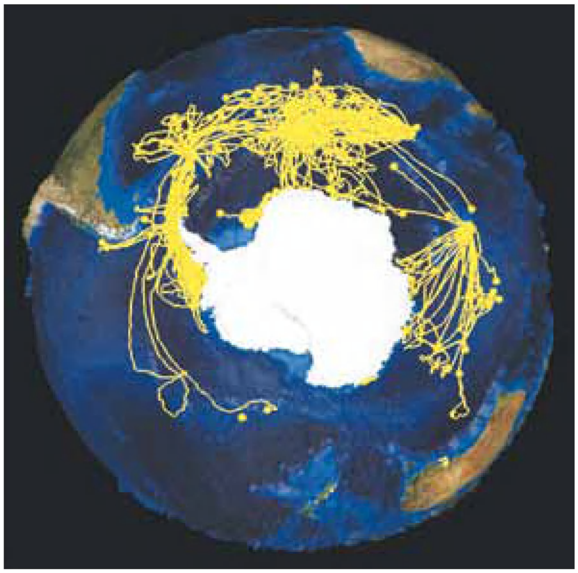

Fig. 3.3-5. Map showing the location of temperature and salinity profiles collected by seals instrumented with oceanographic sensors as part of the MEOP program of the IPY. More oceanographic profiles have been collected in the sea ice zone using seals than using traditional oceanographic tools like ships and floats.

sampling from ice stations, helicopters, autonomous vehicles, moorings and underway observations.

- **Enhanced meteorological observations:** An enhanced atmospheric observing system is needed to improve Antarctic and southern hemisphere weather forecasts. Climate research benefits from improved weather forecasts in the increased accuracy of the flux products derived from Numerical Weather Prediction (NWP) model reanalyses. The air-sea fluxes of heat and moisture are poorly known at high southern latitudes, making it difficult to diagnose the interactions between atmosphere, ocean and sea ice that lay at the heart of climate variability and change.
- **Remote sensing:** Access to high quality remote sensing data is particularly critical in the Southern Ocean, where *in situ* data is difficult to obtain. High priority satellite systems include radar and laser satellite altimetry, ocean colour, scatterometer, infrared and microwave sea surface temperature, passive microwave and synthetic aperture radar. Continuity of space-based measurements is absolutely essential, since these are the sole major source of data for the whole of the continent and its surrounding ocean, where measurements on the ground or on the sea are difficult, dangerous and not normally made year-round. Recommendations for satellite observations of the cryosphere, including sea ice, are given in the Cryosphere Theme document produced for the Integrated Global Observing Strategy (IGOS) Partnership (www.eohandbook.com/igosp/cryosphere.htm).

The scientific achievements of IPY, summarised in *Chapter 2.3*, demonstrate the power and value of integrated, multi-disciplinary observations in the Southern Ocean. Sustained measurements of the Southern Ocean are needed to address some of the most urgent issues facing society, including climate change and its impacts and the effective management of marine resources. IPY demonstrated the feasibility and relevance of a sustained Southern Ocean observing system. The SOOS plan presents a community view of what needs to be measured as part of a Southern Ocean observing system. The challenge in the years ahead is to build on these IPY achievements to ensure a sustained commitment is made to observing the Southern Ocean. These observations will be key contributions to the Global Ocean Observing System (GOOS), which itself is the ocean component of the Global Climate Observing System (GCOS). The GCOS advises the Parties to the UN Framework Convention on Climate Change what observations to make, where to make them and to what standards. In turn, both GOOS and GCOS are elements of the Global Earth Observing System of Systems (GEOSS) developed by the Group on Earth Observations, a partnership between governments and international organisations (http://earthobservations.org/).

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3.4 International Arctic Systems for Observing the Atmosphere (IASOA)

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Introduction

International Arctic Systems for Observing the Atmosphere (IASOA) is a program developed to enhance Arctic atmospheric research by fostering collaborations among researchers during International Polar Year (IPY) 2007–2008 and beyond. The member observatories are Abisko, Sweden; Alert and Eureka, Canada; Barrow, U.S.A.; Cherskii and Tiksi, Russian Federation; Ny-Ålesund, Norway; Pallas and Sodankylä, Finland; and Summit, Greenland (Fig. 3.4-1). All of these observatories operate year-round, with at least minimal staffing in the winter months and are intensive and permanent. IASOA is one of the few IPY projects focusing on atmospheric research in the Arctic, as shown in the IPY "honeycomb" plot of projects (Fig. 3.4-2).

In this chapter we present information about the IASOA project's goals and accomplishments during IPY, including our participation in high-profile meetings and conferences, our commitment to supporting long-term atmospheric measurements in the Arctic, the development of a comprehensive web site (www.iasoa.org) and observatory upgrades.

IASOA Outreach and Legacy Activities

International Polar Year Media Day

During the last few weeks of IPY, the outreach and education staff at the IPY International Program Office organized a "media blitz" to showcase IPY projects. As a part of this, IASOA was featured on 10 February 2009 on www.ipy.org. For this media day, researchers at each IASOA observatory were asked to provide up-to-date information on IPY research at their observatories and to be available for journalists to interview by phone. On www.iasoa.org a media day page was created (Fig. 3.4-3), which highlighted recent activities at six of the observatories (http://iasoa.org/iasoa/index.php?option=com_content&task=blogcategory&id=40&Itemid=147).

American Geophysical Union (AGU) Sessions

In an effort to encourage and support pan-Arctic research, IASOA proposed a session to the 2008 Fall American Geophysical Union (AGU) conference. The response to our session was very good, with enough abstracts to have both oral and poster sessions. Authors were encouraged to submit papers on studies using data from two or more IASOA observatories. Twenty-seven papers covering a broad range of topics were presented. All abstracts submitted to our AGU session can be found on the IASOA web site science page: http://iasoa.org/iasoa/index.php?option=com_content&task=blogcategory&id=41&Itemid=149.

Cooperative Arctic Data and Information Service (CADIS)

The Cooperative Arctic Data and Information Service (CADIS) is an IPY data management and archival project, primarily for Arctic Observing Network (AON) and Study of Environmental Arctic Change (SEARCH) principal investigators (http://aoncadis.ucar.edu/home.htm, Fig. 3.4-4). The National Science Foundation (NSF) supports CADIS, which is a joint project of the University Corporation for Atmospheric Research (UCAR), the National Center for Atmospheric Research (NCAR) and the National Snow and Ice Data Center (NSIDC). IASOA is currently in the exploration phase of supplying metadata and data links to CADIS.

Fig. 3.4-1. Map of IASOA stations.
(Illustration: Lisa Darby)

IASOA post-IPY Legacy Plans

Now that IPY is over, we are planning for IASOA's future. As part of the process of establishing a legacy of operations for IASOA after IPY, IASOA has requested that the International Arctic Science Committee (IASC) consider endorsing IASOA.

We anticipate that IASOA will function as one of the building blocks for the atmospheric component of Sustaining Arctic Observing Networks (SAON).

We are also currently in the planning stages for establishing a scientific steering committee that will oversee the continuation of the promotion of pan-Arctic research utilizing measurements obtained at the IASOA observatories. Ideally we would like to have two representatives from each observatory participate. Additionally, we will organize science meetings focusing on atmospheric measurements from IASOA observatories.

IASOA Web Site

The IASOA website (www.iasoa.org, Fig. 3.4-5) is a continually evolving resource for Arctic researchers. There is a page for each IASOA observatory, which includes a general overview of the observatory, a listing of available measurements and principle investigators, links to data bases, news stories and observatory contacts (Fig. 3.4-6). In recent months we have posted more information about available data sets. The easiest way to look for information about Arctic atmospheric data is through the "Observatories-at-a-Glance" page (Fig. 3.4-7). We provide links directly to the data when possible, otherwise we post contact information for requesting the data. Also in recent months we have added a "Weather-at-a-Glance" page that shows web cams and current weather data for each observatory. We have also added a travel blog page so visitors to our web site can see pictures from various observatories. We welcome contributions from researchers to post on the web site, particularly links to data bases, news stories and meeting announcements.

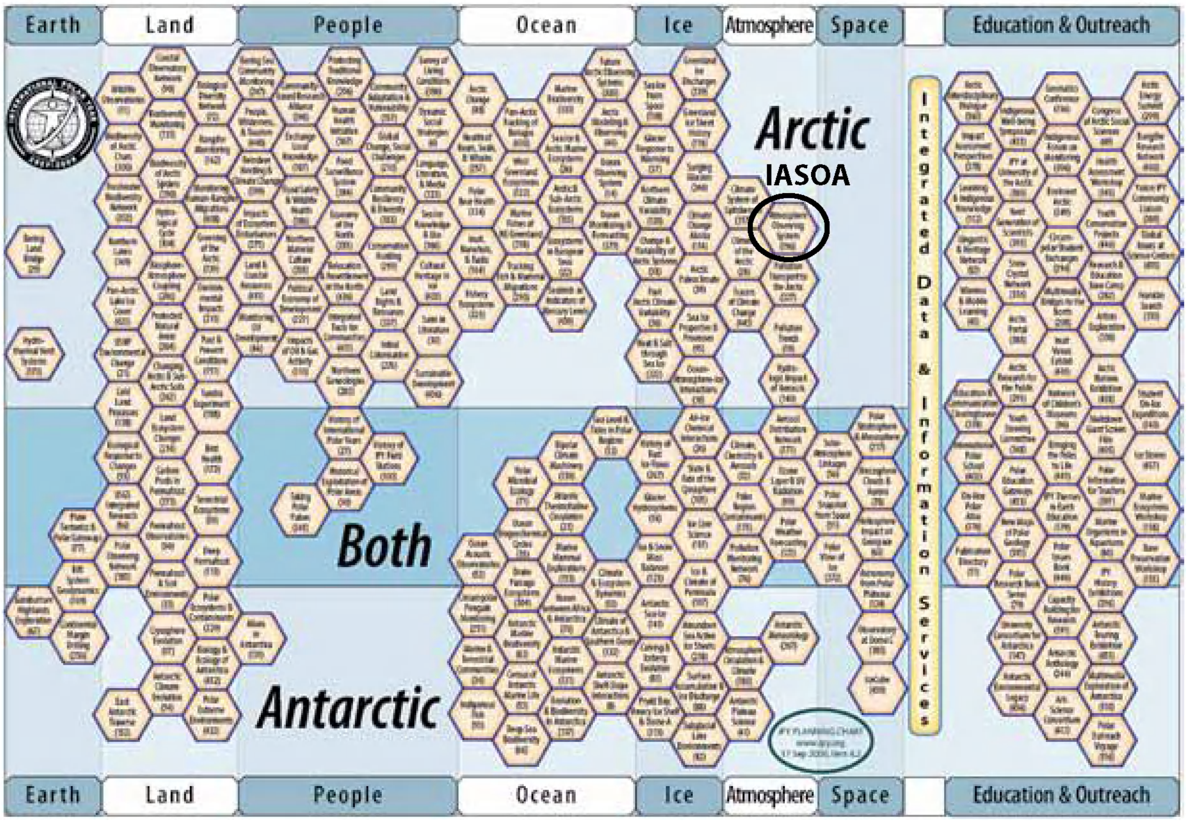


Fig. 3.4-2. IPY project chart showing the position of the IASOA project (no. 196).

Observatory Upgrades

Numerous instrument upgrades, new instrument installations and new programs occurred over the course of IPY at several of the IASOA observatories. A few examples follow.

Eureka, Nunavut, Canada *(80.050 N, 86.417 W, 10 m ASL (32.8 ft ASL))*

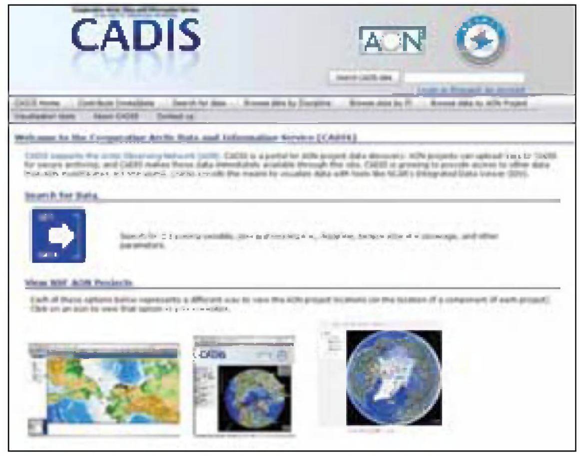
- A new flux tower (Fig. 3.4-8)
- Several CIMEL sunphotometers for the Aeronet Network
- A Baseline Surface Radiation Network (BSRN) station
- Starphotometer
- Precipitation sensor suite
- VHF wind tracking radar
- All sky imager
- Spectral airglow temperature imager
- The Canadian Network for the Detection of Atmospheric Change (CANDAC) Millimeter Cloud Radar (MMCR) replaced the National Oceanic and Atmospheric Administration (NOAA)/ Study of Environmental Arctic Change (SEARCH) MMCR.
- Rayleigh-Mie-Raman lidar and a tropospheric ozone lidar
- With IPY funding, the level of technical support at the site was increased to provide more reliable data collection and transmission
- In addition to equipment upgrades, Eureka scientists hosted visiting diplomats as part of the "Northern Diplomatic Tour," as well as Grade 11-12 students and teachers as part of the Northern Experience Program.

Summit, Greenland *(72.580 N, 38.48 W, 3238 m ASL (10623.4 ft ASL))*

- Summit observatory released a strategic plan highlighting climate sensitive year-round observations, innovative research platforms and operational plans to increase renewable energy to maintain the pristine platform. Summit also has a new multi-channel gas chromatograph for

Top left -
Fig. 3.4-3: Screen shot of media day page.

Top right -
Fig. 3.4-4: Screen shot of CADIS web site main page.



Bottom left -
Fig. 3.4-5: IASOA home page.

Bottom right -
Fig. 3.4-6: Summit, Greenland site page.

Fig. 3.4-7: Screen shot of Observatories-at-a-Glance page.

continuous measurement of trace halocarbon and chlorofluorocarbons gas concentrations.

- A CO_2 and NOx flux facility went online in summer 2008. The flux facility was built underground and covered with snow, with only the flux tower exposed.
- The new Temporary Atmospheric Watch Observatory was constructed.

Cherskii, Russian Federation *(69°N, 161°E)*

- A collaboration between the University of Alaska Fairbanks (UAF) and NOAA has resulted in tower measurements of CO_2 and CH_4. The CH_4 measurements will be combined with new modeling methods developed at NOAA to infer regional-scale CH_4 fluxes. These estimates will complement CH_4 fluxes determined by UAF using a flux gradient method. This work is timely and important due to the large carbon stores, mostly CH_4, that could be released from permafrost regions in response to Arctic warming.

- The researchers at Cherskii also partnered with The Polaris Project (www.thepolarisproject.org/), providing undergraduate students with the chance to do field work in the Siberian Arctic.
- Scientists at Cherskii are comparing disturbed and undisturbed areas of permafrost to determine the effects of thawing permafrost.

Barrow, United States *(71.323 N, 156.609 W, 11 m ASL (36 ft ASL))*

- Barrow observatory has two new systems for aerosol size and chemistry composition, as well as new persistent organic pollutant (POPs) measurements. The meteorology measurement and data system has been completely upgraded.
- Barrow provided ground services and lodging for the Polarcat campaign.

Tiksi, Russian Federation *(71.580 N, 128.92 E)*

Tiksi is located in a boundary region at the confluence of Atlantic and Pacific influences, resulting in exposure to a wide variety of air mass types. Atmospheric conditions range from pristine to polluted, providing a natural laboratory to assess the radiative effects of aerosols and resulting cloud properties and also the influences various pollution source regions of Russia, Northern America, Europe and Central Asia have on regional air quality.

Tiksi is located in the Lena River basin. The Lena River is the only major Russian River for which most of the drainage basin is underlain by permafrost, making it hydrologically complex and particularly vulnerable to climatic warming. Tremendous stores of carbon are presently locked in the permafrost of this river basin, and the regimes of precipitation and evaporation are very important for regional changes in the surface fluxes of CO_2 (increases to atmosphere with surface drying) and CH_4 (increases to atmosphere with surface wetness).

The Laptev Sea is an area of such large ice production that it has been termed "the ice factory of the Arctic Ocean." As such, this region is the source of much of the sea ice that transits the Arctic Ocean and exits through the Fram Strait.

Given all of these critical features of the Tiksi region that are relevant to understanding climate change, the need to modernize and upgrade the facilities at Tiski has been recognized by several Russian, U.S. and European agencies. Collaborations have been established among the following agencies to implement the modernization of the Tiksi Hydrometeorological Observatory: Roshydromet Arctic and Antarctic Research Institute (AARI), NOAA, the Russian Academy of Sciences (RAS), the U.S. National Science Foundation (NSF) and the Finnish Meteorological Institute (FMI, Makshtas, 2007). During and after IPY, numerous planning meetings among these agencies have taken place, as well as agency visits to Tiksi. Some of these meetings included:

- The Logistics Team Meeting held in St. Petersburg in March 2009, resulting in a construction plan for finishing the site and Clean Air Facility improvements in August 2009).
- A Science Team Meeting held in Boulder in May 2009, resulting in the finalization of a science plan with 14 identified joint science projects.
- The Operations Team met in September 2009 to work out the details of continuing operations,

Fig. 3.4-8. New flux tower at Eureka.
(Photo courtesy of Rob Albee)

including how to incorporate new projects from the NSF, the Russian Academy of science, other agencies (e.g. the National Aeronautics and Space Administration) and other countries. Details about the September 2009 trip to Tiksi, including a list of recently completed and planned installations can be found on the IASOA web site: http://iasoa.org/iasoa/index.php?option=com_content&task=view&id=282&Itemid=175 (English) and http://iasoa.org/iasoa/index.php?option=com_content&task=view&id=281&Itemid=174 (Russian)

As a result of these intensive collaborations, in spring 2010 the following installations will be completed at the Tiksi Hydrometeorological Observatory:

Spring 2010 Installations	Measured Parameters
Automated meteorological station (AMS)	Air temperature, humidity, ground temperature, wind speed and direction, atmospheric pressure
Climate Reference Network (CRN) station	Temperature, precipitation solar radiation, surface skin temperature, surface winds, soil moisture and soil temperature at 5 depths
Vector-M Upper Air Measurements	Air temperature, relative humidity, instantaneous and average wind speed and direction, atmospheric pressure
Baseline Surface Radiation Network (BSRN) station	Direct, downward and upward solar radiation at various spectral intervals
Global Atmosphere Watch (GAW) station	Primary greenhouse gases (CO_2, CH_4, CO, H_2); N_2O, SF_6; water vapor concentrations

These installations mark the beginning of continued observatory upgrades and international collaborations.

Summary

The International Polar Year 2007–2008 was a fantastic opportunity to harness the immense interest in Arctic meteorology during this time of rapid change. The concepts behind IASOA were articulated in IPY Proposal (http://classic.ipy.org/development/eoi/proposal-details.php?id=196). The goals of the program, as outlined in the proposal, have been addressed during and after IPY with very limited funding. So far, the significant outcomes of the IASOA program are (Darby et al., 2009):

- The IASOA web site (www.iasoa.org)
- Strong collaborations among SEARCH scientists and engineers at several of the IASOA observatories
- Instrument loans to observatories (e.g., NOAA/ESRL loaned a cloud radar to FMI)
- The science sessions at AGU where scientists became more acutely aware of scientific investigations and data sets at many of the observatories
- The new instrumentation and infrastructure at the Tiksi Hydrometeorological Observatory.

There is still much work to do for IASOA to reach its full potential and we look forward to serving the Arctic atmospheric community.

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3.5 Meteorological Observing in the Antarctic

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Reviewers:
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The International Geophysical Year of 1957–58 (IGY) provided a big impetus towards setting up continuously operated stations in the Antarctic. Over forty were constructed during and following the IGY years, of which over a dozen are still operating today. This was the peak of manned observation in Antarctica and since then the number of staffed stations has declined (Fig. 3.5-1), though this is offset by an increasing number of automatic stations (Fig. 3.5-2). Some improvement to the observing network took place during International Polar Year of 2007–2008 (IPY), however, the main thrust of IPY initiative was a boost to polar research.

Most manned stations are at coastal sites, primarily so that stores can easily be transported ashore. This means that in some ways their weather is not a true representation of the continent as a whole, as they are much milder due to the influence of the sea. Automatic stations are much more widely spread across the continent and give a broader picture of the meteorology.

At most manned stations meteorological observations are made regularly throughout the "day" according to WMO standards, however, there is increasing reliance on automatic systems during the "night". Surface temperature, humidity, sunshine, pressure, wind speed and direction are largely measured by automated instruments, but an observer is needed to estimate the visibility and the amount, type and height of clouds, although automatic instruments are being introduced. An observer also needs to keep note of the weather: rain, snow, fog, gale etc., as well as more unusual phenomena, such as diamond dust, halos, mirages and the aurora australis. Traditional weather observing on the polar plateau brings additional problems, with the combination of very low temperature and high altitude. At the Russian Vostok station special suits are worn for outdoor work under these conditions.

The observations are expressed in a numeric code and transmitted to meteorological centres, largely in the northern hemisphere, using the Global Telecommunication System (GTS), the meteorological equivalent of the Internet, where they join thousands of other observations from all over the world. The observations are processed by super-computers, used to forecast the weather and archived for climate studies. The transmission technique has steadily improved since IGY when HF radio was the only medium available to send data from Antarctica in real-time. Satellite relay became widely used in the 1980s, either using Data Collection Platforms (DCPs) transmitting to geostationary satellites at fixed times or random transmissions making use of the ARGOS service on polar orbiting satellites. During IPY, email transmission over permanent Internet links became more common along with short data burst (SDB) transmissions on the Iridium mobile phone system.

Automatic stations (Fig. 3.5-3) generally measure a reduced range of parameters, usually pressure, temperature and wind, although some may measure humidity and have housekeeping data such as snow depth. Where there is significant snow accumulation, stations require annual maintenance visits while others may not be revisited after deployment. Most provide real-time access to their data, but others store the data locally for recovery during maintenance visits. Several new stations were set up during IPY. In particular, Russia installed automatic weather stations (AWS) at their formerly manned stations at Leningradskaya, Molodezhnaya and Russkaya, resuming a data series that was interrupted due to closure of these stations in the 1990s. In addition the private operator Adventure Network International, installed an AWS at their Thiel Mountains site and, in a co-operative arrangement with the British Antarctic Survey and U.K. Meteorological

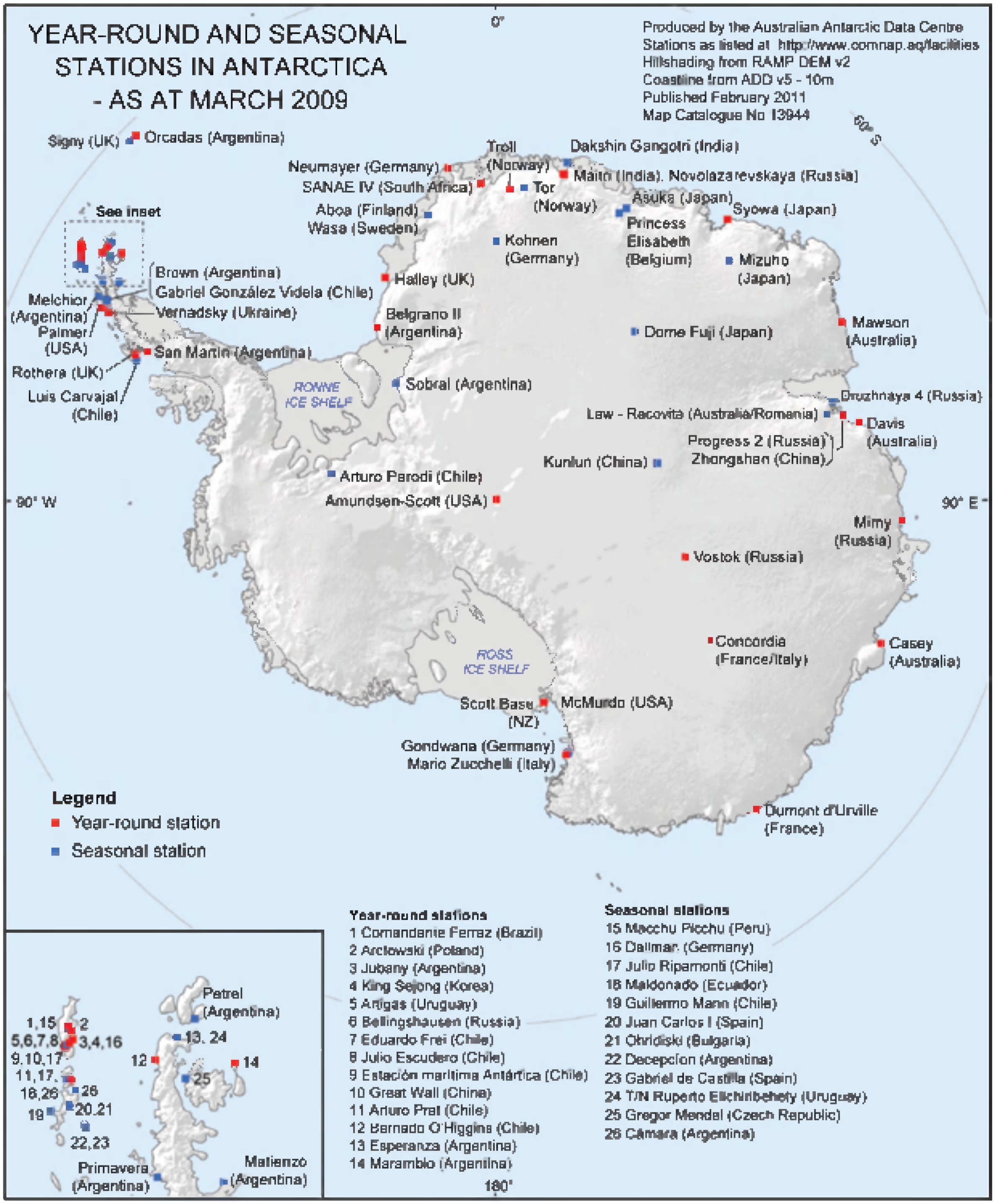

Fig. 3.5-1. Antarctic stations at the end of IPY, March 2009.
(Courtesy: Australian Antarctic Data Centre)

Office, made the data available on the GTS. Altogether there are now 35 manned stations, complemented by about 65 AWS with data available in real-time, and over a dozen more whose data is available after some delay. Major AWS networks are run by Australia (Bureau of Meteorology), Italy (PNRA), the Netherlands (Utrecht University), U.K. (British Antarctic Survey) and U.S.A. (University of Wisconsin).

In general, it should be stressed that despite the renovation of several manned stations, such as Neumayer (Germany), and the establishment of new station Princess Elisabeth (Belgium) during IPY period, the availability of operational synoptic data could still be improved. No new funding was available for this particular purpose, so some already planned projects were re-badged as IPY projects. For example, IPY COMPASS project was essentially a continuation and expansion of the SCAR READER project. Although READER data is still being collected, by 2010 only about half of SCAR Member countries had contributed their full synoptic data sets for the IPY years. The global financial situation is likely to impact on funding and in future real-time data is likely to become restricted to those sites where it is necessary to meet operational and forecasting needs.

Weather

Stations near the Antarctic coast are on average quite cloudy because of the frequent passage of depressions and the influence of the sea. The further a station is inland, the less cloudy it becomes. Signy (60°S) has an average cloud cover of 86%, Halley (76°S) 66% and the South Pole an average of 41%. Visual observation of cloud height is difficult at stations on ice shelves or the polar plateau, where the high albedo reduces contrast and there are no references to estimate height. Cloud lidars give a big improvement in

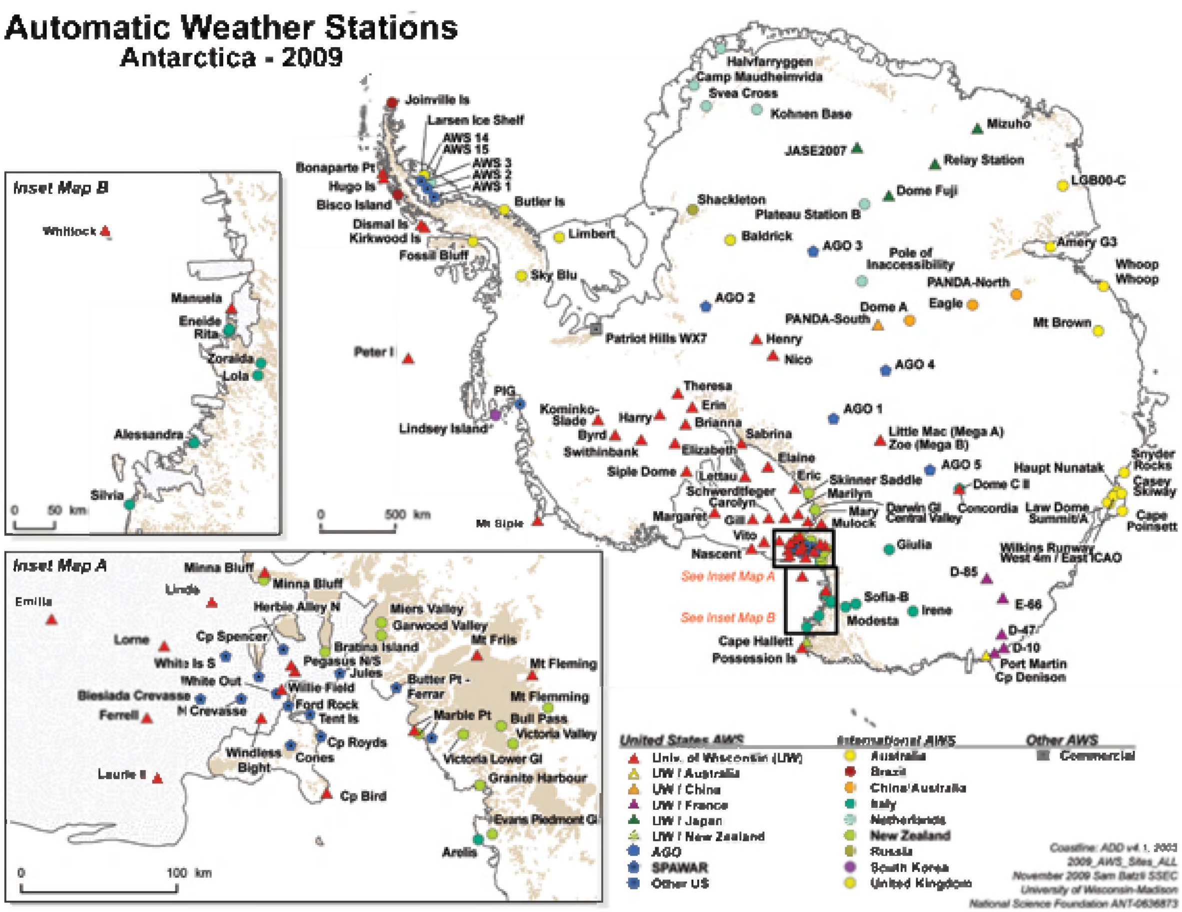

Fig. 3.5-2. Location of AWS sites.

(Image: University of Wisconsin–Madison)

Fig. 3.5-3. Servicing the AWS at Butler Island (U.K./U.S.A.). (Photo: Jon Shanklin)

the measurements and can also monitor precipitation falling from clouds (Fig. 3.5-4).

Measuring the amount of precipitation is difficult. The snow is generally dry and what falls into a standard rain gauge just as easily blows out again. Equally, precipitation that has fallen elsewhere or at a previous time can be blown around by the wind and into the gauge. A simple technique is to measure the depth of freshly fallen snow and assume that in the long term there is a balance between transported and falling snow. Specially designed snow gauges may provide a solution, but gauges that work well in temperate regions where snow falls do not cope well with Antarctic precipitation and further design studies are needed (Fig. 3.5-5). Electronic precipitation detectors using scintillation in an infrared beam are now being deployed in Antarctica and combination of the outputs of two detectors at different heights may provide the necessary discrimination between precipitation and transport.

Upper atmosphere

The Antarctic atmosphere is very clear as there are few sources of pollution. On a fine day it is possible to see mountains well over 100 km away. In these conditions, estimating distances can be very deceptive. Objects may appear to be close by, when in fact it would take many hours of travel to reach them. Automatic instruments, which use infra-red scintillation and scattering to measure near-surface visibility, are becoming more common, however, some have difficulty in discriminating variation in visibility above 20km. Higher in the atmosphere, the stratospheric aerosol load, largely originating from volcanoes, is measured using sun tracking pyrheliometers or photometers. In IGY, the primary instrument was the Angstrom pyrheliometer, a manual device, which even in skilled hands, took ten to fifteen minutes to complete an observation. By IPY a number of stations had installed automatic sun-photometers, either as part of an international network or stand-alone. These use measurements through a series of filters to calculate the amount of obscuring material in the solar beam (Fig. 3.5-6).

Fig. 3.5-4. Vaisala CT25K cloudbase recorder at Rothera (U.K.).
(Photo: Jon Shanklin)

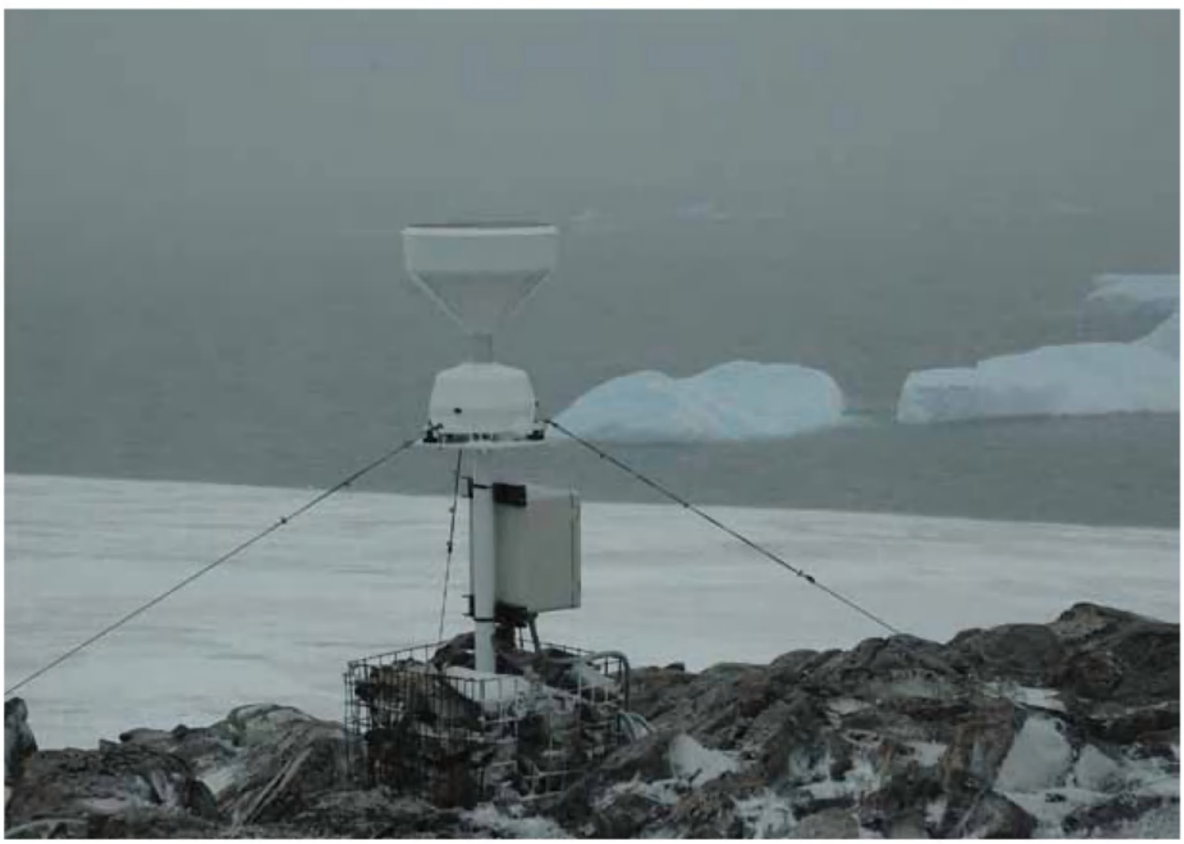

Fig. 3.5-5. A modern aerodynamic automatic tipping bucket gauge at Rothera (U.K.). It doesn't work well in Antarctica, particularly in light snow or strong wind, and needs a shield.
(Photo: Jon Shanklin)

At approximately a dozen stations, balloons are launched once or twice a day each carrying a package of meteorological instruments known as a radiosonde (Fig. 3.5-7). The instrument package signals back the temperature, humidity and pressure to an altitude of over 20 km, with wind speed and direction found by tracking the package with global positioning system sensors. One particular problem affected latex balloons during winter: the combination of low ambient temperature and darkness made the balloon fabric brittle and they burst early, often before reaching 100 hPa. The traditional remedy was to briefly dip the balloon in a mixture of oil and avtur immediately prior to launch and to allow excess fluid to drain off. This plasticized the fabric and gave much improved performance, however, it did have significant health and safety implications. Modern balloons such as the Totex TX series, which use a synthetic rubber, perform much better, with even 350 gram balloons regularly reaching above 20 hPa in the summer and still managing 50 hPa during the winter.

Special ascents are sometimes made to help study the lower part of the atmosphere called the troposphere, where weather systems are active. These include flights to investigate very stable conditions in the lowest layer, which mainly occur during the winter and other flights to study, for example, depressions forming offshore. Such studies are augmented by atmospheric profiles measured using captive packages carried aloft by kites or blimps, or by sodars (sonic radars). Further studies are made using instrumented aircraft to study the composition of clouds *in situ.*

Ozone

The *ozone* hole was discovered in ground-based observations from Antarctica and most manned stations continued with long term measurements of the ozone column during IPY. Ground-based sensors include the traditional Dobson ozone spectrophotometer, the Brewer spectrometer and the SAOZ spectrometer, or variants of these. (Fig. 3.5-8) All use the sun as a source and measure the differential absorption of light as it passes through the ozone

Fig. 3.5-6. Sonde launch at Halley (U.K.). (Photo: BAS)

layer. At a few stations, ozone sondes are flown that give precise profiles of ozone in the atmosphere. These bubble air through a cell generating a current that is proportional to the amount of ozone present. Satellites give a global view of the ozone layer, but need the ground-based data both for scale verification of their sensors and to determine aging trends in the harsh environment of space.

The ozone holes during IPY years were broadly typical of those seen during the period of maximum ozone depletion between 1990 and 2010. The 2007 polar vortex was large and at times quite elliptical, hence significant ozone depletion was already present in early August. By contrast the 2008 vortex was more stable, giving a late start to the ozone hole and producing a long lasting hole (Fig. 3.5-9).

The creation of the Antarctic ozone hole is dependent on the stable south polar vortex giving very cold temperatures in the ozone layer, allowing polar stratospheric clouds to form throughout its centre during the winter. By contrast, the Arctic polar vortex is less stable and the temperature within it is generally warmer so that the clouds are much less frequent. Chlorine and bromine from CFCs, and halons and other ozone-depleting substances undergo complex reactions on the cloud surfaces. The reactions create halogen oxides, which can then photo-catalytically destroy ozone in the presence of sunlight. Levels of these ozone-depleting substances in the atmosphere were declining during IPY and just after its close, all of the world's governments had finally signed the basic Montreal Protocol.

Recent research shows that the ozone hole has played a significant role in determining the recent climate of Antarctica. Its presence has stabilized the temperature of the bulk of the continent and contributed to the continued warming of the Antarctic Peninsula. Global warming of the near surface of the planet feeds back into the ozone hole process by creating a colder stratosphere. This will delay the recovery of the ozone hole, which is likely to continue forming each year, until the last decades of this century.

Fig. 3.5-7. Tracking skyradiometer at Rothera (U.K.). (Photo: Jon Shanklin)

Fig. 3.5-8. Brewer at Marambio (Argentina).
(Image: Servicio Meteorologico Nacional)

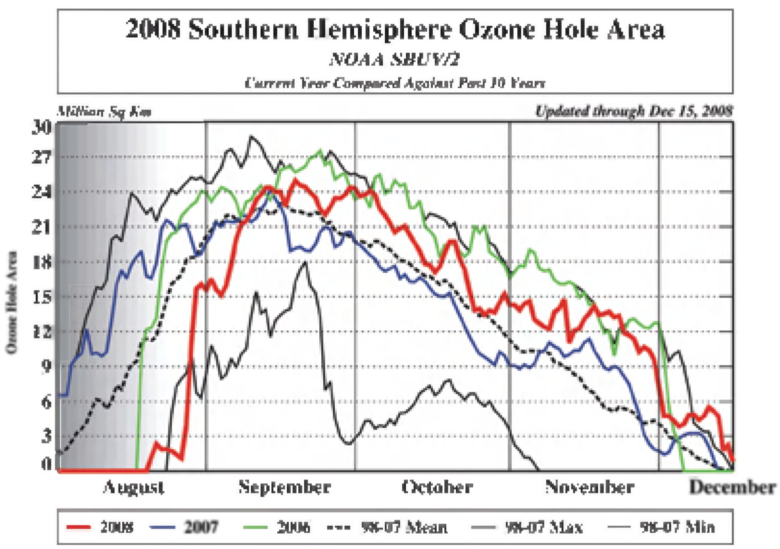

Fig. 3.5-9. The development of the ozone hole from 2006 to 2008.
(Image: NOAACPC courtesy Craig Long)

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3.6 The Sea Ice Outlook

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Introduction

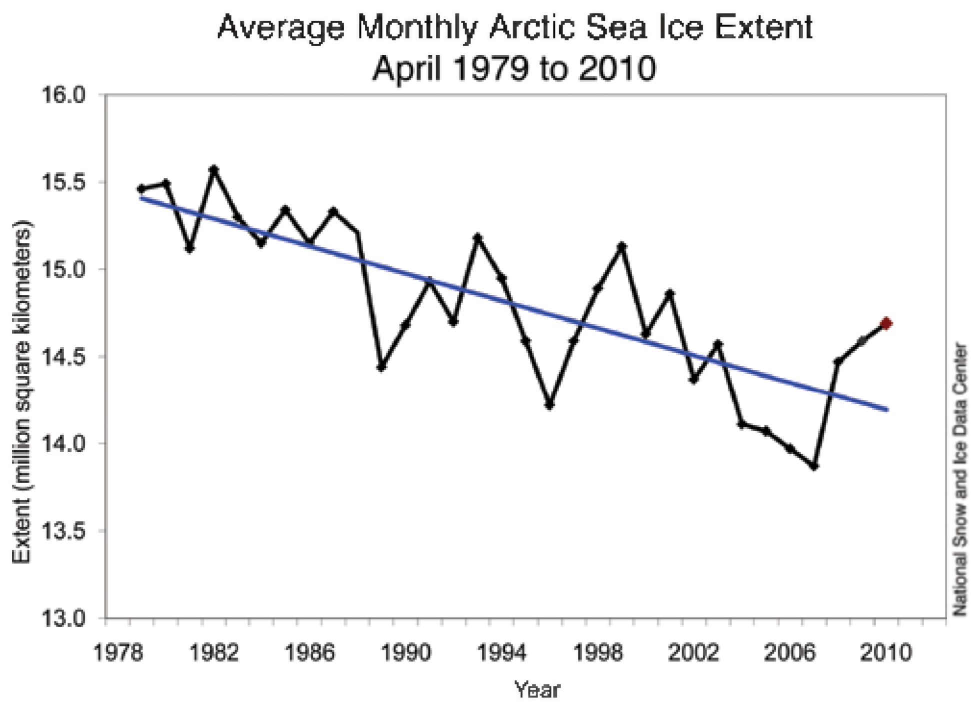
IPY catalyzed significant additional funding and redirection of some existing support that was used to investigate a number of critical scientific issues in the Arctic. Enhanced study of Arctic sea ice was a focus for a number of research groups. In the U.S., the pre-existing Study of Environmental Arctic Change (SEARCH) program supported a number of activities related to Arctic sea ice. In Europe, IPY project Developing Arctic Modeling and Observing Capabilities for Long-term Environmental Studies (DAMOCLES) was supported as an integrated ice-atmosphere-ocean monitoring and forecasting system. The SEARCH and DAMOCLES activities were linked through a special coordinating activity called "SEARCH for DAMOCLES (S4D)". One of the coordinating activities was a joint workshop held in March 2008 at Palisades, NY (SEARCH, 2008; see www.arcus.org/search/meetings/2008/aow/index.php for more information). One outcome of the workshop was recognition by the participants of the need for better understanding of the Arctic sea ice system, given the drastic and unexpected sea ice decline observed by satellites in summer 2007 (Fig. 3.6-1). The sea ice cover retreated to well below its previous record minimum extent, with potentially substantial physical, biological and socio-economic impacts on the Arctic. This fact underscores the immediate need for increased integration and coordination of sea ice observations and modeling. As a result, several participants agreed to pool their insights and work collaboratively to prepare an "outlook" on how Arctic sea ice extent might evolve over summer 2008. It was also agreed that other interested experts should be invited to participate in this activity and thus the SEARCH-DAMOCLES Sea Ice Outlook (SIO) effort was initiated.

Preparations for undertaking the SIO involved formation of a "core integration group", led by James Overland, and an "advisory group". Broad international participation was sought; North America and Europe were well represented in these two groups from the outset. A Japanese group joined the effort later in 2008 and 2009.

The SIO groups developed an open and inclusive process for conducting the work to ensure that any scientist could participate. The objective of the SIO is to produce monthly reports during the arctic summer sea ice season that synthesizes input received from participating scientists representing a broad range of scientific perspectives:

1. Each month during the summer sea ice melt season, a request to the international arctic science community (http://siempre.arcus.org/4DACTION/wi_ai_getArcticInfo/3606) solicits information on the expected state of the September arctic sea ice.
2. The community submissions are synthesized and reviewed by the Sea Ice Outlook Core Integration Group and Advisory Group (www.arcus.org/search/seaiceoutlook/organizers.php).
3. An integrated monthly report is produced that summarizes the evolution and expected state of Arctic sea ice for the September mean Arctic sea ice extent, based on the observations and analyses submitted by the science community. These reports are posted in the "monthly reports" section of the SIO website (www.arcus.org/search/seaiceoutlook) and widely distributed (see Fig. 3.6-2, June 2009 Report).
4. The process for producing the monthly Sea Ice Outlook reports is repeated through September of each sea ice season.

Fig. 3.6-1. Average monthly sea ice extent from 1979 to 2010 shows a continued decline. The rate of sea ice decline since 1979 has increased to 11.2 percent per decade.
(NSIDC - http://nsidc.org/images/arcticseaicenews/20100504_Figure3.png)



5. Retrospective analyses after the season examines the success of the Sea Ice Outlook in advancing scientific understanding of the arctic sea ice system, and provide guidance to future research efforts.

The results from the Outlook activities as of late spring 2009 are summarized in a paper by Overland et al., (2009).

Summary of 2008 and 2009 efforts

The projections of the Sea Ice Outlook groups for the September 2008 minimum ice extent, based on May data, had a median value of 4.2 million square kilometers (msk) and a range of 3.1 to 5.5 msk (see Fig. 3.6-1). The median value is roughly the same as the minimum observed in September 2007 (4.3 msk). With observations from early summer, the projected median sea ice extent value increased to 4.9 msk for the July Outlook with a range of 3.2 to 5.6 msk. Both of these Outlook projections are substantially lower and nearer to the observed September 2008 minimum value (4.5 msk) than to the 1979–2000 mean value (7.1 msk) or to the linear trend line of previous September minima (5.6 msk). Both sea ice models and seasonal melting projections provided the main semi-quantitative information for the 2008 SIO.

In a retrospective analysis, the SIO team determined that the agreement between projections and observations is consistent with the conclusion that initial conditions of spring sea ice are often an important factor in determining ice development over the course of the summer. They also noted that the role of summer atmospheric forcing is important, but was less important in 2008 compared to 2007, which had very unusual atmospheric circulation patterns. The SIO team felt that this result bodes well for future seasonal Sea Ice Outlooks. They concluded that during the next few summers it will be important to track potential recovery or further decline of the summer ice pack with late spring/early summer satellite and *in situ* sea ice observations providing important information.

Following the SIO effort for summer 2008, the participants agreed to continue and prepare similar reports during summer 2009 and again in 2010. The same process used in 2008 was repeated for 2009. The initial Outlook released in June and based on May data showed a mean projected value for September sea ice extent minimum of 4.7 msk and a range of 3.2 to 5.0 msk (see Fig. 3.6-1). For the August report, based in July data, the mean projected value for September sea ice extent minimum was 4.6 msk, with a range of 4.2 to 5.0 msk, with more than half of the 14 estimates in a narrow range of 4.4 to 4.6 million square kilometers, representing a near-record minimum. All estimates were well below the 1979–2007 September climatological mean value of 6.7 million square kilometers. The uncertainty/error values, from those groups that provided them, were about 0.4 million square kilometers, thus most of the estimates overlapped.

In actuality, the 2009 Arctic sea ice minimum extent was reached on 12 September 2009, according to the National Snow and Ice Data Center (NSIDC; http://nsidc.org/arcticseaicenews/2009/091709.html), with a value of 5.1 msk (Fig. 3.6-3). In a retrospective analysis, the SIO team concluded that September 2009 sea ice extent was driven by preexisting sea ice conditions at the end of spring, as well as variable wind patterns and cloudiness over the course of the summer. They stated that 2007 remains as an anomalous year, dominated by steady meteorological conditions during the entire summer that were favourable for sea ice loss, while in 2009, August and September wind patterns and increased cloudiness were not conducive to major sea ice loss.

The SIO team stated concern over the fact that all 2009 Outlook projections were below the observed September 2009 value. Yet they noted that, when projection uncertainty is taken into account, as well as it can be, the observed value is within an expected range of values. This was explored further by two groups from Germany and the U.S.A. that provided ensemble simulations with coupled ice-ocean models allowing for probabilistic assessments of expected minimum ice extent (Zhang et al., 2008; Kauker et al., 2009). The Outlook participants remained concerned over the convergence of the Outlook projections into a narrow range. They agreed that the last point emphasizes that further development and analysis of probabilistic

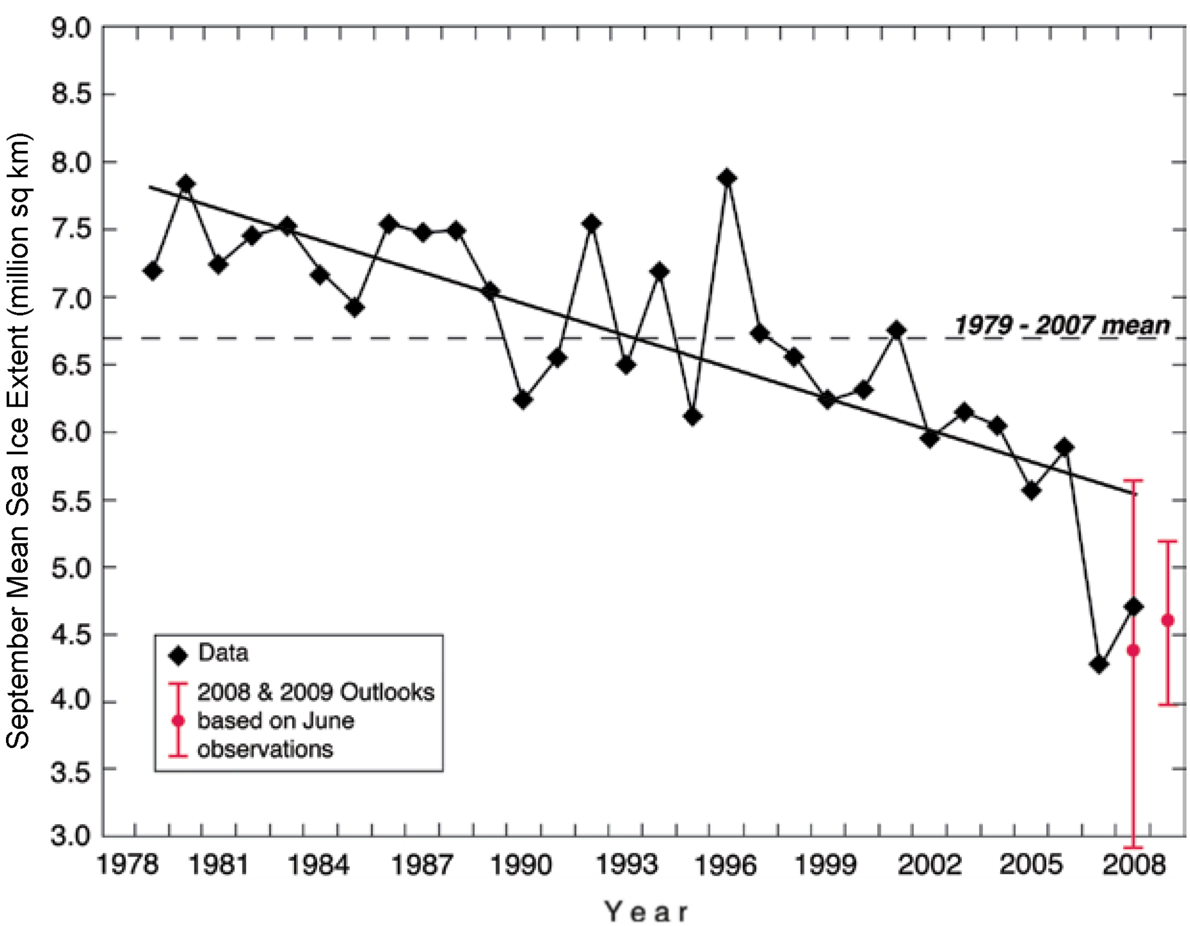


Fig.3.6-2. Observed monthly mean Arctic sea ice extent in September (million sq km), 1979–2008. The vertical red lines shows the median value and range of estimates for the June 2008 and 2009 outlook forecasts for the following September sea ice extent.

forecast ranges and measures of uncertainty will be critical to improvement in future efforts.

The SIO team stated that the sea ice evolution in 2009 signals that it could be several more years, in a probabilistic sense, before conditions favour another major sea ice loss event. Nevertheless, they noted that the increase in sea ice extent for 2009 relative to 2008 does not exceed past interannual variability in a near-continuous, 30-year downward trend in summer sea ice extent (Fig. 3.6-4).

They also noted that melt-out of sea ice near the North Pole continues to be less than in the Beaufort and Siberian sectors because of the decreasing importance of solar forcing. They concluded that this may be a limiting factor in the rate of future sea ice loss.

In 2009, the outlook also included a regional outlook examining ice evolution in several regional sectors of the Arctic by nine contributing research groups (Fig.3.6-5). Combining statistical models, ensemble simulations and heuristic approaches, seven of the nine categorical forecasts were accurate. These results indicate that a thorough understanding of local ice conditions and long-term records of ice variability can go a long way towards enhancing the reliability of such regional projections on seasonal time scales. Forecasts of seasonal break-up of coastal ice, of relevance for a number of different stakeholder groups, also demonstrated that cloudiness and down-welling shortwave radiation plays a key role in driving summer ice retreat, both at the hemispheric and local level (Petrich et al., in prep.).

In thinking about how to improve the ability to forecast sea ice conditions in future summers, the SIO team stated:

- Consideration of multiple sources of data, including visual observations, is important for reducing

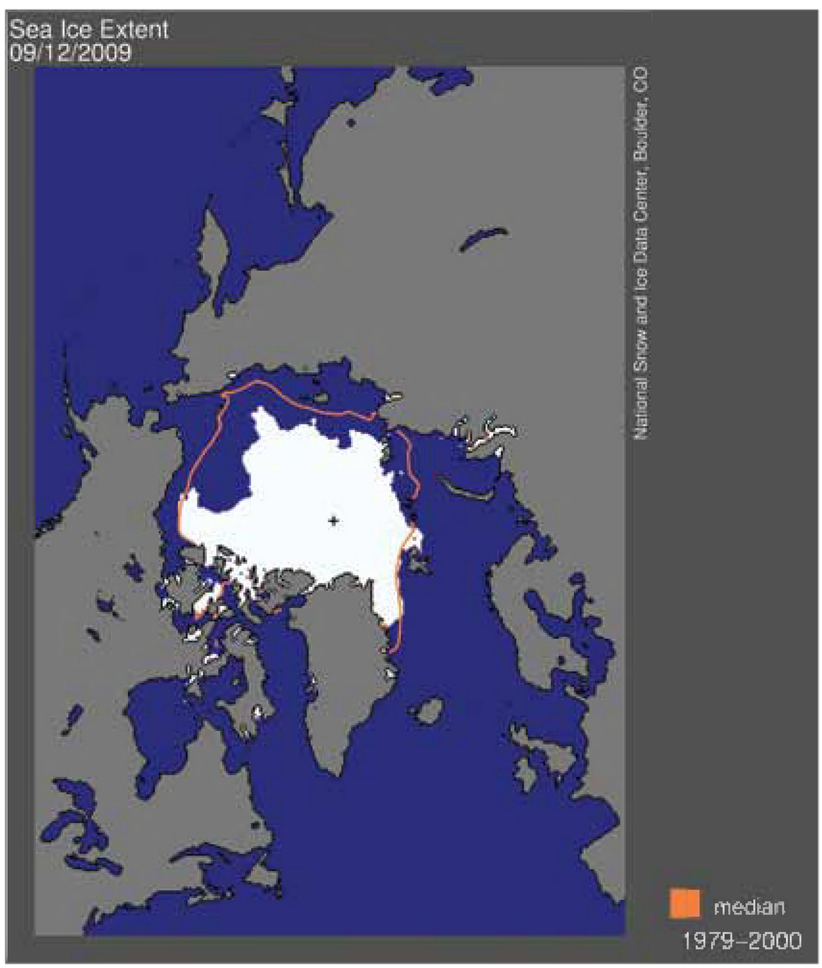


Fig.3.6-3. Minimal sea ice extent for summer 2009 reported on 12 September 2009.
(Photo: NSIDC)

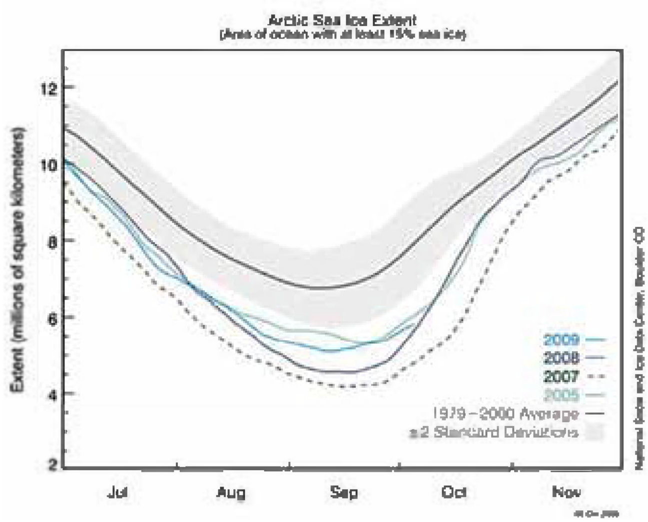


Fig.3.6-4. Daily arctic sea ice extent from passive microwave satellite data (SSM/I). The solid light blue line indicates 2009 relative to 2005, 2007 and 2008. The solid gray line indicates average extent from 1979 to 2000.
(National Snow and Ice Data Center)

uncertainty in the Outlooks. Buoys provide key observations for mapping and attributing summer ice loss: drift, bottom vs. top melt, amount of snow accumulation, nature of ponds (even if anecdotal from webcams) and thickness of level ice. Considerable effort should be made to estimate thickness distributions of ice and snow cover needed to initialize simulations. Aircraft and other reconnaissance are also helpful.

- Because of the importance of initial conditions for the sea ice state, more work is needed on remote sensing retrieval and interpretation of spring and summer ice concentrations and ice conditions, even if the present operational algorithms are not changed.
- Both full sea ice models and seasonal melt projections applied to detailed sea ice distributions and trajectories provided the main semi-quantitative information for the Outlook.

The SIO for 2009 went further than in 2008 by looking not only at the progression of ice melt, but also evaluating the rate of regrowth of ice in the fall. There was evidence that growth of ice in October and November was retarded and in fact the sea ice extent in portions of fall 2009 was less than in the corresponding period of the record minimum year of 2007.

The SIO team is continuing the Outlook process again in 2010. While it is too early to state with confidence, there is a possibility that the SIO process might continue and evolve into one of the valuable "legacy" activities of the IPY.

The specific outcomes of the Outlook activities include the following:

- Synthesis of remote-sensing or ground-based observations and modeling efforts to further understanding of variability and seasonal-scale predictability of the Arctic atmosphere-ice-ocean system.
- Creation of a forum that allows both the scientific community and educated laypeople to obtain better insight into cutting-edge Arctic system research.
- Enhanced scientific communication between field researchers, remote-sensing experts and modelers at time scales commensurate with the rapid change observed in the Arctic (i.e. faster than typical scientific publication cycles).
- Improved information exchange between researchers in academia and government agencies tasked with operational support in Arctic areas, in particular by providing a testbed for different forecasting approaches and creating a forum that allows agency personnel to draw on the broad expertise of the international research community.

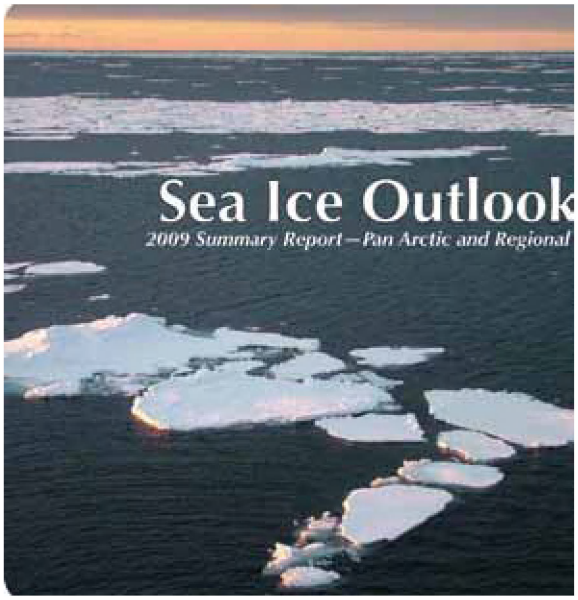


Fig.3.6-5. Sea Ice Outlook: 2009 Summary Report www.arcus.org/search/seaiceoutlook/2009_outlook/2009_pan-arctic_summary.php

How the IPY changed the science

One of the major goals of the IPY was to encourage greater international collaboration. The SIO is an excellent example of the added value that can be obtained by bringing together scientists from diverse institutions. Would there have been a SIO effort at all if the joint SEARCH-DAMOCLES workshop hadn't been held? Or would the effort have been a U.S.-only effort rather than an international one? We can't answer these questions, but we do know that as a result of an international workshop, there were 18 groups participating in the 2009 Outlook process from seven different countries. They employed different approaches to the problem, including sophisticated numerical models, statistical evaluations and pattern matches with prior years. Each group was willing to state openly their projection for the sea ice minimum extent and their method for arriving at the value. In addition to the value of collaboration and information sharing, the rapid communication required to complete the monthly reports meant that the groups were quickly reanalyzing based on rapidly changing environmental conditions and learning from each other as the reports were released. The pace of advancement of scientific understanding most certainly exceeded that which would have resulted from traditional single group publications that were months to years in arrears of actual events.

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3.7 Global Cryosphere Watch and the Cryosphere Observing System

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The cryosphere collectively describes elements of the Earth system containing water in its frozen state and includes sea-, lake- and river-ice, snow cover, solid precipitation, glaciers, ice caps, ice sheets, permafrost and seasonally frozen ground (Fig. 3.7-1). The cryosphere is global, existing in various forms at all latitudes and in approximately 100 countries. "The State and Fate of the Cryosphere" (IPY project no. 105) provided a framework for gaining a better understanding of the state of the cryosphere, as well as its past, present and future variability in time and space. The project aimed to:

- **assess the current state** of cryospheric parameters in the high latitude regions, providing a **snapshot** of the cryosphere and an evaluation of its current (IPY) state in the context of past states and projections of the future;
- **formulate the observational requirements** of cryospheric variables for weather, climate and hydrological monitoring and prediction and for other environmental assessments (IGOS-P Cryosphere Theme);
- **strengthen international cooperation** in the development of cryospheric observing systems.

In order to gain a more complete understanding of the role of the cryosphere in the global climate system, it was recognized that the cryosphere is arguably the most under-sampled domain in the climate system and that a more comprehensive, coordinated cryospheric observation system is needed. Some international programmes such as the Global Climate Observing System (GCOS) address the cryosphere in part, but none cover it in total. A programme dedicated to observing the cryosphere was deemed necessary to create a framework for improved coordination of cryospheric observations and to generate the data and information needed for both operational services and research. IPY 2007–2008 provided a unique opportunity to develop polar observing systems and, by doing so, began to close one of the most significant gaps in global observations. The Integrated Global Observing Strategy (IGOS) Cryosphere Theme and the Global Cryosphere Watch (GCW) were major outcomes.

The Cryosphere Observing System: Legacy of IPY 2007–2008

During the early phase of IPY, it was recognized that there was a strong need for close coordination of cryospheric observations serving the various user communities and nations, a need to strengthen national and international institutional structures responsible for cryospheric observations, and a need for increased resources to ensure the transition of research-based cryosphere observing projects into sustained observations. The likelihood of achieving these goals would be significantly enhanced through the development of a comprehensive, coordinated, integrated and coherent approach of the kind represented by an Integrated Global Observing Strategy (IGOS) theme. An IGOS theme for the entire cryosphere would provide economies of scale and ensure that the cryosphere is adequately addressed by the observing systems that support climate, weather and environmental research and operations. Led by the Climate and Cryosphere (CliC) project of the World Climate Research Programme (WCRP) in collaboration with the Scientific Committee on Antarctic Research (SCAR) and in consultation with several IGOS partners, the IGOS Cryosphere Theme proposal was implemented as a major contribution

Fig. 3.7-1. Examples of the cryosphere.

to IPY and to improving our ability to describe the state and fate of the cryosphere. We refer to the IGOS Cryosphere Theme's goal of a coordinated, robust network of snow and ice measurements as CryOS, the Cryosphere Observing System.

Three major workshops were held in Canada, sponsored by the Canadian Space Agency (CSA), Japan co-sponsored by the Japan Aerospace Exploration Agency (JAXA), in cooperation with the Japan Agency for Marine-Earth Science and Technology (JAMSTEC), and the Netherlands sponsored primarily by the European Space Agency (ESA) to engage the scientific and user communities. Input from approximately 100 scientists in 17 countries provided the basis for the IGOS Cryosphere Theme Report. The report is a robust compilation of observing system capabilities, needs and shortcomings, with separate chapters covering the elements of the cryosphere. Specific recommendations for each cryospheric element (e.g., terrestrial snow, ice sheets, permafrost) are listed in the individual chapters of the report. An example for snow is shown in Table 3.7-1. General recommendations are given for the near-, mid- and long-term, with near-term recommendations focussing on the IPY period. The report was accepted by the IGOS Partners in May 2007, subsequently published with the support of the WMO and first "released" at the Group on Earth Observations (GEO) Plenary Meeting in Capetown, South Africa, November 2007. It has since been widely distributed and has provided the guidance for many IPY initiatives. More information is available at http://igos-cryosphere.org.

The initial phase of CryOS development coincided with IPY. The approach was to engage relevant IPY projects and increase coordination between them with the objective of producing legacy datasets and the capability to extend them continuously after the end of IPY. In this regard, the IGOS Cryosphere Theme team and the collective cryosphere community have been very successful. Accomplishments during IPY include:

- an evaluation of current measurement capabilities, observing system requirements and gaps;
- a comprehensive set of recommendations in three time frames;
- improved coverage of cryospheric elements in the GCOS Implementation Plan and contributions to the GCOS-CEOS (Committee on Earth Observation Satellites) plan for satellite-based products;
- efforts to ensure an IPY legacy through the Group on Earth Observations (GEO) Work Plan;
- involvement in the satellite mission planning process resulting in the approval of three orbital cycles of coordinated, experimental inter-satellite SAR interferometry, the Global Monitoring for Environment and Security (GMES) Sentinel-1A C-band SAR mission, the GMES Sentinel-3A SAR altimeter mission that will provide sea-ice thickness measurements, RADARSAT Modified Antarctic Mapping Mission (MiniMAMM) SAR mapping of Antarctica and CryoSat-2;
- new satellite products for real-time applications, e.g. sea ice concentration, thickness and motion from optical imagers, and a variety of other new satellite products and acquisitions coordinated through Global Interagency IPY Polar Snapshot Year (GIIPSY) project and the IPY Space Task Group (*Chapter 3.1*);
- contributions to the planning of ongoing SCAR scientific research projects including ISMASS (Ice Sheet MASS balance and sea-level), ASPeCT (Antarctic Sea Ice Processes and Climate), PPE (Permafrost and Periglacial Environments) and AGCS (Antarctica in the Global Climate System).

The community involvement in CryOS gave it the credibility needed for these accomplishments, the

Parameter	C T O	Measurement Range			Measurement Accuracy		Resolution				Comment or Principal Driver
							Spatial		Temporal		
		L	H	U	V	U	V	U	V	U	
Snow Cover	C	20	100	%	15-20	%	1	km		day	e.g. MODIS
	T	0	100	%	10	%	0.5	km	1	day	Hydromet
	O	0	100	%	5	%	0.1	km	12	hr	
Snow Water Equivalent, satellite (Shallow)	C	0	0.2	m	2-10	cm	25	km	1	day	e.g. AMSR-E
	T	0	0.3	m	3	cm	0.5	km	6	day	Hydromet
	O	0	0.3	m	2	cm	0.1	km	12	hr	
Snow Water Equivalent, satellite (Deep)	C	none	–	–	–	–	–	–	–	–	Need HF SAR
	T	0.3	3	m	10	%	0.5	km	6	day	Hydromet
	O	0.3	3	m	7	%	0.1	km	12	hr	
Snow Water Equivalent, in situ (Shallow)	C	0	3	m	1	cm	1	m	30	day	Hydromet
	T	0	3	m	1	cm	1	m	7	day	Hydromet
	O	0	3	m	1	cm	1	m	1	day	
Snow Depth, satellite (Shallow)	C	0	-0.7	m	5-35	cm	25	km	1	day	e.g. AMSR-E
	T	0	1	m	10	cm	0.5	km	6	day	Hydromet
	O	0	1	m	6	cm	0.1	km	1	hr	Transportation

Table 3.7-1. A portion of the observational requirements and gaps table for snow, from the IGOS Cryosphere Theme report.

first time this has been done internationally for the cryosphere. The community that started with CliC and SCAR expanded through CryOS. The Cryosphere Theme team has been, and continues to be, an active participant in several related IPY initiatives in which the Theme Report has proved its usefulness as an authoritative source of requirements in cryospheric observations and recommendations on the means to establish them. The Space Task Group for IPY has been an important implementation mechanism for some of the space-based recommendations of the Theme. In particular, the GIIPSY project has worked with space agencies to develop new satellite products and special acquisitions (examples of new satellite products developed for IPY are given on Figs. 3.1-2 and 3.1-6 in *Chapter 3.1*).

The Theme activities and recommendations played an important role in the three IPY Workshops on Sustaining Arctic Observing Networks (SAON) in 2007 and 2008 (Stockholm, Edmonton and Helsinki), as well as in the 2008 U.S.-Canada GEO Workshop on Water and Ice (Washington, D.C.). The Committee on Earth Observation Satellite (CEOS), which was an IGOS Partner and is a GEO Participating Organization, has evaluated a number of potential gap analysis "threads", where gaps in the observing system were identified by following a thread from a high level question, through products and service, to models and satellite measurements. One of the threads addresses the question "How do changes in the cryosphere impact sea level?" Currently, the Theme is contributing to the Arctic Council's Snow, Water, Ice and Permafrost in the Arctic (SWIPA) project (www.amap.no), which will produce a report in 2011 on the state of cryosphere in the Arctic.

Thus, there is no question that the development of the IGOS Cryosphere Theme has been a worthwhile effort, resulting in a comprehensive assessment of the cryosphere observing system and a significant contributor to other observing system efforts. The development and acceptance of the IGOS-P Cryosphere Theme Report, which provided the conceptual framework for a Cryosphere Observing System (CryOS), may now provide the basis for a more comprehensive, coordinated and integrated cryospheric observing system (Figs. 3.7-2 and 3.7-3) and be a central part of WMO's new initiative, Global Cryosphere Watch (GCW).

Global Cryosphere Watch – an IPY Legacy

The Global Cryosphere Watch (GCW) was stimulated by several initiatives, in addition to the IGOS Cryosphere Theme, all of which identified the urgent need for a sustained, robust end-to-end cryosphere observing and monitoring system, not only for polar regions, but also globally, These included the "Scope of Science for the IPY 2007–2008" produced by IPY Joint Committee, IPCC WG1 and WG2 reports, the Arctic Climate Impact Assessment (ACIA) and the 2nd Conference on Arctic Research Planning (ICARPII), Sustaining Arctic Observing Networks (SAON) and WMO's desire for integrated observations of the polar environment as part of its establishment of integrated observing systems over the globe. The Fifteenth World Meteorological Congress (Cg-XV, May 2007) supported the concept of establishing a Global Cryosphere Watch as a WMO legacy of IPY 2007–2008.

A WMO ad-hoc expert team on GCW (Geneva, December, 2008) explored the feasibility of such a global system and prepared recommendations for its development. The GCW, in its full/comprehensive concept, would include observation, monitoring, assessment, product development, prediction and related research. It should build on and integrate what is being done already. It should provide authoritative, clear, understandable and useable information on the past, current and future state of the cryosphere for use by the science community, decision and policy makers, media, and the public. Response from widespread consultation within WMO, with the National Meteorological and Hydrological Services and other potential partners, organizations, agencies and the scientific community was very positive.

To develop an effective GCW, the expert team agreed on some basic principles and characteristics for the initiative. GCW:

- would be a mechanism for implementing IGOS Cryosphere Theme (CryOS);
- should ensure a comprehensive, coordinated and sustainable system of cryospheric observations and information, and access to related information to allow full understanding of the cryosphere and its changes;
- should initiate a comprehensive cryosphere observing network "CryoNet", a network of reference sites in cold climate regions operating a sustained, standard program for observation and monitoring changes in components of the cryosphere for developing and validating models and remote sensing products, and producing valuable long-term records, while covering key areas of the globe with cryospheric observations;
- will be based on the premise that agreed-upon standards, recommended practices and procedures will apply to the cryospheric observing systems. Where these do not currently exist, GCW would work with WMO and partners to develop appropriate best practices, guidelines and standards. This

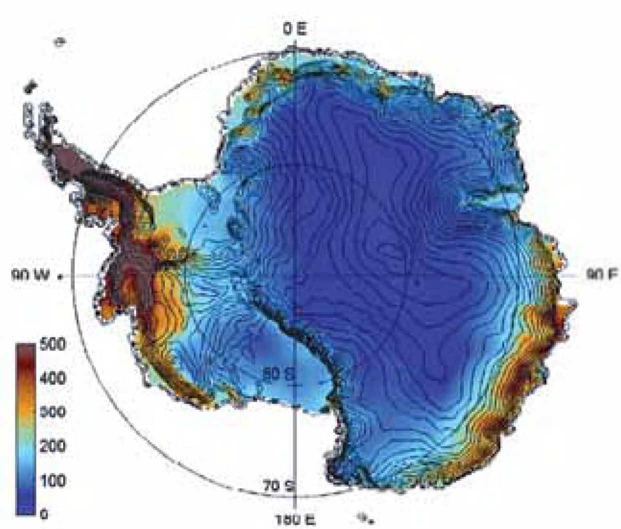

Fig. 3.7-2. Antarctic snow accumulation over Antarctica from merged satellite-in situ observations.
(IGOS Report 2007, 49, courtesy of British Antarctic Survey)

should include homogeneity, interoperability and compatibility of observations from all GCW constituent observing and monitoring systems and derived cryospheric products;

- will include all elements of the cryosphere at national, regional and global scales, and appropriate temporal and spatial requirements. It should provide access to data and information on past, present and future cryospheric conditions, drawing on operational and research-based observation and monitoring (*in situ* and space-based monitoring) and modeling.
- would improve monitoring of the cryosphere through the integration of surface- and space-based observations, which is essential to understand global climate change, optimizing knowledge of current environmental conditions and exploiting this information for predictive weather, climate and hydrological products and services;
- should provide a mechanism to ensure availability of real, near-real time and non-real time access to cryospheric data and products, ultimately through the WMO Information System (WIS). GCW will respect partnership, ownership and data-sharing policies of all observing components and partner organizations;
- should have an organizational, programmatic, procedural and governance structure that will significantly improve the availability of, and access to, authoritative cryospheric information;
- would logically encompass: standardization of instruments and methods of observation, WIS information infrastructure and end product quality assurance;
- should organize assessments of the cryosphere and its components on regional to global scale to support climate change science, decision-making and formulation of environmental policy;
- is the response to meet the need for integration of cryospheric data and information, work with

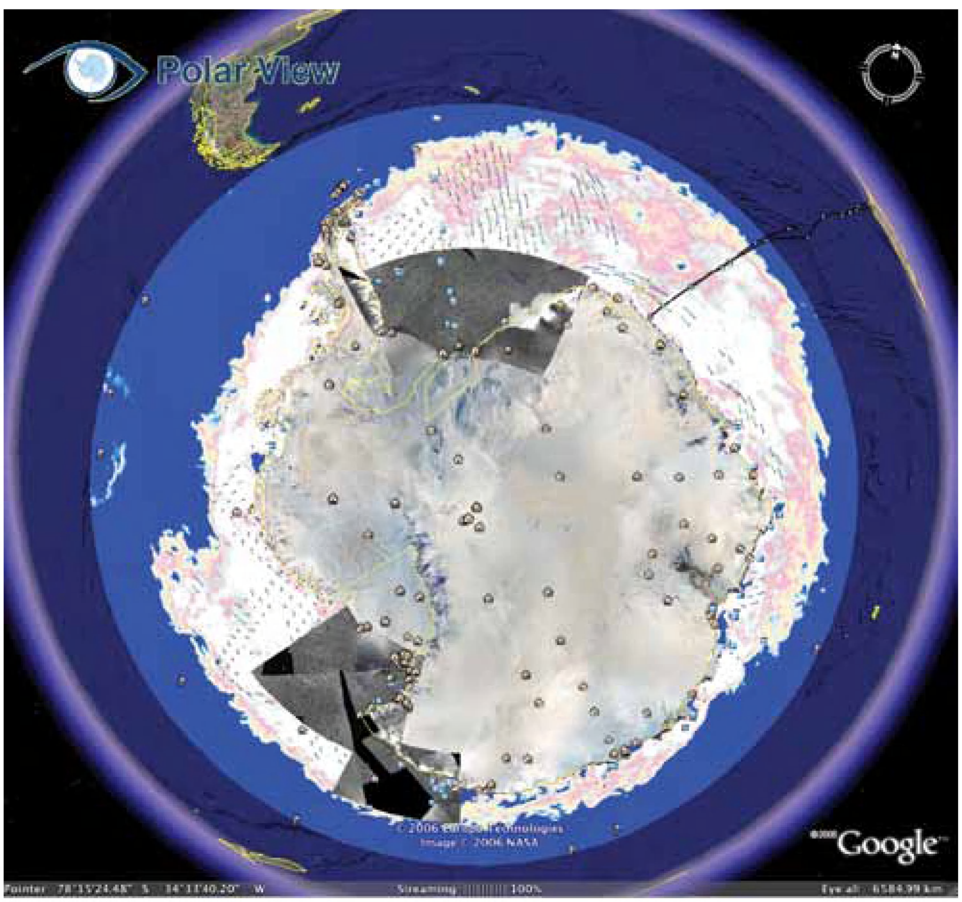

Fig. 3.7-3. Google Earth visualization of Polar View data over Antarctica, including AMSR-E ice cover, ice drift from ENVISAT ASAR, drift buoys, ASAR 3-day mosaic, and meteorological stations.

(IGOS Report 2007, 65; courtesy of British Antarctic Survey) and build on existing programs such as GCOS, and work with external partners such as space agencies, World Data Centres and external cryospheric observing programs.

Pilot projects to demonstrate operation of GCW were strongly endorsed by the community during consultations. They will focus on the elements of the cryosphere and identify how the projects would: contribute to implementing CryOS, meet the GCW principles and characteristics, contribute to demonstrating integration of cryospheric data and information from research to prediction, and provide authoritative cryospheric information. Pilot projects would develop and strengthen partnerships with operational and research organizations and international programs, such as NSIDC, BAS, GCOS, GTOS, WCRP, GPCC and the many space agencies, in addition to NMHSs.

A key to the ultimate success of GCW is to have a GCW portal that will serve as the "single-point entry" to access GCW data, information and products. There are several portals now being implemented for other related studies. The concept of the portal and demonstration of its attributes and characteristics need to be defined. The portal must be WIS compliant. A pilot project to demonstrate the operational capabilities of a GCW portal and prepare a design document for the portal, without an agency having to commit to long-term operation of the portal, is one approach.

The community also stated the need for a limited number of demonstration projects that would focus on regional or national contributions as well as focus on specific tasks to demonstrate standardization, integration and interoperability. There was a very strong desire to implement a standardized network of cryospheric observatories (reference sites/supersites) in cold climate regions for long-term monitoring. Initially, this is to involve a few stations, which would build on existing cryosphere observing programs or add standardized cryosphere observing programs to existing observing facilities to minimize operating costs (e.g. CryoNET) and would be suitable for validation of satellite and model outputs of cryospheric elements.

Successful implementation of GCW will require the engagement of WMO Members and other research and operational agencies engaged in cryospheric observation, monitoring, assessment, product development and research. The WMO Panel of Experts on Polar Observation, Research and Services (EC-PORS) provides the guidance and momentum for implementing GCW in co-operation with the Observing and Information Systems Department and the World Climate Research Program. The latter has provided the stimulus for both CryOS and GCW and close liaison with WCRP and GCOS is envisaged.

3.8 Sustaining Arctic Observing Networks (SAON)

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In advance of International Polar Year 2007–2008, a "framework report" was released in 2004 (Rapley et al., 2004) to lay out the concept, vision, rationale and objectives for the planned IPY. According to this report, "the fundamental concept of the IPY 2007–2008 is of an intensive burst of internationally coordinated, interdisciplinary, scientific research and observations focused on the Earth's polar regions", with a corollary aim of "leaving a legacy of new or enhanced observational systems, facilities and infrastructure". The Arctic Council (AC) is the only intergovernmental body that focuses on the Earth's northern polar region, the Arctic and, in its Salekhard Declaration (2006), responded positively to the plan for IPY and especially to the desire for a legacy of observational capability.

The Arctic Council Ministers stated that they "welcome the International Polar Year (IPY) 2007–2008, as a unique opportunity to stimulate cooperation and coordination of Arctic research", "urge Member States and other entities to strengthen monitoring and research efforts need to comprehensively address Arctic change and to promote the establishment of a circumpolar Arctic observing network", and "request the SAOs to direct the Arctic Monitoring and Assessment Program (AMAP) to cooperate with other AC working groups and relevant scientific bodies in continuously reviewing needs and gaps in climate monitoring in the Arctic so that coordinated action might be taken to ensure the full realization of a comprehensive Arctic observing network". Taken together, these Ministerial statements stimulated the creation of a coalition of Arctic organizations that became known as the Sustaining Arctic Observing Networks Initiating Group (SAON-IG).

The SAON-IG began its work in early 2007 and adopted the goal of developing a set of recommendations on how to achieve long-term Arctic-wide observing activities that provide free, open and timely access to high-quality data that will realize pan-Arctic and global value-added services and provide societal benefits. It decided to pursue this goal by holding a series of workshops to gather information from a broad spectrum of scientists, government agencies, indigenous organizations and non-governmental organizations, and distilling this information into actionable recommendations. To cement the relationship between the SAON-IG and IPY, the Swedish and Canadian IPY Committees agreed to take the lead in the launch of the SAON initiative by running a succession of workshops together with the SAON-IG. Sweden also agreed to create the SAON website – www.arcticobserving.org (see Fig. 3.8-1) and operate it for an initial period. In late 2009, Sweden and Iceland facilitated transfer of the SAON website to the Arctic Portal complex that also houses the international IPY website. All materials related to the workshops described below are available from this website.

The first SAON workshop took place in Stockholm, Sweden on 12-14 November 2007; it was hosted by the Swedish IPY Secretariat and addressed the question: Are current Arctic observing and data and information management activities sufficient to meet users' needs? The second SAON workshop took place in Edmonton, Canada, 9-11 April 2008 and was hosted by the Canadian IPY Secretariat. This workshop addressed the question: How will Arctic observing and data and information management activities be coordinated and sustained over the long-term? The third SAON workshop was held in Helsinki, Finland 15-17 October 2008, hosted by the Finnish Meteorological Institute. The scope of the workshop included recommending a successor to the SAON-IG that would continue the development of a program of internationally coordinated, sustained observations in the Arctic. An important element was to synthesize the advice and information gathered at previous workshops into the final set of recommendations.

From the very first workshop, there was a sentiment that international top-down coordination at the level of operational and funding agencies was needed. Also expressed was the need for an international body to facilitate coordination and work toward intercomparability and easier sharing of data. At the second workshop, during a breakout session composed mostly of government agency officials, the desire to have a coordinated and sustained set of observing networks and a coordination mechanism was not disputed. This group also expressed the feeling that all interested countries and agencies should be welcomed in this effort and that there must be a linkage between the research community and the operational and services community. During the third workshop, another breakout session of mostly government officials made a number of points: integration and coordination of observing activities are ways to provide value; data sharing is important; an intergovernmental statement of intent and cooperation agreements among agencies would be useful; and opportunities for early success should be identified. There was a sentiment that a sharp focus on defined projects would be of greater value in achieving international agreement than more sweeping statements of open ended nature. It must be stressed that no attempt was made to arrive at consensus views during these workshops. Nevertheless, there was no disagreement with the general view that improved coordination among national Arctic observing activities was essential and that some type of formal structure would be needed to make this happen (see: Fig. 3.8-2).

One smaller additional SAON-workshop was held in St Petersburg, Russia prior to the SCAR-IASC IPY Science Conference in July 2008 (*Chapter 5.5*). A number of Russian scientists and government officials provided their insight on current and future observing activities in the Russian sector of the Arctic.

In September 2008, the SAON process was introduced to the Asian Forum on Polar Science in Seoul, Korea (*Chapter 5.3*). There is a strong and growing interest in the Arctic by Asian countries and their participation in long-term observations in the

Fig. 3.8-1. SAON website - www.arcticobserving.org/.

Fig. 3.8-2. Cover page of the SAON brochure (2009) www.arcticobserving.org/.

Arctic area is greatly welcomed by the SAON process.

The final action of the SAON-IG was to produce a report, released in December 2008, based on the collective effort of the 350 people who participated in the various SAON-IG activities (see Fig. 3.8-3). These participants identified many opportunities to enhance the value of observations through better coordination within and among existing networks. These existing networks provide significant amounts of high quality data and are the foundations, or building blocks, on which the future of SAON will be built. Yet the SAON process confirmed that existing observing activities do not adequately cover the Arctic region, data are fragmentary and not always easily available, and only a part of existing Arctic observing is funded on a long-term basis.

The SAON-IG made four recommendations that can be summarized as follows:

1. The Arctic Council should lead the facilitation of international collaboration among government agencies, researchers and northern residents, especially indigenous people at the community level, to promote a sustainable pan-Arctic observing system.
2. The governments of the Arctic Council member states should commit to
   a. Sustaining their current level of observing activities and data and information services;
   b. Creating a means to make data and information freely, openly and easily accessible in a timely fashion.
3. The Arctic states are urged to increase intergovernmental cooperation in coordinating and integrating Arctic observing activities.
4. Arctic Council member states are urged to welcome non-Arctic states and international organizations as partners to the international cooperation that will

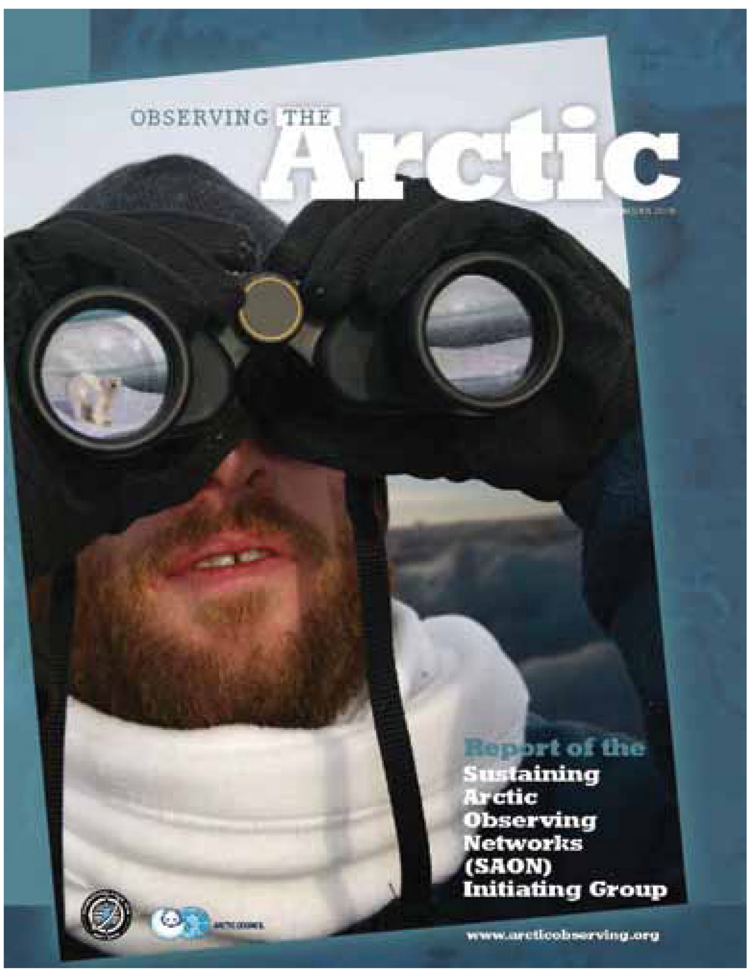

Fig. 3.8-3. Cover page of SAON Report, "Observing the Arctic" (2008) distributed at the Senior Arctic Officials (SAO) meeting in Tromsø in April 2009 www.arcticobserving.org/.

be necessary to sustain and improve Arctic observing capacity, and data and information services.

The SAON-IG agreed to present its report to the Arctic Council in April 2009 in Tromsø and at that point to disband, leaving the Arctic Council with the opportunity to consider its role in future development of sustained Arctic observing (see Fig. 3.8-4). After deliberation, the Arctic Council accepted the main points of the SAON-IG recommendations and provided its decisions in the Tromsø Declaration. This declaration stated that the Arctic Council will:

a. Support continued international coordination to maximize the legacy of IPY within the following areas: observations, data access and management, access to study areas and infrastructure, education, recruitment and funding, outreach, communication and assessment for societal benefits, and benefits to local and indigenous people.
b. Recognize the valuable contribution of the Sustaining Arctic Observing Networks (SAON) process as an IPY legacy to enhance coordination of multidisciplinary Arctic data acquisition, management, access and dissemination, encourage the continuation of this work with emphasis on improving sustained long-term observation, and welcome the participation of indigenous organizations in future work.
c. Decide to take the lead in cooperation with IASC and other relevant partners in the continuation of the SAON process, including to consider ways to develop an institutional framework to support circum-Arctic observing, and the preparation and implementation of a workplan for the next two years to initiate work on priority issues including sustained funding and data management.
d. Call for consultations involving national funding and operational agencies to create a basis for

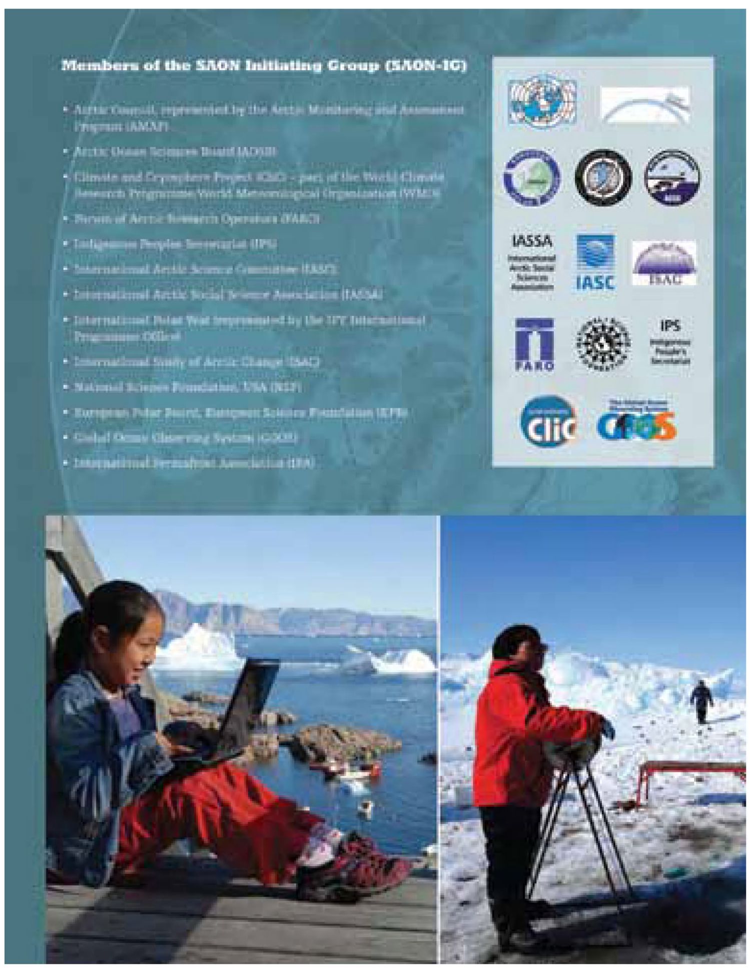

Fig. 3.8-4. Members of the SAON Initiating Group (IG) with their logos.
(From the SAON IG Report, 2008)

internationally coordinated funding and shared infrastructure and enhance the recruitment of young scientists into polar science.

e. Encourage the exploration of ways to continue the innovative forms for IPY outreach and the presentation of outcomes of the IPY, including the use of scientific data and traditional knowledge in future assessments.

As a direct result of these statements, the Arctic Council, International Arctic Science Committee and World Meteorological Organization formed the SAON Steering Group (SG) to continue to develop the SAON process. Co-chaired by John Calder (AMAP) and David Hik (IASC), the Arctic Council was represented by one representative formally appointed by each of the eight Arctic Countries and representatives of relevant AC Working Groups and Permanent Participants. The SAON SG reaffirmed the SAON-IG's vision of "free, open, and timely access to high-quality data that will realize pan-Arctic and global value-added services and provide societal benefits" and determined that its three top priority tasks were to engage government agency officials to seek a path toward sustained Arctic observing, to work more closely with local Arctic communities to better integrate community-based observations with scientific observations and to improve data management and data access practices.

Members of the SAON SG attended an IPY Data Management workshop in Ottawa, Ontario in September 2009. They were informed of the plans for creating an international comprehensive data base of all IPY projects over the next year or so. It was acknowledged that the SAON networks should be incorporated in this data base, even though many pre-dated the IPY. To ensure that this happens, the SAON SG and the IPY Data Management Subcommittee (DMS) held a joint workshop during the IPY conference in Oslo in June 2010 (*Chapter 5.6*) to share information on current data management practices of the networks and expose the networks to the desired data management practices developed by the IPY DMS (*Chapter 3.11*).

Members of the SAON SG engaged with community-based monitoring groups to explore integration of their results with those obtained by the scientific community. A very useful collaboration was developed with the Exchange for Local Observations and Knowledge of the Arctic (ELOKA) project created under IPY funding from the U.S. National Science Foundation (*Chapter 5.2*). The goal of ELOKA is to facilitate the collection, preservation, exchange and use of local observations and knowledge of the Arctic by providing data management and user support services. A key challenge of community-based research and monitoring is to have an effective and appropriate means of recording, storing, and managing data and information. Another challenge is to find an effective means of making such data available to Arctic residents and researchers, as well as other interested groups such as teachers, students, scientists and decision makers. Without a network and data management services to support these efforts, a number of problems have arisen such as, misplacement or loss of extremely precious data from Elders who have passed away, lack of awareness of previous studies causing repetition of research, research fatigue in communities and wasted resources, as well as a reluctance or inability to initiate or maintain community-based science activities without an available data management system. Thus there is an urgent need for effective and appropriate means of recording, preserving and sharing the information collected in Arctic communities. Geographic Information Systems and web-based mapping are important for displaying and communicating community-based science. Rather than duplicating work, the SAON SG looks to ELOKA as one of the key building blocks for the future sustained Arctic observing network and will seek ways to enhance its capabilities.

A workshop for government agency officials was held in March 2010 in association with the "State of the Arctic" Conference in Miami, Florida. Approximately 60 participants discussed the merits of the SAON process and provided recommendations for the actions needed to transform SAON from the planning stage to the implementation stage. The main recommendation was to define specific tasks with their resource requirements that should form the initial phase of implementation. Explicit was the recognition that financial commitments would be needed from the interested governments and that the central component of SAON would almost certainly have to be funded as a project activity. Additional tasks would also need support, but could be conducted either as in-kind contributions or funded activities. Examples of specific tasks were suggested with most focused on data sharing and access, improving coordination among sites and networks, defining standards and best practices, improving geospatial displays of data, linking observations to models and forecasts, and exploring solutions to wide-spread issues and problems.

The SAON SG agreed to develop specific project descriptions for the implementation of SAON and to discuss the concept of an "institutional framework" for continuation of the SAON process. These objectives were described to the Arctic Council at its meeting in April 2010. The Senior Arctic Officials expressed wide-spread support for SAON and options for implementation were presented at the Deputy Ministers meeting in late May 2010.

The SAON SG met in Reykjavik in August 2010 to discuss the scope of SAON and the roles and responsibilities of SAON and existing monitoring networks and government agencies. The SAON SG agreed that SAON itself will not undertake observations, conduct research, perform scientific analysis or assessment, nor be a source of funding for these activities. SAON will identify issues, gaps and opportunities related to Arctic observing and data sharing and take a multi-national approach to demonstrate improvements to the current situation, and consequently, SAON will work with a broadly defined Arctic observing community and with national and multi-national organizations and non-governmental partners. The Arctic Council Senior Arctic Officials and IASC Executive Committee endorsed these views and called for the preparation of an implementation plan for SAON and an initial list of SAON activities or tasks.

The SAON SG recommended that the implementation phase should adopt a task-based approach, with voluntary participation by any country or organization that could make a contribution to the goals of SAON. These tasks could include support for data management and data sharing, development and enhancement of observing activities, and synthesis of existing observation information. Members of each Task Team and their partners would be responsible for providing the resources needed for each task. To provide an initial focus, the SAON SG asked its members and some of the existing observing networks to propose tasks that could be undertaken during the next few years.

The report of the SAON SG to the Arctic Council and IASC (SAON SG, 2011) recommended that the Arctic Council (AC) and the IASC jointly establish a SAON Council, with each organization providing a permanent Co-Chair. The Council would report to both the AC and the IASC. The Council would be composed of representatives of participating countries, along with representatives of Arctic Council Working Groups and Permanent Participant organizations, and IASC. The WMO would be a member of Council, with other international organizations invited at a later stage. The Council would be supported by a Secretariat drawn from the existing Secretariats of the Arctic Council Arctic Monitoring and Assessment Program and the IASC. A key feature of the SAON Council is that it would establish its own rules of operation and not be bound by either the AC or IASC rules. In this way, both Arctic and non-Arctic countries may participate on an equal basis. If the Arctic Council and IASC support these recommendations the SAON Council will convene in 2011. SAON will represent a major advance in securing the legacy of IPY 2007-2008.

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3.9 The Circumpolar Biodiversity Monitoring Program (CBMP)

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Overview

The Circumpolar Biodiversity Monitoring Program (CBMP), an IPY "cluster program" (no.133) was initiated in 2003–2004 as an international network of scientists and local resource-users working together to enhance Arctic biodiversity monitoring to improve detection, understanding and reporting of significant trends in biodiversity and to inform management decisions (Strategy, 2004; Zöckler and Harrison, 2004). The CBMP was established as the cornerstone program of the Conservation of Arctic Flora and Fauna (CAFF) Working Group of the Arctic Council. Launched in 2005 and currently led by Canada, the CBMP has over 60 global partners, 33 of which are Arctic biodiversity monitoring networks connected to the CBMP. Many of these networks received substantial support from IPY and became integrated parts of its activities (CAFF 2006a,b; Fleener et al., 2004; Russel and Kofinas, 2004; Petersen et al., 2004). Arctic Nations currently spend over $500M monitoring biodiversity, yet there is an urgent need to improve coordination, data management and sharing.

The CBMP takes an ecosystem-based management approach and operates as a network of networks by coordinating existing species, habitat and site-based networks (Fig. 3.9-1). The CBMP has started the establishment of four Expert Monitoring Groups—Freshwater (1), Marine (2), Coastal (3) and Terrestrial (4)[1]—that were tasked with developing long-term integrated monitoring plans for the major Arctic systems: marine, freshwater, coastal and terrestrial, respectively. Furthermore, a special focus group is currently developing a protected-areas monitoring framework and another community-monitoring guidance group was called for in 2009. Also, the CBMP has begun the development of coordinated reporting and outreach tools, including a suite of Arctic biodiversity indicators, as well as a web-based data management and depiction tool (data portal) for biodiversity data.

The CBMP was strategically linked to a number of other Arctic biodiversity conservation-related efforts. It is a part of the Global Earth Observations-Biodiversity Observation Network (the Arctic-BON) and a member of the 2010 Biodiversity Indicators Partnership (2010 BIP), a global network aimed to improve the tracking and reporting of Convention on Biological Diversity indicators. The CBMP has been identified as the biodiversity component of the Sustaining Arctic Observing Networks (*Chapter 3.8*) initiative and was also closely linked with other Arctic Council initiatives in protecting arctic biodiversity. The CAFF Working Group supported the Convention on Biological Diversity of 1993 (CBD) and its so-called '2010 Biodiversity Target' (www.cbd.int/2010-target/),[2] and charged CBMP to monitor the Arctic region's progress towards this global initiative to arrest the biodiversity loss.

Across the Arctic biodiversity conservation community there is a wide range of data sources, formats and subjects. As a network of networks, the CBMP seeks to provide universal access to these resources through its publications (the *Arctic Species Trend Index*) and on-line data portal (the *Arctic Data Portal*). The CBMP has asked partner programs within the Arctic Council as well as other organizations to contribute to its data collection efforts.

During IPY years, the CBMP was and continues to

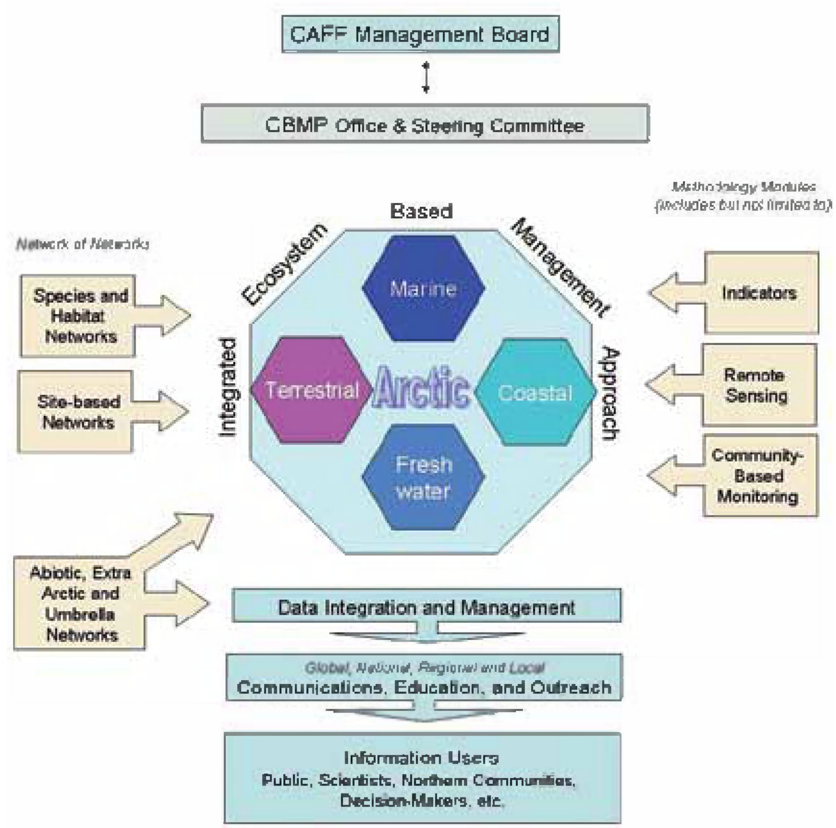


Fig. 3.9-1. CBMP organizational structure linking species networks, indicators and integrated ecosystem-management planning to information and decision-makers. (Courtesy: CBMP)

be focused on the following nine key initiatives: 1) CBMP Data Portal, 2) the Arctic Species Trend Index (the Headline Indicator for CBMP), 3) Integrated Arctic Marine Biodiversity Monitoring Plan (developed by the CBMP's Marine Expert Monitoring Group), 4) Integrated Arctic Freshwater Biodiversity Monitoring Plan (developed by the CBMP's Freshwater Expert Monitoring Group), 5) Community-Based Monitoring Handbook, 6) Pan-Arctic Protected Areas Monitoring Plan, 7) Circumpolar Polar Bear Research and Monitoring Plan, 8) Circumarctic Rangifer Monitoring and Assessment Network (CARMA, IPY no. 162), and 9) Circumpolar Monitoring Strategies for Ringed Seals and Beluga Whales. These key CBMP initiatives are described below.

CBMP Data Portal

Circum-arctic biodiversity research and monitoring currently comprise a multitude of networks that produce information in diverse formats with little integration. Much of this information remains inaccessible, unreported, or in non-user-friendly formats. Two of the CBMP's key objectives are to create an accessible, efficient and transparent platform to house and display information on the status and trends in Arctic biodiversity, and to integrate biodiversity information with relevant abiotic information (Fig. 3.9-2). By facilitating this, CBMP aims to improve the accessibility of biodiversity trend data, as well as the capability to correlate such trends with possible drivers. The ultimate goal is to accelerate data sharing and analysis.

The CBMP has initiated the development of a biodiversity data portal in the form of a user-friendly web-based information network that accesses and displays information on a common platform, so that users can share data over the Internet (http://cbmp.arcticportal.org). When fully operational, the portal would access to immediate and remotely distributed information about the location of Arctic biological resources, population sizes, trends and other parameters, including relevant abiotic information. The pilot version of the data portal was launched

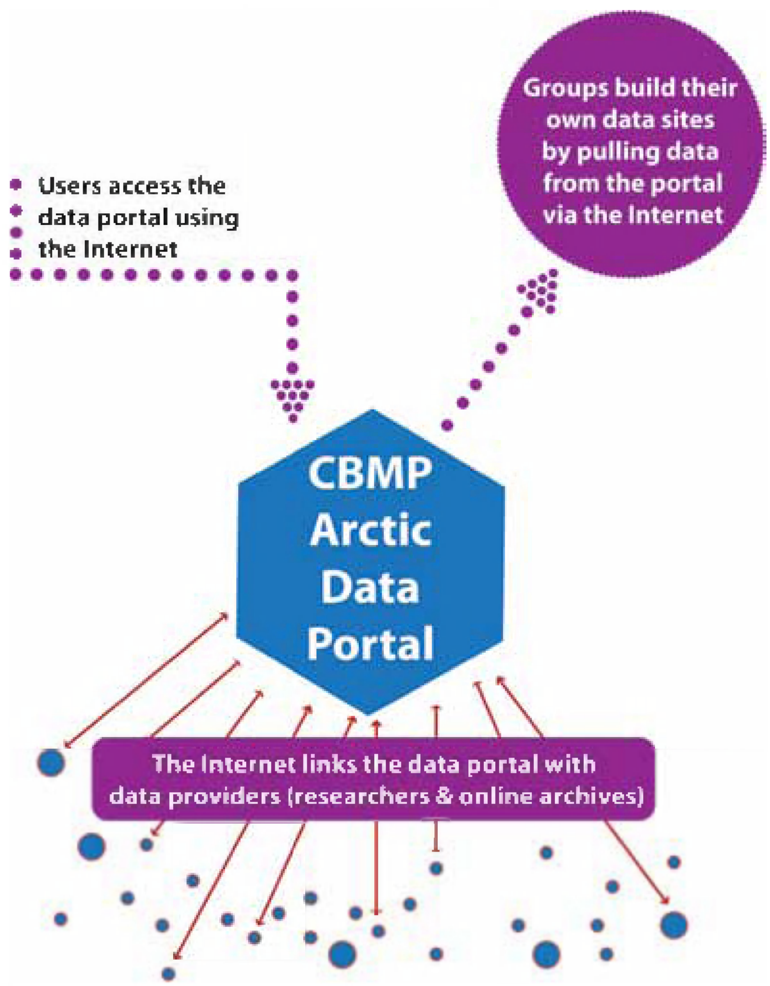


Fig. 3.9-2. Simplified data portal schematic linking data sources and providers to various user groups via the CBMP data portal.
(Courtesy: CBMP)

in November 2009 and displays the information on the distribution and abundance of almost 60 Arctic seabird species (Fig. 3.9-3). The development of this interoperable and distributed web-based system was initiated by the CAFF Circumpolar Seabird Group (CHASM, 2004; Hagemejer et al., 2004, see below) that focuses on accessing information on seabird colonies in the Arctic, including location, colony size by species, productivity and other parameters.

In addition to providing a focal point for Arctic biodiversity information, the data portal provided an effective conduit for experts to share information via the Internet. The most recent data source linked to the data portal is the Arctic Breeding Bird Condition Survey (ABBCS). The data portal project is a joint effort by the Circumpolar Seabird Group, the Circumpolar Biodiversity Monitoring Program, U.S. Fish and Wildlife Service and United Nations Environmental Program (UNEP) World Conservation Monitoring Centre with the participation of all the Arctic countries and Arctic Council observer organizations.

The Arctic Species Trend Index (Headline Indicator for the CBMP)

The Arctic Species Trend Index (ASTI – McRae et al., 2010) is an effort commissioned and coordinated by CBMP; it uses population-monitoring data to track trends in marine, terrestrial and freshwater Arctic vertebrate species. The index allows for a composite measure of the overall population trends of Arctic vertebrate populations between 1970 and 2004.

Fig. 3.9-3. Screenshots of the CBMP data portal. On the left are population data locations and summary information being provided from a distributed data node. On the right is an example of an analysis tool that indicates where a seabird colony is located as it relates to various land-use designations. (Courtesy: CBMP)

The index can also be organized to display trends based on taxonomy, biome, or region (Fig. 3.9-4). The index currently tracks almost 1000 Arctic vertebrate population datasets of 365 species by biome, taxa, migratory status, etc.

To facilitate the examination of regional trends, the Arctic was divided into three sub-regions: Sub-Arctic, Low Arctic and High Arctic. Species population data were classified by the broad habitats they inhabit (land, lakes and rivers, or oceans). Ocean habitats were further delineated by ocean basin: Arctic, Atlantic, or Pacific. The individual populations in the ASTI were further classified based on migratory status, trophic level and other relevant categories. The ASTI allows for tracking broad trends in the Arctic's living resources and identifying potential causes of those trends, whether they are responses to natural phenomena or human-induced stressors (Figs. 3.9-5 and 3.9-6).

The development of the index was a collaborative effort between the CBMP, the Zoological Society of London, UNEP World Conservation Monitoring Centre and the World Wildlife Fund (Gill and Zöckler, 2008). Funding for the project was provided by the Government of Canada. The first assessment indicates that the abundance of tracked High Arctic Species declined 26% between 1070 and 2004, whereas Low Arctic species have increased in abundance and the Subarctic species, though in decline since the mid-1980s, show no overall change over the 34-year period (McRae et al., 2010). Although the ASTI currently represents population data for 35% of all Arctic vertebrate species (a very high proportion for such an index), more information is needed to understand how Arctic vertebrate populations are faring.

Marine Expert Monitoring Group— Integrated Arctic Marine Biodiversity Monitoring Plan

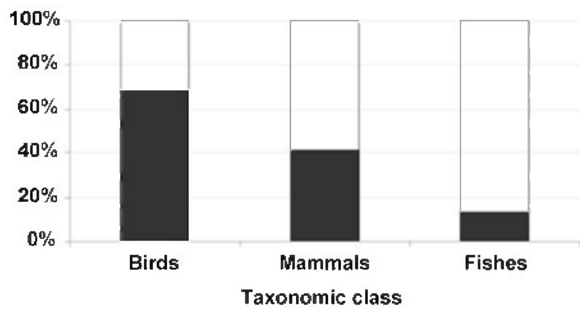
The goal of the Marine Expert Monitoring Group (MEMG) of CBMP is to promote and coordinate marine biodiversity-monitoring activities among circumpolar countries, and to improve the ongoing communication among scientists, community experts, managers and disciplines both inside and outside the Arctic. Specifically, the MEMG is charged with developing a multi-disciplinary, integrated, pan-Arctic long-term marine biodiversity monitoring plan, and facilitating its implementation (Vongraven et al., 2009).

Co-led by Reidar Hindrum (Norway) and Kathleen Crane (U.S.A.), and with 15 members from Russia, Denmark/Greenland, Canada, Iceland, Aleut International Association and the Arctic Council's Arctic Monitoring and Assessment Programme (AMAP) Protection of the Arctic Marine Environment (PAME), the MEMG has been working to develop the marine biodiversity monitoring plan since 2008 (Table 3.9-1). Norway convened the first MEMG planning workshop in January 2009 in Tromsø, Norway. It brought together scientists and community-based experts from across the Arctic and launched the process of identifying the key elements (drivers, focal ecosystem components, indicators and existing monitoring programs) that should be incorporated into a pan-Arctic monitoring plan.

Fig. 3.9-4. (a) Arctic terrestrial ecosystems as defined by floristic boundaries (credit: AMAP Assessment Report, 1998); and (b) Regional divisions of the marine Arctic, as determined by the CBMP Marine Expert Monitoring Group. Note that this map is preliminary and boundaries will be modified to align with the Arctic Large Marine Ecosystem delineations once finalized.

(Courtesy: CBMP)

Fig. 3.9-5. (left) Data Coverage by Taxonomic Class that were represented in the ASTI analysis. Black bars represent proportion of Arctic species in each class for which there are population data available. White bars are the proportion of Arctic species with no available population-trend data. (McRae et al., 2010)



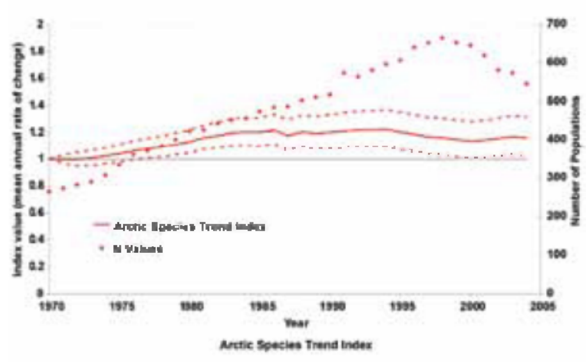


Fig. 3.9-6. (right) ASTI (with 95% confidence intervals) for all species within the Arctic boundaries and total population (N) values for that year, for the period 1970–2004. (ASTI, n=306 species, 965 populations). (McRae et al., 2010)

Table 3.9-1. General timeline of the Marine Expert Monitoring Group

August 2008	MEMG established
December 2008	MEMG Background Paper edited
January 2009	1st MEMG Workshop
April 2009	First Workshop Report completed
November 2009	2nd MEMG Workshop
June 2010	Integrated Monitoring Plan completed and submitted for CAFF review

This first workshop drew heavily on the background paper (Volgrled, by the Norwegian Polar Institute). This workshop report detailed the existing monitoring programs and the focal ecosystem components, drivers and indicators to be considered as part of a monitoring plan for each focal marine area. Upon completion of the draft plan, a second workshop was held in Washington, D.C. (Fall 2009) to identify key partners and a process for implementing the monitoring plan.

The MEMG identified eight focal areas for the initial monitoring program development: 1) Atlantic Arctic Gateway, 2) Pacific Arctic Gateway, 3) Arctic Basin, 4) Hudson Complex, 5) Baffin Bay – Davis Strait – Lancaster Sound, 6) Beaufort Sea – Amundsen Gulf – Viscount Melville – Queen Maud, 7) Kara – Laptev Seas and 8) the Arctic Archipelago. The six countries participating in the MEMG—Canada, Greenland/Denmark, Iceland, Norway, Russia and the U.S.—have chosen or are in the process of choosing sentinel stations in each marine area that have long monitoring histories and are likely to be monitored in the future. Stations are chosen based on discipline e.g. benthos, plankton, ice species, fish, seabirds, marine mammals and polar bears. Sentinel station maps are being produced for each of the disciplines and are supported by the participating countries (Fig. 3.9-7).

Freshwater Expert Monitoring Group—Integrated Arctic Freshwater Biodiversity Monitoring Plan

The establishment of a Freshwater Expert Monitoring Group (FEMG), suggested in 2008 (CBMP, 2008) and co-led by Canada and Sweden, is aimed at facilitating an integrated, ecosystem-based approach to the monitoring of Arctic freshwater biodiversity. The group was created to support the development of an integrated, pan-Arctic monitoring plan to include optimal sampling schemes, common parameters and standardized monitoring protocols, and to identify critical monitoring gaps and develop strategies to fill gaps in data. The group also serves as a forum for providing on-going scientific and traditional knowledge to enhance current monitoring. The FEMG is expected to make full use of existing monitoring and data drawn on the expertise from both inside and outside the Arctic and from other relevant disciplines (e.g. climate science), incorporate both community-based knowledge and science-based approaches, and use new technologies, such as remote sensing and genetic bar-coding, where appropriate.

The group was initiated in May 2010. It includes community, scientific and indigenous experts. The group will not only work with existing research stations and monitoring networks to develop integrated, forward-looking monitoring programs,

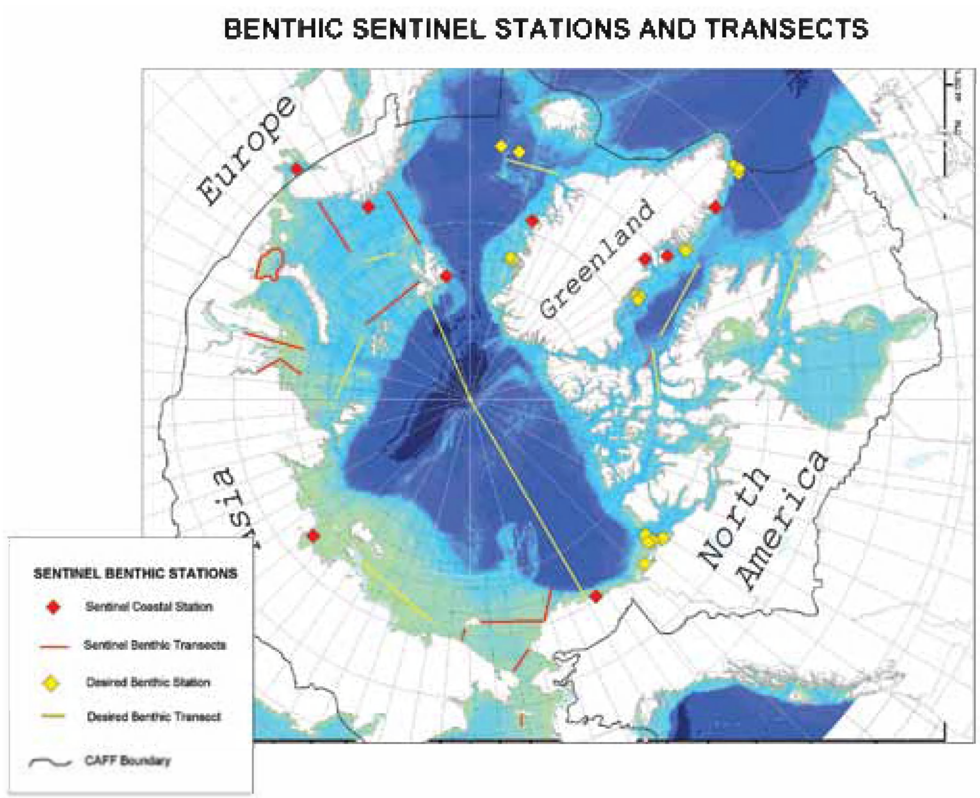


Fig. 3.9-7. Arctic Marine Biodiversity Benthic Sentinel Stations Marine Expert Monitoring Group, CBMP 2010.

but will also focus efforts on the retrieval and use of historical information, be it traditional knowledge or archived scientific data.

Community-Based Monitoring Handbook

Community-based monitoring (CBM) is a complex research field that is becoming an essential and often required component in academic research and natural resource management (Fleener et al., 2004; Huntington, 2008). It is often used as a validation of results produced by conventional research methods. CBM enabled researchers to reach beyond traditional data collection strategies by using the best available knowledge, be it academic, indigenous or local. CBMP commissioned the development of a *Community-Based Monitoring Handbook* (Gofman and Grant Friedman, 2010). The handbook aims to enhance the role of community-based observations in the current and emerging Arctic research projects. Handbook recommendations could easily be applied to broader monitoring efforts and in non-Arctic regions.

The *Handbook* reviews several ongoing community monitoring programs, such as the Arctic Borderlands Ecological Knowledge Co-op (http://taiga.net/coop/), Bering Sea Sub Network: International Community-Based Environmental Observation Alliance for Arctic Observing Network (IPY no.247 – *Chapter 3.10*), Community Moose Monitoring Project and Community Ecological Monitoring Project, ECORA (Integrated Ecosystem Approach to Conserve Biodiversity and Minimize Habitat Fragmentation in the Russian Arctic, www.grida.no/ecora/), Fávllis (Sámi Fisheries Research Network www.sami.uit.no/favllis/indexen.html), Marine Rangers Project in Australia (www.atns.net.au/agreement.asp?EntityID=4923), Siku-Inuit-Hila Project (*Chapter 3.10*) and Snowchange Network in Finland (www.snowchange.org/web/index.php). The handbook is written for a diverse audience that includes scientists, students, Arctic community residents and government officials.

Pan-Arctic Protected Areas Monitoring Plan

In addition to the ecosystem-based Expert Monitoring Groups, the CBMP aims to establish a Pan-Arctic Protected-Areas Monitoring Group, recognizing that protected areas represent important existing platforms for the implementation of pan-Arctic, coordinated biodiversity monitoring. The CBMP is working collaboratively with the various national and regional Arctic protected-areas agencies to identify current biodiversity-monitoring efforts and opportunities for establishing a standardized suite of parameters that can be monitored within protected areas (Gill et al., 2008). The main objective is to identify a small suite of biodiversity measures that would be common across the Arctic and implemented in the same way by the agency responsible for its respective protected area. This pan-Arctic set of measures will allow coordinated reporting of biodiversity in Arctic protected areas and provide a broader context to regional changes, thereby assisting managers in monitoring changes within their own protected areas.

During 2010, the Pan-Arctic Protected Areas Monitoring Group held workshops focused on reviewing current monitoring programs and selecting a suite of standardized parameters to monitor and indicators to report. The goal is to track and promote implementation of the monitoring plans.

Circumpolar Polar Bear Research and Monitoring Plan

Despite the sustained attention given to polar bears *(Ursus maritimus)*, we have only limited baseline information on most polar bear regional populations and a poor understanding of how polar bears will respond to a rapidly changing Arctic climate (Table 3.9-2). Meeting this challenge requires an efficient coordinated effort spanning all Arctic regions. An integrated pan-Arctic research and monitoring plan is needed to improve our ability to detect trends in polar bear populations, understand the mechanisms

Table 3.9-2. Current status, trends, harvest and risk of decline for polar bear populations.
(Unpublished data, courtesy of Dag Vongraven, Norwegian Polar Institute)

Population	Abundance Estimate	Year of Estimate	Annual Kill (5-year mean)	Trend	Status	Estimated Risk of Future Decline (10 years)
East Greenland	unknown	–	58	Data deficient	Data deficient	Data deficient
Barents Sea	2650	2004	no catch	Data deficient	Data deficient	Data deficient
Kara Sea	unknown	–	n/a	Data deficient	Data deficient	Data deficient
Laptev Sea	800-1200	1993	n/a	Data deficient	Data deficient	Data deficient
Chukchi Sea	unknown	–	n/a	Decline	Reduced	Data deficient
Southern Beaufort Sea	1526	2006	44	Decline	Reduced	Moderate
Northern Beaufort Sea	1202	2006	29	Stable	Not reduced	Data deficient
Viscount Melville Sound	161	1992	5	Data deficient	Data deficient	Data deficient
Norwegian Bay	190	1998	4	Decline	Data deficient	Very high
Lancaster Sound	2541	1998	83	Decline	Data deficient	High
M'Clintock Channel	284	2000	2	Increase	Reduced	Very low
Gulf of Boothia	1592	2000	60	Stable	Not reduced	Very low
Foxe Basin	2300	2004	101	Data deficient	Data deficient	Data deficient
Western Hudson Bay	935	2004	44	Decline	Reduced	Very high
Southern Hudson Bay	900-1000	2005	35	Stable	Not reduced	Very high
Kane Basin	164	1998	11	Decline	Data deficient	Very high
Baffin Bay	1546	2004	212	Decline	Data deficient	Very high
Davis Strait	2142	2002	60	Decline	Not reduced	Very high
Arctic Basin	unknown	–		Data deficient	Data deficient	Data deficient

driving those trends and facilitate more effective and timely conservation responses. Such a plan was called for in the March 2009 Meeting of the Parties to the 1973 Agreement on Polar Bears. CAFF/CBMP and the IUCN/SSC Polar Bear Specialist Group (funded by the U.S. Marine Mammal Commission) have agreed to initiate the development of this plan.

This project has established a Pan-Arctic Polar Bear Research and Monitoring Plan to be adopted across the Arctic. The plan will identify standardized parameters for 'reference populations,' extensive measures[3] for 'secondary populations,' optimal sampling schemes, population models and new methods for research and monitoring.

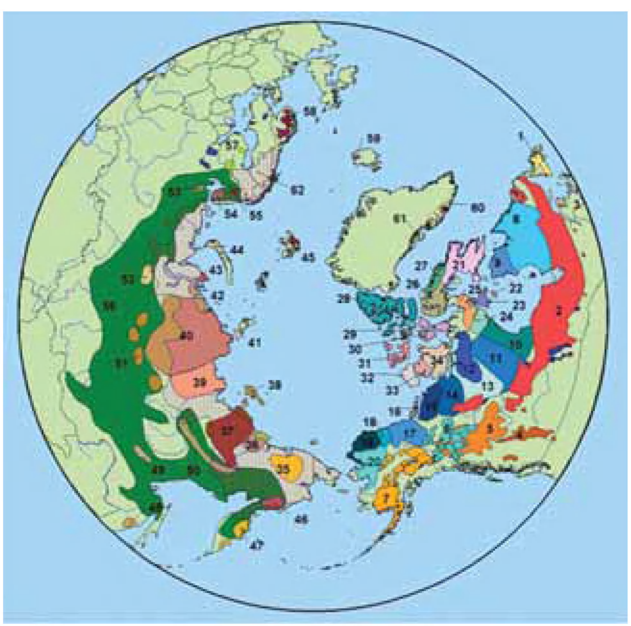
Circum-Arctic Rangifer Monitoring and Assessment Network (CARMA)

CARMA (IPY no.162, since 2005) is a consortium of scientists, managers and community experts who have a common interest in the future survival of the northern *Rangifer* (caribou and wild reindeer) herds (www.carmanetwork.com). CARMA is primarily focused on the status of most of the large migratory *Rangifer* herds in Eurasia and North America (Russel and Kofinas, 2004) and, as yet, does not deal with the woodland caribou and Peary caribou populations in North America or forest and marine reindeer in Fennoscandia and Russia (Fig. 3.9-8). It also does not focus on the domestic reindeer herds and the herding economy, which are the domains of the EALÁT project (IPY no. 399 *Chapter 3.10*).

Presently, CARMA is funded primarily under the Canadian IPY program; this funding supports more than 30 regional projects in caribou/reindeer physiology, body composition, pathogens, regional herd assessment and modeling, habitat assessment and community training (www.carmanetwork.com/display/public/Projects).

Observations from community members, particularly caribou and reindeer hunters, collected in the field or via various co-management groups are an important component of CARMA (*Chapter 3.10*). CARMA's overall objective is to produce a pan-Arctic assessment of the vulnerability of *Rangifer* herds to global changes. This will be accomplished by conducting cross-herd comparisons among a number of regional herds that have active CARMA partners and a substantial retrospective database. To accomplish that objective, CARMA has developed six "synthesis questions" (www.carmanetwork.com/display/public/Research+Tools) related to the role of seasonal habitat changes, individual

Rangifier Herds of the Circumpolar North



1 Newfoundland
2 Boreal
3 Atlantic
4 Southern Mountain
5 Northern Mountain
6 Yukon
7 Alaska
8 George River
9 Leaf River
10 Qamanirjuaq
11 Beverly
12 Ahiak
13 Bathurst
14 Bluenose East
15 Bluenose West
16 Cape Bathurst
17 Porcupine
18 Central Arctic
19 Teshekpuk
20 Western Arctic
21 South Baffin Island
22 Coats Island
23 Southampton Island
24 Lorillard
25 Wager Bay
26 North Baffin Island
27 Northeast Baffin Island
28 Eastern Queen Elizabeth Islands
29 Bathurst Island
30 Prince of Wales-Somerset-Boothia
31 Western Queen Elizabeth Islands
32 Banks Island
33 Northwest Victoria Island
34 Dolphin-Union
35 Chukotka
36 Sudrunskaya
37 Yana-Indigirka
38 Novosibiriski Ostrova
39 Lena-Olenek
40 Taimyr
41 Severnaya Zemlia
42 Gydan
43 Belyi
44 Novaya Zemlia
45 Svalbard
46 Parapolskii
47 Kamchatka
48 Amur
49 Okhotsk
50 Yakutsk
51 Evenkiya
52 Nadym-Pur (Yamal Okrug)
53 Arkhangelsk Oblast
54 Terskii Bereg (Kola)
55 Laplandskii Zapovednik (Kola)
56 Range of Forest Reindeer
57 Finland
58 Norway
59 Iceland
60 Greenland
61 Greenland Feral Reindeer
62 Range of Domestic Reindeer

Fig. 3.9-8. Rangifer herds of the Circumpolar North. (CARMA and Environment Canada 2007, www.carmanetwork.com) herd dynamics, pathogens and predators and human pressure on caribou/reindeer herds to be integrated in the "cumulative assessment model."

Circumpolar Monitoring Strategies for Ringed Seals and Beluga Whales

The U.S. Marine Mammal Commission and U.S. Fish and Wildlife Service convened an international workshop in Valencia, Spain 4–6 March, 2007 to develop monitoring strategies for Arctic marine mammals (Simpkins et al., 2007). Outcomes of the meeting included linking population responses to key factors and recommendations for a monitoring framework for arctic marine mammals, including the key factors that drive their population dynamics, such as health status, trophic dynamics, habitat quality and availability, and the effects of human activities (Fig. 3.9-9). Some of these factors are likely to respond quickly to climate change and new human activities in the Arctic; those changes, in turn, might trigger rapid changes in the status of marine mammal species. Two marine mammal species, ringed seals and belugas, have been selected as case studies under the CBMP-led monitoring framework for Arctic marine mammals (Simpkins et al., 2007).

Circumpolar Seabird Expert Group (CBird)

The concept of a Circumpolar Seabird Group (CBird) was approved by CAFF in 1993 in recognition that Arctic countries often share the same seabird species' populations and, therefore, share joint responsibility for their conservation. CBird has been instrumental in addressing the priority of circumpolar Arctic seabird conservation. Over the years, it has published two conservation action plans (for Murres and Eiders), six CAFF technical reports, two editions of the *Circumpolar Seabird Bulletin,* three posters, 13 progress reports and participated in numerous meetings and workshops.

CBird is one of the groups of under the CBMP program. It meets once a year to evaluate the status of its many projects, such as the Circumpolar Seabird Colony Database, Circumpolar Seabird Monitoring Plan, Birds of Arctic Conservation Concern, International Ivory Gull Conservation Strategy, Seabird Information Network, Harvest of Seabirds in the Arctic and others (Petersen et al., 2008). Funding for the Seabird Information Network and Circumpolar Seabird Colony Database was recently obtained and promises to accelerate the completion of these projects.

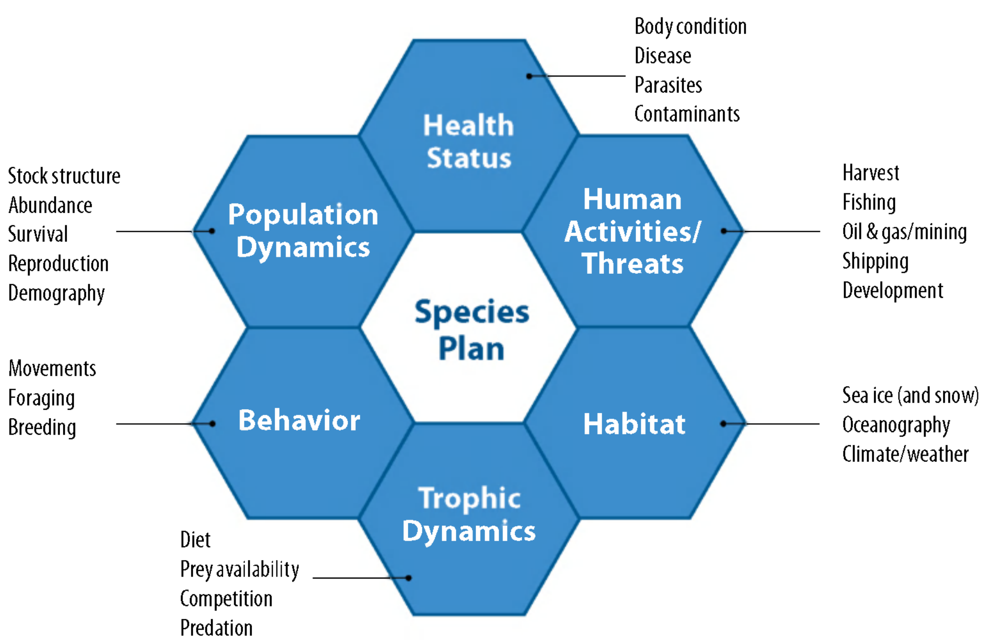


Fig. 3.9-9. The components of a comprehensive plan for monitoring the status of a marine mammal species or stock, including population dynamics, the factors that influence those dynamics, and examples of parameters that might be monitored for each factor. (Simpkins et al., 2007)

Summary: The Circumpolar Biodiversity Monitoring Program as an IPY Legacy

IPY 2007–2008 was instrumental in both marketing and implementing the concept of international coordination of polar research and monitoring. It, therefore, became an important catalyst for Arctic biodiversity monitoring, which was an important factor in the successful implementation of CAFF's Circumpolar Biodiversity Monitoring Program. With the CBMP successfully implemented during IPY to coordinate and integrate many Arctic expert biodiversity-monitoring networks in place, we can build on this progress to ensure continued long-term, coordinated monitoring of the Arctic living resources.

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Notes

[1] Four CBMP Expert Monitoring Groups (EMG) are the (1) Freshwater, (2) Marines, (3) Coastal and (4) Terrestrial EMGs. The Coastal and Terrestrial EMGs have yet to be initiated.

[2] In April 2002, the Parties to the Convention on Biological Diversity committed themselves to achieve by 2010 a significant reduction of the current rate of biodiversity loss at the global, regional and national level as a contribution to poverty alleviation and to the benefit of all life on Earth (www.cbd.int/2010-target/). That pledge is known as '2010 Biodiversity Target.'

[3] Extensive measures are parameters measured less intensively in areas with limited monitoring resources as part of a larger, scaled research and monitoring approach involving reference populations (monitored intensively) and secondary populations (monitored less intensively).

3.10 Human-Based Observing Systems

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Introduction

The *Arctic Climate Impact Assessment* report (ACIA) was the first seminal scientific overview of the Arctic environment to include indigenous knowledge and a discussion of its relationship to environmental research and management (ACIA, 2005). The report identified five key areas in which indigenous knowledge and observations have proven particularly illuminating about climate change research. These are: (1) changes in weather, seasons, wind, etc.; (2) sea ice; (3) permafrost and coastal erosion; (4) marine life; and (5) land-based animals, birds, insects and vegetation (Huntington and Fox, 2005). At the same time, the ACIA report noted the lack of integration or linking of indigenous and scientific observations of climate change and the interpretation of these observations. It cited a lack of trust between the indigenous and scientific communities, which ultimately determines how indigenous data and observations can best be incorporated into scientific systems of knowledge acquisition and interpretation (Huntington and Fox, 2005). Nonetheless, the ACIA team viewed further extensions of collaborative research as the most promising model and recommended involving indigenous communities in research design and setting the research agenda, to ensure that the polar science is relevant locally.

That recommendation was also reflected in the *Framework* document produced by the IPY Planning Group roughly at the same time (Rapley et al., 2004). The 'framework' science plan for IPY 2007–2008 advanced "six interdisciplinary observational strategies" for IPY, including one focused on observations in human- and community-based developments, in order to "investigate crucial facets of the human dimension of the polar regions, which will lead to the creation of datasets on the changing conditions of circumpolar human societies" (Rapley et al., 2004: 7). This emerging focus on human- and community-based observations was further strengthened in later IPY documents and science projects (Allison et al., 2007; Hovelsrud and Krupnik, 2006; Krupnik and Hovelsrud, 2009). Two scientists working with indigenous communities on environmental monitoring (Lene Kielsen Holm from Nuuk, Greenland and Tatyana Vlassova from Moscow, Russia) served on the IPY Subcommittee on Observations.[1]

IPY 2007–2008 has engaged an unprecedented number of Arctic residents in its many projects through "research planning, observation, processing and interpretation of the various data sets created" (Allison et al., 2007). In the special section of the final IPY Science Outline titled "Integration of the Knowledge and Observations of Polar Residents," local communities were recognized to be "integral" and "vital" to the IPY data collection, monitoring, data analyses and data management processes, particularly in the social, physical and biological disciplines. Such engagement of polar residents was anticipated to play a dual role in the IPY efforts. First, it was viewed as an integral part of many science-driven observational projects that involved local communities and their knowledge; that is, observations and interpretations of the changing polar environment. This referred primarily to social and human-oriented studies but also, increasingly, to projects undertaken by scientists in physical and biological disciplines, like the research in sea ice dynamics, climate variability, marine and terrestrial ecosystem health, and environmental change. Second, and at least as important to the IPY 2007–2008 agenda, were the projects initiated by polar communities and indigenous organizations, involving their own knowledge and observations of local processes and phenomena (see more in *Chapter 5.4*). The scope of such efforts increased dramatically, in large part thanks to IPY 2007–2008. It now includes the sustainable use of local resources, primarily in fisheries, exploitation of reindeer/caribou populations and environmental-friendly tourism; indigenous culture and language sustainability; increased resilience of local economies and social systems through co-management, self-governance and information exchange among local stakeholders; and interactions with the industrial development in the polar regions, including monitoring of environmental and social impacts, primarily in oil and gas, and other mineral exploitation (Allison et al., 2007).

The extent to which this has been attempted and success attained is provided in the following sections of this chapter. It overviews a fraction of IPY 2007–2008 projects—eight in total—out of a much larger group of international and national initiatives during IPY years that included, what is increasingly referred to as, Community-Based Monitoring or CBM (see Gill and Barry (2008); *Chapter 5.4*) where researchers work with individual local experts or via community-run observational networks. The overall number of known IPY projects that employed community-based monitoring is probably close to 20-25 (Hovelsrud and Krupnik, 2006). Though not every proposed initiative in that group eventually received funding and was implemented, many other local ventures during IPY years engaged indigenous observers and local communities in environmental, health and social monitoring efforts.[2] The impact of these activities will be fully understood as more project reports and publications become available.

Project Overviews

The eight international IPY projects reviewed in this chapter (no. 46, 157, 162, 166, 187, 247, 399, and 408) submitted the most detailed accounts of their respective community-based monitoring efforts. The projects differed substantially in their geographic scope as well as in the number of communities and local experts involved, from truly circumpolar studies covering the entire Arctic region (no. 157, 162) or its major sections (no.166, 399) to regional (no. 46, 247) and even community- or area-specific ventures (no. 187, 408). Four of the reviewed projects are focused on the land-based resources and processes: Traditional Indigenous Land Use Areas in the Nenets Autonomous Okrug (MODIL-NAO, no. 46), Circum-Arctic Rangifer Monitoring and Assessment Network (CARMA, no. 162), Reindeer Herders Vulnerability Network Study (EALÁT, no. 399), and Monitoring the

Fig. 3.10-1. Vehicle tracks across summer tundra near the oil terminal Varandey; driving on unfrozen ground leads to a rapid destruction of the tundra cover and is considered an unlawful activity in Russia, though rarely prosecuted.
(Photo: Association of Nenets People Yasavey, September 2002)

Human-Rangifer link (NOMAD, no. 408). Three others are oriented toward the sea, ice, marine and coastal resources: Sea Ice Knowledge and Use (SIKU, no. 166), Exchange for Local Observations and Knowledge of the Arctic (ELOKA, no. 187), and the Bering Sea Sub-Network (BSSN, no. 247). The largest project, both in its geographic scope and the number of communities involved, Community Adaptation and Vulnerability in Arctic Regions (CAVIAR, no. 157) has a number of land-focused case studies in reindeer herding and terrestrial resource use, but also incorporates coastal fisheries and other marine resources and concerns.

Besides an unprecedented diversity in geographic setting and local conditions, the eight reviewed projects cover major fields identified by IPY planners as "integral" or "vital" to the IPY program. These include climate change; analysis of major forces, both environmental and social, that forge the development of the polar regions; and the polar-global linkages, in terms of the impacts of global processes upon polar environments and societies, and vice versa. They also illuminate the main areas that are instrumental to the successful integration of indigenous and scientific knowledge, such as the monitoring of climate and polar ice change, the impact of industrial development upon polar land and waters, and co-management of the vital polar biological resources, both on land and at sea.

The contribution of the eight IPY 'case' projects in community-based monitoring is reviewed here along three main factors: (1) innovative local observation and monitoring strategies implemented in each project; (2) new and improved knowledge acquired through respective research; and (3) what scientists from other IPY disciplines may learn from observational records produced by each project. Four land-focused projects are presented first (no. 46, 162, 399, and 408) followed by three projects in marine environment monitoring (no. 166, 247, and 187). The most diverse project (no. 157), which also has the most complex approach and methodology, offers a natural transition to the concluding summary section.

MODIL-NAO

The project, "Monitoring of the Development of Traditional Indigenous Land Use Areas in the Nenets Autonomous Okrug, NW Russia" (MODIL-NAO no. 46) was initiated by the representatives of the local organization of indigenous people (Association of the Nenets People, Yasavey) in collaboration with the Norwegian Polar Institute (http://npolar.no/ipy-nenets/). It was implemented by a joint Norwegian-Russian team of 20+ participants, including scientists, key partners in local communities, local experts and technical personnel.

Observation and monitoring strategies. The MODIL

Fig. 3.10-2. Drilling sites often completely destroy large patches of the former tundra pastures; but little effort is made to keep the affected areas as small as possible.

(Photo: Association of Nenets People Yasavey, September 2002)

Fig. 3.10-3. Modern-day Nenets herding camp in the Varandey Tundra.
(Photo: Association of Nenets People Yasavey, September 2002)

NAO Project was initiated by the Association of the Nenets People-Yasavey in response to the growing concerns by indigenous stakeholders over the deterioration of environment, new health risks and alienation of their pasture lands by oil and gas industry across their traditional area in Northwestern Arctic Russia (Figs. 3.10-1, 3.10-2). Collaboration between scientists and representatives of local indigenous communities (Fig. 3.10-3) ensured the exchange of data collected and the verification of the interpretation of the project results. In seeking to document changes in land use across the Nenets Autonomous Okrug (NAO) due to oil- and gas-related activities, the project employed a number of complementary techniques. First and foremost were extensive on-site interviews with local reindeer herders (103 total, most with maps and audio recordings) regarding their observations of change in pastures, landscape, vegetation, level of pollution, etc. The change in socio-economic conditions and influence of oil development on traditional livelihoods was assessed based on the questionnaire survey (Fig. 3.10-4).

Another important research technique was the mapping of the impacts of oil development in the study area from the interpretation of satellite images. The project developed the first GIS database with public Internet access (through GoogleEarth) combining indigenous people's traditional and industrial modern land use data. The traditional land use data held in the GIS database has been collected from the same six study areas across the Nenets Autonomous Okrug, while oil-related data attempt to cover the entire area of activities. The project database also includes a collection of federal (Russian) and regional (Nenets AO) legislations as well as outlines of judicial issues relevant for indigenous people and modern industrial land use.

New and improved knowledge. Local observations collected during the MODIL-NAO project drew attention to the increasing pressure affecting Nenets reindeer-herding communities in this area of the Russian Arctic. New stress factors ranged from socio-cultural, such as the loss of traditional knowledge, decreasing prestige of reindeer herding and growing unemployment, to concerns regarding the deterioration and reduction of the pasture areas and the responsibility of oil companies for pollution, poaching, reindeer harassment, and other destructive impacts upon traditional land use. The project noted the lack of influence exerted by the Nenets herders in oil and gas installation planning, and the paucity of effective environmental regulation and enforcement in the region. While documenting many negative impacts of oil and gas development in their region, local residents acknowledged certain improvements in the economic situation due to investments by oil

Fig. 3.10-4. MODIL-NAO workshop at which local representatives from villages were trained as interviewers for the questionnaire survey. (Photo: Winfried K. Dallmann, September 2007)

companies in the social security system. A further vulnerability was noted regarding the decreased availability of traditional food and potentially negative health effects should traditional foods be substituted with store-bought foods.

Value for other IPY science fields. MODIL-NAO has created a comprehensive project report (Dallmann et al., 2010) and a GoogleEarth-based GIS database (Fig. 3.10-5) accessible through the Internet (http://npolar.no/ipy-nenets), which is intended to serve indigenous stakeholders, local and international specialists in environmental protection, community leaders, and policy-makers. The database is an open product that will be maintained and expanded via future monitoring and research. This GoogleEarth-based atlas and database were conceived to support the Nenets people and their organizations in planning and discussing the land use issues and to combat the degradation of their traditional pasture areas through oil development. The project produced an 'IPY 2007–2008 snapshot' of the environmental and socio-economic conditions in one of the Arctic regions most heavily affected by oil and gas development and of its indigenous people struggling to maintain their life ways and economic practices under the growing industrial pressure on their land and resources.

CARMA

The CircumArctic Rangifer Monitoring and Assessment Network (CARMA no. 162 www.carmanetwork.com/display/public/home) involved an extensive network of more than 60 participants from the U.S.A., Canada, Norway, Greenland, Russia, Iceland and Finland. Representatives were drawn from agencies, indigenous organisations, co-management boards and universities, which enabled the creation of a network for sharing information and mutual learning. The project sought to assess the vulnerabilities and resilience of wild, barren ground caribou herds *(Rangifer tarandus)* to global change and further to document people's relationship with this important resource.

Observation and monitoring strategies. The project established a standard protocol for collecting data for monitoring caribou herd conditions, health, range, population levels, and remotely sensed data (*Chapter 2.9*) (www.carmanetwork.com/pages/viewpage.action?pageId=1114257). Local hunters from several participating communities in Alaska, Nunavut, Nunavik, Canadian Northwest Territories, Labrador, Greenland, Arctic Norway, and the Taymyr and Chukotka areas in Russia have been involved in these activities; they have been trained to report the information based upon systematic monitoring of individual local caribou herds. To ensure consistency of data collection across many Arctic regions, special videos on how to collect body condition data on reindeer have been developed. Indigenous user communities were also engaged in the development of the Caribou Atlas project, which sought to document scientific and indigenous names and uses for parts of the caribou. Local perspectives of change have been documented through videography. A documentary "Voices of Caribou People," involving six caribou user communities in North America, has been produced recording indigenous perspectives of change. All relevant information on the project can be accessed on its website (www.carmanetwork.com/display/public/home).

New and improved knowledge. The CARMA project is based on both western science and community experience, and the synthesis of the knowledge gained will be compiled in a project volume (to be published in 2011) describing the current understanding on how large migratory herds of *Rangifer* function across the circum-Arctic zone in various habitats. This will include an emphasis upon: 1) the characteristics of the herds; 2) the current state of knowledge on herd regulation; 3) how we can monitor and link changes to habitat to individual condition and health to responses at the population level; 4) how managers can assess the vulnerabilities of the herds; and 5) what will be the likely impacts of global change on the future of the herds.

Value for other IPY science fields. The CARMA team gained extensive experience, particularly in standardizing monitoring and reporting practices used by local stakeholders, in the videography research methods, as well as in the analysis of data and records collected on 20-some individual herds across the Arctic region. It will be useful to all similar projects focused on monitoring of other Arctic species with geographically wide, often trans-national distribution that cannot be successfully assessed and monitored by the respective national wildlife agencies. The contribution of indigenous stakeholders is being viewed as absolutely essential to the success of any such efforts. The project has developed several simulation models in caribou herd population dynamics and distribution change under numerous environmental, socio-economic and cultural variables. These will serve in the scientific analysis and function as decision-support tools for caribou management groups, scientists and policy makers. The project has also built a database and meta-database as a legacy for further efforts in monitoring Arctic caribou herds.

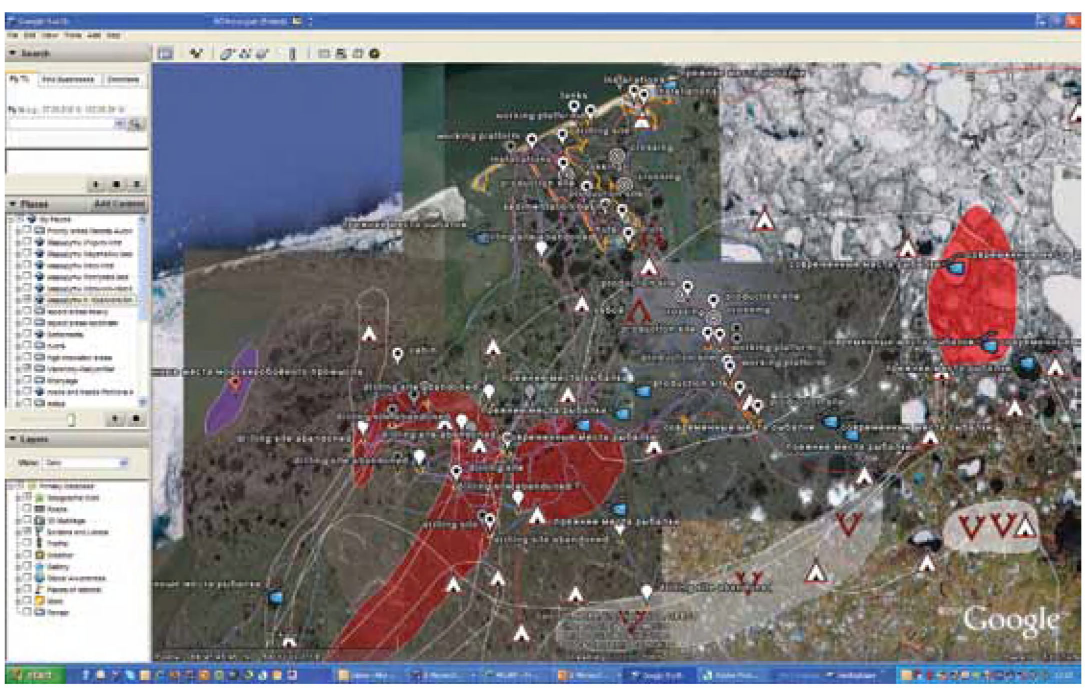

Fig. 3.10-5. Combining data on traditional reindeer herders' land use and satellite image interpretation of oil activities on combined. GoogleEarth maps (Photo: Winfried Dallmann)

EALÁT

The EALÁT project (IPY no. 399), "Reindeer Herders Vulnerability Network Study: Reindeer Pastoralism in a Changing Climate," was initiated by the Association of World Reindeer Herders (WRH) and coordinated by the Sámi University College (SUC) and the International Centre for Reindeer Husbandry (ICR) in Kautokeino, Norway. The project was provided institutional and personnel support from six other nations: Russia, Finland, Sweden, the U.K., Iceland and the U.S.A. With the aim of reducing the vulnerability of reindeer herders, their communities and management authorities through increasing preparedness for effects of climatic change and variability, the IPY EALÁT project developed research, information, teaching and outreach activities across the circumpolar north. The main focus of the project has been the Sámi (Norway, Sweden, Finland and Russia), particularly in the Norwegian county of Finnmark and also the Nenets people, involving detailed case studies in Sapmi, Yamalo-Nenets Autonomous Okrug (region), Sakha-Yakutia and Chukotka Okrug in Arctic Russia - (http://icr.arcticportal. org/index.php?option=com_content&view=frontpage&Itemid=78&lang=en).

The IPY EALÁT project voiced concern that societal transformations associated with globalization are leading to the loss of understanding of Nomadic reindeer herding practices. These practices represent models in the sustainable exploitation and management of northern terrestrial ecosystems through the incorporation of generations of adaptive experience. Key aims of the project are thus to ensure that traditional knowledge is made available, communicated and is used alongside scientific knowledge in governance, public plans and development projects.

Observation and monitoring strategies. EALÁT project acts as a venue through which Arctic reindeer-herding communities and groups can cooperate with each other and can communicate with international research and educational institutions in bringing and sharing new knowledge. Community-based workshops (such as those held in Kautokeino, Norway, Salekhard, Russia, Kanchalan in Chukotka, Topolinye in Sakha-Yakutia and Inari, Finland) have been used as prime venues for knowledge generation and exchange. They brought together reindeer herders, scientists and local and regional authorities to address the challenges of climate and land-use change through a focus on adaptation, traditional knowledge and the provision of best technology and scientific knowledge to local herders. The new partnerships included cooperation with the Norwegian Meteorological Institute and the Arctic and Antarctic Research Institute in St. Petersburg (AARI) that led to statistical downscaling of place-based climate scenarios. Workshop outcomes were reported to the Arctic Council and published on the multi-lingual project website that presents information in Sámi, English and Russian (http://icr. arcticportal.org/index.php?option=com_content&view=frontpage&Itemid=78&lang=en).

The main aim of the project was to empower reindeer herders and the communities in which they live with the best technologies available combined with traditional skills and knowledge, including systematic monitoring of reindeer health, behaviour, pasture conditions, etc., to further enhance the development of sustainable reindeer husbandry and improve the efficiency of local adaptation strategies

New and improved knowledge. The EALÁT project demonstrated that the human-ecological systems in the North, in this case, based upon reindeer pastoralism, are sensitive to climate change due to the high variability of Arctic climate and the characteristic ways of life of indigenous peoples. It is important to support capacity building for indigenous societies facing climate change and the loss of grazing land through enhanced recruitment of young scientists from local communities and by supporting institution building for indigenous organizations.

The project also revealed that the restructuring and flexible adjustment of reindeer herds may decrease the vulnerability to climate change. It indicated the need to modify government incentives and to improve understanding of bio-diversity and traditional knowledge. The EALÁT project is concerned with the major increase in human activities linked to climate change and with the resulting loss of grazing land for reindeer and caribou. Grazing land has to be protected as an adaptive measure to cope with climate change and to support sustainable Arctic societies.

Value for other IPY science fields. One the project's main contributions is making traditional herders' knowledge available to many more people via community workshops, scholarly and public presentations, and dissemination to the Arctic Council. Another major contribution is to pave the way for wider application of traditional knowledge, alongside scientific data, in governance, public plans and industrial development projects.

IPY EALÁT has produced a series of scientific and popular articles, book chapters and lectures. A major project volume comparing the vulnerability of reindeer herding in Finnmark, Norway and Yamal AO, Russia, is scheduled for publication in 2011. A website, www.reindeerportal.org, has been launched as a major platform for outreach information concerning reindeer herding in the circumpolar north. A forty-minute film will be released in mid 2010.

The IPY EALÁT consortium has established a unique institutional data- and knowledge-sharing network in the circumpolar North. It should be maintained for the future cooperation between peoples and states beyond the IPY era. In implementing these efforts, the Association of World Reindeer Herders, the International Centre for Reindeer Husbandry and the Sami University College have taken the initiative to establish a *University of the Arctic Institute for Circumpolar Reindeer Husbandry* (UArctic EALÁT Institute) as a legacy of International Polar Year 2007–2008. It has already developed courses in reindeer herding and human-coupled ecosystems (more than 30 students at the bachelor's level). Both master's and PhD students (seven) work within the EALÁT project and a special online course for reindeer herders (with 40 students) has been developed by EALÁT at the Sami University College. It is envisaged that the institute will expand the network thereby further advancing the goals of IPY and IPY EALÁT.

NOMAD

The 'Social-science migrating field station: Monitoring the Human-Rangifer link by following herd migration' Project (NOMAD, no. 408) ran from early 2006 until September 2009. The project was focused upon the Kola Peninsula in Northwestern Russia. It involved a multi-national team from Bulgaria, Russia, Denmark, Norway, Sweden and Finland

Fig. 3.10-6. NOMAD Expedition camp at Ketkozero Lake, Kola Peninsula, 21 April 2007. Twenty years ago, calving used to take place approximately in this area; but these days the female herd passes by already in April, before the lake ice melts, eager to get away from human presence and to give birth closer to the Barents Sea coast. (Photo: Vladislava Vladimirova)

Fig. 3.10-7. Spotting the fall reindeer migration, near Lake Porosozero, Kola Peninsula 15 September 2007. Local herders: Kamrat (to the left) and Grigorii Khatanzei (in the middle); Yulian Konstantinov, project PI is to the right. (Photo: Vladislava Vladimirova)

(Vladimirova and Konstantinov 2008; www.polarjahr.de/NOMAD.201.0.html) plus substantial input from the local Sámi, Nenets and Komi reindeer-herders.

Observation and monitoring strategies. In contrast to fixed-site monitoring, a mobile research facility permitted the team of researchers to follow the herd in the same manner as the herders practice throughout the year (Fig. 3.10-6) and thus closely observe human-reindeer *(Rangifer)* interactions. By placing the team in close contact with the migrating reindeer herds, NOMAD applied an innovative field method of data gathering and evaluation. NOMAD engaged several reindeer herders in its data collection and interpretation (Fig. 3.10-7) thereby ensuring the continual functioning of the research camp as well as communication and coordination with the host community. The field station may be used for future research.

New and improved knowledge. NOMAD observations show that over the last 20 years reindeer husbandry practices in this part of Arctic Russia have changed from highly intensive to highly extensive, with an increasing reliance on fence-building, snow-scooters and heavy tracked vehicles. The associated institutional change, however, has had several "unintended" consequences. All parties involved in the herding business make efforts to retain a state-supported and controlled "private-in-the-collective" form, rather than shift to independent private herding. Climate change discourse that is eagerly invoked by all parties in this rapidly changing environment (see Huntington and Fox, 2005) is often used as a political instrument to sustain the current herding cooperatives as meta-state farms.

Results of this research were shared with the local community via several presentations and through publications in the local newspapers, and involvement at the Village Professional School in the area hub Lovozero that teaches reindeer herding as a subject. A wider community was addressed by a conference organized by the Murmansk State Pedagogical University and by a seminar on the International Sámi Day (6 February 2008). The expedition diaries were posted as a blog at www.polarjahr.de/NOMAD-Blog-und-Forum.196.0.html.

Value for other IPY science fields. The NOMAD project produced mainly qualitative data (in textual and visual format), including extensive diaries, interview transcripts (Fig. 3.10-8) and video footage. Certain quantitative data can be useful to other IPY projects (e.g. for components of the Circumpolar Biodiversity Monitoring Program, CBMP – *Chapter 3.9*). The most important outcome of the project is the concept of synergetic development, that is, of rapid cascading changes triggered by both natural and social transitions. To local users, such a *synergetic* development often appears as a catastrophe to which they cannot adapt. The main reason is that under a *synergetic* transition certain components, like economic and property change, may be obscured or ignored, whereas the impact of others, like climate change or decline in reindeer population, is exaggerated in local discourse. NOMAD teaches that *all* factors are to be properly addressed to develop reasonable explanation and mitigation strategy.

SIKU: Documenting Indigenous Knowledge of Sea Ice

The "Sea Ice Knowledge and Use (SIKU): Assessing Arctic Environmental and Social Change" project (IPY no. 166 http://gcrc.carleton.ca/siku) produced the first detailed insight and comparative documentation of the patterns of indigenous knowledge and use of sea ice across the core section of the Arctic region, from the Bering Strait to Greenland. The continuous active use of and transmission of sophisticated local knowledge related to sea ice is currently threatened by socio-economic changes, weakening of indigenous languages and the ongoing transformation of the polar ice through rapid climate change (Fig. 3.10-9).

Observation and monitoring strategies. Indigenous partners from more than 30 communities in Canada, U.S.A. (Alaska), Greenland and Russia (Chukotka) have been involved in the SIKU project. Their contribution was provided through a variety of techniques, including individual, group and community meetings and testimonies; local ice and weather monitoring; and historical and GPS-based mapping. Altogether, indigenous monitors from ten communities in Alaska, Canada and Russian Chukotka – Barrow, Clyde River, Gambell, Novo-Chaplino, Provideniya, Shaktoolik, Sireniki, Uelen, Wales and Yanrakinnot – were engaged in daily ice and weather observations between 2006 and 2009 (Krupnik, 2009; 2010; Krupnik and Bogoslovskaya, 2008). In addition, six Nunavik communities in Eastern Canada (Akulivik, Ivujivik, Kangiqsujuaq, Kangiqsualujjuaq, Umiujaq and Kawawachikamach) developed their own system of sea ice monitoring based upon weekly ice measurements, site visits and interviews (http://climatechange.krg.ca/index.html). In three Alaskan communities (Barrow, Gambell and Wales) the observations were extended for a fourth winter thus providing an unbroken indigenous record of four consecutive ice seasons:

Fig. 3.10-8. Vladislava Vladimirova interviews two retired herders, Nikolai Galkin (to the left) and Ivan Chuprov, on 9 December 2007 in Lovozero, Kola Peninsula.
(Photo: Tatyana Sherstiuk)

Fig. 3.10-9. Two hunters watch for seals from the top of ice pressure ridge. Gambell, St. Lawrence Island, Alaska, February 2008. (Photo: Igor Krupnik)

2006/2007, 2007/2008, 2008/2009 and 2009/2010.

When setting local ice and weather observations, village monitors were asked, at a minimum, to report daily temperature, wind direction, wind speed and the ice condition at each location. They were also encouraged to add local details they believed were important, such as data on subsistence activities; marine mammals, birds and terrestrial species; community events; and personal travel across the observation area (Fig. 3.10-10). All village monitors were also asked to include local terms, place names and key descriptions in their respective native languages whenever possible. This resulted in a more nuanced, contextualized and community-vetted documentation of indigenous knowledge and the use of ice. The age of monitors varied from 33 to 84, with the main group in the 50s and 60s age-group. Altogether, local SIKU observations in 2006–2009 produced a dataset of more than 150 monthly logs from nine communities totalling several hundred pages. It constitutes a unique database of its kind on local ice and weather conditions on the ground, but also on subsistence activities, communal life, personal travelling and the status of environmental knowledge in several communities during the IPY era.

New and improved knowledge. The project offered a unique window to learn how indigenous ice and weather monitoring is organized and to identify the key parameters of sea ice dynamics as directed by indigenous hunters. For example, local monitors identify the ice not only by its age, thickness, type, etc. (as ice scientists also do), but also by its history during a particular ice season; how many times it was broken and refrozen and even by its geographic origin. In the Bering Strait region, hunters can detect where the incoming ice has originated, whether it carries game (or not) and whether it is safe and stable to travel. On St. Lawrence Island, hunters distinguish four to five different 'waves' of the passing spring ice, according to their origin, whereas on the scientists' scale it is just one single 'spring break-up' period.

Hunters also use several 'proxy' indicators to judge

Fig. 3.10-10. Group of hunters camping on ice near a calved iceberg frozen into the first-years ice, Nunanvut, Canada.
(Photo: Gita J. Laidler 2007)

Fig. 3.10-11. Igah Sanguya (foreground) of Clyde River, Nunavut, and Toku Oshima of Qaanaaq, Greenland, watch for bowhead whales during the spring hunt at the floe edge off Barrow, Alaska in 2007. The two along with other Inuit from Clyde River and Qaanaaq were in Barrow as part of the Siku-Inuit-Hila Project, a sea ice knowledge exchange project between scientists and Inuit from Greenland, Nunavut, and Alaska, and a parter project of the SIKU initiative (IPY no. 166).
(Photo: Shari Gearheard, 2007)

the safety of ice or ice dynamics through the season, including tides and currents, persistent winds of certain direction, local current gyres unknown to the oceanographers, recurrent weather cycles, animal and bird behaviour and many other indicators. Altogether, experienced hunters may use up to 30 various indicators throughout the winter to monitor and assess ice safety and availability of game animals.

Value for other IPY science fields. Most of the information on which hunters based their assessment of sea ice and of individual ice season is not available in standard instrumental records. But thanks to the observational records accumulated during the SIKU project, we may eventually learn how to 'read' some of the past and current ice data by applying indigenous indicators. For example, satellite imagery, the main source of modern scientific analysis of sea ice conditions, cannot detect early forms of ice that look like 'open water' on the images, but these early forms of ice formations are carefully detected by local monitors. The beginning of the ice season may be thus established with much higher precision. This same 're-calibration' applies to the spring break-up time, with local observers documenting ice deterioration and disintegration much more intimately than satellite imagery can ever afford. Local monitors can, similarly, identify many local forms of ice, including the presence of thick and/or multi-year ice (Fig. 3.10-11) that is crucial for ice modelling and assessment, which may not be easily tracked by other sources. These and other examples illustrate why many of the sea ice scientists are now anxious to include indigenous data under their observation programs (*Chapters 3.6 and 5.2*) and why many weather and ice forecasting services in the post-IPY era are deliberately reaching out to local stakeholders and their knowledge (*Chapter 5.2*).

BSSN

The "Bering Sea Sub-Network (BSSN): International Community-Based Observation Alliance for the Arctic Observing Network" (IPY no. 247) focused its research on developing a process for gathering and managing local observations on the environment and subsistence harvest in six Bering Sea coastal communities: Gambell, Sand Point and Togiak in Alaska (Fig. 3.10-12), U.S., and Kanchalan (Chukotka), Nikolskoye and Tymlat (Kamchatka) in Russia. BSSN was implemented by the Aleut International Association (www.aleut-international.org) in collaboration with the University of Alaska, Anchorage, the Alaska Native Science Commission, and UNEP/GRID-Arendal (Norway) (www.bssn.net/). It was also a project of the Conservation of Arctic Flora and Fauna (CAFF) Working Group of the Arctic Council. There were approximately 330 participants in the pilot phase of the project, including researchers, staff, collaborators and interviewees (Fig. 3.10-13).

The six communities studied during the Pilot Phase (2007-2009) share a dependency upon the Bering Sea and its biological resources, such as fish, birds, marine mammals and other marine organisms. BSSN provided the opportunity for local communities to contribute to the overall efforts to increase our knowledge and understanding about processes affecting the Bering Sea by sharing local observations and perspectives on the environment.

Observation and monitoring strategies. In the BSSN project, for the first time, diverse indigenous communities formed an organized regional network for gathering, processing and data storage of local observations about the change in the environment and about species important for traditional fishing and hunting. Particular attention was paid to the development of standard questionnaire for data reporting and monitoring, and to the training of local monitors and research assistants. The BSSN team developed a network model consisting of the following steps: 1) a survey utilizing uniform questionnaires to be used across the area; 2) training of local research assistants to conduct interviews; and 3) a centralized database of local datasets to be used for further community and research needs. Of equal importance is improving data accuracy as questionnaire entries are collected by local project associates and entered in their original languages.

New and improved knowledge. In the BSSN project, the pilot phase findings point to several trends that will be tested in further studies, such as 1) the higher rate of diseased fish (e.g. Whitefish and salmon) on the Russian side of the Bering Sea, possibly as a result of anthropogenic factors, such as contamination; 2) increased instances of encounters with species new

Fig. 3.10-12. BSSN Research Assistants Esther Fayer (left) and Olia Sutton (center) with an Elder in Togiak, Alaska.
(Photo: Aleut International Association (AIA)

Fig. 3.10-13. Local Koryak residents participating in the BSSN monitoring interviews with Svetlana Petrosyan (second from right), Community Research Assistant. Tymlat, Kamchatka.
(Photo: Aleut International Association (AIA)

to the area (e.g. White King salmon), particularly in the Alaskan communities; and 3) an increase in abundance of certain species in the study the area (e.g. whales) that indicates shift in spatial distribution likely due to climate change.

Value for other IPY science fields. The BSSN project through its pilot phase (available at www.bssn.net) paved the way to a much larger study (Phase II), which is funded by a five-year grant from the U.S. National Science Foundation. It will continue and expand the gathering of local observations in the Bering Sea region, particularly in the field of wildlife distribution and habitat change that is useful to other science disciplines. The project metadata has been published through ELOKA, CADIS (Cooperative Arctic Data and Information Service) and IPY DIS (International Polar Year Data and Information Service). BSSN has presented project progress reports in a number of conferences and symposia, including Arctic Council meetings, IPY Open Science Conference in 2008 and the 5th Northern Research Forum, Anchorage 2008.

Preserving and Sharing Indigenous Knowledge: ELOKA

For projects and organizations that work with local and traditional knowledge and other social science information, there are few, if any, resources to help with data management and archiving (Fig. 3.10-14). ELOKA, the Exchange for Local Observations and Knowledge of the Arctic (IPY no. 187) was conceived as an IPY initiative to provide the first data management and user support network for local and traditional knowledge (LTK) and community-based research and monitoring activities in the Arctic (see http://eloka-arctic.org/, also *Chapter 5.4*).

Observation and monitoring strategies. ELOKA originally comprised two partners, the community of Sanikiluaq in Nunavut, Canada and the Narwhal Tusk Project (IPY no. 163) located in three Nunavut communities and one Greenland community (*Chapter 5.4*). ELOKA now collaborates with the SIKU project (IPY no. 166), Alaska Native Science Commission, Bering Sea Sub-Network (BSSN – IPY no. 247), Seasonal Ice Zone Observing Network (SIZONet), Muohta ja

Fig. 3.10-14. Community members in Clyde River, Nunavut, work on mapping present day and traditional travel routes for the Igliniit Project, a sub-project in the Inuit Sea Ice Use and Occupancy Project (ISIUOP-SIKU IPY no. 166). Clockwise from bottom right: Sivugat Palluq, Jacopie Panipak, Elijah Kautuq, Apiusie Apak, Laimikie Palluq, David Iqaqrialu, Peter Paneak, Jayko Enuaraq, Amosie Sivugat, Raygilee Piungituq, Aisa Piungituq, James Qillaq.
(Photo: Shari Gearheard, 2008)

Fig. 3.10-15. The Siku-Inuit-Hila Project, a sea ice knowledge exchange project between scientists and Inuit from Greenland, Nunavut and Alaska, and a parter project of the SIKU initiative (IPY no. 166), established community-based sea ice monitoring in the communities of Qaanaaq, Clyde River, and Barrow. Here David Iqaqrialu and Teema Qillaq (left) check on one of the Clyde River sea ice monitoring stations with visiting Qaanaarmiut Toku Oshima and Mamarut Kristiansen, who use the same system to observe sea ice in their home community of Qaanaaq Greenland. (Photo: Andy Mahoney, 2008)

Jiekna (Snow and Ice), SnowChange, CADIS, IPY DIS and NSIDC.

The goal of ELOKA is to develop a data management and user support service to facilitate the collection, preservation, exchange and use of local observations and knowledge of the Arctic. ELOKA team has not done community-based monitoring as a part of its IPY mission, but rather it collaborated with other projects and communities in need of storing and processing of their observational data (Fig. 3.10-15). As such, ELOKA is deeply involved in developing protocols for various data storage, online and other access engines, and in standardizing templates for records collected in IPY projects and beyond. ELOKA is also spearheading an effort to organize a network of services ('Data Centres') for local and traditional knowledge and community-based monitoring in the North. Such efforts require building new partnerships among various international organizations, universities, researchers, government agencies, science projects, and communities engaged in Local and Traditional Knowledge (LTK) and community-based monitoring (CBM) research and data management (*Chapter 5.4*).

New and improved knowledge. Once the practical templates for recording, storing and managing data and information are designed and the initial challenge of implementing an effective searchable database is achieved, ELOKA mission enters its second phase. It involves ensuring that the data stored may be exchanged between Arctic residents and researchers, as well as other interested groups such as teachers, students and decision-makers. The main challenge is that to ensure the integrity of the data, local providers retain control over certain sensitive components of the dataset, as they see it fit or in accordance to their cultural values and economic needs. None of those issues have been resolved in the previous data-management efforts involving local communities, hence ELOKA innovations in interactive web-based presentations, search tools and electronic and digital products may be indispensable.

Value for other IPY science fields. The ELOKA project is still under development and it is currently in its second post-IPY phase, 2009–2012, thanks to additional funding provided by the U.S. National Science Foundation. Its ultimate goal is to provide a searchable, web-based database for efforts in local monitoring and documentation of knowledge about the Arctic, covering all Arctic areas and primarily environmental themes. When this database is put in place, its data providers will be any project or organization that works with local and traditional knowledge (Fig. 3.10-16) and its prospective users include northern residents, educators, scientists, students, organizations, governments and the public.

CAVIAR

The "Community Adaptation and Vulnerability in Arctic Regions," CAVIAR project (IPY no. 157) initiated coordinated community vulnerability studies in 26 communities across eight Arctic countries. The main research areas were in Alaska, Arctic Canada (Nunavut, Inuvialuit, Yukon, Northwest Territories, NWT), Arctic Russia (Kola Peninsula, Yamal-Nenets AO, Nenets AO), Fennoscandia (Lapland in Finland, Finnmark and Nordland Counties in Norway, Norrbotten in Sweden) and West Greenland (Qeqertarsuaq). The CAVIAR project was designed with the intent to: document the particular environmental conditions to which local communities are sensitive; assess the strategies employed when dealing with change in the Arctic; identify the factors that facilitate or constrain adaptive capacities and resilience of local communities; and integrate information from local and indigenous knowledge with scientific knowledge (see Ford et al., 2009; Pearce et al., 2008; 2009). To achieve this, relationships were established with several organizations of polar indigenous people including the Inuit Circumpolar Conference, the Sámi Council, the World Reindeer Herders Association, Greenland Home Rule Government, Inuit Tapiriit Kanatami, the Government of Nunavut, the Inuvialuit Joint Secretariat and Nunavut Tunngavik Incorporated. More information on the specific project activities is available at http://ipy.arcticportal.org/news-a-announcements/item/2097-caviar-community-adaptation-and-vulnerability-in-arctic-regions.

Fig. 3.10-16. Lasalie Joanasie (left) and Shari Gearheard, one a hunter and one a researcher and both residents of Clyde River, Nunavut, keep an eye on a passing polar bear while travelling the sea ice off the coast of Baffin Island near Clyde. (Photo: Edward Wingate, 2009)

Fig. 3.10-17. Meeting with officers of Lebesby Municipality (Kommune), Finnmark, Northern Norway in 2008. The participants are discussing climate and adaptation of relevance to municipal planning. (Photo: Grete K. Hovelsrud, CICERO)

Observation and monitoring strategies. Through applying a common vulnerability assessment framework (Smit et al., 2008; Ford et al., 2008; 2010; Sydenysmith et al., 2010), the project has documented a range of stresses and exposures encountered by local communities across the Arctic, related to climatic, ecological, social, economical, cultural and political changes. The project developed a participatory methodology, including both local/indigenous and scientific knowledge that best explains how combinations of environmental and societal exposure sensitivities create vulnerability and necessitate community adaptation.

Data has been collected through extensive fieldwork using primary sources (interviews, focus groups, participant observation, questionnaires – Figs. 3.10-17, 3.10-18) and established protocols and procedures from secondary sources (government records on socio-economic and climate conditions, satellite imagery, reports). The development, in association with the Norwegian Meteorological Institute and the Arctic and Antarctic Research Institute in St. Petersburg (AARI), of downscaled climate change projections for the Norwegian and Russian cases study sites provided essential and innovative tools in supporting community understanding and response. The development of the climate scenarios was an iterative process among the local communities, who defined the relevant climate elements, and the scientists making and analysing the models (Hovelsrud and Smit, 2010).

New and improved knowledge. The CAVIAR project has designed and framed the research in collaboration with local communities, allowing for multiple drivers and conditions in each locale, a prerequisite for understanding adaptation and vulnerability to change. For each case, the researchers investigated the aspects of current conditions, livelihoods and institutions that increased the manner and degree of community sensitivity. Some common aspects emerge across many of the studied cases despite their cultural, geographic or economic differences. These include, in broad terms, the consequences of changes in coupled social-ecological systems with respect to resource accessibility, allocation and extraction policy; limited economic opportunity and markets access constraints for distant northern communities; demographics; attitudes and perceptions of change; local-global linkages; infrastructure; threats to cultural identity and well-being; transfer of local and traditional knowledge; economic and livelihood flexibility; and enabling institutions. These aspects

Fig. 3.10-18. Local researcher and Inuit hunter Roland Notaina records changes to hunter's travel routes in the Ulukhaktok region. Changes in sea ice have affected travel routes to polar bear hunting areas forcing hunters to travel further and over precarious ice conditions. (Photo: Tristan Pearce)

are rarely independent of each other and frequently combine across scale and sectors, which may facilitate or limit adaptation in each particular case.

The 26 community case studies undertaken in eight Arctic countries under the same general methodology and in the course of relatively short period (2006–2009) illustrate the importance of integrating natural and social sciences. Without the input from both we would not have fully understood how the particular biophysical changes in the fisheries in northern Norway or in the river deltas in Northwest Territories in Canada have had consequences for communities.

Value for other IPY science fields. The CAVIAR project has demonstrated the complexities involved in understanding the linkages in coupled social-ecological systems. The involvement of local partners from the start and integration of their perspectives and knowledge increases the possibility of producing locally relevant results. The method of communicating the 'downscaled' climate change results will be useful for other projects, particularly to climate and sea ice scientists working on bringing their more general models and projections to down to the regional and local scale.

The CAVIAR metadata will be held under the Norwegian IPY data portal organized by the Norwegian Meteorological Institute. Besides contributing evidence to multiple media and conference events and the publication of numerous journal articles, a full project volume (Hovelsrud and Smit 2010) featuring 15 case studies was published in 2010. Numerous presentations on the CAVIAR project have been held in the case communities, for decision-makers and at international scientific meetings.

Conclusion

This overview of eight projects in local and community-based monitoring launched during IPY 2007–2008 introduces a complex and multi-layered field in its formative stage. On the one hand, several IPY-generated efforts in community-based monitoring produced impressive sets of local data related to areas critical to the IPY science themes, such as climate change, environmental preservation, status of the Arctic land and waters, documentation of indigenous knowledge, impacts of modern industrial development in the polar regions and the like. Several projects, such as CAVIAR, BSSN, EALÁT, CARMA and others, invested substantial effort in developing standard observational protocols and used the same or close methodologies across large study areas. This has allowed for new comparative analyses across a broad sample of participating communities and regions.

Nevertheless, little coordination was achieved among many IPY 2007–2008 efforts in community-based monitoring and the documentation of local knowledge. There was hardly a common vision on what particular aspects of polar environment and change are more (or less) important to the common understanding of natural, physical and social developments at the Poles. Individual project teams had several productive meetings during their planning and implementation years and they shared information broadly and freely. Nevertheless, there was no 'across-the board' exchange and comparison of the goals and needs of community-based monitoring projects in IPY 2007–2008 and no 'multi-project' meetings to develop a common agenda, in the way it has been done for oceanography, meteorology, satellite observations and other more 'matured' science disciplines.

For these and other reasons, the field of community-based monitoring and local knowledge documentation in IPY 2007–2008 was very much a 'work in progress.' One should acknowledge that the field had not even developed until the late 1990s and that it has been advanced to the polar research arena only by the time when IPY 2007–2008 was being planned—via ACIA Report (2005), the International Conference for Arctic Research Planning (2005), the development of the U.S. SEARCH (Study of Environmental Arctic Change) program, the *Inuit Qaujimajatuqangit* (Inuit traditional knowledge/values/way of thinking) movement in Nunavut and across Arctic Canada (see www.gov.nu.ca/hr/site/beliefsystem.htm) and a few summary publications available by that time (McDonald et al., 1997; Krupnik and Jolly, 2002; Helander and Mustonen, 2004; Oozeva et al., 2004; and others). Its status may be thus compared to the original science plan for the first IPY of 1882–1883 of three pillars (same time, same methodologies, many nations – *Chapter 1.1*), of which only two—same time and many nations—have been implemented.

Of course, to reach maturity the field of community-based observations and monitoring does not have to wait for its 'second' and 'third' IPY in the next 50 or 75 years. Several important publications based upon the IPY projects reviewed in this chapter are already published (Hovelsrud and Smith, 2010; Krupnik et al., 2010) or will be produced shortly and the overall impact of IPY 2007–2008 studies will increase manifold in the coming years. In addition, many projects are laying groundwork for rapid expansion of the field through new funding to expand their scope of operation in terms of time, community engagement and geographic coverage during the post-IPY era and beyond (like EALÁT, ELOKA, BSSN). Another line of action would be to argue for a radical change of approach to community-based monitoring—from short-term research and pilot projects funded via national science agencies or scientific initiatives (like IPY 2007–2008) to permanent activities, like SAON (*Chapter 3.8*), supported by regional governments and major indigenous organizations. This would naturally encourage local capacity building, self-government and developing new formats of community-based education and knowledge preservation. Certain IPY projects, particularly EALÁT and BSSN, are clearly moving in this direction (see more in *Chapter 5.4*). Yet other IPY initiatives are increasingly viewing themselves as precursors to the future 'services' for both indigenous and scientific communities to emerge as the lasting legacy of the post-IPY era. Two examples of this new strategy including ELOKA and a new project called "Sea Ice for Walrus Outlook" (SIWO) (*Chapter 5.2)*. Similarly, SAON, the Sustained Arctic Observing Networks initiative, has identified community-based monitoring as a priority for future Arctic research and monitoring activities (*Chapter 3.8*).

The field of indigenous and community-based monitoring has emerged as one of the least anticipated, yet most inspirational, outcomes of IPY 2007–2008. To achieve its full potential, it needs new successful efforts, more resources and continuation of its momentum into the post-IPY era.

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Notes

[1] Two first lead authors for this chapter are both members of the IPY Joint Committee and also PIs on their respective IPY projects with strong focus on indigenous and local monitoring of environmental and social change (CAVIAR, IPY no. 157 and SIKU, IPY no. 166).

[2] Other IPY projects with substantial component of local and indigenous monitoring include: Understanding environmental change and its biological, physical, social, subsistence and cultural effects in national parks and protected areas of Alaska, Chukotka and the Yukon through research, monitoring, education and outreach (no. 21); International Study of Arctic Change (ISAC, no. 48); Network for Arctic climate and biological diversity studies (no. 72); Circumpolar Biodiversity Monitoring Program (CBMP, no. 133); Present-day processes, past changes and spatiotemporal variability of biotic, abiotic and socio-environmental conditions and resource components along and across the Arctic delimitation zone (PPS, no. 151); Narwhal Tusk Research (NTR, no. 163); Community Resiliency and Diversity (no. 183); Engaging Northern Communities in the Monitoring of Country Food Safety and Wildlife Health (no. 186); Environmental baselines, processes, changes and impacts on people in sub-arctic Sweden and the Nordic Arctic regions (no. 213), and other.

3.11 The State of Polar Data–the IPY Experience

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Introduction

International Polar Year 2007–2008 (IPY) was the world's most diverse international science program. It greatly enhanced the exchange of ideas across nations and scientific disciplines. This sort of interdisciplinary exchange helps us understand and address grand challenges, such as rapid environmental change and its impact on society. The scientific results from IPY are only now beginning to emerge, but it is clear that deep understanding will require creative use of myriad data from many disciplines.

The ICSU IPY 2007–2008 Planning Group emphasized the need to "link researchers across different fields to address questions and issues lying beyond the scope of individual disciplines" and noted the importance of data in enabling that linkage. Furthermore, they planned to "collect a broad-ranging set of samples, data, and information regarding the state and behavior of the polar regions to provide a reference for comparison with the future and the past, and data collected under IPY 2007–2008 will be made available in an open and timely manner." In some ways, data were seen as the centerpiece of IPY: "In fifty years time the data resulting from IPY 2007–2008 may be seen as the most important single outcome of the programme." The planners, therefore, incorporated data management as a formal part of the overall IPY Framework (Rapley et al., 2004).

Now, most IPY field programs have ended. They have produced a lot of data. Are those data available? Are they well-documented for broad, interdisciplinary use and long-term preservation? Are they supported by robust and useful organizations and infrastructure? Have we enhanced interdisciplinary science and data sharing? Have we met the data goals of IPY? In short, what is the state of polar data?

This report is the result of the collective experience of the IPY data management community, especially participants at an IPY data management workshop in Ottawa, Canada hosted by the Canadian Ministry of Indian and Northern Affairs 29 September – 1 October 2009. Section 1 provides background and describes the state of data management before IPY. Section 2 describes the IPY data plans, strategy and progress toward meeting IPY plans and objectives. Section 3 assesses how well IPY performed against specific objectives and discusses lessons learned in four broad data management areas that follow the structure of the IPY Data Policy and Strategy, namely:

- data sharing and publication;
- interoperability across systems, data and standards;
- sustainable preservation and stewardship of diverse data; and
- governance and conduct of the virtual organization that coordinates data access and stewardship around the globe.

An overall summary and final recommendations for multiple IPY stakeholders is provided at the end of this Chapter.

Background

In 2004, when IPY planners were developing the Framework Document (Rapley et al., 2004), the state of polar data management was highly variable across disciplines and nations, and even between the Arctic and Antarctic. Some disciplines, such as oceanography and meteorology, had extensive experience in international collaboration and data sharing. These disciplines had also developed fairly robust data systems either for specific global experiments (e.g.

the World Ocean Circulation Experiment) or as part of ongoing global networks (e.g. the International Arctic Buoy Program). Other disciplines, notably in the life and social sciences, had little established culture of collaboration and data sharing. Many investigators in all disciplines viewed the data they collected as their hard-earned property to be guarded and only shared sparingly or with significant restriction. Regardless of discipline, when the data were managed in data centers or repositories, the data centers tended to be very focused on their specific discipline. There was very little interoperability, or even open sharing, across disciplines.

At the national level, some countries had very open data policies while others were more restrictive—curtailing commercial use, for example. Other countries had no explicit data policy or were highly restrictive. Some countries had well-established data centers, some did not. No country had data centers covering all polar disciplines. By the time of IPY, the Scientific Committee on Antarctic Research (SCAR) had made some progress on encouraging international data sharing through its Standing Committee on Antarctic Data Management (SCADM) and the associated Antarctic Master Directory, which describes many data sets from Antarctica and the Southern Ocean. Many nations involved in SCAR had nominally established National Antarctic Data Centers, but the capacity and participation of the different nations was highly variable. The existing relationship between SCADM and the Global Change Master Directory (GCMD), through the Antarctic Master Directory, was key to the establishment of the IPY Metadata Portal by the GCMD.

In the Arctic, some programs – notably those under the Arctic Council, such as the Arctic Monitoring and Assessment Programme (AMAP) – had structures for international collaboration and data sharing, but there was no overarching body to coordinate Arctic data management as a whole. In the 1990s, the Global Resource Information Database (GRID) and the United States Geological Survey (USGS) established the Arctic Environmental Data Directory. This directory eventually had members in all Arctic nations and Arctic Council working groups, but it inexplicably closed early in the 21st century.

At the global level, an International Council for Science (ICSU) Program Area Assessment questioned the viability and collaboration of World Data Centers and recommended a major overhaul of ICSU data structures (ICSU, 2004). The Global Earth Observing System of Systems (GEOSS) was just getting started and was paying little attention to the unique observational and data requirements of the polar regions.

Recognizing this chaotic state of polar data management, IPY planners included a basic data management plan in the IPY Framework Document based on guidance from the Joint Committee on Antarctic Data Management[1] and the World Climate Research Programme's Climate and Cryosphere Programme (WCRP-CliC) Data and Information Panel. The plan recommended creating an IPY Data Policy and Management Subcommittee (Data Committee) to develop the IPY data policy and strategy. The strategy was to be implemented by a "full-time, professional data unit," the IPY Data and Information Service (IPYDIS). Furthermore, the plan required each project to develop and fund specific data management plans, including dedicated data managers within projects. Throughout the document, the planners emphasized the need to start early, plan data management in advance of data collection and fully fund data management within individual projects and through the IPYDIS. They also emphasized the need to reuse or re-engage existing systems such as the World Data Centers.

ICSU and the World Meteorological Organization (WMO) established the Joint Committee (JC) for IPY in fall 2004 but were unable to provide support for the recommended Data Committee. In consultation with the polar data management community, the JC appointed an unfunded Data Subcommittee late in 2005. The Subcommittee met for the first time in March 2006, prior to an initial IPY data workshop sponsored by the U.S. National Science Foundation (NSF) and hosted in Cambridge, U.K. by the British Antarctic Survey and the International Programme Office (IPO). At this initial meeting, the Data Subcommittee worked to finalize the IPY Data Policy and was guided by the participants at the workshop on comprehensive data management planning. This was a critical workshop for IPY. The recommendations from this workshop and the IPY Data Policy provided the foundation for subsequent Data Subcommittee plans and IPYDIS activities. A workshop report is available at http://nsidc.org/pubs/gd/Glaciological_Data_33.pdf. Unfortunately, the workshop occurred after investigators had already submitted their coordination proposals to the JC. As a result, investigators were agreeing, in their proposals, to a data policy that was not complete and they were submitting generally cursory data management plans with very little guidance and no review by the Data Committee.

The IPY Data Policy was completed and endorsed by the JC in mid-2006. It builds off existing ICSU, WMO and related policies, but seeks to better encourage international and interdisciplinary collaboration as well as further the themes and objectives of the IPY. The policy has generally been praised as forward-looking in its call for open and timely release of data with limited exceptions and for formally crediting data authors. As part of their coordination proposal to the JC, all IPY projects agreed to adhere to the Data Policy, but much in the culture of science, resisted open and timely access.

The IPYDIS was initially proposed and endorsed as an IPY project (no. 49) in collaboration with the Electronic Geophysical Year (see Box1). The original proposal involved a diverse global group of several dozen data managers, scientists and specialists. Over time, the partnerships evolved to incorporate data activities within individual IPY projects and national IPY data centers and coordination services, as well as many previously existing national and international data centers, including the SCADM data network. A key challenge, however, was to fund the effort. Starting in mid-2007, NSF supported a small coordination office for the IPYDIS at the National Snow and Ice Data Center to track the data flow for IPY. This office was to help researchers and data users identify data access mechanisms, archives and services; they would also provide information and assistance to data managers on compliance with standards, development of a union catalog of IPY metadata and other data management requirements for IPY. Another coordination office, focused on near-real time and operational data streams, was established at the Norwegian Meteorological Institute. Together, these offices have provided a general communication forum for all matters related to accessing, managing and preserving IPY and related data (http://ipydis.org), but they are modest efforts, ending soon. The IPYDIS announcement of opportunity recommended in the Framework document (Rapley et al., 2004) never materialized and national funders varied in their requirements for data management within individual projects.

The JC made several written appeals to individual nations defining requirements and requesting formal support for IPY data management within projects, nations and internationally. Eventually, some support emerged at the national level, primarily through the creation of national data coordinators and national IPY data systems. Data committee members worked hard within their countries, often behind the scenes, to make this possible. Unfortunately, most of the support came well after IPY had started and there was little success in creating the core cyber infrastructure to support the full suite of IPY data, build interoperability across systems and enable international coordination.

Box 1 The Electronic Geophysical Year

In 1999, the International Union of Geodesy and Geophysics (IUGG) called on its scientific associations to propose activities to mark the 50-year anniversary of the IGY. The International Association of Geomagnetism and Aeronomy (IAGA) responded through a resolution passed at the IUGG General Assembly in Sapporo in 2003 to lead an Electronic Geophysical Year (eGY).

The eGY began on 1 July 2007 and ended on 31 December 2008, exactly 50 years after the start and end of IGY. Support for eGY came from IAGA, IUGG, NASA, the United States National Science Foundation, United States Geological Survey and the Laboratory for Atmospheric and Space Physics (LASP) at the University of Colorado. In kind contributions came from the American Geophysical Union (AGU), the National Centre for Atmospheric Research in Boulder, Colorado and the volunteer labor of eGY participants.

The eGY focused the international science community to achieve a step increase in making past, present and future geoscientific data (including information and services) rapidly, conveniently and openly available. The themes of the eGY included electronic data location and access, data release and permission, data preservation and rescue, data integration and knowledge discovery, capacity building in developing countries (mainly improving Internet connectivity) and education and outreach. Promoting the development of virtual observatories and similar user-community systems for providing open access to data and services was a central feature of the eGY.

Principal legacies of the eGY are stronger awareness of the role that informatics plays in modern research, expanding adoption of virtual observatories and similar systems for accessing data, information and services, and an expanding infrastructure at the international and national levels. As with the IGY, the mission of the eGY is being carried forward through existing or newly formed national and international organizations (Peterson et al., in prep.).

In the period leading up to the start of IPY, data stewardship was undervalued despite robust data management plans within the Framework Document, strong recommendations of the ICSU Program Area Assessment and telling examples from earlier international projects.

Developments and Current Status of IPY Data

Following the March 2006 Cambridge workshop, the Data Committee began their work in earnest, despite a general lack of funding. The Committee conducted a series of outreach activities, including conference sessions and town hall meetings. The Committee also appealed to national committees and funding agencies, wrote reports to sponsors and provided general information for the public and IPY participants. Many documents are available at http://ipydis.org/documents. See alsowww.earthzine.org/2008/03/27/securing-the-legacy-of-ipy/. These activities continued through IPY and beyond.

In fall 2006, ICSU's Committee on Data for Science and Technology (CODATA) endorsed the Data Committee as a formal CODATA Task Group. The current Data Subcommittee formally ended in October 2010 when its current term as a Task Group ended. Some IPY data managers recently applied for task group renewal, under a new charter and new membership, for a third two-year term extending through October 2012.

Data Management Planning

Starting in 2006, the Data Subcommittee and IPYDIS Office made multiple attempts to contact each of the funded IPY science projects to determine their data management plans (Education and Outreach projects and unfunded projects were not considered). Based on these multiple surveys, Mark Parsons, manager of the IPYDIS, made a subjective assessment of each project's data management plan. The assessment focused on short-term distribution plans because there was insufficient information to truly consider the full data life-cycle, notably long-term preservation. The results of the assessment are shown in Fig. 3.11-1 with colour codes representing the data management plan status of each project in the IPY "honeycomb" (project) chart. The honeycomb was a popular way of displaying all of the IPY-endorsed collaborative projects and was roughly arranged by discipline and region.

A fuller assessment of the data management plans that considered the full data life cycle would probably look worse. Many projects were unaware of appropriate long-term archives and many archives do not exist. At a cursory level, it appears that only the 30 projects with good data distribution plans have adequately considered long-term preservation. This leaves 94 IPY projects collecting data without clear plans or resources for archiving their data.

It is also telling that many projects never responded. The gaps in the Land and People columns may reflect an actual lack of data management planning and structure. The gaps in the Ocean, Ice and Atmosphere columns are more likely to reflect a lack of participation in the overall IPY organization because these disciplines typically have fairly robust

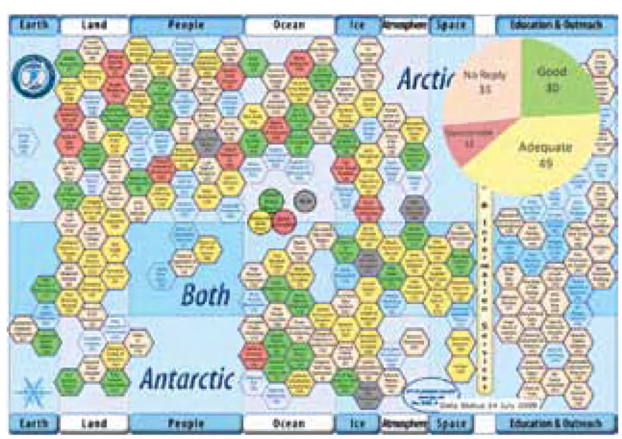

Fig. 3.11-1. Status of IPY Project Data Distribution Plans, July 2009. Good data distributionn plans are those with a clearly designated and funded repository for their data. Adequate plans are those that may not have identified permanent archives or professional data managers, and there may be some minor funding or coordination issues. Questionable plans do not have any data management plan or identified repository; data management funding may not have been identified; or they did not provide sufficient information to adequately assess their plan. Some projects did not respond to the survey, even after multiple queries. Of the funded science projects, 13 reported that they are not collecting data. So they are not included in the assessment.

data management structures. Unfortunately, many of these robust data management structures are very independent or siloed and do not necessarily collaborate with other systems.

IPY Data Strategy

As IPY began, the Data Subcommittee laid out a basic four-point data strategy briefly described in points A to D below, and summarized in Fig. 3.11-2.

A. Identify and share the data (Identification).
Goal: *all metadata by March 2009*

All projects should create brief descriptions of their IPY data in a standard metadata format in accordance with the IPY Metadata Profile. Metadata should be provided to the IPY Metadata Portal at the GCMD (http://gcmd.nasa.gov/portals/ipy/) or at an appropriate national registry. National registries should enable ready discovery of their holdings through the GCMD either through metadata sharing, such as the Open Archives Initiative Protocol for Metadata Harvesting (OAI-PMH) or open search (ISO23950) protocols. National data coordinators greatly facilitate this process.

B. Serve the data in interoperable frameworks (Availability).
Goal: *ongoing demos of integration, all data available March 2010*

All IPY projects should make their data fully and openly available in standard data formats through standard data access mechanisms. Data may be served by individual projects or by designated archives, but the data must be linked directly to the discovery level metadata described above. IPY projects and data centers should work to make their data as interoperable as practical and to work with other projects and data centers to develop targeted interoperability arrangements. Projects and centers should also participate in global interoperability initiatives, notably the Global Earth Observing System of Systems (GEOSS) and the WMO Information System (WIS).

C. Preserve the data (Preservation).
Goal: *all data in secure archives by March 2012*

All IPY data and associated documentation (including metadata) should be deposited in secure, accessible repositories within three years after the end of the IPY. Archives should follow the ISO-Standard Open Archival Information System Standard Reference Model. National governments and international organizations must develop means to sustain archives over the long-term.

D. Coordinate the process (Coordination).
Goal: *ensure broad international collaboration and agreement on standards*

Nations should designate national data co-ordinators and participate actively in the IPYDIS to ensure the other elements of the strategy are met. Note the original strategy envisioned the coordination role fading out as data were secured, but actually coordination still needs to continue for several years.

The JC endorsed this strategy in October 2007. Subsequently, the JC, the IPO and the Data Subcommittee actively urged participating countries to designate national data coordinators and support IPY data archives. To date, 16 countries have designated national IPY data coordinators. Some nations formally designated IPY coordinators through national IPY Committees, research councils or other agencies. Because some IPY countries are only active in the Antarctic, their SCADM representatives act as *de facto* IPY coordinators. Many of these coordinators were not designated until well after IPY began and some will not continue very long after the IPY.

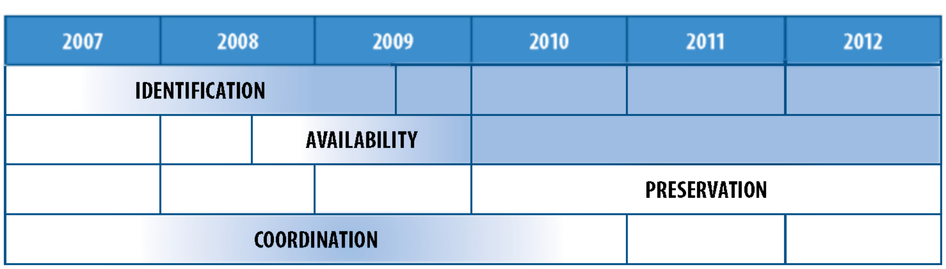

Fig. 3.11-2. Timeline for implementing the IPY Data Strategy

IPY has led to the creation of many new national, disciplinary and project-level data portals, but implementation of the IPY Data strategy is now a year or more behind schedule. We still strive to have all of the data in secure archives by 2012. At the time of writing, about 400 data sets were described in the IPY metadata portal at the GCMD. Given that there were tens of thousands of IPY investigators, this is likely to be a very small percentage of the data collected. The GCMD acts as a central portal to all IPY data, but as of yet, not all available data are advertised there. Several nations, including Canada, China, New Zealand, Norway, Sweden and Russia have developed national IPY data portals. In addition, many project data portals have been developed: the Antarctic Drilling Project, the Arctic Observing Network, the Circumpolar Biodiversity Monitoring Programme, the Polar Earth Observing Network, the SCAR-Marine Biodiversity Information Network and others. These portals are working to become increasingly interoperable and provide data through a common portal. Meanwhile, they do provide access to approximately 1000 datasets not yet available through GCMD (see below).

Assessment of Performance against Strategic Objectives

In the following subsections, we provide an assessment of how well IPY performed against specific objectives within each of the four elements of the data strategy and discuss lessons learned as well as what IPY sponsors and data centers can do to advance IPY data management. We provide a simple five-star rating system as a quick summary assessment for each objective. Key lessons and recommendations are highlighted throughout and then summarized below for aspects of data sharing and publication; interoperability; preservation; and coordination and governance.

Data sharing and publication

Objectives

1. *Data should be accessible soon after collection, online wherever possible, in a discovery portal such as the GCMD.*

Assessment: ★★★☆☆

Significant amounts of IPY data are available. In some countries, including Canada, Sweden, China,

Country	Coordinator	Affiliation
Australia	Kim Finney	Australian Antarctic Data Centre
Belgium*	Bruno Danis, Maaike Van Cauwenberghe	SCAR Marine Biology Information Network
Canada	Scott Tomlinson	Indian and Northern Affairs Canada
China	Parker Zhang, Zhu Jiangang	Polar Research Institute of China
France	Thierry Lemaire	French Polar Institute
Germany	Hannes Grobe	Alfred Wegner Institute
Japan*	Masaki Kanao	National Institute for Polar Research
Malaysia*	Talha Alhady	
Netherlands	Ira van den Broek	Royal Netherlands Institute for Sea Research
New Zealand*	Shulamit Gordon	The New Zealand Antarctic Institute
Norway	Øystein Godøy	Norwegian Meteorological Institute
Russia	Alexander Sterin	Russian Research Institute for Hydrometeorological Information
Spain*	Oscar Bermudez	
Sweden	Barry Broman	Swedish Meteorological and Hydrological Institute
United Kingdom	Julie Leclert	British Antarctic Survey
United States	Mark Parsons	National Snow and Ice Data Center

**Ad hoc or self-designated through their role in SCADM*

Table 3.11-1. National IPY Data Coordinators.

Netherlands, Norway and the United States, some data are being made available much earlier after collection than they were historically. For example, in the U.S., investigators in the IPY Arctic Observing Network Program routinely share their data in an open system within a few months after they return from the field. There is no embargo period as there has been in the past and program officers keep investigators accountable. Less progress has been made in other countries. Data availability is also highly variable across disciplines due, in large part, to existing procedures and special circumstances. For example, social science data has proven to be a particular challenge especially when data for human subjects are involved. Overall, data sharing is commonly recognized as a scientific imperative, but the technical mechanisms require further development and the cultural norms of science still resist sharing.

2. *Data users should provide fair and formal credit to data providers.*

Assessment: ★★☆☆☆

Data citation is increasingly recognized as a valid process, but implementation is sporadic at best. The issue is a growing topic of discussion in the data management and scientific publication communities and the IPY guidelines are gaining increased attention (Nelson, 2009; Parsons, Duerr and Minster, 2010).

Discussion

Data policy

The IPY Data Policy emphasizes the need to make data available on the "shortest feasible timescale." Rapid changes in the polar regions make this need to share data more acute because alone, no single investigator or nation can understand these changes. We note that underlying any discussion related to Arctic science is an awareness of rapid climate change in the Arctic and the occurrence of a unique and dynamic set of phenomena. A recurrent theme is whether the Arctic has moved to a "new state" or has passed a "tipping point." These terms are becoming more explicit in the literature and formal discussions of science (e.g. Hansen, 2007; SEARCH, 2005; Walker, 2006). Furthermore, climatic changes and other factors of modernity are driving large changes in Arctic society (ACIA, 2005). Similarly, science is confronted with rapid change. Fast growing data volumes pull us from hypothesis-driven science to science that seeks hypotheses and patterns in the data, be they climate model projections or the wisdom of an Inuit hunter. Nevertheless, the IPYDIS still struggles to identify data from IPY and make them broadly available.

The first issue is simply to identify what data were collected as part of IPY. The JC endorsed certain internationally collaborative efforts as IPY projects, but these collaborations were not always recognized or funded by individual nations and some countries paid scant attention to the international program when funding national IPY projects. This ad hoc approach, along with a lack of rigor in enforcing the data policy during project planning and implementation has made it very difficult to describe exactly what data were collected as part of IPY.

The Data Subcommittee has developed a specific definition of "IPY data". Data centers and investigators should identify and specifically flag their IPY data. To date, approximately 1400 data sets have been catalogued in the Global Change Master Directory and other portals as resulting from the IPY. This is likely to be a small fraction of the actual data collected.

More challenging and more important than simple identification is the actual unrestricted release and publication of the data. The IPY policy of general openness built from existing policies appears to be an initial success; fewer people now challenge the principle of open data access. The timely release requirement of the IPY policy is vague because no specific time limit is indicated, but it does require investigators to act quickly to meet the ideals of open data. This requirement has made some participants uncomfortable, but it keeps a certain pressure on data providers and forces the community to develop fair and equitable data sharing mechanisms.

It is significant that the community conversation about data sharing is no longer concerned with *whether* to share data, but rather with *when* and *how*. For example, the Norwegian data coordinator found investigators were more willing to share their data in common formats once they were provided basic data conversion tools. Other countries, such as Canada and Sweden, required adherence to the IPY data policy as a requirement for project funding. They then discovered that they needed to educate investigators on basic data management concepts, such as the difference between data and metadata, and that they also needed to provide data archives to which the investigators submit their data. These are promising developments and the conversation on the particulars of open access must continue. IPY sponsors need to lead this conversation, developing more consistent and rigorous data policy across organizations and nations to ensure rapid and open data sharing. Good data policy helps move open data sharing forward, but it must be enforced. IPY has had the greatest success with timely release of data in countries that explicitly require data sharing as part of funding arrangements and withhold future funding until data are made available. This was demonstrated in the Netherlands, the United States, Canada and possibly elsewhere.

Ultimately, to maximize their value and reuse, data should be made freely available in the public domain. This is a major focus of the Polar Information Commons (PIC, polarcommons.org), an ICSU project following from IPY to establish an improved framework for polar data sharing and preservation. A central tenet of the PIC is that data should be as unrestricted as possible, but scientists need to establish norms of behavior that ensure proper, informed and equitable data use. Some of the norms have been established or reinforced as part of IPY and the community should continue this discussion working to share data in the PIC framework.

The national data coordinators described above have been invaluable in identifying IPY data and helping investigators publish their data. Ideally, professional data managers should be directly included as part of data collection efforts, whether in the field or in the lab. These "data wranglers" can significantly improve the consistency and completeness of data and, therefore, the quality of the science in addition to ensuring that data policy obligations are met (Parsons, Brodzik and Rutter, 2004).

Demonstrating the value of data centres

Data centers also need to encourage data submission by clearly demonstrating value. In other words, data providers need to see a benefit in submitting their data to a professional archive. Of course, the ultimate benefit is the long-term preservation of and access to the data, but providers want to see immediate, practical benefit from the efforts they have made to archive the data. This benefit can be as simple as having submitted data immediately appear on a map in a WMS or Google Earth, but a broader benefit should also include increased provider recognition and possibilities for collaboration.

Different data management strategies for different types of data

IPY discovered that different strategies are necessary for different types of data. Because of IPY efforts, routine operational and remote sensing data are more broadly available than ever (*Chapter 3.1*), but much of the data collected by individual researchers or field projects remain largely inaccessible. The IPY Operational Data Coordinator in Norway has helped the European Center for Medium Range Weather Forecasting (ECMWF) to make their re-analyses more broadly available (http://ipycoord.met.no/). An active collaboration of national space agencies, the IPY Space Task Group, has led to greater collaboration and fewer restrictions in data access across remote sensing programs. Polar science is still very dependent on conventional, in situ research collections, however, these data tend to be less accessible. In some cases, there are legitimate restrictions to protect privacy or sensitive assets, but most restrictions are rooted in the culture and norms of science. Different disciplines have different attitudes and norms of behavior around data sharing (Key Perspectives Ltd., 2010). They also have highly variable data infrastructures. These disciplinary disparities were not well-recognized by IPY data planners. There was a tacit assumption that data management philosophies were the same in all disciplines, as it is in many geophysical disciplines.

Ultimately, we are talking about cultural differences in data sharing across disciplines; discussing a change in culture can be sensitive, especially in the context of the Arctic. Yet it is important to note the parallel rapid change in both science and the polar regions. These changes in environment and society create uncertainty and tension that foster a sense of urgency and a need for adaptation. An indigenous Arctic participant at an IPY Sustained Arctic Observing Network (SAON) workshop urged, "[w]e have no time to argue over how we feel and how we observe the changes. We need to work together." At a Canadian workshop, another northerner quoted Robert Hutchings in *Mapping the Global*

Future, "[l]inear analysis will get you a much-changed caterpillar, but it won't get you a butterfly. For that you need a leap of imagination." (National Intelligence Council, 2004). Furthermore, open data are central to the integrity of science. As the controversy around the emails stolen from the British Climate Research Unit illustrate, scientists are under greater scrutiny than ever. Data and methods need to be fully open and accessible to for science to be beyond reproach.

This new world of change, urgency and scrutiny creates a context in which a data sharing network must operate while some elements of science lag behind. The reward structures of academic research and scholarship remain largely the same as they were 50 years ago. For example, some scientists who spend a lot of time in the field monitoring various parameters often feel they get less respect in the scientific community. Collecting data takes time away from analysis and journal publication, yet the intellectual effort in collecting and compiling data is not adequately recognized. This can increase the proprietary attachment "monitoring scientists" will have for their data. They feel compelled to restrict access to their data until they get an opportunity to publish something based on the data they collect because publication is a primary measure of a scientist's merit. The data themselves should be considered a valuable and recognized publication in their own right. Indeed, data sharing itself can be a means toward greater interdisciplinary collaborations and publications.

Data citation

The IPY Data Policy encourages formal recognition of data providers: "...users of IPY data must formally acknowledge data authors (contributors) and sources. Where possible, this acknowledgment should take the form of a formal citation, such as when citing a book or journal article. Journals should require the formal citation of data used in articles they publish." Furthermore, the IPY Data Subcommittee has developed specific guidelines on how to cite data (http://ipydis.org/data/citations.html) and data citation is encouraged by many disciplines (Costello, 2009; Klump et al., 2006; Schofield et al., 2009). Nevertheless, data citation remains erratic. Few journals explicitly require data to be cited and referees rarely demand it during peer review. More importantly, data publication is rarely considered by promotion panels or tenure review boards even though the intellectual (and physical) effort behind most data collections rival that of a journal article. Overall, investigators see little incentive to publish their data, especially if it is not routinely cited.

Building from the IPY guidelines, data centers need to provide the clearest possible guidelines on how their data should be cited. They need to work with the broader community to continue to research closely related issues such as accurate citation of different versions and changing time series, the use of unique and permanent identifiers, and potential peer review processes. This is an ongoing discussion in the data management community and while there are many issues outstanding, IPY guidelines provide a firm foundation. Digital Object Identifiers (DOIs) also emerge as the *de facto* standard for identifying complete data collections, if not the specific elements of a collection. ICSU bodies, such as CODATA, could help further develop data citation standards and guidelines.

Finally, any discussion of data sharing must consider how researchers define their personal and professional identities, and how that affects their attitudes toward collaboration and data sharing. Polar research is rooted in the age of heroic exploration. There is a romance and toughness associated with historic polar exploration that attracts some people to study the poles. The difficulty of collecting data in the poles helps create a narrative that researchers use to define themselves and to create bonds with other members of their research community. The physical challenge and difficulty of collecting data in the poles not only helps define the identity of the researchers, but also can create a sense of proprietary ownership that can restrict data sharing to narrow communities of a single discipline or a few colleagues. Scientists can exhibit a sort of cliquishness restricting access of those they consider "outsiders" or of those they fear may misunderstand and therefore misuse their data.

Issues of trust are not unique to scientists. A major concern expressed by Arctic residents is that researchers come in and take information and knowledge from the North without permission or that they might reuse data in new ways without checking with the people who provided the knowledge behind the data. See *Chapters 3.10 and 5.4* for more on challenges around handling community-based monitoring and local and traditional knowledge. IPY has done much to build trust and enhance collaboration across disciplines and cultures. To sustain this collaboration, we need to encourage greater data sharing by building familiarity and relationships. Sponsors should continue to support cross-disciplinary workshops that include scientists, northern residents and other stakeholders. Data managers need to be included to help facilitate the equitable means of data sharing and mutual respect necessary for productive collaboration.

Interoperability

Objectives

1. *Metadata should be readily interchangeable between different polar data systems to enable data discovery across multiple portals.*

Assessment: ★★★☆☆

The main IPY data portal is hosted by the GCMD and builds from the success of the Antarctic Master Directory developed in partnership with SCADM. The Data Committee created a metadata profile for the GCMD's Directory Interchange Format (DIF) with crosswalks to other geospatial metadata standards. Multiple IPY data centers have adopted the profile and several have begun automatically sharing metadata through open protocols. The most challenging issue has been agreeing on and harmonizing specific controlled vocabularies, especially those describing scientific parameters. The IPY profile uses the GCMD's science keywords, which are broadly, but not universally adopted. They also grow from a geophysical perspective and are less complete in other areas, especially social sciences.

2. *Data from different projects, disciplines and data centers should be easily understood and used in conjunction with each other in standard tools and analysis frameworks.*

Assessment: ★★☆☆☆

The interdisciplinary nature of IPY inhibits interoperability of data. Different communities use different data formats, tools and exchange protocols. Some standard data formats, such as the Network Common Data Form – Climate and Format (NetCDF-CF), which includes usage metadata, are becoming more broadly adopted especially in the oceanic and atmospheric sciences, but there is still great variability. Some data are in closed proprietary formats (especially if they were generated with specialized commercial sensors) and there are thousands of variations of ASCII formats even within similar scientific disciplines. Open Geospatial Consortium data and image sharing protocols (WMS/WFS/WCS/KML) are broadly used by many disciplines and form the foundation of the emerging Arctic and Antarctic Spatial Data Infrastructures. The Open-source Project for a Network Data Access Protocol (OpeNDAP) is also used for sharing data and provides network interfaces to data within several tools (e.g. MATLAB, Ferret), but is mostly used within the oceanographic community.

3. *Data should be well-described so as to be useful for a broad audience.*

Assessment: ★☆☆☆☆

The IPY Data Policy required detailed documentation and adoption of formal metadata standards. Standards have been more broadly adopted, but detailed documentation is still lacking for most data.

Discussion

Wikipedia defines interoperability as "a property referring to the ability of diverse systems and organizations to work together (interoperate). The term is often used in a technical systems engineering sense, or alternatively in a broad sense, taking into account social, political, and organizational factors that impact system to system performance." In the IPY, with its interdisciplinary focus, interoperability also includes the ability of scientists to effectively access and use data from disciplines in which they are not expert. This suggests that IPY needs to consider the broader definition of both technical and social interoperability. We discuss many of the social and political issues elsewhere. Here, we focus primarily on technical and organizational issues, and use a more narrow definition from the Institute of Electrical and Electronics Engineers (IEEE)[2]: "the ability of two or more systems or components to exchange information and to use the information that has been exchanged."

From this perspective, interoperability often revolves around the organization and completeness of metadata, the structure of the data itself, and the availability and use of tools used to discover, assess, access and manipulate the metadata and data. We, therefore, consider technical interoperability at several different levels or stages of the data flow.

Data submission

Earlier, we discussed some of the social issues restricting data submission. In addition, we need to consider the difficulty and cumbersomeness of formally describing and submitting data to an archive. Investigators need practical methods to publish their data. Several nations have created specific data systems to handle IPY data and have provided tools and assistance to help investigators describe and submit their data and documentation. Some countries conducted data provider workshops to educate providers on the importance and mechanisms for data publication. Provider training has proven to be very effective at improving both the quantity and quality of data submissions, but it is vital to have clear and explicit data submission instructions and tools. IPY data centers should continue to develop and improve tools for investigators to easily describe and submit their data from the field and the lab. They should provide specific instructions or "cookbooks" to help data providers meet their policy obligations.

Where applicable, data centers should share these tools and also coordinate instructions, metadata schemas and content to make processes similar across disciplines and locations. This will aid with data discovery and assessment across centers. The Polar Information Commons is one attempt at harmonizing data submission that seeks to enable highly distributed, cloud-based data distribution and discovery through XML-based broadcasts of basic RDF-structured metadata. It builds on the principles of open, linked data to reduce dependency on centralized registries and ultimately to make barriers to sharing as low as possible. Polar data centers should use and re-purpose PIC tools to broadly expose their data.

Data discovery and assessment

Finding and making sense of diverse IPY data is a significant challenge, even with powerful search engines such as Google. Search engines and data portals rely on sufficient, consistent metadata to assess relevance, rank listings and narrow searches, especially for specialized items like scientific data. Current practice is to create portals to data set description catalogs or registries that contain consistently formatted metadata, increasingly with a direct link to the online data and an automated request scheme for off-line data.

IPY has resulted in a number of data catalogs, both at the national and international level, including the overarching IPY metadata portal at GCMD. There are multiple different metadata formats and vocabularies in use by these catalogs. This complicates both the submission as well as the use of these catalogs. The Data Committee defined an IPY metadata profile that being used at several IPY data centers and at the GCMD. The profile needs to be extended and cross-walked to the ISO19115/19139 standard, which is emerging as the most broadly mandated geospatial standard.

As a result of IPY, several data centers have established pilot projects to exchange metadata records using the IPY profile and the Open Archives Initiative Protocol for Metadata Harvesting (OAI-PMH). Metadata from centers in Canada, Norway, Sweden, the U.K. and the U.S. are directly provided to the GCMD. In addition, certain projects will provide more specialized discovery services on subsets of the data. For example, there is collaboration between the European Developing Arctic Modelling and Observing Capability for Long-term Environment Studies (DAMOCLES) project and the U.S. Arctic Observing Network (AON) to share data, not just metadata, between their respective data systems. This is the beginning of the "IPY Union Catalog" outlined in the 2006 Cambridge Workshop. More data centers need to adopt the IPY profile and join the union catalog to provide both a central and specialized portals to distributed data.

The greatest challenge for data centers in adopting the profile is adhering to the required GCMD science keywords. In some cases, the keywords may not adequately describe certain data types and disciplines (e.g. indigenous knowledge) or data centers may have adopted other vocabularies more specific to their discipline (e.g. oceanography). Much more work needs to be done in this area of semantics to develop more complete vocabularies and taxonomies, crosswalks between them and potentially even structured ontologies. The interdisciplinary data and use cases produced by IPY can be the starting point for funding agencies to support more semantic research, applications and communities of practice around polar research.

Data access

Data discovery, without actual access, is not very useful so it is critical that data catalogs include direct links to the exact data described. Too often, metadata registries only provide an e-mail contact or a link to another search engine that may then permit actual access to the data. Data providers must work with data centers to make all digital data available online and data centers must provide direct links to that data in their shared metadata records.

The pre-IPY and, in many cases current, situation is that there are many data centers holding data in many different formats without much uniformity or standardization. The data may or may not be fully described; this is necessary to enable the user to judge the quality and fitness for purpose of the data. As a result, it is almost impossible to get an overview of data holdings. If the user does get access to the data, the user has to convert formats and do much data manipulation before being able to use the data. Many users may easily spend more than half of the time of a project trying to locate, obtain and convert data, instead of doing science. The situation becomes even more problematic if one tries to find and use data across disciplines in an interdisciplinary research project.

IPY has demonstrated geospatial interoperability, primarily through Open Geospatial Consortium (OGC) protocols, WMS, WCS and KML in particular. The Senior Arctic Officials of the Arctic Council recently approved the Arctic Spatial Data Infrastructure, an initiative that grew out of two IPY data conferences that invited all Arctic national mapping agencies to provide topographic data openly through OGC protocols. In the Antarctic, the Standing Committee for Antarctic Geospatial Information (SCAGI) is already serving topographic data through OGC protocols from the Antarctic Digital Database. In addition, KML was widely adopted by many IPY projects as an easy way to display diverse data in a three-dimensional context. Nevertheless, there is a great disparity of formats for IPY data.

Data centers and science communities need to work together to identify a small set of well-defined formats. These formats must be well-described, open source and function independently of platform and operating systems. Self-describing formats, which include descriptive metadata embedded in the data file, are especially useful. Some disciplines in the IPY have had some success standardizing around NetCDF, with Climate Forecast (CF) extensions, and tools are increasingly available to convert formats. No one format is going to work for all disciplines or applications so data centers need to be flexible and provide data in multiple formats, especially self-describing formats.

Much IPY data is in simple ASCII text formats. ASCII is a useful, sustainable, highly portable, human readable format, but it can be problematic. It is so flexible that data can be represented in many specific implementations. These implementations are what most generally consider the data format. They can be very general like XML or can be very well-defined, such as a precise tabular layout relating to data from a particular instrument. There are literally thousands of ASCII formats used to described polar data with great variability even within disciplines. Science communities need to recognize that interoperability begins at the time of data collection. It starts with using the same protocols and measurement techniques, which can, in turn, drive data formats. Funding agencies should support community workshops to harmonize techniques and formats within disciplinary communities. In one example that grew out of IPY, Fetterer (2009) describes a community attempt to define data management best practices for sea ice field measurements.

Data use

Perhaps the greatest value of data lies in its reuse, now and by future generations of scientists. Much of what we have already discussed in terms of metadata, semantics, and formats also improves the usability of the data. It is also important to have comprehensive documentation for each data set to enable non-expert use and to avoid misuse. Data centers and scientists need to collaborate to produce accurate documentation. It is especially important to explicitly describe data uncertainties (Parsons and Duerr, 2005). Data centers should formally engage users to advise on the presentation, documentation and appropriate application of the data while recognizing that no one group can represent all interests. Where possible, make use of the English language within data and documentation, to ensure the broadest international use.

Preservation

Objectives

1. *All raw IPY data should be preserved and well-stewarded in long-term archives following the ISO-standard Open Archives Information System Reference Model (ISO, 2003).*

Assessment: ★☆☆☆☆

Plans for the *long-term* management of IPY data are even worse than what is shown in Fig. 3.11-1. Many disciplines do not have long-term archives. Long-term, archival standards are still evolving and adherence to good practices is highly variable cross projects and disciplines. Beyond ongoing government commitment in some disciplines, no clear and sustainable business models have emerged to support long-term data stewardship.

2. *Data should be accompanied by complete documentation to enable preservation and stewardship.*

Assessment: ★☆☆☆☆

Most documentation is *ad hoc* and largely geared towards discovery. Some guidelines on documentation have been developed on a disciplinary or project basis, but some issues, such as describing detailed and ongoing provenance, have not been resolved in the general archiving community.

Discussion

"In fifty years time the data resulting from IPY2007–2008 may be seen as the most important single outcome of the programme."
(Rapley et al., 2004)

Because much IPY data collection has only recently been completed, it is hard to assess progress in data preservation at this stage. Nonetheless, the IPY data policy emphasized that data preservation should be considered during project planning. We can, therefore, look to the data management plans of each project to assess the readiness of IPY data to be preserved appropriately. As discussed already, it appears that only 30 projects have adequately considered long-term preservation. This leaves 94 IPY projects collecting data without clear plans or resources for archiving their data and it has been a challenge to simply identify all the IPY data collected, let alone ensure they find their way to secure archives. The data coordinators listed in Table 3.11-1 have been essential in this effort, but their level of ongoing support and activity is highly variable and many will not continue in their role as a national IPY data coordinator beyond 2010. All told, there is deep concern about the likelihood of being able to adequately preserve much of the IPY data legacy.

Many may have assumed that the ICSU World Data Centers (WDCs) would be the natural home for much IPY data since they were established to manage the data collected during the IPY's predecessor, the International Geophysical Year (IGY). In retrospect, that seems unrealistic and may reflect the perspectives of the IPY data planners who largely came from physical science disciplines. Certain WDCs have contributed in developing an IPY data system, but the WDCs as a whole have not been a central or leading force for IPY data management. As ICSU President, Catherine Bréchignac, noted in her remarks at the IPY 'closing celebration' in Geneva, "an unfortunate but crucial impact of IPY was to help expose weaknesses in the current collection of WDCs and it is hoped that the new World Data System (WDS) will better serve polar science in the long run by growing a true data network." Parsons (2009) provides further "Observations on World Data Center Involvement in the International Polar Year" and although critical issues need to be resolved, we still look to the emerging WDS as the long-term IPY data archive. This is in keeping with the recommendations of the ICSU ad hoc Strategic Committee on Information and Data (ICSU, 2008) and the charters of both the WDS and its sister advisory body, the ad hoc ICSU Strategic Coordinating Committee for Information and Data (SCCID). Both bodies see IPY as a critical test case.

Many of the issues already discussed above have direct impact on data preservation, but critical issues can be summarized as follows:

- Only a small proportion of projects completed data management plans to identify long-term repositories for their data.
- Identifying data sets, especially research collections, and obtaining metadata remains a large challenge and many projects have still not provided any

metadata.

- Many national and international data centers have not been engaged in IPY data preservation.
- Many investigators are unclear about their data preservation responsibilities or where they should submit their data. In many disciplines, long-term archives simply do not exist.
- There is no comprehensive data preservation strategy reaching across disciplines and nations.
- There needs to be a way to preserve the tools, systems and ancillary data that have been developed through IPY.
- Preservation description information (ISO, 2003) is generally lacking, especially detailed information about provenance and context.

Two general causes underlie these issues:

a) the ability and willingness of scientists to invest time to prepare data for preservation, and
b) sustained resources for data centers to preserve IPY data and ensure coordination across these centers.

Ability and willingness of scientists to prepare data for preservation

Scientists need incentives to share and describe their data and to adhere to relevant data strategies and policies. Incentives can include both rewards and punishment or "carrots and sticks." Incentives for investigators should include recognized data citations and increased value of data through easier data integration and analysis. Experience in IPY and SCADM has shown the most effective enforcement mechanism is through funding mechanisms that either withhold some funding or reduce the ability of scientists to obtain future funding opportunities if they do not adhere to the data policy. At the same time, data centers need to provide tools and guidance to make data submission to archives as easy as possible.

Ultimately, long-term preservation needs to be a consideration throughout the entire scientific process. This requires a major shift in some of the institutions of science. Universities need to include data management instruction as a core requirement of advanced degrees. They should consider data publication and stewardship equally with journal publication in conferring degrees, advancement and tenure. Scientific journals and reviewers must also demand clear citation and availability of any data used in a peer-reviewed publication.

Sustained resources for preservation

An obvious major issue with data preservation is having appropriate long-term repositories. Even though there are many IPY data centers, many disciplines do not have discipline-based data centers at all. Currently only 13 IPY projects are being actively supported in data preservation by World Data Centers. Clearly, as recommended elsewhere, IPY data preservation should be a major focus of the renewed World Data System that ICSU is developing.

Data preservation requires resources. There is a need for new business models that can provide sustained support for dynamic and evolving scientific data. We are encouraged by efforts around their world, such as the U.S. NSF DataNet program, the European Commission e-Infrastructure initiative and the Australian National Collaborative Research Infrastructure System that work toward these sustainable models. The experience from IPY is that data preservation is most successful when nations commit program resources to data management and coordination, and provide an explicit repository for preservation. Future polar programs should be supported by an early commitment of resources for data management and coordination. This support should include resources for repositories to cover all disciplines included in the program. Funding for national and international data centers is often uncertain; as a result, they have limited ability to support new programs.

IPY was very interdisciplinary, but science data stewardship in the past has been primarily discipline focused. To fully support programs such as IPY, it is vital to ensure that all disciplines have well-funded permanent data repositories and to encourage these repositories to collaborate and support interdisciplinary work. Nations should fund archives to fill disciplinary gaps and require archives to work together on standards and interoperability as a contingency of their funding.

Another important issue identified through IPY is the lack of an overall consistent strategy for all polar data preservation. It will take much more discussion across disciplines and data centers to develop this strategy, but as an example, IPY data and information could be divided into five broad categories:

1. Project management information, project background and administrative documents
2. Raw data, metadata and documentation (including a proper citation)
3. Processed data, revised metadata and documentation (including updated citation)
4. Data outputs, derived products and tools
5. Publications

By dividing the data and information into categories, we can begin to define consistent retention schedules across disciplines for IPY legacy. Each retention schedule will be defined by asking the question of "what would be useful in the future". This may then lead to some categories only being kept for the short-term and others, such as raw data, being kept in perpetuity. It is vital to remember here that data are only useful if fully documented and are even more valuable with contextual information, therefore, those factors will also have to be considered when deciding on the retention schedules for each of these categories of data and information. IPY sponsors need to establish a forum, probably within the International Arctic Science Committee (IASC) and SCAR, for developing a comprehensive polar data preservation strategy. This strategy must include a data acquisition component to acquire IPY data that have not been securely archived. The development of this strategy should be closely coordinated and allied with the PIC, WIS, and WDS implementation.

Coordination and Governance

Objectives

1. Identify, evolve, or develop a sustained virtual organization to enable effective international collaboration on data sharing, interoperability and preservation.

Assessment: ★★☆☆☆

Antarctic data issues are coordinated through SCADM, SCAGI and the recently endorsed *SCAR Data and Information Management Strategy* (Finney, 2009). The Arctic has no overarching data strategy or focal point. Furthermore, polar issues (unique phenomena, extended darkness, complex logistics, polar projections, etc.) need to be better considered in global data organizations such as GEOSS, WIS and the evolving WDS.

Discussion

To address all of the issues discussed so far and to maximize the legacy of IPY, it is imperative to have a governance mechanism. Good governance will help develop preservation strategy, coordinate policy, agree on common standards and develop interoperability agreements to enable broad interdisciplinary data discovery. The IPY process has provided the scientific research and data management communities many opportunities to learn lessons on scientific data management for a multidisciplinary, multijurisdiction program. In general, having a dedicated coordination body, with national representatives for data management, has proven to be a very important aspect of the success of the IPY program. As well, having dedicated data coordinators in countries involved in IPY has been critical. These coordinators also need to have sufficient authority to apply the requirements of the data policy to the research.

It is also useful for this coordination body, in this case the IPY Data Management Committee, to have resources to hold national and international meetings and workshops. These workshops are important to develop common understanding and to develop broad buy-in for the overall data strategy, specific tactics and protocols related to data management.

The governance and coordination of polar data management is an important activity that needs to be continued. At the same time, it is recognized that many existing global and national data committees and systems exist. There is little appetite to create a new international coordination body that may be redundant with existing bodies. Rather than establishing a new international organization dedicated to polar scientific data management, we seek a governance structure that integrates polar data and the unique issues around polar data into existing global data systems, virtual organizations and governing bodies. That said, IPY revealed that these bodies do not currently address the needs highlighted by IPY. These needs include broad interdisciplinary collaboration, monitoring of unique polar phenomena (e.g. sea ice) in conditions that challenge remote and in situ sensing methods, extensive use of diverse research collections even in operational context, complex logistical support, geospatial tools optimized to handle polar projections and representations, etc.

A major initial focus of this governance structure will be to formally transition the activities of the IPY Data Committee and IPYDIS into relevant international data structures and organizations.

Members of the IPY Data Committee have proposed a new CODATA Task Group to help plan this transition, but SCAR and IASC are the most logical organizations to provide leadership in this area. Antarctic data issues are coordinated through SCADM and SCAGI and are guided by the *SCAR Data and Information Management Strategy.* The Arctic has no overarching data strategy or focal point. The Arctic Council has shown leadership in certain areas, such as in the Arctic Monitoring and Assessment Programme (AMAP), and by endorsing and initiating the Arctic Spatial Data Infrastructure, but this only represents a subset of polar data. Furthermore, Arctic data are collected by many nations outside of the Arctic. IASC, which has broader international representation, still lacks any sort of data coordination body. The Sustained Arctic Oberving Network (SAON) process *(Chapter 3.8)* has provided an opportunity and has consistently considered data sharing issues, but it remains unclear how data issues would be coordinated under SAON.

Both SCAR and IASC have benefited from their increased coordination during IPY. They must continue coordination over data policy and governance issues. SCAR and IASC must also consider global connections and work to be actively engaged and directly represented in the development and implementation of the WDS, WIS and GEOSS. National data coordinators need to have sufficient authority to implement recommendations and sufficient time to dedicate to the initiative.

The following are some critical governance and coordination issues that must be addressed:

- Disciplines must achieve better integration on standards and exchange protocols. The strength of IPY was the multidisciplinary nature of the research. This also exposed many shortcomings in terms of integration of research and results, particularly between disciplines with differing approaches to data and data management. There is much to be gained by having better integration of data across all disciplines of a given project; more meaningful results, better understanding of processes and the resulting science questions, and exchange of techniques and knowledge transfer among team members.
- IASC must develop a data policy and strategy considering the existing SCAR strategy while ensuring input from social and health sciences. IASC and SCAR must ensure their data policies and strategies work in harmony. Consistent international data policies are important in ensuring that requirements of project participants are well understood and not open to interpretation based on jurisdiction. In addition, consultation among the physical, health and social sciences should occur to harmonize the unique data management requirements for each discipline. CODATA and the Polar Information Commons are important partners in this area.
- Networks established by IPY must be maintained to continue and enhance information flows among groups, nations and organizations. The formal and informal networks established during IPY are valuable resources and should be maintained if possible. The communication among groups through these networks has been beneficial in moving the agenda for data management forward. Future polar data management will involve well-connected groups that will form a web connecting communities of practice, international networks, national organizations and intergovernmental organizations.
- The IPY community must develop and sustain sufficient data infrastructure. An important lesson learned from the IPY process is that there needs to be sufficient pre-existing infrastructure to support the requirements set out in the data policy and that data strategies need to address infrastructure gaps and development plans. Many countries found that the researchers were willing to abide by the IPY data policy and submit their data to an archive only to discover that no relevant archive existed.

Summary and Conclusion

The IPY has provided an excellent case study of data management for an intensive, international and highly interdisciplinary project—the sort of project that will increasingly be needed to understand and address grand societal challenges, such as rapid climate change. IPY revealed a critical global need for better planned, funded and integrated data management, but this is not a new revelation. Important assessments, such as the ICSU Program Area Assessment (ICSU, 2004), the SCAR Data and Information Management Strategy for Antarctica (Finney, 2009) and even the IPY's own framework document made clear recommendations on how to address integrated data management. Therefore, another grand challenge is to recognize the value of data management, act on these recommendations and fund the full data life cycle, especially advance planning and long-term preservation. IPY data centers need to provide clear direction and the science community at large needs to move more rapidly toward a culture of open data to truly realize the benefit of the large and diverse IPY data collection.

This report outlined IPY overall performance against key objectives. The results are summarized in Table 3.11-2. The discussion sections also included many specific recommendations, many of which parallel those in existing reports. Rather than recount all the details here, we provide a summary of actions that different IPY stakeholders should take in the short-term to ensure the availability and preservation of IPY data and actions that, over time, work to develop a sustained polar data system. Stakeholders include IPY investigators and the general polar science community, the international sponsors of the IPY (ICSU, WMO, IASC and SCAR), the national funding agencies that made IPY a reality and the data centers working to support IPY.

IPY investigators and the scientific community

In the short term: IPY investigators must publish their data immediately in an appropriate archive. Published data should include full documentation, including detailed descriptions of data uncertainty and appropriate use. What constitutes "complete documentation" is variable across disciplines and user communities, but the U.S. Global Climate Change Research Program (1999) provides sensible guidelines. Digital data should be in an open, non-proprietary format, ideally a standard, self-describing format used broadly within their discipline. Where possible, data should be fully in the public domain and free from restriction. Data authors should also provide basic discovery-level metadata to the GCMD or appropriate national registry including a direct link to online data. If no appropriate archive is available, investigators should seek guidance from their funding agency or consider publishing the data within their own institution. Regardless of where the data are archived, investigators should still register their data in the GCMD or a national registry.

Over time: The overall scientific community needs to recognize the value of good data stewardship in order to create consistent time series and to speed and maximize data reuse. Data publication should be formally recognized and promoted. Scientific journals and reviewers must demand clear citation and availability of any data used in a peer-reviewed publication. Universities, government agencies and scientific institutions in general should consider quality data publication and stewardship as equal to journal publication when conferring degrees, advancement and tenure. To foster this culture change, universities need to include data management instruction as a core requirement of advanced degrees.

International sponsors

In the short term: ICSU, through the World Data System, must lead an aggressive initiative to ensure all IPY data are in secure archives by June 2012. The initiative must include an active data rescue program to identify and preserve unavailable IPY data with a special focus on data from the life and social sciences. The WDS must be an active partner in the Polar Information Commons to ensure that valuable data shared through PIC mechanisms end up as well-curated collections in secure archives. ICSU and WMO must be strong and determined voices on the need to fund ongoing data stewardship.

IASC must develop an effective and pragmatic data strategy to ensure active pan-Arctic data sharing and collaboration. The *SCAR Data and Information Management Strategy* (Finney, 2009) provides an initial blueprint while IASC and SCAR collaboration on data issues must continue in a real and tangible way. It is telling that there is still no focal point for coordinating Arctic data management. SAON may provide an initial focus and is a logical leader of an initial pan-Arctic data strategy, but it is important that this strategic

Table 3.11-2. Summary assessment of how well the IPY performed against specific data management objectives.

Objective	Assessment
Data Sharing and Publication	
Data should be accessible soon after collection (online wherever possible) in a discovery portal such as the GCMD.	★★★
Data users should provide fair and formal credit to data providers.	★★
Interoperability	
Metadata should be readily interchangeable between different polar data systems to enable data discovery across multiple portals.	★★★
Data from different projects, disciplines and data centers should be easily understood and used in conjunction with each other in standard tools and analysis frameworks.	★★
Data should be well-described so as to be useful for a broad audience.	★
Preservation	
All raw IPY data should be preserved and well-stewarded in long-term archives following the ISO-standard Open Archives Information System Reference Model(ISO 2003).	★
Data should be accompanied by complete documentation to enable preservation and stewardship.	★★
Coordination and Governance	
Identify, evolve or develop a sustained virtual organization to enable effective international collaboration on data sharing, interoperability and preservation.	★★

effort extend beyond the Arctic Council to include all nations collecting data in the Arctic and to address research data, not just data gathered from observing networks. The proposed CODATA Task Group will help address some of these issues, but IASC must be dedicated to making work. Finally, IASC, SCAR, ICSU and WMO must aggressively work to ensure polar issues are addressed in global data systems, notably the WIS, GEOSS and WDS.

Over time: ICSU and WMO must continue to lead the global discussion to harmonize data policies to promote openness as rapidly as possible, while recognizing legitimate, moral restrictions. These restrictions should be extremely limited and not include commercial or proprietary restrictions of publicly-funded data. Data should be shared under the least restrictive terms possible and be fully in the public domain wherever possible.

ICSU and WMO must include a detailed and funded data management plan as an integral part of any future scientific initiative they lead. The value of advance planning and support cannot be overstated.

National funding agencies

In the short term: National funding agencies must support data archiving and insist that data from projects they fund be archived. Agencies must create new archives where appropriate archives do not exist, ideally in collaboration with the WDS and other countries. Nations should also maintain (or establish) national IPY data coordinators for the next three years to help ensure all IPY data are identified and archived. These coordinators should be supported to participate in international coordination activities.

Research funding agencies should take advantage of the interdisciplinary use cases generated by IPY science questions to support activities that improve interdisciplinary data management and interoperability. This support could be for workshops around certain issues of interoperability (e.g. common metadata content and data formats), the development of communities of practice or fundamental research on semantic and data visualization approaches to aid interdisciplinary data use. IPY created unique interdisciplinary data management challenges that also present opportunities.

Over time: Funding agencies should collaborate with ICSU and WMO in the establishment of consistent open data policies. Agencies also need to develop consistent data strategies that include enforcement mechanisms to ensure data policies adherence. The IPY experience suggests that the most effective enforcement mechanism occurs when funding is linked to policy adherence.

Data Centers

In the short term: Data centers must develop partnerships with other data centers in other countries and other disciplines to enhance data accessibility and interoperability. Data should be exposed through common open protocols and web services (e.g. OGC) and be available in multiple standard formats. Data centers must adhere to the IPY metadata profile and share their metadata with GCMD and other relevant data portals and systems (e.g. WIS).

Over time: Data centers should partner with their scientific community. They should work with their community to meet user needs and demonstrate the value of submitting data by making the data more accessible, useful and integrated with other data. They should assist data providers by providing tools, documentation and assistance to help providers document and publish their data. Data centers should encourage proper credit for data providers by providing citation recommendations for all data sets.

IPY pushed polar science to new level of interdisciplinary collaboration. This collaboration was perhaps IPY's greatest success, but truly capitalizing on this success requires that the data collected during IPY be readily discoverable, useful and preserved. IPY highlighted critical data management issues, fundamental strategic differences in Arctic and Antarctic data management and how interdisciplinary science can challenge some assumptions of data management institutions. At the same time, the global scientific community increasingly recognizes the need for open data linked across borders and disciplines. This recognition is evident in everything from a special *Nature* issue on data sharing (461:7261) and the rapid growth of informatics foci in some scientific unions to major data initiatives, such as the U.S. DataNet program and the European Inspire program. The polar science community must take advantage of their renewed collaboration and the international enthusiasm to ensure the most significant IPY legacy – the data.

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Notes

[1] Note JCADM was a joint committee between SCAR and the Council of Managers of National Antarctic Programs (COMNAP) but formal links with COMNAP ceased in January 2009 and JCADM became a SCAR Standing Committee and was thus renamed the Standing Comittee on Antarctic Data Management (SCADM).

[2] Institute of Electrical and Electronics Engineers. IEEE Standard Computer Dictionary: A Compilation of IEEE Standard Computer Glossaries. New York, NY: 1990.

PART FOUR

IPY Public Programs; Publishing and Archiving IPY; New Generation of Polar Scientists

Coordinating Editor: David Hik
Reviewer: Ian Church

Introduction

David Hik

Three critical aspects of the IPY 2007–2008 program that were identified early in the planning process (*Chapter 1.3*) included capturing the interest of educators, the public, government officials, and media; preserving the scientific and public records of all IPY related activities; and attracting and developing the next generation of polar scientists. The three chapters in this section provide a summary of the organizational approach that evolved during IPY for planning and managing these aspects of the overall program, and a brief overview of some related activities and events during IPY.

It is impossible to provide a complete inventory of all of the Education, Outreach and Communication (EOC) activities that took place during IPY, but *Chapter 4.1* describes how these efforts were planned and some of the main events that brought together teachers, students, researchers, artists, journalists, media officers, film-makers, book publishers, program managers and the public. Throughout IPY, barriers to public and formal science education, such as language, age and culture, were overcome by cooperation and enthusiasm. The EOC Subcommittee and its national counterparts (*Appendix 5*) provided a tremendous catalyst, but many other groups also 'adopted' IPY and conducted activities in classrooms, in communities, on the Internet, and in other public spaces that provided an outlet for sharing information about IPY and connections between the polar regions and the rest of the planet (Fig. 4.0-1).

Archiving and cataloguing IPY publications and products has been a critically important and continuing activity (*Chapter 4.2*). Since the full impact of IPY will not fully emerge for several more years, all IPY participants will need to be mindful of the need to submit their diverse contributions to the IPY Publications Database and IPY archives. Many records may have been lost already, both physical and electronic; so, a sustained and committed effort to archive the IPY documentation will be essential in post-IPY years.

Early career scientists and students were particularly instrumental in the success of IPY (*Chapter 4.3*). The Association of Polar Early Career Scientists (APECS) emerged from IPY as a mature interdisciplinary organization for students, postdoctoral researchers, early faculty members, educators and mentors that could stimulate research collaborations and support the development of future leaders in polar research, education and outreach. The Polar Resource Book *"Polar Science and Global Climate: An International Resource for Education and Outreach"* (Kaiser, 2010), stands out as a major accomplishment of the IPY EOC Subcommittee and APECS. This volume will ensure that outreach and education efforts catalyzed by IPY will continue to inspire educators, students and both established and emerging polar researchers for years ahead.

The final assessment of IPY efforts in mobilizing knowledge and resources to strengthen international science for the benefit of society is still being completed. The International Council for Science (ICSU), in partnership with the International Arctic Science Committee (IASC) and the Scientific Committee on Antarctic Research (SCAR), are supporting APECS and other partners to conduct an inventory of IPY EOC activities and to assess the lessons learned about the effectiveness of EOC programming and networks during IPY (Fig. 4.0-2). Their report will be completed during 2011.

It is clear already that innovative ideas, creative and user-friendly tools of the digital era, extensive partnerships and considerable volunteer support allowed IPY to meet and even exceed many of the EOC, archiving and career development objectives that were articulated at the beginning of its planning phase in 2002–2003 (*Chapters 1.2 and 1.3*). It certainly

Fig. 4.0-1. Many Education, Outreach and Communication activities during IPY 2007–2008 provided opportunities to share information about changes in the polar regions. (a) High school students participating in the Students on Board program on-board *CCGS Amundsen* (Photo courtesy: 'Students on Board' project); (b) rest stop during Antarctic field course of the International Antarctic Institute (Photo: Patti Virtue); (c) polar bears in downtown Winnipeg, Canada (Photo: David Hik); (d) IPY International Program Office staff (David Carlson, Nicola Munro and Rhian Salmon) at the EOC Subcommittee meeting in Bremerhaven, October 2006 (Photo: Karen Edwards).

Fig. 4.0-2. A word cloud created from the education, outreach and communication programs included in IPY EOC assessment, as of 23 January 2011. (www.apecs.is/education-outreach/ipy-outreach-assessment)

exceeded anything that was done in the earlier IPYs and in IGY 1957–1958. However, these activities required considerable planning and resources, and still need to be sustained. Future polar science programs and the institutions that support and finance polar research need to ensure that EOC, archiving and career development activities are integrated within science plans and are provided with sufficient resources within these same budgets. Why make this investment? Because in 50 years it is very likely the investment IPY 2007–2008 made in EOC and archiving and career development opportunities will still be among its most visible outcomes.

Reference

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4.1 IPY Education Activities

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In June 2010, 114 teachers from twenty countries joined together in Norway at the Oslo IPY Science Conference. The teachers came to take part in a ground-breaking event – a conference that merged science and education in a unique way. After a two-day workshop in which they attended background science talks and participated in hands-on polar science activities, the teachers spent the rest of the week attending conference talks and poster sessions, giving oral or poster presentations, and interacting with scientists and other educators (Box 1).

The Oslo PolarTEACHERS Workshop was just one of the culminations of several years of hard work by a dedicated group of scientists, education and communication professionals, and the IPY International Programme Office (IPO) staff. By the end of the official observing period of IPY 2007–2008, there was an active and engaged community of approximately 750 teachers, media officers, journalists, early career scientists and IPY national contacts from more than 30 countries. Many of these people served as hubs for further propagation across their own local and national networks.

IPY 2007–2008 also stimulated the active engagement of thousands of teachers, students and other citizens around the world in learning and communicating about the polar environment. This was accomplished through a combination of international collaboration, the cultivation of a global community of enthusiastic professional scientists and educators, and the creative use of free and low-cost technologies.

This chapter reviews a few of the many successful international education, outreach and communication (EOC) initiatives that took place during IPY 2007–2008. (Box 2)

Box 1 Quotes from participants in the two-day workshop

I have also been able to build collaborative relationships with other professional educators, but more importantly with scientists actively working in the field. There is now an open window to incorporate hands on interactive real-time science into my classroom, thank you.

J. Worssam, U.S.A.

Through the many posters and sessions, I have seen an incredible array of classroom applications relating to polar science – many of which I plan to have in place within the context of my own class for September start-up. I have a new-found network of educators and scientists with whom to collaborate as we inspire youth to become both curious and actively engaged with our planet.'

J. Phillips, Canada

I also feel that the opportunity to experience a really professional, international, science conference has given me an insight as to what I should be helping students learn to do to make it in the critical world of the scientific research.

H. Demynchuk, U.S.A.

In our country, among the scientific community there is no harmony regarding global warming. The way education and outreach were recognized here, as equally important as science itself is not the case in our country!

D. Garasic, Croatia

Historical background and overview

When preparing the IPY program, the ICSU-WMO IPY 2007–2008 Joint Committee (JC) realised the value of public involvement in promoting an understanding of polar research and its importance. They also recognised that, to attract world-wide attention and to engage and develop a new generation of polar researchers, they needed to develop international cooperation and partnerships within the science community, as well as to engage all other sectors of society from school children to policy-makers.

The JC insisted that major IPY-endorsed projects have EOC embedded in their programs in order to give IPY a high profile and impact. All science projects were required to include the following:

- An education and outreach component
- The involvement of non-traditional polar nations
- A plan to leave a positive legacy
- An investment in the next generation of polar scientists.

EOC Subcommittee

At its first meeting in March 2005 in Paris, the JC (JC-1, *Chapter 1.5*) identified a need for an international EOC group to coordinate the communication of IPY science to the public on a global basis, as well as to give polar science greater visibility. They decided that this group should form an advisory Subcommittee to the JC that would serve as a focal point for developing international education, outreach and communication programs. By working with specialized education, outreach and communication institutions and centres dedicated to polar science, the Subcommittee would 'identify, stimulate, and coordinate international opportunities to promote, support, and add value to IPY'.

The broad role of the EOC Subcommittee was to:

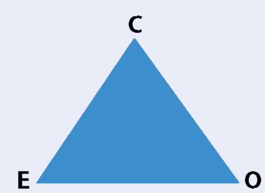
- coordinate international communication activities;
- formulate a broadly accepted framework for IPY 2007–2008 education, outreach and communication; and
- serve as a forum for the exchange of ideas to assist National Committees in their communication efforts.

The JC felt that the EOC framework should be adaptable to the business, language and cultural needs of each participant, while retaining a clear direction, identity and 'voice' for IPY 2007–2008. Leading educators and professional communicators were invited to serve on this critical subcommittee.

The EOC Subcommittee was also asked to work with the endorsed IPY projects to improve their EOC plans and to support their efforts to secure national or international funding to carry out their designated activities. In addition, the Subcommittee reviewed and approved endorsement of 59 proposed IPY 2007–2008 EOC projects that were independent of any specific IPY science projects.

The initial Subcommittee was composed of ten members from nine countries who were specialists in media relations, education (formal and informal), science-art partnerships and science communications. The committee membership was later expanded to 14, representing 11 countries. The committee was revamped again in late 2009 to prepare for the 2010 Oslo IPY Science Conference. At that time, there were 14 official members and 10 *ex officio* members from 14 countries (Box 3).

Several early workshops, most notably in Washington, D.C. (2004) and Boulder, Colorado (2005), contributed many good ideas to the early planning for IPY



Box 2
What is EOC?

Although not separate or mutually exclusive, the following working definitions were adopted for IPY:

Education refers to efforts designed to promote the development of programs, infrastructure and resources needed to improve knowledge of polar-focused science, technology and humanities. These formal educational efforts mainly occur within classrooms. Formal education is not necessarily limited to curricula, but ranges from teacher training to classroom science experiments.

Outreach, sometimes called informal education, is used here to refer to experiences for learning outside of formal classroom environments through stimulating media, exhibits and community-based programs. Examples of outreach activities include field trips, museums exhibits, zoo exhibits, lecture series, computer software, school competitions, quizzes and essay writing.

Communication is used here to identify interactions with the print, television, radio, internet and film media.

EOC activities. The first face-to-face meeting was held in January 2006 in Paris and was attended by the two Co-Chairs, (Jennifer Pink and Margarete Pauls), David Carlson, and two committee members (Lars Kullerud and Jean De Pomereu). While several other members of the Subcommittee managed *ad hoc* face-to-face meetings at venues of opportunity, most of the committee work during this period was conducted via conference calls.

During the period from January to June 2006, the Subcommittee reviewed 52 EOC proposals resulting from the 31 January 2006 deadline on Call for Proposals. A web design team was formed as part of the Subcommittee to develop a concept, a set of functions and prototype for the IPY website. Another team assumed responsibility of developing consistent media briefing materials for each IPY project. During this period, Rhian Salmon was hired as the Education Outreach Coordinator, a position that would work closely with the Subcommittee (*Chapter 1.6*).

The first meeting of the full EOC Subcommittee took place from 19-21 October 2006 in Bremerhaven, Germany with funding from the Alfred Wegner Institute and the British Antarctic Survey. During the meeting the group produced an Action Plan based on the goals and audiences envisioned in the IPY Framework document.

In this plan, they identified key messages and audiences, as well as organizations and communities who could become potential partners and collaborators. Based on the key question, *'Why are the polar regions and polar research important to all people on Earth'*, the Subcommittee suggested specific internationally-coordinated actions they felt could maximize the public impact of IPY.

After the Bremerhaven meeting, most of the Subcommittee work was carried out by conference calls and email contact, although there were also several face-to-face meetings that were sponsored by various IPY partners. These included meetings in Cambridge, U.K. (June 2007), Strasbourg, France (March 2008, Fig. 4.1-1), Geneva, Switzerland (February 2009) and Edmonton, Alberta, Canada (October 2009). These meetings were critical for maintaining enthusiasm among the Subcommittee members and for allowing extended time for reflection, review and planning for future events. Selected members of the working groups also

Box 3 EOC Subcommittee

2007

Margarete Pauls, *Germany* (Co-Chair)
Sandra Zicus, *Australia* (Co-Chair)
Linda Capper, *U.K.*
Jean de Pomereu, *France*
Edith Fanta, *Brazil*
Rachel Hazell, *U.K.*
Louise Huffman, *U.S.A.*
Tove Kolset, *Norway*
Lars Kullerud, *Norway*
Linda Mackey, *Canada*
Mark McCaffrey, *U.S.A.*
Birgit Kleist Pedersen, *Greenland*
Rodion Sulyandziga, *Russia*
Patricia Virtue, *Australia*

2009

Official members:
Margarete Pauls, *Germany*
Sandra Zicus, *Australia*
Miriam Almeida, *Brazil*
Rashmi Asthana, *India*
Jean de Pomereu, *France/Belgium*
Geoff Green, *Canada*
Rachel Hazell, *U.K.*
Louise Huffman, *U.S.A.*
Tove Kolset, *Norway*
Lars Kullerud, *Norway*
René Malherbe, *Netherlands*
Liz Murphy, *Australia*
Khadijah Abdul Rahman Sinclair, *Malaysia*
Elena Sparrow, *U.S.A.*

Ex officio:
Kristen Ulstein, *Norway*
Jenny Baeseman, *Norway* (APECS)
Dave Carlson, *U.K.* (IPY IPO)
Karen Edwards, *Canada* (Canadian IPY Secretariat)
Jacinta Legg, *France* (ICSU)
Jerónimo López-Martínez, *Spain* (JC)
Nicola Munro, *U.K.* (IPY IPO)
Mélianie Raymond, *Denmark* (APECS EOC)
Rhian Salmon, *U.K.* (IPY IPO)
Carine Van Maele, *Switzerland* (WMO)

attended one or more of these meetings to provide additional input and perspectives.

The EOC Action Plan

The EOC Action Plan called for a high-impact global campaign to increase polar awareness, targeted at key sectors with key messages. This plan served as the basis for EOC decisions and work throughout IPY 2007–2008, although it was modified and refined as time progressed and needs changed.

From the varied IPY themes and goals the Subcommittee eventually distilled one simple key message: *Polar Science - Global Impact.* This was further subdivided into three main priorities:

- Shrinking snow and ice: Rapid change in the polar regions
- Global linkages: Interactions between the poles and the rest of the Earth
- Neighbours in the North: Living in the Arctic, and human impacts in the polar regions

For target audiences, the Subcommittee decided to focus primarily on information providers who would transmit their learning on to others. These included:

- teachers in both formal and non-formal settings
- media officers and science journalists
- undergraduates, graduate students and early career polar scientists
- IPY researchers

The original Action Plan also included decision makers, tourists, Northern communities, artists and writers as important audiences. Due to limited resources (both financial and human), the Subcommittee had to set priorities and chose not to target these groups directly.

EOC Working Groups

The Bremerhaven meeting (2006) also provided the initial focus and energy for the establishment of effective working groups who would be responsible for carrying out specific tasks. The working groups included members of the EOC Subcommittee, as well as other interested educators, communicators, artists and researchers of the Association of Polar Early Career Scientists (APECS, *Chapter 4.3*). Working group membership was fluid and the groups continually evolved and changed throughout the IPY period in order to adapt to the varying needs and priorities. The groups kept in contact with each other through a combination of regular conference calls, Skype calls, emails and Google Groups.

Formal Education

This group included professionals from primary through tertiary education who would be responsible for the selection and promotion of educational

Fig. 4.1-1. Participants at the Strasbourg meeting.
(Photo: Karen Edwards)

resources, support for teachers, and development of opportunities for students. By the time of the launch of IPY, the formal education working group had split into two groups: one focusing on the needs and interests of teachers and the other on tertiary education. A natural evolution occurred as the tertiary education group eventually blended with the APECS group, which was focused on undergraduate students through up to five years post-doctorate.

Informal Education

Educators working in venues such as museums and science centres would focus on networking, sharing resources and promoting IPY events and activities internationally. This group eventually merged with the formal education group because members realised that most IPY activities could be incorporated into both formal and informal education settings and would serve the needs and interests of both.

Media

A group of media professionals would be responsible for information dissemination and networking, to develop an internationally coordinated media campaign, providing a framework for each IPY participant organization and building local campaigns, issuing press releases, and facilitating media visits to the poles.

Community Building

This working group was established to provide a direct link between the EOC Subcommittee and community-building activities occurring within the existing networks focused on youth, early career scientists, artists and Arctic communities. Working group members were charged with developing ideas that would benefit and support all of these networks, such as methods for communication and sharing of information. The group was intended to include representatives of each community as well as members of the EOC Subcommittee.

Products, Services, Events

This was a flexible working group to help create the IPY website, develop methods for branding of IPY products and work with different IPY partners depending on the nature of the product being developed.

Endorsed IPY EOC projects

The solicitation, evaluation and endorsement process for international EOC projects that were not connected to a specific science project was the same as that of the science projects. This process has been described in more detail in *Chapters 1.4* and *1.5*. Fifty-nine EOC projects were eventually endorsed by the JC (see IPY planning charts in *Appendix 6*), however, only about 30% of these were successful in getting funding. Some of the successful projects were aimed mainly at the scientific, research and government communities, while others focused more on the general public or students (primary school through university). A few of the success stories are briefly described.

International Polar Year Publications Database (IPYPD) (no. 51)

http://nes.biblioline.com/scripts/login.dll

The goal of the IPYPD was to identify and describe all publications that resulted from, or were about IPY 2007–2008, as well as the three previous IPYs. The IPYPD is part of the IPY Data and Information Service (IPYDIS) and was a joint project of the Arctic Science and Technology Information System (ASTIS), the Cold Regions Bibliography Project (CRBP), the Scott Polar Research Institute (SPRI) Library, the Discovery and Access of Historic Literature of the IPYs (DAHLI) project and NISC Export Services (NES). As of May 2010, the database contained 3992 records (*Chapter 4.2*).

The University of the Arctic: Providing Higher Education and Outreach Programs for the International Polar Year (no. 189)

www.uarctic.org

The University of the Arctic (UArctic) brings together more than 100 universities, colleges, indigenous organizations and other institutions in eight countries in the Circumpolar North for collaborative higher education and research.

The UArctic IPY education and outreach program included a cluster of different projects that reflected a continuum of learning as a lifelong process. The projects targeted different audiences and used different approaches: 1) primary and secondary students through teacher professional development workshops on science teaching and research; 2) undergraduate students via education and research experience; 3) graduate students through integrated education and research; 4) early career scientists and university faculty via professional development; and 5) communities and the general public through formal and informal continuing education as well as adult education.

The UArctic IPY cluster included 21 different approved projects, of which 13 were eventually funded. The successful projects included:

- Arctic Lake Ice and Snow Observatory Network (ArLISON): Scientists, Schoolteachers and Students Pursuing Polar Science Together *(no. 006)*
- New Generation Polar Research (NGPR) Symposium *(no. 019)*
- Adapting SENCER to the Arctic: Improving Polar Science Education as a Legacy *(no. 036)*
- Indigenous Knowledge Systems, Science and K-12 Education *(no. 163)*
- International Sea Ice Summer School 2007 *(no. 164)*
- Monitoring Seasons Through Global Learning Communities Project also called 'Seasons & Biomes' *(no. 278)*
- UArctic Higher Education and Outreach Programs *(no. 404)*
- Resilience and Adaptation of Social-Ecological Systems: Global-Local Interactions in a Rapidly Changing North *(no. 509)*
- EarthSLOT: An Earth Science, Logistics and Outreach Terrainbase for the IPY *(no. 685)*
- Ice e-Mysteries: Global Student Polar e-books *(no. 1253)*
- Nutshimiu Atusseun: Opening Paradigms for Education in the North (OPEN) *(no. 1254)*
- International Polar Year IV: Context and Promise course *(no. 1260)*
- Muskwa-Kechika Artist Camp Collection: Online Repository and Virtual Gallery *(no. 1261)*

Arctic Energy Summit (no. 299)

www.arcticenergysummit.org

The Arctic Energy Summit was an initiative of the Arctic Council's Sustainable Development Working Group. A technology conference in Anchorage, Alaska in October 2007 brought together more than 300 researchers, academics, government leaders, industry representatives and residents from 14 countries for presentations of technical papers on significant Arctic energy research, panel discussions and keynote addresses on major policy areas of concern or interest. The group also developed a bilingual (English and Russian) website with information about energy in the Arctic, and produced a series of newsletters.

Tectonic Map of the Earth's Polar Regions (TEMPORE) (no. 315)

The Commission for the Geological Map of the World (CGMW) TEMPORE project produced a new tectonic map of the Antarctic at 1:10,000,000 scale. The project was international in scope, involving earth scientists from many countries, although most of the preparatory activities were coordinated at VNIIOkeangeologia in Russia.

Global Snowflake Network (GSN) (no. 336)

http://education.gsfc.nasa.gov/how/snowflake.html

The Global Snowflake Network (GSN) is a NASA-funded program that involved the general public in collecting and 'classifying' falling snowflakes. The data are being compiled into a global database, along with satellite images, to help climatologists and others who study climate-related phenomena gain a better understanding of winter meteorology as they track various snowstorms around the globe. The project also provided thermochrons to classrooms to help students carry out winter research. The website includes videos and written information about the snowflake protocol, as well as downloadable data sheets.

Interpolar Transnational Art Science Constellation (I-TASC) (no. 417)

The Interpolar Transnational Art Science Constellation (I-TASC) is a non-profit organization supported by the South African National Antarctic Program (www.sanap.ac.za) and the South African National Energy Research Institute (www.saneri.org.za). It is a decentralized network of individuals and organisations working collaboratively in the fields of art, engineering, science and technology on interdisciplinary development and tactical deployment of renewable energy, waste recycling systems, sustainable architecture and open-format, open-source media.

I-TASC enabled collaborative research projects between artists, scientists and engineers in Antarctica during the 2008-2009 austral summer through the development of the Catabatic Experimental Platform for Antarctic Culture (ICEPAC). ICEPAC is a solar- and wind-powered mobile research station that can house a six-person crew for up to 30 days.

The science centre Espace Mendes-France and Ellipse organised a series of events around the I-TASC project during IPY. An I-TASC terminal was installed in the Espace Mendes-France to provide real-time information on the activities of the I-TASC project and display environmental data collected by ICEPAC. The ICEPAC projects were also part of the second Bienal del Fin del Mundo, an art exhibition focused on weather, climate and Antarctica that took place from January through May 2009 in Rio de Janeiro and Sao Paulo in Brazil, the South African Antarctic base SANAE IV, and Ushuaia and El Calafate in Argentina.

Polar Books Collection (no. 440)

www.unep.org/Publications/PolarBooks/

The Polar Books Collection is a contribution from the United Nations Environment Programme (UNEP) to the legacy of IPY. It features a collection of books about the Arctic and Antarctica that reflect IPY themes and are internationally endorsed by IPY. The collection includes books on polar science, accounts of polar research and perspectives on the future of the Arctic and Antarctic, as well as storybooks and classroom activities, collections of tales and essays, and photographs of polar wildlife, landscapes and people.

The website, which is managed through UNEP/GRID-Arendal, also has an online Polar Resource Library with education and outreach materials, as well as materials developed by the IPO and the IPY EOC Subcommittee and working groups. Materials in this library include full books, book excerpts, posters, photos, artwork, teachers' guides and activity sheets. Contents of this virtual library can be used freely for education and outreach purposes.

Antarctic Environmental Legacy (no. 454)

The Antarctic Southern Ocean Coalition (ASOC) conducted a project with the goal of enhancing the environmental legacy of IPY by:

- raising the environmental awareness of scientists and visitors,
- assessing the environmental impacts of IPY and highlighting the needs for proper environmental management, and
- examining the global public's perception of Antarctica and its wilderness values.

International Action on Global Warming (IGLO) (no. 455)

IGLO was officially launched on 1 March 2007 to coincide with the start of IPY. IGLO is designed to raise worldwide public awareness about global warming and the particular ways that the polar regions influence Earth's climate, environments, ecosystems and human society. IGLO's communication and education materials include a toolkit that science centres and museums can use for their own IPY activities.

Ice Stories: Dispatches from Polar Scientists (no. 457)

http://icestories.exploratorium.edu/dispatches/index.php

In a project funded by the U.S. National Science Foundation, the Exploratorium in San Francisco gave polar scientists cameras and blogging tools, and asked them to document their field work. The Ice Stories project began in Antarctica in November 2007 with a series of webcasts from the South Pole and the McMurdo and Palmer research stations. It continued for two years, shifting to the Arctic in the northern summer of 2008 and back to the Antarctic for the 2008-2009 austral summer. The blog format allowed visitors to ask questions of the scientists and to post comments. The use of RSS feeds, Twitter, and video and audio presentations from the field added to the interactive nature of the project. Over a two-year period, more than 250 dispatches, 100 videos and 1,000 photos were posted on the ice stories website. Exploratorium staff also travelled to the Arctic and the Antarctic, where they spoke with scientists during live webcasts. The webcasts are also archived on the website.

Cape Farewell, Science, Education & Culture of Climate Change (no. 460)

www.capefarewell.com/home.html

This project brought artists, scientists and communicators together to stimulate the production of art founded in scientific research.

IPY Media initiatives

A focus on journalists and international media networks was a key way of getting information about IPY research into the public arena. By the March 2007 launch of IPY, a media group containing Press

Officers from most of the IPY-participating countries and agencies had been formed. A core media working group met approximately every fortnight by telephone conference and circulated notes to the larger group via a Google Group. The media working group identified their key objectives as:

- deliver high profile, highly engaging and effective media campaigns to promote IPY at local, national, regional and international levels;
- create, through media relations, unprecedented levels of awareness and engagement in polar science; and
- deliver the above with minimum financial resources.

The ICSU and WMO press offices agreed to take responsibility for IPY 'corporate' communications and media relations, such as sending out announcements for the international launch and other official IPY news. It was envisioned that the press offices for national polar operators, funding agencies and major IPY-endorsed projects would also develop their own media campaigns. In addition, the media working group requested that all participating press offices send copies of any press releases or media advisories to the IPO to be posted on the IPY website.

In the lead-up to the launch, working group discussions focused on the implementation of strategy surrounding the launch, development of press packs, availability of images and video footage, lists of journalists, and the broader dissemination of information.

The launch event catalyzed more than 20 national events that attracted the attention of local, national and international media. Media monitoring done by the British Antarctic Survey showed an average of 200-300 media mentions monthly over the first year after the launch, peaking around Polar Days and news releases about research.

Christine Rüth, Margarete Pauls and Beatrice Dernbach also did a study of press releases and media reports from the period January 2007 to January 2008 in four countries that they felt represented a broad picture – Australia, Canada, Germany and India. They calculated that a total of 147 press releases had been issued by the IPY IPO, the Alfred Wegner Institute, and Canadian, Indian and Australian institutions during that time. Using the search terms 'International Polar Year', 'Antarctica' and 'Arctic', they found more than 2900 English-language media reports for the same period. The vast majority of the media reports (more than 2200) were found in more than one country. The top news stories were about the shrinking Arctic summer sea ice, the IPY launch, the Intergovernmental Panel on Climate Change report, Al Gore winning the Nobel Peace Prize, Belgium's new Antarctic research station and the Census of Antarctic Marine Life.

In February 2009, the last official observing month of the IPY 2007–2008, daily news items about different IPY research were posted on the website, leading to another peak in media stories.

In addition to press releases, the international IPY EOC community used several other channels to spread the word about the research and its importance. For example, in July 2007, more than 100 journalists attended special IPY sessions at the World Conference of Science Journalists held in Melbourne, Australia. The IPY website was also an important conduit for media information and is discussed in more detail below.

International EOC Initiatives

IPY Website

The IPY.org main website was developed using an open-source Content Management System. The website went live at the beginning of January 2007 with six main categories: News, Calendar, Weblogs (IPY stories), Links and Resources, Projects, and General Information. The site was designed so that any member of the IPY community could promote their project within the appropriate category. It allowed access to the same material by discipline, or by specific area of interest of user (Educators, Participants and Press).

Over the IPY period, the website was a major channel of distribution for information about the various IPY science and social science projects, as well as general information about the polar regions.

In June 2009, the site was moved to the Arctic Portal for archiving purposes.

Launch of IPY 2007–2008

The Official Opening Ceremony to launch IPY 2007–2008 took place on 1 March 2007 at the Palais de la Découverte, a science museum in central Paris, France. The event was hosted by ICSU and the WMO.

In the lead-up to the launch, EOC Subcommittee and working group members had fortnightly telephone discussions focused on media plans, the organization of resources, developing a launch activity for teachers around the world, building up a network of educators and connecting to already-existing educational programs and networks.

One of the main themes of IPY 2007–2008 was the study of Earth's changing ice and snow, and its impact on the planet and people's lives. The education working group chose this theme for the launch and developed an information flyer with two simple ice activities that could be done at schools, science centres, or homes. The flyer, *Breaking the Ice*, was translated into German, Italian, Spanish, French, Japanese, Portuguese and Inuktitut by EOC volunteers. It was posted on the IPY website with links to other related activities and resources. The IPY web team used a Google Earth map and a free on-line geobrowser tool called Tagzania (www.tagzania.com) to create a page where people around the world could launch a 'virtual balloon' showing their location and make comments about the ice experiments or their interest in IPY. On the day of the launch, 251 'balloons' were launched from 31 different countries. The international launch also stimulated many national and regional events, a sample of which are described below.

Argentina

Argentina held a launch event in Ushuaia, Tierra del Fuego, at midnight on 28 February. Local artists provided dance and music performances; power point and video presentations showed images from both poles, and children in Ushuaia presented their demands for an environmentally sound future.

China

China produced a live television program of the international launch in Paris, as well as featuring the launch on China Weather Television and beginning the development of a six-part series about the Arctic. They also prepared an introduction about IPY and a short video that was posted on the China Meteorological Public Service Website.

Portugal

A one-day event took place at the Pavilion of Knowledge in Lisbon to open a new science exhibition, *The polar regions and their importance on Earth,* highlighting the importance of the polar regions and the science already conducted by Portuguese polar scientists (Fig. 4.1-2). The event included a gathering of the Portuguese polar scientific community, science colleagues from the U.S.A. and the U.K., the Portuguese Minister of Science and Higher Education, and the President of the Foundation for Science and Technology of Portugal, and resulted in extensive national media coverage. The day's events also included the launch of a book on Portugal's strategy for IPY, and a presentation of the national education and outreach program, LATITUDE60!

Sweden

A two-day event in northernmost Sweden celebrated the start of IPY with the launch of a 1500-cubic meter IPY weather balloon. The balloon was a symbol of nations working together and was launched by Embassy representatives from the United States, Australia, the Netherlands and Germany. The program included scientific presentations, IPY stamp presentations and a cultural event at the Ice Hotel and Old Homestead restaurant. On the second day there was a tour of the Swedish Institute for Space Physics and the Swedish Space Centre at Esrange.

International Polar Days 2007–2008

The EOC community facilitated a successful sequence of eight quarterly Polar Days that engaged individuals and institutional partners from 50 countries in easy and fun polar activities. The Polar Days evolved out of the successful launch EOC activity. Over a two-year period, Polar Days involved nearly all of the funded IPY Projects in one or more of the quarterly focus areas (sea ice, ice sheets, changing earth, land and life, people, above the poles, and oceans). The Days were planned around the solstices and equinoxes to mark the changing solar cycle, which is most extreme in the polar regions.

For each of the Days, the working groups produced both a two-page science summary and a flyer with a simple educational activity related to the theme. The summaries and activity flyers were translated into many languages by volunteers before being posted on the IPY website and distributed to the EOC community through a variety of Google Groups. The media

Fig. 4.1-2. Students in Portugal took part in ice experiments at the Lisbon Pavilion of Knowledge for the launch of IPY.
(Photo: José Xavier)

working group prepared and distributed press releases. The tradition of a virtual 'balloon launch' on Tagzania was also continued for each of the Polar Days.

Many of the Days also included 'live events' using various web-casting, video-conferencing and radio formats (Fig. 4.1-3). During the events, students and others could speak directly with IPY researchers and ask questions. Many of these events have been archived and can be accessed on the IPY website. The IPO and the EOC Subcommittee worked with different researchers, partners and collaborators on each of the Polar Days. The Days evolved into Polar Weeks due to their popularity and to incorporate multiple events and time zones. Highlights of each of the Polar Days are briefly described below.

Sea Ice – 21 September 2007

In September 2007, the National Snow and Ice Data Center announced that the Arctic summer minimum sea ice extent was at an all-time low. At this time, the German vessel *Polarstern* was in the Arctic on a sea ice research trip that was part of the DAMOCLES project. At the same time, the Australian-led SIPEX project was studying sea ice in the Antarctic. SIPEX was part of the larger IPY-endorsed ASPeCt sea ice research project. SIPEX involved 45 scientists from eight different countries, as well as two teachers who developed educational activities and real-time opportunities for classrooms and media around the world. The sea ice Polar Day included a live radio interview with sea ice scientists on board the Australian research vessel *Aurora Australis*. Activities related to sea ice, posters, information about IPY sea ice projects, contact information for sea ice scientists and relevant links all were included on the IPY website. The activity flyer was posted in 18 different languages.

Ice Sheets – 13 December 2007

The December Polar Day focused on ice sheets to take advantage of several IPY Antarctic traverses that were taking place during the austral summer. Daily web updates were available from the Norwegian-U.S. Scientific Traverse of Antarctica, the U.S. International Trans-Antarctic Scientific Expedition and the Swedish-Japanese Traverse. The educational activity flyer was translated into 19 different languages.

Changing Earth, Past and Present – 12 March 2007

Changing Earth was based on IPY research into how the polar regions have changed and continue to change over a variety of timescales. This Polar Day included four live events that participants could join via internet, telephone, or at participating science centres. The World Ocean Observatory (Liz Murphy) and ARCUS PolarTREC each hosted a web conference with participating IPY scientists. The IGLO project (described earlier in the chapter under 'Endorsed EOC Projects') teamed up with NASA to present two videoconferences. Science centres in Mexico, China, Australia, U.S.A., Wales, Portugal, Egypt and South Africa participated in the live videoconferences, and the material was also presented as a webcast for others to see at a time convenient to them. The activity flyer was produced in 19 languages.

Land and Life – 18 June 2008

IPY research related to polar landscapes and polar terrestrial ecosystems formed the basis for the fourth Polar Day. Three live events were held, two by the World Ocean Observatory and one by ARCUS PolarTREC, involving IPY scientists who were studying Arctic tundra dynamics, permafrost, Arctic coastal erosion and Arctic bird health. The World Ocean Observatory events have been archived and can be viewed at www.thew2o.net/events/polaryear/events.htm. The activity flyer was available in 17 languages.

People – 24 September 2008

The Canadian IPY Secretariat and the Canadian Federal Program Office took the lead in developing educational activities for the People Polar Day. The Day focused on people's perceptions of the polar regions. CKLB Radio, an independent Aboriginal community radio station based in Yellowknife, NWT, Canada, hosted a 24-hour internet radio stream. Researchers and community leaders gave presentations on the dynamics of life at the poles and answered questions from students around the world about polar environments, animals and local customs. There were three opportunities for students to speak live with researchers and the radio show announcers. These opportunities were timed to correspond with school hours for Europe, the Americas and Australasia.

Students and teachers were also encouraged to share their ideas globally in a Classroom Discussion and Gallery on a specially designed web forum http://polarday.tiged.org (the site was designed by TakingITGlobal). Twenty-one classes registered on the website, posted artwork or PowerPoint presentations and discussed what life was like in the Arctic regions. All of these activities are archived at www.ipy.org. The activity flyer was translated into 36 languages.

Above the Poles – 4 December 2008

This Polar Day explored the regions above the snow in Antarctica and the Arctic. Two live events were held in conjunction with the International Year of Astronomy. The European event, called *Looking Up: Weather, Atmosphere, and Space* was hosted by Liz Murphy of Global Media. In this web-conference, participants interacted with a meteorologist in Antarctica, atmospheric scientists in the U.K., astronomers, and school classes gathered at the Scott Polar Research Institute in the U.K.

ARCUS PolarTREC hosted an event timed for the Americas: *Looking Out and In; Observations of, and from, the Polar Regions.* Participants explored polar astronomy and learned about ways to use publicly available satellite images to learn about the polar regions. There was also a live connection to South Pole Station in Antarctica. The activity flyer was available in 13 languages.

Polar Oceans and Marine Life – 17 to 26 March 2009

Polar Oceans Day was so popular that events such as live webcasts, public talks, radio programs, school visits and videoconferences were scheduled over an entire week. The different events involved participants in at least nine different countries including, Brazil, Canada, France, Germany, Malaysia, Mexico, Scotland (U.K.) and U.S.A.

Fig. 4.1-3. Connecting to a live event at the TUNZA UNEP conference in Stavanger, Norway during the June 2008 'Land and Life' Polar Day.
(Photo: José Xavier)

Two international events were specifically developed for teachers, members of the public and school classes around the world. The University of Alberta held a videoconference with live webcast and text chat, while ARCUS PolarTREC hosted a webinar.

Among other events of note was a public Polar Evening at the Musée (Cite des Sciences) at La Villette, for French and German speakers. This included an international panel of polar experts, a live connection to researchers in the Arctic and simultaneous translation into French and German.

In Manitoba, Canada, university postgraduate students simulated Arctic research activities with 150 middle school and high school students. In Malaysia, the University Information and Technology MARA (UiTM) organised and hosted a forum aimed at helping more than 100 university students from the UiTM Association of Environmental Law and the Science Association understand the effects of climate change on the polar regions and how it is affecting other parts of the world. This program included a live connection to Portuguese IPY researcher and APECS member José Xavier on a ship in the Antarctic.

CKLB radio in Canada also featured a special Polar Oceans Day broadcast from and to communities across the Arctic, which they streamed to the internet.

International Polar Weeks 2009-2010

In the second half of 2009, as the official IPY was winding down, the IPY EOC community decided to hold two Polar Weeks as a lead-up to the 2010 IPY Oslo Science Conference. Instead of continuing with narrow subject-based topics, the group decided to focus on the importance of the polar regions to the world as a whole under the theme *'What happens at the poles affects us all'*.

5-9 October 2009

Educational activities for the October 2009 Polar Week were chosen from the developing Polar Resource Book (see the next section) in order to get feedback to help with the book development and refinement process. The concepts behind the chosen activities were reinforced through two related live events:

CKLB Radio hosted a discussion on the future of the Arctic. Students had the opportunity to participate in an in-class role play exercise (taken from the Polar Resource Book) to begin to understand the complexity of the situation in the Arctic and the conflicts of interest between economic, environmental and social issues. The students took on the roles of politicians, nongovernmental organizations, researchers and economists. These perspectives were represented by CKLB studio panellists. The students first did the activity in their classrooms and then presented the outcomes of their discussions either live on the radio or via pre-recorded statements and questions. Students from Canada, Brazil, Portugal, Norway and Greenland posed questions to the panelists. A podcast of the radio show is in the CKLB audio library (www.ncsnwt.com/audiolibrary.html, under 'Ends of the Earth', October 12, Show 38, Segments 1 & 2).

ARCUS PolarTREC hosted a real-time event called Live from IPY: Polar Bear Response to Sea Ice Loss. The speakers were part of a team who were studying polar bear response to sea ice loss in the Arctic Ocean, and included PolarTREC teacher, Cristina Galvan and University of Wyoming scientists led by Dr Merav Ben-David.

15-19 March 2010

The March 2010 Polar Week focused on local community-building activities and tried to stimulate global enthusiasm for the Oslo IPY Science Conference. It took place during the period of the State of the Arctic Conference and included live web streaming of that event. The web streaming allowed real-time video and text chat so that participants could make comments and ask questions. More activities from the Polar Resource Book were also trialled.

APECS encouraged universities and organizations around the world to host a public talk as part of an International Lecture Series.

Polar Resource Book

Overview

Polar Science and Global Climate: An International Resource for Education and Outreach (Kaiser, 2010) is an interdisciplinary educational resource book that was developed by Association of Polar Early Career Scientists (APECS) members and IPY EOC Subcommittee members, and coordinated by the IPY International Programme Office (IPO). The impetus for the book arose from the success of the IPY Youth Steering Committee initiatives and the International Polar Day activities, as well as requests from teachers for additional resources. The success of Polar Days was largely due to the collaborative efforts of researchers and educators, so the book was planned to continue and strengthen this partnership.

The book is intended for both researchers and educators, and contains background information about IPY and polar research, activities that can be done in a classroom or other educational setting, descriptions of IPY education and outreach projects, examples of best practices stimulated by IPY, tips for scientists presenting their research to non-technical audiences, and an indigenous perspective on the importance of IPY for polar research in the Circumpolar North (Box 4).

The development process

In 2008, the possibility of doing a book was first brought to the attention of APECS by the Belgium Youth Steering Committee. After discussion with both APECS members and the EOC subcommittee, it was decided to make it a joint project of the two groups. The groups worked together to develop a vision document and made their first contacts to potential publishers.

A global call was then circulated through IPY Google Groups and other IPY networks to both researchers and educators, asking for potential contributions to the book. Criteria for submissions included:

- Submissions should be either practical learning activities for the classroom or other learning environment (for *Chapter 1*), or outreach activities and programs inspired by IPY (for *Chapter 3*)
- Preference would be given to polar science education or outreach activities that were associated with IPY events and/or programs
- Submissions should be related to one of IPY research themes
- Activities could be classroom, laboratory, or field-based
- Activities needed to be scientifically accurate, flexible and easy to use in different learning environments.

After 142 submissions of intent were received from more than 18 countries, a Polar Resource Book (PRB) Development Working Group was formed to review

Box 4 The Polar Resource Book at a Glance

Prelude – Gives a history of previous International Polar Years and provides important background information about IPY 2007–2008 research and its relevance.

Chapter 1: Teaching Polar Science – Contains 29 reviewed and tested interdisciplinary education activities, produced from more than 80 international contributions. The activities can be used by both educators working in formal and informal settings, and scientists who want to share their science with the public through programs and presentations at schools or other education venues. The material within the chapter is organized in sub-sections by polar themes. Each of the six themes has an introduction to key concepts and important research questions and from three to six related activities. Supporting material such as extended activities, student handouts, web links and visuals are included on a supplementary CD-ROM.

Chapter 2: Tips and Tricks for Science Presentations – Brings together the expertise of scores of experienced educators and communicators from around the world. It is intended for researchers who would like to improve their effectiveness at communicating their research to the public.

Chapter 3: Outreach Initiatives – Highlights 76 different education and outreach projects that arose from IPY programs around the world. The projects include student outreach programs, university-level initiatives and public programs.

Chapter 4: IPY and Local Competence Building – Presents an indigenous perspective from the Circumpolar North about the important role of traditional knowledge in climate change research in the Arctic.

the submissions. This group included members from Brazil, Malaysia, Germany, Australia, U.K., U.S.A., the Netherlands, New Zealand and Canada. The group communicated using web based mediums such as Skype, Dropbox, Google Groups and YouSendIt to work across time zones and continents.

In a three-week process, the working group reviewed the submissions based on the agreed-upon criteria and requested full submissions from selected contributors. The contributors were given a month to send in a completed activity or project description, including photographs, diagrams and other supporting materials. For *Chapter 1*, the working group also identified topic gaps in submissions and sent out a repeat call for education activities addressing specific topics.

The development process for *Chapter 1* also involved continual feedback and revision. These submissions were sent to the chapter editor, who added any needed background information and/or extra illustrations. Each of the activities was tested and instructions clarified where needed. After the submissions were edited to a standard format, the revised activities were sent back to the authors for approval. After author approval, the edited activities were sent to one or more science reviewers, who checked the accuracy of the concepts and the background information, and at least one education reviewer, who reviewed them for educational suitability and ease of use. The activities were revised again based on reviewers' comments and returned to the authors for final approval. A final chapter edit was done by the general editor to ensure standardization with the rest of the book.

Publication and distribution

Early in 2009, the IPO staff began searching for a publisher and funding to develop and print the book. In May 2009, Pearson Custom Publishing (Edexcel) in the U.K. agreed to publish the book. Funding for production was received from the IPO, the Canadian Federal IPY Program Office, the Canadian IPY Secretariat and U.S.A. National Academies.

A Polar Resource Book (PRB) team consisting of a general editor, a coordinator, two associate editors and a graphic designer was formed to create the final product. Bettina Kaiser (Germany) was hired as general editor for the book in June 2009. She worked together with the IPO staff and the PRB Development Working Group to expand the overall concept and create a prototype to use when seeking funding for printing. Bettina also oversaw all aspects of the production, including liaising with the publisher, working on copyright issues, layout and design, final content and scheduling.

In September 2009, Sandra Zicus (Australia) and Becky Allen (U.K.) were hired to serve as editors for *Chapters 1 and 3* respectively. Karen Edwards (Canada) took on the role of overall project coordinator and Sandy Riel (Canada) was hired as graphic designer.

Design and layout decisions were partly based on the prototype, and then discussed at an EOC Subcommittee meeting in Edmonton, Alberta in October 2009. The final layout was created by Sandy Riel and Bettina Kaiser, based on the feedback from the Subcommittee members. Copyright was carefully negotiated to protect the rights of the contributors and allow users to reproduce sections for educational purposes, while still meeting the needs of the publisher.

Funding for the printing was a collaborative process with 15 different partners. Four thousand copies of the book were distributed free of charge to participants at the Oslo IPY Science Conference in Norway.

The book has also been approved for addition to the IPY Polar Books Collection (www.unep.org/Publications/PolarBooks/) and may be purchased through the Pearson website.

Oslo IPY Science Conference

The success of IPY 2007–2008 derived in part from a close connection between science and EOC. Since EOC had been a priority from the beginning of IPY, it was clear that the Oslo IPY Science Conference in June 2010 was an ideal place to showcase some of the collaborative accomplishments. The EOC Subcommittee worked closely with the conference organizers to build a strong program that included EOC presentations and posters, an international teacher workshop, a hands-on community polar event on the wharf, and a polar film festival.

EOC Theme 6: Polar Science Education, Outreach and Communication

Theme Committee: *Louise Huffman, Chair (U.S.A.), Rene Malherbe (Netherlands), Jean de Pomereau (Belgium), Melianie Raymond (Denmark), Elena Sparrow (U.S.A.), Sandra Zicus (Australia)*

Session Conveners: *Margarete Pauls (Germany), Elena Sparrow (U.S.A.), Lucette Barber (Canada), Jean de Pomereau (Belgium), Stephanie Pfirman (U.S.A.),*

Co-Conveners: *Miriam Almeida (Brazil), Karl Thorstein Hetland (Norway), Rene Malherbe (Netherlands), Nathalie Morata (France), Allen Pope (U.S.A.), Walter Staveloz (U.S.A.), Kristin Timm (U.S.A.), Bego Vendrell (Spain), Janet Warburton (U.S.A.), Peter West (U.S.A.), Jose Xavier (Portugal)*

The IPY EOC Subcommittee successfully lobbied the organisers of the Oslo IPY Science Conference to include an EOC theme for both oral presentations and posters in the conference that was equivalent and parallel to the other conference themes (*Chapter 5.6*).

More than 250 abstracts were submitted to this theme from people in more than 20 countries. The presentations and posters highlighted books, festivals, events, expeditions, classroom materials, films and other IPY science communication activities. The theme was divided into five related strands:

- *Learning together: The impacts of integrating education, outreach and research in IPY* – Tangible and identifiable impacts, from national, political, organizational, community and individual perspectives.
- *Incorporating polar science into formal education settings* – Examples and successes at primary, secondary and tertiary levels.
- *Adventures in the Field: Impacts of field programs for students, teachers, artists, writers and others* – Descriptions and assessments of research immersion and adventure learning programs.
- *Global learning: The impact of the media* – Analysis and lessons from IPY impact in print, film, television, radio and web-based technologies.
- *Informal initiatives and polar inspiration: IPY in museums, art, films, books and drama* – Documenting and assessing exhibitions, events (including polar days/weeks), performances and polar books, from the viewpoint of IPY and of partner organizations.

Selection of abstracts and organization of the sessions within the EOC theme were handled by IPY EOC members and others involved in the work of IPY. Abstracts of all of the accepted oral and poster presentations have been archived on the IPY Oslo Science Conference website (http://ipy-osc.no/).

PolarTEACHERS Workshop

Coordinator: *Karl Torstein Hetland, Norwegian Centre for Science Education*

Committee: *Miriam Almeida (Brazil), Karen Edwards (Canada), Louise Huffman (U.S.A.), Khadijah Abdul-Raman Sinclair (Malaysia), Sandra Vanhove (Belgium) Sandra Zicus (Australia)*

The teacher conference was developed to give teachers and other educators an opportunity to share their experiences and to interact with researchers and other educators from around the world. Thanks to generous funding from the Research Council of Norway, 114 teachers received a reduced conference registration fee, full accommodations, plus a special two-day workshop. Participants could also elect to receive two graduate-level credits from the University of Alaska-Fairbanks.

To apply for the workshop, teachers had to either submit an abstract for an oral presentation or poster to Theme 6, or write a statement indicating how they would use what they learned in an educational setting. The committee received 276 applications and selected participants based on the quality of their applications and geographical diversity, with priority given to educators who taught in primary or secondary schools.

The introductory part of the teacher conference took place at the University of Oslo on 6-7 June 2010. Prominent IPY researchers introduced the teachers to different aspects of polar science through a series of lectures. Alternating with the lectures were breakout groups where the teachers had the opportunity to try a variety of polar science experiments and activities discussed in the lectures (Figs. 4.1-4 and 4.1-5). Activities were taken from the newly published *Polar Science and Global Climate: An International Resource for Education and Outreach.* After the two-day workshop, the teachers attended science conference presentations and poster sessions, and had numerous gatherings for networking, sharing and international social interactions.

Fig. 4.1-4. (left) Teachers participating in albedo experiment at PolarTEACHERS workshop in Oslo, Norway.

Fig. 4.1-5. (right) Teachers participating in paleoenvironmental change experiment at PolarTEACHERS workshop in Oslo, Norway.

Together, scientists and teachers are a force to be reckoned with – powerful and determined. I have never met so many researchers and scientists who are so willing to provide information and make connections with classroom teachers and our students. From paleontology to reindeer husbandry, I believe the connections forged at this IPY Science Conference in Oslo will be strengthening my own and my students understanding of and concern for the polar regions and climate change. Excited, affirmed, connected – this is how I leave the IPY conference.

Caitlin Munroe
Teacher, Manaugh Elementary School,
Cortez, Colorado U.S.A.

PolarCINEMA

Coordinator: *Mare Pit (Germany)*

Committee: *Rene Malherbe (Netherlands), Khadijah Abdul-Rahman Sinclair (Malaysia), Jennifer Bellman (Canada), Amy Lauren Lovecraft (U.S.A.), Erlend Hermansen (Norway)*

The PolarCINEMA was a mixture of screenings, debates and open discussions with film makers, educators, scientists and the public on the success and impact of the medium in increasing our understanding of the Arctic and Antarctic and their relation to the rest of the globe. It showcased and celebrated productions that were inspired by the polar regions and that helped increase public awareness of their importance

The PolarCINEMA Committee received 90 applications from 17 different countries. Almost two-thirds of the films were documentaries that were developed from IPY science projects. Sixty-nine productions, ranging from podcasts to feature films, were finally selected by the committee for official screening in Oslo. Half of them (38) made it to the large screen where 24 productions were shown in full and 12 in fragments used to illustrate a certain lecture or combined with a personal presentation. The PolarCINEMA was run by two committee members: one in the role of host and one as a practical assistant and organizer.

The films were well attended and provided unique viewpoints of science in extreme environments. The audience for the morning sessions varied between small to moderate (15-30), but was therefore very enthusiastic and participated in some great discussions. With the passing of the day the PolarCINEMA grew fuller and fuller. The late morning screenings attracted around 60-100 people and the afternoon sessions around 50-75. The full final screenings in the afternoon usual got at least 100 people in the cinema seats up to a full house of about 200. In almost every case, about 80% of the audience stayed at the sessions and screenings from beginning till end. All in all, the PolarCINEMA might have drawn the most varied and integrated public besides the plenary sessions.

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4.2 Publishing and Archiving IPY

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Introduction

Igor Krupnik

All earlier IPY/IGY initiatives produced abundant publications in various formats (including their own publication series) and created voluminous archival records. It comes as no surprise that all of the science bodies that steered the earlier IPY/IGY programs—International Polar Commission in IPY-1, Commission for the Polar Year in IPY-2 and CSAGI in IGY 1957-1958—addressed the issues of the publishing and archiving of their materials. The IPY-2 and IGY governing committees initiated and produced major reference bibliographies of their respective ventures (Laursen, 1951; Beynon, 1971); they also launched monumental publication series, with substantial supervision by specially appointed publication committees (*Chapter 1.1*). Also, IPY-1 and IPY-2 established centralized depositories for all generated publications and archival records (in St. Petersburg and Copenhagen, respectively). IGY organizers, instead, opted for the system of several coordinated World Data Centers (WDC), in addition to several archives that amassed substantial documentary collections (*Chapter 1.1*).

Therefore, it was clear to the organizers of IPY 2007–2008 that their venture should also develop a consistent publication and archival policy. Unlike in the previous IPY/IGYs, in IPY 2007–2008 those tasks were split and have been addressed by different actors and at different time. The plans to create a working system to track IPY 2007–2008 publications were discussed as early as December 2004 and by summer 2005 a proposal to establish the IPY Publications Database (IPYPD) became an endorsed IPY project no. 51 (see below). Roughly at the same time several proposals were submitted for the 'IPY Publication series' and for series of popular books about IPY and the polar regions. Some of them also became official IPY projects (nos. 79, 244, 440), and the first 'IPY books' were available in print as early as in 2007-2009.[1] All these activities took place with a blessing, but no direct intervention, from the ICSU-WMO Joint Committee.

The process of 'archiving IPY' had a very different trajectory. It was literally initiated by the Joint Committee at the JC-6 meeting in Quebec City, Canada in October 2007, six months after the official start of IPY. By that time, voluminous records related to the origination and early planning for IPY in 2002-2005 had been already accumulated at the IPO, on the IPY official website http://classic.ipy.org/index.php, at some national IPY committees' offices, and in personal collections of some of the early IPY champions. No centralized policy, however, existed with regard to the storing, cataloguing and preserving (archiving) these materials. The JC was justly poised to take the lead in that field.

The plans for 'archival policy' for IPY 2007–2008 were discussed at the JC-6 meeting on two occasions: in conjunction with the IPY data policy (agenda item 9.6) and the forthcoming 'IPY publications' (agenda item 7.6 - *Chapter 1.5, Appendix 3*). During the meeting the idea was floated about establishing a *centralized* archival depository for all IPY-related documentary materials under the auspices of the IPO and JC (as had happened in IPY-1 and IPY-2). The name of the venerable Scott Polar Research Institute (SPRI) in Cambridge, U.K. was mentioned as prospective partner for such a critical task.

Fortuitously, another IPY-related development following the JC-6 meeting helped advance these initial plans. In November 2007, an international conference, 'Making Science Global: Reconsidering the Social and Intellectual Implications of the International Polar and Geophysical Years' (Fleming, 2007) was held at the Smithsonian Institution in Washington, DC. Several IPY scientists (Cornelia Lüdecke, Sverker Sörlin, Fae Korsmo) and other scholars prominent in IPY/IGY historical research were speakers at the conference (Launius et al., 2010); Igor Krupnik attended the meeting as a JC observer. The message from many papers and statements at the conference was clear. Science historians were expecting IPY organizers to secure the documentation pertaining to the origination and implementation of IPY 2007–2008, including the internal paperwork and JC session minutes, in the same way as it was done for the previous IPY/IGYs. Full access to this organized documentation would be viewed by science historians as an indicator of the obvious success of IPY 2007–2008 in the interests of researchers, students, science writers and the planners of the next IPY.

Following the 'Making Science Global' conference, communication intensified among several interested parties in JC, IPO and the Scott Polar Research Institute. In February 2008, Igor Krupnik forwarded a special memo, 'IPY 2007–2008 Legacy and Documentation Records' addressed to the JC Co-Chairs and other critical players on the Joint Committee (Krupnik, 2008). The memo outlined critical steps needed to establish the IPY documentation and archival depository; to produce a concise historical narrative on the origination and early planning for IPY (*Chapters 1.2, 1.3, 1.4*); and to launch a special IPY publication series, with several volumes dedicated to the early history of IPY 2007–2008 and the proceedings of the JC and other important meetings. The latter proposal followed in the footsteps of the *Annals of the International Geophysical Year 1957-1958* (particularly its volumes I, IIa, IIa, IX, X, etc.); it was discussed at the JC-7 meeting in St. Petersburg, Russia in July 2008, but did not materialize during the JC tenure, except partly in certain chapters of this Report (*1.5, 1.6, 1.7*).

The second section of this Chapter explores at length how the efforts to 'archive' IPY 2007–2008 were eventually implemented following the initial impulse from JC. At the time of writing, both the IPY Publication Database (IPYPD) and the emerging centralized archival collection at the Scott Polar Research Institute remain 'work in progress,' work which will continue for many years following the official close of IPY in June 2010. Both ventures will require special attention from any future body to succeed the ICSU-WMO Joint Committee and, obviously, some additional funding during the post-IPY era.

Tracking IPY 2007–2008 Publications

Ross Goodwin[2]

The data gathered during the IPY 2007–2008 observational period will be used to conduct research and publish results for many years to come. It is difficult to estimate at this time how many publications will result from this IPY. The most recent similar research program was the 1957-1958 International Geophysical Year (IGY). The final IGY bibliography (Beynon, 1970) contained almost 6000 references and was completed twelve years after the end of the IGY. The earlier bibliography prepared for IPY-2 contained about 1000 entries and took almost 18 years to accomplish after the official end of IPY-2 (Laursen, 1951). It is probably reasonable to assume that IPY 2007–2008 will eventually result in about 20,000 publications.

A bibliographic database of the publications that result from IPY 2007–2008 will be of great benefit to polar researchers, managers of polar programs, and to those working in polar education, outreach and communication activities. Many IPY publications will be listed in discipline-oriented databases, but such databases are often unknown to researchers in other disciplines. Social science publications and grey literature are often not listed in any of the discipline-oriented databases. Without an IPY bibliographic database, obtaining an inter-disciplinary view of IPY outcomes, or a view of results by geographic region, would require searching many databases and would naturally miss many publications. An IPY bibliographic database will be of even greater value if its design ensures that IPY publications are also included in all appropriate ongoing polar bibliographic databases, so that IPY publications remain accessible in the distant future when users no longer think to search the IPY database itself.

Building the IPY Publications Database

In December 2004 the Arctic Science and Technology Information System (ASTIS) at the Arctic Institute of North America, University of Calgary, submitted an Expression of Intent (no. 462) to the IPY Joint Committee for a Canadian IPY Publications Database. Upon learning that the Joint Committee would endorse only multi-country projects, ASTIS began looking for partners for an international IPY publications database. By spring 2005, four organizations had agreed to work together to create a combined IPY Publications Database (IPYPD). Such a combined database would attempt to identify and describe all publications resulting from, or about, IPY 2007–2008 and the three previous IPY/IGYs. The Cold Regions Bibliography Project (CRBP) at the American Geological Institute in Alexandria, VA (U.S.A.) maintains the Bibliography on Cold Regions Science and Technology and the Antarctic Bibliography. The Scott Polar Research Institute (SPRI) Library at the University of Cambridge in U.K. produces the SPRILIB databases and assists the CRBP with the Antarctic Bibliography. The Arctic Science and Technology Information System (ASTIS) at the Arctic Institute of North America, University of Calgary, produces Canadas national northern database and other specialized databases. National Information Services Corporation (NISC) in Andhra Pradesh, India was, at that time, combining these databases and others to produce the Arctic and Antarctic Regions (AAR) database describing more than one million publications related to polar regions.

These four organizations established an informal consortium and prepared a joint proposal to create the IPYPD as part of the IPY Data and Information Service (IPYDIS), which was led by the U.S. National Snow and Ice Data Center (NSIDC) at the University of Colorado. The IPY Joint Committee endorsed the proposal (IPY no. 51)[3] in August 2005. During 2006 the members of the consortium began creating new records for IPY publications, as well as identifying existing IPY/IGY publication records in their databases. Beginning in September 2006, programmers at NISC's related company, NISC Export Services Pvt. Ltd. (NES), used ideas and feedback from the other members of the consortium to create the IPYPD database and website. In early 2007 the Discovery and Access of Historic Literature of the IPYs (DAHLI) project at the U.S. National Snow and Ice Data Center joined the IPYPD consortium to provide coverage of publications it collected from the first three IPY/IGYs (IPY 1882-1883, IPY 1932-1933 and IGY 1957-1958).

The IPYPD was made available online at www.nisc.com/ipy on 1 March, 2007, the first day of IPY 2007–2008.

NISC has since been purchased by EBSCO Publishing, which began producing AAR in-house in summer 2009. Because EBSCO does not have the ability to accept records from the many polar libraries and databases that were contributing records to AAR, no records from those sources, or from the IPYPD, have been added to AAR since that time. NES was not purchased by EBSCO, and continues to make the IPYPD available.

Aspects of the Database Design

As described in more detail elsewhere (Goodwin et al., 2007; Goodwin et al., 2010a; 2010b), the IPYPD makes use of the existing system for indexing polar literature. Depending on their subject and geographic scope, IPY 2007–2008 publications are reported to ASTIS, CRBP or the SPRI Library. Simplified somewhat, the rule that researchers are requested to follow is that publications about northern Canada are reported to ASTIS, about the Antarctic and about non-living things to CRBP, and about biological and human research to SPRI. The number of indexing organizations was deliberately limited to three in order to avoid making this reporting rule more complicated. The three organizations prepare records in their usual ways for use in their existing databases, but tag IPY records so that they can be identified and sent to NES quarterly for inclusion in the IPYPD.

Publications from the first three IPY/IGYs are identified, indexed and digitized by the DAHLI project, as that project's resources allow. In addition, the other three indexing organizations are identifying publications from previous IPYs that are already in their databases, and doing some new indexing of publications from previous IPY/IGYs. Records from the first three IPY/IGYs are tagged for inclusion in the IPYPD in the same manner as records for IPY 2007–2008 publications. The IPYPD Basic search page allows users to restrict their searches to any of the four IPY/IGYs by using the "IPY" menu, as shown in Fig. 4.2-1.

Using NES's BiblioLine software and the existing infrastructure for the AAR database allowed the IPYPD consortium to create its database at a very low cost. Because of NES's automatic duplicate detection there is no problem if more than one of the indexing organizations indexes the same IPY publication. NES's COMPARE technology identifies duplicate bibliographic records, no matter in which format or publication type they arrive. This technology merges similar records provided by more than one contributor into a composite record that binds index terms and abstracts from all the merged records. The BiblioLine software provides Basic, Advanced and Expert search modes, with many powerful search and display capabilities.

As shown in Fig. 4.2-2, the records in the IPYPD include citations, detailed subject and geographic indexing terms, and, in most cases, abstracts. Most IPY 2007–2008 publications are available online, and the records describing these publications contain DOIs or URLs linking to PDF files of the publications. Some of the publications from the previous IPY/IGYs were also already available online, and others are being digitized by the DAHLI project.

The IPYPD considers IPY publications prepared for education, outreach and communication (EOC) purposes to be equal in importance to research publications, and provides a method to search for just EOC publications using the "Audience" menu, as shown in Fig. 4.2-1. Most EOC publications that describe IPY 2007–2008 activities are being created by IPY projects, but it was decided to also include in the IPYPD those publications about IPY 2007–2008 activities that are being created by non-IPY organizations such as general-interest magazines.

The "Reporting Your Publications" page of the IPYPD website tells researchers how to determine to which organization an IPY publication should be reported, describes what information researchers should send when reporting a publication, and defines what is meant by IPY publications.

One of the objectives of the IPYPD project was to index a publication once and then to use the resulting bibliographic record in many ways. In addition to

Fig. 4.2-1. IPYPD Basic search page

Fig. 4.2-2. Sample IPYPD record

being available in the IPYPD itself, all IPYPD records created up to June 2009 are available in the AAR database, which is widely used by polar research organizations. (Records created since that date may also eventually appear in AAR, if EBSCO is successful in developing the capability to accept external records.) The IPY records prepared by each of the indexing organizations also appear in those organizations' main databases: the Bibliography on Cold Regions Science and Technology, the Antarctic Bibliography, the SPRILIB database and the ASTIS database. Some of the indexing organizations also make their IPY records available in other databases, as described in a later section. Users of all of these databases will learn of IPY publications that are relevant to their needs, even if they are unaware of the IPYPD or of the IPY/IGYs. The IPYPD will leave a legacy of records in many databases describing IPY publications, thus ensuring that the results of the IPY/IGYs are always available and accessible.

Current Database Contents

As of June, 2010 the IPYPD listed 3992 publications from all *four* IPY/IGYs: IPY-1, IPY-2, IGY and IPY 2007–2008. The distribution of publications by IPY is shown in Table 4.2-1. Because some publications are about more than one IPY, the sum of the numbers of publications is greater than 3992.[4] Note that at present there are more IGY publications in the database than IPY 2007–2008 publications. Also note that the database lists only 27% of the approximately 1000 known IPY-2 publications, and only 33% of the approximately 6000 known IGY publications.

International Polar Year **1882-1883**	444
International Polar Year **1932-1933**	272
International Geophysical Year **1957-1958**	1960
International Polar Year **2007–2008**	1439

Table 4.2-1. Distribution of publications by IPY (June 2010)

The distribution of IPYPD publications by year of publication is shown in Fig. 4.2-3. Publications

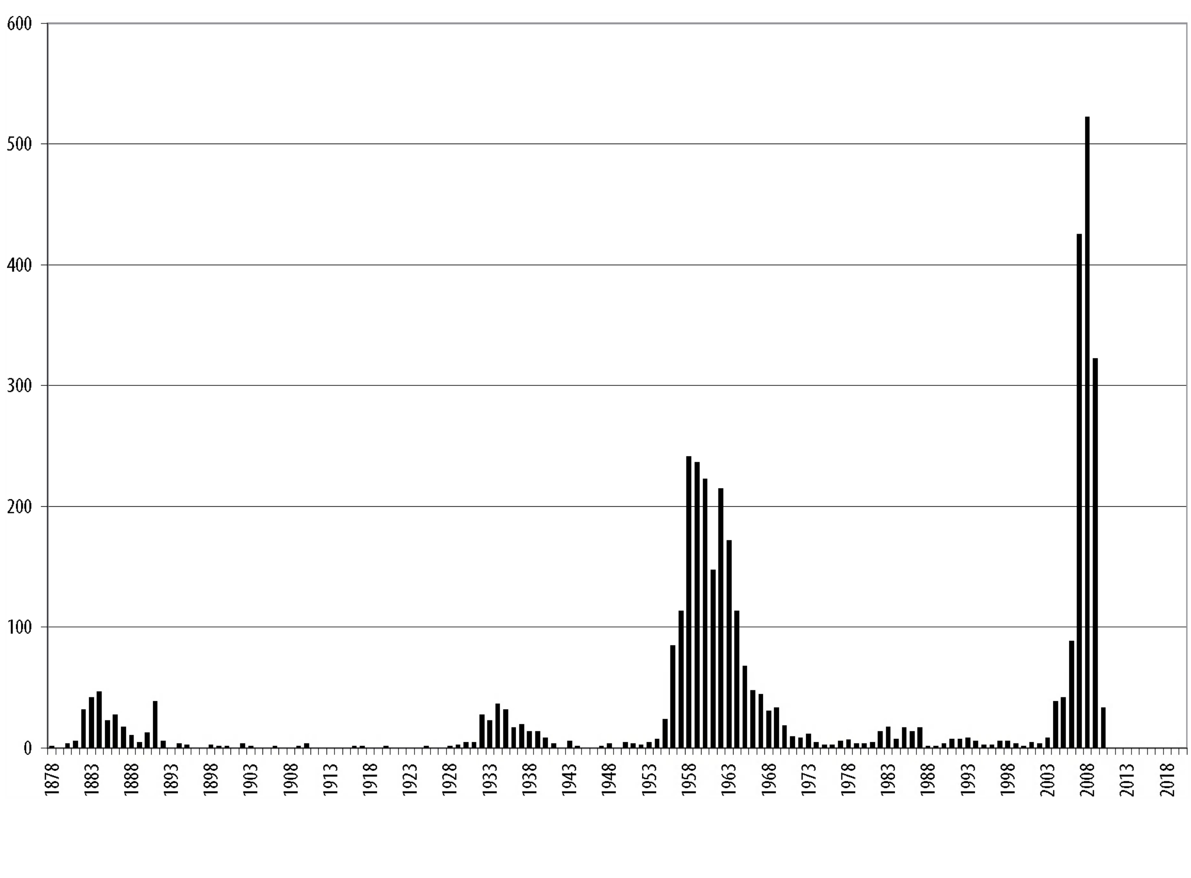

Fig. 4.2-3. IPYPD publications by publication year, 3992 publications, June 2010

produced to commemorate the 100th anniversary of the first IPY caused the small peak in publications during the 1980's. If the IPYPD consortium is successful in identifying and creating records for almost all IPY-2 and IGY publications the area under the IPY-2 peak will eventually be four times as large as it is now, and under the IGY peak will eventually be three times as large. If the estimate that IPY 2007–2008 will result in 20,000 publications is correct, and if the IPYPD consortium is successful in creating records for almost all of them, the area under the IPY 2007–2008 publications peak will eventually be fourteen times as large as it is now.

IGY publications peaked in 1958, the second observational year of IGY. It will be interesting to see in which year IPY 2007–2008 publications peak. The IPYPD consortium's guess is that it will be in 2010 or 2011.

The distribution of IPYPD publications by audience is shown in Table 4.2-2. Education, outreach and communication (EOC) publications are those that were written for members of the public or for K-12 students. Surprisingly, IPY-1 has the highest proportion of EOC publications. This is because of the many accounts of IPY-1 expeditions, especially the disastrous Greely expedition to Ellesmere Island, which have been written for the general reader (including those produced many decades after IPY-1). IPY 2007–2008 EOC publications have almost ceased, while the production of research publications has yet to peak.

Table 4.2-2. Distribution of publications by audience

Audience	IPY-1	IPY-2	IGY	IPY 2007–2008
Researchers	261	199	1519	915
Public or K-12	251	98	537	591

IPY Bibliographic Activities by Individual IPYPD Participants

Arctic Science and Technology Information System (ASTIS). ASTIS has created the bilingual Canadian IPY Publications Database at www.aina.ucalgary.ca/ipy, which describes publications from Canadian IPY projects, as well as publications from foreign IPY projects that have studied northern Canada. As of June 2010, this database described 1926 publications, of which 1447 are from IPY 2007–2008 and the remainder are from the previous IPY/IGYs. ASTIS has examined the available bibliographies for the first three IPY/IGYs and has created records for all Canadian IPY publications that were found.

Because of their importance to Canadian IPY researchers and funding agencies, ASTIS has chosen to include published conference abstracts in the Canadian IPY Publications Database, even though conference abstracts are not included in the IPYPD. Of the 1447 IPY 2007–2008 publications in the Canadian database, 703 are conference abstracts. Another unique feature of the Canadian database is that in addition to tagging records by IPY, ASTIS is also tagging them by individual research project. A large menu lists about 140 projects, subprojects and expeditions, including 113 IPY 2007–2008 projects.

ASTIS uses Canadian IPY records in its many subset databases, all of which are accessible from http://arctic.ucalgary.ca/index.php?page=astis_database. These databases include the Yukon Biodiversity Database, the Inuvialuit Settlement Region Database, the Nunavut Database, the Nunavik Bibliography, the Circumpolar Health Bibliographic Database, the Kluane Lake Research Station Bibliography, etc.

Cold Regions Bibliography Project (CRBP). The CRBP, produced by the American Geological Institute (AGI), is attempting to document IPY publications in the areas of physical science and engineering for the Arctic region and in all sciences for Antarctica. An online list of current IPY publications is maintained at www.coldregions.org/ipypubs.htm. These publication references are derived from either the Bibliography on Cold Regions Science and Technology or the Antarctic Bibliography. The list is arranged alphabetically by author surname and currently contains 346 references. The list is now long enough that the CRBP is considering revising the format to allow easier access. Initially, these references were primarily to publications about planning for IPY. Scientific research results have been appearing slowly and, with the exception of lists provided by a few national programs, large numbers of publications have not yet been reported to the CRBP.

In addition to IPY 2007–2008 publications, the CRBP has begun to identify and tag references from the first three IPY/IGYs that are contained within the Bibliography on Cold Regions Science and Technology or the Antarctic Bibliography. As of June 2010, the CRBP had tagged 1224 references across all of the

IPY/IGYs. The 16-volume *Arctic Bibliography* (1954-1975), a collection of more than 114,000 references spanning the time periods of the first three IPY/IGYs, has also been examined by the CRBP. 341 records have been identified as of June 2010. To identify and tag these records, the CRBP has depended primarily on data contained within the references themselves. Comparison of the CRBP databases to bibliographies for the various IPYs has not been attempted to any great degree and is not currently funded.

Scott Polar Research Institute (SPRI) Library. The broad remit of SPRI's collecting policy has meant a considerable overlap with that of the other IPYPD participants. SPRI is primarily responsible for recording publications from IPY projects concerned with the biological, medical, social and human sciences, and about IPY in general (e.g., publications about the organization and operation of the entire IPY; education, outreach and communication publications that discuss the entire IPY rather than focusing on a particular subject or geographic region). Until the closure in 2010 of the International Programme Office of IPY, also based in Cambridge, material was regularly deposited by the IPO. The IPO has been instrumental in ensuring the collection of much ephemeral material which might otherwise go unrecorded.

SPRI's IPY records also appear in the SPRILIB databases at www.spri.cam.ac.uk/resources/sprilib and monographic records in the University of Cambridge Newton catalogue at www.lib.cam.ac.uk/newton. They are also included in the Institute's serial publication, *Polar and Glaciological Abstracts*, issued three times per year. As an adjunct to the project, library staff have also begun to tag published material from the first three IPY/IGYs.

Discovery and Access of Historic Literature of the IPYs (DAHLI). NOAA's Climate Data Modernization Program (CDMP) is funding DAHLI's digitization activities. Materials in the Carnegie Institute's holdings have been digitized, in addition to materials at the University of Colorado library. Current digitization efforts include seven boxes of materials from the University Corporation for Atmospheric Research (UCAR). DAHLI's records related to IPY-1, IPY-2, and IGY (several hundred total) currently appear on the DAHLI Bibliography page at http://nsidc.org/dahli/bibliography.html.

Two Problems

Identifying IPY 2007–2008 Publications. The *International Polar Year 2007–2008 Data Policy* (IPY Joint Committee, 2008) and the *IPY 2007–2008 Scholarly Publications Policy* (IPY International Programme Office, 2008) both require that all IPY 2007–2008 publications be reported to the IPYPD. When the consortium members began work on the IPYPD in 2005 they naively assumed that this requirement would make it relatively easy to identify IPY publications. Discussions with IPY researchers have revealed that while researchers are very attentive to the wishes of the organizations that fund their research, they are much less attentive to the wishes of the IPY Joint Committee, which provides no funding. The IPYPD consortium suspects that many IPY researchers will never even visit the international IPY website, let alone read the policy documents that are available there.

This should not be a problem in the case of researchers funded by national programs established specifically to provide funding for IPY projects, since such programs will hopefully enforce the reporting requirements on the projects that they have funded. For example, the Government of Canada Program for IPY has its own *Canadian IPY 2007–2008 Data Policy* (Canadian IPY Data Management Subcommittee, 2009) which requires the reporting of publications to the IPYPD via ASTIS. The Program forwards to ASTIS the lists of references from researchers' annual reports. It appears that, because of this, the IPYPD coverage of Canadian IPY publications is currently more complete than its coverage of IPY publications from other countries. Of the 1439 IPY 2007–2008 publications in the IPYPD as of June 2010, 52% are Canadian IPY publications indexed by ASTIS.

The members of the IPYPD consortium have taken several actions to encourage the reporting of IPY publications. Frequent announcements are made in polar research e-mail lists, newsletters and multidisciplinary journals, and on the consortium members' websites. Conference presentations about the IPYPD are made as frequently as time and money allow. In April 2010 the Director of the IPY International Programme Office made a personal appeal to all of the IPY 2007–2008

Google Groups to report their publications, and asked national IPY contacts to forward his e-mail to all of the IPY researchers in their countries.

In spite of these measures, the number of IPY publications being reported is much lower than expected, and is certainly significantly lower than the number being published. This is a serious problem, since without better reporting it will be impossible to measure the overall publication 'footprint' of IPY 2007–2008, the productivity of individual international IPY projects (that often produce publications in different languages), as well as the rate of publication 'success' in different IPY research fields and areas. Solving this reporting problem is an important challenge facing any successor body to the ICSU-WMO Joint Committee, IPY historians and polar librarians.

Finding, or Creating, Records for Publications from the First Three IPY/IGYs. Fundraising for the IPYPD has, for the most part, been quite successful. The Acknowledgments section below lists the seven organizations that have provided funding so far. However, it has been difficult to find funding for the database's coverage of the first three IPY/IGYs.

The DAHLI project was unsuccessful in obtaining funding from the National Science Foundation for the majority of its planned work. As mentioned previously, both the CRBP and SPRI are attempting to identify records that are already in their databases for publications from the first three IPY/IGYs. Ideally, this would involve searching their databases for every publication listed in the bibliographies of both the IPY-2 and the IGY. No funding is currently available for this task.

Conclusion

The IPYPD consortium has been very successful in creating a cost-effective system for indexing and abstracting IPY publications, and for making the resulting records and their linked PDF files readily available in the IPYPD and other polar databases. However, as discussed in the previous section, it is not at all clear that the IPYPD consortium will succeed at the more important task of identifying, and creating records for, all of the publications of all four IPY/IGYs.

With the exception of Canada, the reporting rate for IPY 2007–2008 publications is poor. The IPYPD consortium requires more help from the IPY Joint Committee (or its successor body), national IPY committees and programs (many of them defunct as of summer 2010), funding agencies, and IPY researchers to identify the large numbers of IPY 2007–2008 publications that have so far gone unreported. Work on the IPYPD will continue for at least the next ten years, and this help from the broad IPY community must continue as well.

The IPYPD presents a unique opportunity to create a common publication database for all four IPY/IGYs. At present the IPYPD contains only about 27% of the publications in the IPY-2 bibliography and 33% of the publications in the IGY bibliography. Many of the missing publications are in the CRBP and SPRI databases, but there is no funding available to find them. Once all of the existing records have been found, additional funding will be required to create new records for the remaining publications in the IPY-2 and IGY bibliographies.

The members of the IPYPD consortium call on the IPY community for help in completing the task of preparing a comprehensive bibliographic database of all four IPY/IGYs.

Archiving IPY 2007–2008

Heather Lane

As stated earlier (see *Introduction*), concrete plans to archive the IPY 2007–2008 documentary records were first discussed at the JC-6 meeting in October 2007. As the Committee discussed future IPY publication and archiving, Igor Krupnik, one of the JC members, suggested that the Scott Polar Research Institute (SPRI) at the University of Cambridge, which has the oldest and one of the largest polar libraries in the world, should be approached as the prospective 'primary depository' for the IPY documentary records and copies of all IPY-generated publications. The suggestion was favourably received by most of the JC members and in November 2007 an informal enquiry was made as to whether the SPRI Library was willing to serve as the main repository of all IPY 2007–2008 publications.

A positive response from SPRI Librarian, Heather Lane, regarding the Library's position and potential resources to serve as the IPY publication depository, enabled Igor Krupnik to advance the issue with David

Carlson, the Director of the IPY Office in Cambridge, and the two IPY sponsors, ICSU and WMO. This also led to the discussions about the possibility of SPRI eventually receiving IPY 2007–2008 documentary archives and, in particular, the planning documents from 2002-2004 onwards. Lane had already held preliminary discussions on this subject with Rhian Salmon in the IPO, prompted by the IPY Joint Committee meeting in October 2007, and had agreed, subject to approval by the JC, to be the central international source for any material arising from IPY and gathered by the IPO itself. In fact, the first batch of published materials and ephemeral or grey literature had already been received from the IPO and added to the IPY Publications Database (IPYPD) under the terms of the agreement set up in early 2005. Krupnik then instigated the actions to be taken by the Joint Committee and the IPY Program Office to ensure that deposit of archival material at SPRI should become the official policy and to prompt its wider advertisement to members of the JC.

The first *ad hoc* meeting for those interested in the question of the IPY planning archive was held in Cambridge in March 2008, involving Karen Edwards from the Canadian IPY Secretariat, University of Alberta, Heather Lane and Paul Berkman from SPRI, Rhian Salmon and David Carlson from the IPO and Igor Krupnik from the JC. These participants formed what was informally known as the IPY 'archiving committee.' Further meetings were held that year, culminating in a Memorandum of Understanding between SPRI and the IPO to establish an archive for planning and implementation documentation/materials relating to International Polar Year 2007–2008. This set out the preliminary structure for the catalogue of the IPY 2007–2008 archival collection (Box 1) and identified the potential depositors.

The intention of this agreement was to facilitate secure and professional archiving of these materials and make them openly available for future researchers.

SPRI and the IPO undertook to cooperate in applying for funding to support those activities relating to the establishment of a managed archive and to help facilitate the future maintenance of the IPY archive. Igor Krupnik was recognised as the official represen-

Box 1 Preliminary Structure (Catalogue) of the IPY 2007–2008 Archival Collection: 1997-2012

(Prepared by Igor Krupnik, March 2008)

1. Early planning for IPY 2007–2008: 1997-2002
2. ICSU files related to IPY planning *(to be requested as copies)*
3. WMO files related to IPY planning *(to be requested as copies)*
4. Other agencies active in IPY planning and implementation: SCAR, ATCM, AOSB, IASC, Arctic Council, IASSA *(requests should be sent for copies of materials related to IPY)*
5. ICSU Planning Group, 2003-2004
6. IPY Joint Committee: Minutes of the JC meetings, correspondence, 'Open Forums'
7. International Programme Office (IPO) and IPY Subcommittees on Data, Observations, and Education: *to be transferred from the IPO*
8. Personal files: JC members, PG members
9. Individual project files
10. IPY-associated public events (IPY opening, press conferences, other public venues):
11. IPY memorabilia
12. IPY-related websites and other electronic formats
13. National IPY Committees: *only if offered to the main collection, no special solicitation.*
14. IPY 'mid-term' conference: St. Petersburg, 2008
15. IPY science conference: Oslo, 2010
16. IPY 2007–2008 Public Policy Conference: Canada, 2012
17. Other major science meetings associated with IPY, 2002-2012: *if offered to the main collection.*
18. National Committee Meeting documentation, national planning, funding related information, etc. *(to be requested as copies)*

tative/liaison for the IPY 2007–2008 Joint Committee with regard to IPY archiving. The agreement specifically excluded the research and scholarly data of IPY, which is being managed separately by various national and international data repositories. The IPY Data and Information Service (IPY-DIS) has responsibility for overseeing the management of these data.

The archive proposed under the agreement was to focus on documentation and materials relating to the planning and implementation of the IPY 2007–2008 programme, assembled both from sources within the international organisation of International Polar Year (including the IPY Planning Group, 2003-2004; the IPY Joint Committee and its subcommittees, and the International Programme Office) and, where practicable, from the national bodies involved in IPY.

A pilot study was proposed to identify the issues arising from archiving of a sample set of readily available material. It was envisaged that the pilot study would run for six months and be undertaken at SPRI under the supervision of Heather Lane with advice, assessment and comment from the *ad hoc* IPY Archiving Advisory Group, comprising Heather Lane (chair) and Paul Berkman (SPRI), Rhian Salmon and Cynan Ellis-Evans (IPY IPO) and Igor Krupnik (IPY JC). However, the required funding was not forthcoming and the study had to be postponed.

Archiving and Access

SPRI then proposed the use of the highly secure DSpace@Cambridge, the digital repository of the University of Cambridge, as a reliable host for the digital elements of the archive (the vast majority). Non-digital materials would be held in an appropriate storage facility within SPRI. Metadata would be established, where necessary, for both digital and non-digital data to ensure appropriate management of the materials.

The archive would be made openly available to future researchers and students and would meet the accessibility requirements for all IPY data and information acceded to by all IPY projects and described in the IPY Data Policy document. All Intellectual Property Rights would remain associated with the relevant person or persons who created the material(s) and to be acknowledged in any subsequent publication or exploitation of the materials.

Development of the Project

During 2008 the participants continued to formulate plans for the archive by email. A further meeting was held at SPRI on 18 November, 2008. In attendance were Heather Lane (SPRI), Elin Stangeland (DSpace@Cambridge project), Cynan Ellis-Evans and Rhian Salmon (IPY IPO) and David Hik (IPY Canada, IPY DiTRL, University of Alberta). It was recognised that an important legacy of IPY 2007–2008 is the collection and storage of IPY related materials in an organized and retrievable format. To accomplish this task, the IPY International Program Office (IPY IPO), Scott Polar Research Institute (SPRI), Canadian IPY Secretariat and DSpace@Cambridge agreed to collaborate to create and maintain two electronic databases as well as a central hard copy repository. At this meeting emerged the concept of the use of the IPY-DiTRL (IPY Digital Resource Library), hosted by the University of Alberta, as a means of enabling holders of relevant electronic files (including email, word-processed documents and Powerpoint presentations) to upload them directly into a central database. It was agreed that the Memorandum of Understanding would be modified by David Hik to include signatories from SPRI, IPY IPO, and IPY-DiTRL.

The International Polar Year Digital Resource Library (Fig. 4.2-4) is an online database containing digital media that have been submitted by IPY researchers, students and other partners. The media are generally in the form of animations, power point presentations, video and audio clips, and PDF files. This digital library is complementary to the various IPY data catalogues (e.g. www.polardata.ca) and the IPYPD publications database (www.nisc.com/ipy). DSpace@Cambridge is a mirror archive that contains copies of all IPY files uploaded to IPY-DiTRL. It was established in 2003 to facilitate the deposit of digital content of a scholarly or heritage nature, allowing the sharing and preservation of this content in a managed environment. Hard copies of materials and access to restricted files are managed by SPRI.

All submissions would occur via DiTRL. There would then be a transfer of this information to DSpace@Cambridge. Setting up DSpace and DiTRL as mirror sites was seen to be good both for the preservation of the archive and for long-term funding. Like DSpace@Cambridge, the University of Alberta system will also be maintained in the long term. Plans already in place

Fig. 4.2-4. Browse screen from IPY-DiTRL.

for DiTRL to develop a more user-friendly querying system were seen to be of benefit, but in late 2008, with the closure of the IPO likely to happen in March 2009 (later postponed until September 2010), having a working system was a great advantage. At this stage, the priority was collecting the information, rather than accessing it. It was envisaged that once the information had been collected it would become easier to obtain funding to develop access.

Electronic Records and Metadata

The IPY "archiving committee" acknowledged that most individual depositors would not wish to upload on an individual file level, as this would be too time consuming. It was decided to suggest that material be uploaded at folder level, e.g. emails sorted by date or files by topics. The folders could be zipped, thus creating one file associated with one set of metadata (cataloguing information). In addition, fields such as creator, date, title, filename, etc., associated with item level cataloguing (i.e. for individual files) occur to a great extent electronically as part of the file and might be extracted automatically to facilitate indexing.

The DiTRL metadata requirements in use at this time asked for some information such as audience, event type and discipline not required for this dataset. A truncated list of fields, to be completed by the person submitting the data, was devised to include:

- Provenance Information (input level information from the depositor, including name, role within IPY and dates of involvement, institution(s) and contact details)
- Filename
- Document Title
- Project number (to be supplemented by the addition of new fields based on chronological development of IPY stages)
- Creator
- Description
- Country/ies
- Keywords
- Start and end dates (for a collection)
- Accessibility: open or closed archives

As submissions through the DiTRL interface commit the depositor to the terms of a click through agreement, a statement on the accessibility of the material had to be devised. This was especially important for bulk-submissions. Depositors needed to be made aware that all information submitted to the IPY Archive would be available for research purposes upon request to the Scott Polar Research Institute, Cambridge (and/or the University of Alberta). Unless otherwise specified, all information and metadata would be made publicly available through a web interface. If specified, (e.g. by selecting CLOSED in the accessibility field), all metadata would be publicly available, but the information itself would only be available upon personal request to the Scott Polar Research Institute. Researchers requiring access to closed information not published on the web would need to request permission from the SPRI Archives. Differences between D-Space and DiTRL created a need for transparency and consistency and the front page of the DiTRL portal was reworded to reflect the collaboration and to provide a common description of the project in terms of capture, archiving and access. A cooperative deposit agreement was also drawn up with the assistance of Elin Stangeland and David Hik.

The committee also recommended that a set of guidance notes should be developed and circulated with the instructions for depositors, covering topics such as:

- Zip collections of files according to date/topic
- Identify documents of special interest individually so that they have their own unique set of metadata and can be easily found. (The same file could appear both within a zipped collection, and as an individual entry.)
- Ask national polar libraries for help/support in the process
- Include as much as possible - the broader the picture, the more valuable the collection as a whole.
- Sort emails and correspondence by date, and in metadata include what was occurring in that time period. Sub-categorize by topic if necessary.
- Do not include material that will also be listed in the publications database – i.e. published material (both print and electronic) reported to the IPYPD www.nisc.com/ipy under the provisions of the IPY Data Policy.

Full instructions were added to the www.ipy.org website (Public_IPY-DiTRL_Upload_Intructions[1].PDF). Files could either be uploaded individually on the DiTRL web interface, or, for larger collections, uploaded by batch submission. For the latter, depositors were asked to store files on a CD or DVD, or transfer them by FTP to the University of Alberta for uploading. They were also asked to complete a simple spreadsheet detailing an overview of the material and could choose to compress multiple files or folders into single zip files to hasten the process.

Plans were in place by January 2009 to begin the collection phase by an open call, but also by targeting individuals, e.g. JC members, planning group and national committees. Hard copy materials would go to SPRI or to national libraries and the IPO was to help by contacting individuals and the wider IPY Community. Using the Polar Libraries Colloquy's established international network, it was envisaged that libraries, archives and depositors could work together at a national level.

Conclusion

Through 2009-2010 work on amassing archival materials related to IPY 2007–2008 has continued steadily. The final transmission of the IPO files from the headquarters at the British Antarctic Survey took place at the end of March 2010, several months prior to the official closure of IPO (*Chapter 1.6*). Among those files transferred to SPRI were 27 folders with correspondence to and from Chris Rapley (who had been Chair of IPY Planning Group) during the early IPY planning in 2002-2005, the largest and the most valuable collection of its kind (Figs. 4.2-5, 4.2-6). A further three boxes of material were also deposited by the IPO. The cataloguing of these and other deposited materials is currently in progress. However, it is already apparent that it may be too late to retrieve the bulk of the electronic files related to IPY 2007–2008 from some national offices, as e-mails from 2003-2006 and even later may be cleaned up automatically via regular computer upgrade and file migration. We may already be facing the routine, if unintentional, destruction/expiration of IPY-related electronic documentation for a major proportion of the planning phase. Those concerned are urged to collect and deposit any materials of relevance as a matter of urgency.

The intention is to manage the digital materials as binary large objects in relation to contributors, organizations and events with the appropriate metadata in a DSpace environment. If funding can be found, future knowledge discovery solutions are being planned for the end-users, rather than the programmers, to select the objects; define and implement the granularity of the objects based on their inherent structural features, and to query the resulting collection of granules to identify relationships within and between the objects. This digital archival process, which departs from the notion of structured and unstructured information, will provide quantitative results from otherwise qualitative sources. Results of the IPY archival program will be invaluable for polar historians and instructive for the development of other international programs in the future.

It remains only to encourage all those involved in the planning and implementation of IPY 2007–2008 to ensure that their individual and project-related archival collections are notified to SPRI (archives@spri.cam.ac.uk) or uploaded as electronic files to the IPY-DiTRL repository. As the IPY 2007–2008 central archival depository keeps growing, in time it will become an invaluable resource for future historians, IPY students, and for the planning of the next International Polar Year.

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Fig. 4.2-6. The physical IPY archive being moved into storage at SPRI by Archivist, Naomi Boneham.
(Photo: R.D. Smith, courtesy SPRI)

Fig. 4.2-5. The first deposit of IPY archival material at SPRI.
(Photo: R.D. Smith courtesy SPRI)

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Notes

[1] For example: Andreev et al., 2007; Arnestad Foote, 2009; Krupnik et al., 2009.

[2] This section is based on Goodwin et al., 2010b.

[3] See http://classic.ipy.org/development/eoi/proposal-details.php?id=51

[4] As of August 2010, the total number of entries in the IPYPD was 4164, including 1607 related to IPY 2007–2008.

[5] The IPY Publications Database can be found at http://nes.biblioline.com/scripts/login.dll

4.3 Early Career Researcher Activities During IPY

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Stimulating the Current and Future Generations of Polar Researchers

The fourth IPY occurred fifty years after the International Geophysical Year. During that time span, the research landscape evolved dramatically: the start of the fourth IPY occurred shortly after the birth of the internet, catalyzing the undertaking of science as a bottom-up process and embracing the notion of "science for society", all important concepts to the research community. Young researchers were often at the forefront of these changes, piloting evolution of or introducing new concepts to the way science was conducted or the means by which it was discussed and shared. Young researchers involved in the fourth IPY injected enthusiasm, energy, creativity and the ability to see things from a fresh perspective, which was appreciated by many, if not most, of the senior researchers leading the various projects. They also had an inherent desire to work across national and disciplinary boundaries that helped to stimulate new research directions and collaborations, which was crucial to the success of IPY.

At the time this chapter was written, the total number of young researchers involved in IPY was not known, however, it was estimated that for each senior researcher on a science project there were one to two graduate students or postdoctoral fellow, indicating that indeed, the science projects of IPY were undertaken by more young researchers than senior, a first for an event of that magnitude. Many talented young scientists were drawn to polar research by a combination of its increasingly innovative, intellectually stimulating and socially relevant nature and its strong connections with polar environments. Nevertheless, these early career researchers faced a number of challenges, including:

1. the emphasis put on increased international/multinational cooperation and the difficulty to comply with this in a system dominated by national research systems;
2. the need for integrated and interdisciplinary research and the inherent challenges in communicating with researchers from other fields of science;
3. the necessity to stay abreast of technological advances, especially in the context of interdisciplinary research, miniaturisation and computerization;
4. the strong focus on communicating scientific results to decision makers and the public; and
5. the undertaking of research in unique and challenging research sites in remote and/or culturally sensitive regions.

The need for innovative, international and interdisciplinary polar researchers evolved dramatically between the third and fourth International Polar Year. Most research projects involved graduate student training, giving a prominent role to young scientists in the research performed over 2007-2009. Nevertheless, few research projects made the professional development tools needed to meet the demands of a career in polar science a central part of their activities. In many ways, the challenges mentioned above were often left to the graduate students to sort out on their own.

In an era newly dominated by electronic communication, the excitement for activities in education, outreach and professional development unexpectedly and spontaneously developed in a coordinated manner at the international level to address these early career challenges. It is this organic growth of projects dedicated to the very central issues faced by young researchers that we outline in this chapter. We first present a few highlights from projects formed by or for early career researchers during IPY and then focus on the formation of the Association of Polar Early Career Scientists (APECS), a major legacy of IPY.

Highlights from Selected IPY Projects

PAN-AME and the Young Scientists Forum

Stig Falk-Petersen

The PAN-arctic cluster for climate forcing of the Arctic Marine Ecosystem was a large network headed by Stig Falk-Petersen of the Norwegian Polar Institute/ARCTOS and Dave Barber of the University of Manitoba/ArcticNet (IPY Project no. 26). As part of this project, approximately 100 PhD students have participated in the ARCTOS PhD-school (www.arctosresearch.net) and the Young Scientist Forum. By providing optimal conditions for young researchers to develop and grow, professionally and personally, these two activities included networking, cultural exchanges, the development of research collaborations and interactions with artists and the maritime industry. As a key component of these projects, more than ten young artists have joined Arctic research cruises together with the young scientists during IPY, creating a meeting place between art and science. The artistic outcome from these cruises was presented at the PolArt exhibition held in January each year in connection with the Arctic Frontiers Conference (www.arctic-frontiers.com).

An example of this type of partnership is exemplified by Svetlana Murzina, one of the students who took part in the Young Scientist Forum and defended her Doctoral thesis on 25 February 2010 at the Institute of Biology Karelian Research Centre of the Russian Academy of Science in Petrozavodsk (thesis title: Ecology and biochemistry of key Arctic fish species *Leptoclinus maculates*). Svetlana attended a cruise together with the young artist Eirin Støen and they have since been working closely together to show science through art. One of the artistic photos of Svetlana, taken by Eirin on an IPY cruise to the Arctic, was shown as part of several exhibitions in Europe.

New Generation of Polar Researchers Symposium

Sheldon Drobot, Susan Weiler and Jenny Baeseman

From 4-11 May 2008, the New Generation of Polar Researchers (NGPR) Symposium brought together a select group of 35 early career polar researchers from 14 countries with various personal and professional backgrounds across the spectrum of social, biological and physical sciences (Fig. 4.3-1). This diverse and ambitious group spent an intensive week learning from each other and from mentors about past, current and future polar research; IPY history and planning; communication and outreach; and development of successful careers in interdisciplinary and international research. Thirty-four early career polar scholars were selected through a competitive application process. A select group of mentors was also invited to share insights, stories and expertise in overcoming obstacles young researchers face, including comparisons of polar research from the 1st IPY (1882-1883) through the IGY to the most recent IPY. This provided a continuum of polar science knowledge and a sense of history that will carry these young leaders forward to the next IPY. More details are available at the conference webpage (http://apecs.is/workshops/ngpr).

Permafrost Young Researchers Network

Hugues Lantuit

The Permafrost Young Researchers Network (PYRN, www.pyrn.org) was established as an IPY education and outreach activity of the International Permafrost Association (IPA) in November 2005 by Hugues Lantuit, Margareta Johansson and Oliver Frauenfeld. The network's main objective was to offer a platform for young permafrost researchers to exchange knowledge and experience through a web 2.0 platform provided by the World Association of Young Scientists featuring blogs, podcasts, videos, galleries, a list of senior scientists, national groups, etc. The network was led and managed entirely by young researchers and constantly grew to reach a total 800 members from 40 countries in April 2010.

With growing success and expectations, the network rapidly evolved to organize much larger activities. It organized a kick-off workshop in Abisko in February 2007 and two workshops on scientific methods in partnership with the Association of Polar Early Career Scientists (APECS) in 2007 and 2008 at the Otto-Schmidt Laboratory in St. Petersburg. These three workshops brought together more than 150 young researchers. In addition, PYRN launched the successfully funded PYRN-TSP (Thermal State of Permafrost) project. The project was conducted in partnership with the IPA and its officially endorsed IPY TSP project. Small teams of young scientists equipped with lightweight drills travelled to understudied areas of the Arctic, Antarctic and mountainous regions, and drilled boreholes to establish temperature monitoring. Results were presented at the major IPY conferences in 2008 and 2010. PYRN also initiated the PYRN bibliography (PYRN-Bib) that inventoried over 1000 theses and dissertations completed since the early 1950s by permafrost scientists and engineers. A special issue of the journal *Permafrost and Periglacial Processes* was organized by PYRN and was successfully released in December 2009 (Christiansen et al., 2007; Lewkowicz, 2009; Bonnaventure et al., 2009). Finally, PYRN organized a series of happenings around the Ninth International Conference on Permafrost in 2008 in partnership with the United States Permafrost Association; the meeting included social events, panels and awards. PYRN was acknowledged as an outstanding component of the IPY legacy of the IPA.

ArcticNet Student Association

Brent Else, ASA

The ArcticNet Student Association (ASA; www.arcticnet.ulaval.ca/students/asa.php) was formed as the student organization of the ArcticNet Network of Centres of Excellence in Canada. One of the major goals of the ASA was to provide training to young Arctic researchers and to provide opportunities for networking. During IPY, the ASA organized the following networking and training events:

- ***ArcticNet Seminar Series*** – This annual series was offered from January-April at the University of Manitoba (Winnipeg, MB). The seminar featured weekly presentations by invited Arctic scientists from a broad range of disciplines and also provided a forum for students to present their research in a friendly and constructive interdisciplinary atmosphere.
- ***Northern Perspectives Workshop*** – This workshop was organized on 28 May 2008 at Université Laval (Québec, QC). The workshop focused on introducing students to how ArcticNet functions as an international research network and also explored Arctic research from an anthropological perspective.
- ***Student Day 2008*** – Each year the ASA organized a meeting of ArcticNet students and also encouraged students from outside of the network (including international students) to attend. The 2008 Student Day (9 December, Québec, QC) was organized in conjunction with the Arctic Change 2008 conference. More than 400 students, government representatives and researchers (including 26 students from northern communities) participated in plenary talks and breakout sessions aimed at fostering information exchange and building research skills.
- ***Inuit Culture Workshop*** – This workshop was held on 22 May 2008 at Université Laval (Québec, QC) and was attended by more than 40 students from four universities. The focus on the workshop was to introduce students to Inuit culture and language and was lead by experts in this field.
- ***Student Day 2009*** – The 2009 ASA Student Day was held on 8 December in Victoria, BC in conjunction with the IPY Early Career Researcher Symposium. The day was once again well attended by international students and featured plenary presentations and training workshops focused on the theme of the day "The Future of Polar Research".

University of the Arctic IPY Higher Education Office

Elena B. Sparrow

A very rich network for higher education and outreach during the fourth IPY existed through the University of the Arctic (www.uarctic.org), a collaborative consortium of more than 90 institutions (e.g. universities, colleges and other organizations) committed to higher education and research in the North, as well as 18 other projects submitted as Expressions of Intent to the IPY Joint Committee, which formed an IPY cluster (www.uarctic.org/singleArticle.aspx?m=135&amid=364).

The coordination office for the UArctic IPY education outreach efforts (www.uaf.edu) was located at the University of Alaska Fairbanks (www.alaska.edu/ipy). At the core of the cluster were UArctic and the International Antarctic Institute (IAI; www.iai.utas.edu.au/). The education outreach programs, including indigenous peoples' knowledge and approaches, reflected a continuum of learning as a lifelong process that targeted different audiences: 1) primary and secondary students through teacher professional development workshops on science teaching and research; 2) undergraduate students via education and research experience; 3) graduate students through integrated education and research and interdisciplinary programs; 4) early career scientists, university faculty via professional development; and 5) communities/general public via continuing education/adult education either through formal or informal ways conducted by cluster members.

Likewise, UArctic's collaborative higher education and outreach programs hosted in member institutions in Arctic countries were many and varied, providing rich learning opportunities for northerners and the greater global community: 1) the Circumpolar Studies Program used academic and indigenous knowledge as well as multi-method delivery in teaching about the North via courses held around the world in the classroom, in the field and online; 2) the UArctic Field School program composed of short, thematic, field-based courses, provided experiential learning in northern locations; 3) the GoNorth program provided the opportunity for non-Arctic residents to go north to the Arctic to learn about the Arctic; 4) the north2north program was a multilateral exchange program that facilitates student mobility in circum-arctic higher education; 5) the Northern Research Forum (www.nrf.is) promoted and enabled open discussion among policymakers, business people and other interest groups, the international community, and the research community; 6) the Open Learning program addressed the need for short-term skills training needed by northern residents; and 7) the Graduate Networks facilitated the education of young researchers through sharing experience and knowledge to promote regional cooperation and identity, build an academic community and develop opportunities for education and communication with policy-makers.

UArctic's education programs together with the other IPY Higher Education and Outreach cluster projects had global linkages and reach, creating a unique network for higher education and outreach during the IPY and beyond.

University of Alaska IPY Postdocs Program and the Young Researcher Network

Jenn Wagaman

As a contribution to the fourth IPY, the University of Alaska (UA) sponsored eleven postdoctoral researchers. Each of the scholars spent two years at a UA campus researching and contributing to the global goals of IPY. They were partnered with top UA scientists and, during their tenure, made important advancements in their fields. UA IPY scholars produced numerous publications, made international contacts through their research and accessed the Arctic from their doorsteps. Nearly half of the scholars have gone on to tenure-track faculty positions, while others continue their research or are serving communities through their research interests.

The UA also provided seed money to begin the University's first Young Researcher Network. Through this project, graduate students from a variety of disciplines conducted outreach in the Fairbanks and outlying communities, including elementary school science projects, community lecture series and hands-on science at several community events.

International Collaboration and Coordination of Early Career Activities

To meet the IPY's goal of including the next generation of polar researchers and the world's youth, an early-IPY grassroots effort by young scientists led by Amber Church and Tyler Kuhn from Canada, was formed under the name of the IPY Youth Steering Committee (YSC), IPY Project no. 168 in 2005. The YSC largely aimed to involve school children and young adults in polar literacy projects and strengthen the communication between students and young researchers. Under the YSC umbrella, national committees were established and, in some cases, gained support from senior colleagues and national science programmes, which were exemplified by the creation of the U.K. Polar Network (UKPN) in 2007. The YSC's scope, however, was limited in time since its main focus was to create activities during IPY.

Progressively, a need for a broader, more encompassing international effort specifically geared towards early career scientists arose; discussions on IPY education and outreach internet forums, similar initiatives in other scientific realms and encounters between like-minded people highlighted the awareness of this need. It also became clear that, these efforts should not only focus on science and career development, but serve and remain driven by early career researchers.

To address these needs, Hugues Lantuit (Germany), Jenny Baeseman (U.S.A.) and Rhian Salmon (U.K.) laid the groundwork for the rationale, structure, connections and future activities of a group to address these efforts on a continual basis in the autumn of 2006. The Association of Polar Early Career Scientists (APECS) was launched on a massive scale in early 2007, at the start of IPY with Jenny Baeseman and Hugues Lantuit as co-directors. A contributing factor to the success of APECS, at its inception and during IPY, was strong support from the IPY International Program Office (IPO), based in Cambridge U.K., which ensured that the goals of APECS would be shared with the community of senior researchers.

The initial group quickly grew through the coordination of disciplinarily-focused groups of young researchers who sought more substantial career development activities and a stronger connection to the senior leaders in their fields. In March 2007, discussions were initiated by the APECS directors with the International Arctic Science Committee (IASC) and the Scientific Committee on Antarctic Research (SCAR) to offer APECS' services to help assure the involvement of early career researchers in major international polar science activities. This early version of APECS started evolving to better serve the needs of early career researchers interested in the polar regions and the wider cryosphere, while including the senior research community to help ensure a continuum of knowledge was created.

The need to ensure the continuation of successful initiatives and activities after IPY led to brainstorming on post-IPY legacy. At the same time, the increase in young researcher initiatives in polar science started to create some confusion in the scientific community, leading to questions of the structure, coordination and even the relevance of such organizations.

Key Steps in the Formation of the Association of Polar Early Career Scientists

To address these issues, a meeting was organized at Sanga Saby outside Stockholm, Sweden in September 2007 to bring together all of these groups and to prepare some long-term sustainable plans. Representatives from APECS and other young researcher groups, such as the Permafrost Young Researchers Network, U.K. Polar Network and the YSC National Committees, met thanks to the sponsorship of the Swedish company Serla, the IPY IPO and other international polar science entities (Fig. 4.3-1). The key outcome of this meeting was the decision to merge these groups into one organization, under the name of APECS, because at this time, APECS had already garnered much support from the senior science community. As part of this merger, APECS adapted its structure to better reflect the multifaceted nature of its increased membership, to include a stronger focus on education and outreach, and to form national committees and representations of other already established young researcher groups (e.g. the ArcticNet Student Association, the Northern Research Forum Young Scientists Network and others). This established APECS as a legacy of the YSC and other IPY projects focused on young researchers. A new structure was launched at the end of the meeting, which included working groups, an advisory committee, an interim Council of the 24 attending participants and an interim Executive Committee elected by the council. Kriss Rokkan Iversen (Norway) received unanimous support as the first APECS President. Jenny Baeseman was appointed as the interim director and was financially supported part-time through the cooperation of the International Arctic Research Center and the Arctic Research Consortium of the United States, both located in Fairbanks, Alaska.

The Executive Committee (including the Director) was charged with establishing the official procedures and documentation for the organization over the next 6-12 months. Most of the communication among the group was conducted using Skype and Google Groups, but it became clear that an in-person meeting was necessary to move things forward more efficiently. Thanks to the coordination by Halldór Jóhannsson and support from the University and City of Akureyri, the Northern Research Forum and the Arctic Portal, the Executive Committee met in March 2008 in Akureyri, Iceland to address strategic planning for APECS and draft the documents that help sustain the organization for years to come; the Terms of Reference (ToR) and the Rules of Procedure (RoP).

During an online APECS Council Meeting on 21 May 2008, sponsored by Liz Murphy Global Media, the new organizational documents were approved. The RoP and ToR included a revision from the interim APECS structure to an open Council, who elects an Executive

Fig. 4.3-1. Participants of the meeting in Stockholm, Sweden, a key moment in the development of APECS.
(Courtesy: APECS)

Committee. The Council controls issues related to APECS governance and structure, and are expected to act on time scales of months to years. The Council mandates the Executive Committee and Director with shorter time-scale decision making and running APECS on a day-to-day basis.

In addition to the TOR and ROP, key progress during this early period included forming an international Advisory Committee of senior researchers and science administrators to provide guidance and support. A website was developed through in-kind support from the Iceland-based Arctic Portal. The website quickly established a virtual home for APECS and, among other features, includes study and job opportunities, meetings, news updates and a discussion forum.

By mid-2008, the increase in APECS members and activities (detailed below) was recognized officially at the SCAR/IASC Open Science Conference in St. Petersburg, Russia where SCAR, IASC and APECS signed a Memorandum of Understanding recognizing APECS as the preeminent organization for polar early-career scientists. This agreement assured the inclusion of young researchers on all SCAR and IASC committees and activities, and paved the way for APECS to continue its efforts with other international organizations.

As APECS continued to grow, it was necessary to establish a more permanent office with a full-time paid coordinator for the association. Attempts were made to try to secure funding in Alaska, but were not successful. Through concerted efforts by Kris Rokken Iversen, Aase Tveito and Olav Orheim, an International APECS Directorate office, lead by Jenny Baeseman, was officially established in January 2009 at the University of Tromsø, Norway. This provided APECS with a solid foundation that helped to consolidate and coordinate APECS's activities and continue to develop the organization well into the future. The support of the IPY IPO and the Joint Committee of IPY were crucial for maintaining such momentum.

Major APECS Achievements from 2007-2009

The phenomenal level of energy and volunteer efforts of talented young researchers and the support of senior mentors around the globe led to the success of APECS on many fronts. A complete list of APECS activities can be found in the APECS IPY Final Report (available at http://apecs.is/publications). A few activities are highlighted below.

International Leadership

Aside from the MoU with SCAR and IASC, APECS has helped to provide many opportunities for young researchers to be involved in interdisciplinary and international science and policy bodies, such as the ICSU Earth System Visioning Committee, SCAR/IASC

BiPolar Action Group, SCAR Scientific and Standing Committees, as well as representatives on many conference organizing committees. Indeed, APECS's motto was to provide a continuum of leadership and to link its activities to established international institutions rather than to act in isolation.

In addition, one of the keys to the success of APECS is the ability to tie other groups together and act as an umbrella organization for international young polar researchers. For example, the APECS Council was made up of representatives from other polar young researcher organizations, such as the ArcticNet Student Association, the Permafrost Young Researchers Network, APECS National Committee Representatives and members at large.

One of the biggest assets of APECS was the number of national committees that work internationally to promote polar research, education and outreach, and play an active role in organizing events and recruiting new APECS members, particularly in countries with emerging polar science programs. APECS has formal National Committees organized in Brazil, Chile, Germany, Italy, Norway, Portugal, Russia, Sweden, South Africa and the United Kingdom (as the U.K. Polar Network).

Education and Outreach

Young researchers around the world have participated in many outreach efforts through classroom visits, public lectures, live connections from the field, blogs and mentoring to name a few (Fig. 4.3-2). These efforts were aided by the coordination of the IPY International Polar Days/Weeks (*Chapter 4.1*). The level of interest and desire to participate in outreach by the current generation of young polar researchers shows a bright future of the incorporation of outreach into all research projects.

Perhaps the major tangible highlight of outreach came from efforts initiated by Mieke Sterken, Melianie Raymond and the APECS Education and Outreach Committee. This group developed the concept of a guide for young researchers to use when conducting outreach. The IPY IPO led an effort to bring the APECS concept together with the IPY Teachers Network to create "Polar Science and Global Climate: An International Resource Guide for Teachers and Researchers" (Kaiser, 2010). This book draws on the experience and expertise of educators and scientists who participated in the global collaboration for education and outreach during IPY and targets those who are interested in engaging students and communities with polar issues beyond IPY. It is particularly aimed at teachers, university students, young scientists and polar researchers who wish to bring polar science into classrooms and other learning environments in a practical and accessible way.

Virtual Tools to Enhance Collaboration

The APECS Website was an important tool for the organization as it served to strengthen communication between APECS members. Throughout IPY, considerable efforts were put into improving the APECS website, which was hosted though in-kind support from the Arctic Portal in Iceland. The APECS website was an invaluable resource for young researchers and anyone interested in polar research. Below is a summary of some of the resources available to APECS members through the website.

On-line Literature Discussion Forum

APECS has created an online polar literature discussion platform (http://apecs.is/literature) where researchers share results, carry on discussions, get

Fig. 4.3-2. Presenting their work at conferences is essential for the development of early career scientists. (Courtesy: APECS)

feedback from senior researchers, develop better communication skills and find new collaborators.

Virtual Poster Session

Sponsored by a grant from the Nordic Council of Ministers, the virtual poster session (http://apecs.is/virtual-poster-session) was an initiative aimed at bringing the poster presentation beyond the walls of the conference hall and creating an online database of polar research poster publications open to the public. This initiative has given communities, academics and the wider public easy and free access to research results. It has also enabled APECS members to discuss their results in a collegial manner during on-line calls, receive feedback from peers, improve their presentation skills and establish new collaborations.

Online Monthly Newsletter

APECS has produced and distributed a monthly newsletter, which has offered a means for polar scientists to keep abreast of current news and events in all fields of research. Components of the newsletter include news and updates, featured research sites, news from partner organizations, new topics from the literature discussion, upcoming meetings and workshops, available polar-related jobs, announcement of APECS activities and welcome words for new members. The newsletter content has been distributed widely through many websites, newsletters and information list-servers.

Various Online Resources

In addition to the above, the website has also featured an interactive membership directory where members could search for potential collaborators, meet new colleagues and find members in their region or in a place that they plan to visit. There was a constantly growing list of polar institutions, organizations and universities offering polar-related courses with each entry including a description, logo and website details. Additionally, a photo gallery with pictures of APECS events as well as from field expeditions of members has been included. An archive of career development presentations, podcasts and videos has also been implemented.

Career Development and Mentoring

A key focus of APECS's activities has been to help early-career scientists network and obtain advice from more experienced researchers and polar professionals.

Fig. 4.3-3. Early career scientists attending an APECS mentoring session.
(Courtesy: APECS)

This helped to enhance the careers of young people more quickly than their predecessors, increasing the level of competency of these new researchers when beginning their careers. Examples of the different ways APECS has helped to create a continuum of polar knowledge and leadership are listed below.

Mentorship Programme

The mentorship programme (http://apecs.is/mentors) has provided an unprecedented opportunity for experienced polar researchers and professionals to network with early-career researchers (Fig. 4.3-3). As part of this programme, APECS has created an online database of mentors who are willing to share their knowledge with and offer guidance to talented early-career researchers. While each mentor decided on their level of involvement, activities included meeting students at conferences, participating in APECS mentor panels and providing general career guidance for young scientists.

Mentor Panels at International Conferences

Over 20 panel discussions have been hosted at major international conferences throughout the IPY period. These were often held as lunchtime seminars and were organized by APECS members. Invited panellists were generally senior researchers and polar professionals, and the sessions were often given a theme to shape and guide the discussion.

Career Development Workshops

APECS has initiated a number of interdisciplinary workshops, facilitating networking among early-career researchers and senior mentors across a wide range of disciplines. The workshops encouraged the sharing of ideas, concerns and expectations and, through a series of devoted presentations and practical sessions, helped early-career researchers gain valuable insight from more experienced colleagues. In an evaluation of a latest workshop held in December 2009 in Victoria, Canada, participants indicated that these workshops were critical to their professional development because they received <20% of this type of training during the course of their graduate education.

Some of the workshops coordinated by APECS during 2007-2010 period are outlined below.

SCAR/IASC IPY Open Science Conference:
Polar Research Arctic and Antarctic Perspectives in the International Polar Year
St Petersburg, Russia, 8 – 11 July 2008

An APECS Career Development Workshop was hosted in collaboration with SCAR and IASC. This workshop was attended by more than 100 young researchers as well as representatives from funding agencies and research councils, including the U.S. National Science Foundation (NSF), the U.K. Natural Environment Research Council (NERC), Antarctica New Zealand, IASC, and SCAR. These agencies and councils provided early-career researchers the unique opportunity to interview potential reviewers and employers about succeeding in polar science. Sessions and panel discussions focused on key skills in proposal writing, conducting remote and logistically complex fieldwork, communicating science and methods to improve research productivity. Funding for the workshop was provided by SCAR, and APECS worked with the International Glaciological Society (IGS), the World Meteorological Organization (WMO) and IASC to help provide travel funding for some participants.

APECS also held a meeting and reception sponsored by the Otto-Schmidt Laboratory, SCAR, IASC and the WCRP Climate and the Cryosphere (CliC) Programme. At this reception, over 250 young researchers and senior mentors shared ideas and developed collaborations.

IPY International Early Career Researcher Symposium
Victoria, BC Canada, 4 – 8 December 2009

Thanks to the generous support of the Canadian Federal IPY Programme Office, APECS together with the Northern Research Forum, the ArcticNet Student Association and the Canadian Polar Commission hosted a career development symposium for 70 international young researchers prior to the ArcticNet Annual Meeting (http://apecs.is/workshops/victoria09). The goal was to bring early-career polar researchers together for a series of career development training sessions to enhance professional skills, to work with senior mentors and to form international and interdisciplinary collaborations. The workshop focused on seven themes: community-based research, funding your ideas, working with policy makers, communicating your research, getting started in science, data management and time management. The training sessions gave concrete and useful advice, insights and skills to help early-career researchers meet the demands of polar science. Senior researchers and polar professionals moderated the sessions, shared advice and mentored the participants.

U.K. Polar Network Career Development Workshop Series, 2009-2011

Beginning in 2009, the UKPN started holding career development workshops for its members, primarily aimed at master, doctoral and post-doctoral levels. These events had the goal of promoting not only scientific progress and acquiring new skills, but also career development, networking and outreach. To ensure a high level of interaction, participants were encouraged to present a poster as well as to get involved with organizing the workshop (e.g. chairing a session).

Enhancing Interdisciplinary Research Training

A major focus of IPY was to look at research questions with a multidisciplinary perspective. This was needed to enhance the understanding of rapidly changing polar regions. To help prepare young researchers to work in these interdisciplinary environments, APECS participated in the organization of various activities to help members enhance their interdisciplinary research skill set. Below are a few highlights over the IPY years.

IMPETUS 2008 – Polar Ocean Observation and Monitoring

St. Petersburg, Russia, 19 – 22 November 2008

This techniques-oriented workshop was jointly organized by the Otto-Schmidt Laboratory for Polar and Marine Research in Saint-Petersburg (OSL), APECS and the Permafrost Young Researchers Network (PYRN) and attended by 85 young researchers from 20 countries. Financial support was received from the German Federal Ministry of Education and Research, the Arctic Ocean Science Board (AOSB), the U.S. Arctic Research Commission (USARC), the Gordon & Betty Moore Foundation (GBMF), the British Antarctic Survey (BAS), the Leibniz Institute for Marine Science (IFM-GEOMAR), Alfred-Wegener-Institute for Polar and Marine Research, the Integrated School of Ocean Sciences (ISOS), IASC, SCAR, CliC and Aanderaa Instruments. This event followed a 2007 IMPETUS workshop on permafrost also organized by the same groups.

APECS/UNIS/UArctic Interdisciplinary IPY Polar Field School

University Center on Svalbard (UNIS), 15 June – 3 July 2009

This three-week course, hosted by UNIS, APECS, IPY Norway and the University of the Arctic, brought together 24 talented undergraduate and masters students from 11 nations that were selected from nearly 300 applicants (http://apecs.is/field-schools/apecs-schools/past-field-schools). The interdisciplinary polar experience in the high Arctic focused on the IPY themes and covered topics including climatology, glaciology, marine and terrestrial biology, geology, oceanography, permafrost and the human dimension. The Field School combined lectures, seminars, field excursions and project work, and gave the students valuable experiences in all aspects of polar research from the practical to the theoretical.

Similar field schools have been planned for June/July 2010 and 2011. This has been made possible thanks to additional funding from the Norwegian Ministry of Foreign Affairs and support received from UArctic, IPY Norway and UNIS. APECS was again an important contributor in the execution and organizing of this IPY Field School in Svalbard in 2010 and 2011 (http://apecs.is/field-schools/apecs-schools/svalbard2010).

APECS/IARC International Field School

Bellingshausen Station, Antarctica, 10 – 26 January 2010

This field school took place at the Russian Bellingshausen Station on King George Island, South Shetlands, Antarctica in January, 2010. International and interdisciplinary, the field school exposed participants to different Antarctic research techniques necessary for understanding one of the world's regions that is most affected by climate change. Fieldwork and trips were complemented with lectures at the station. To avoid excessive disturbance to the wildlife and respecting the protected areas, all field trips were in permitted areas and were guided by experienced scientists. When weather conditions did not permit outdoor activities, the participants gave interdisciplinary lectures, with subjects varying from social, natural and physical science.

APECS Polar Policy Essay Contest

International, February and March 2009

APECS, together with the organizers of the Antarctic Treaty Summit, invited young researchers to share their thoughts and opinions in an essay contest focusing on how to better integrate science and policy, and on the needs for new policy dealing with current issues in the Antarctic as well as the Arctic. The winner of this essay contest received a fellowship covering travel costs and conference fees to represent the new generation of polar researchers at the Antarctic Treaty Summit and presented her work at this meeting.

Summary

Most research projects rely on the efforts of graduate students and postdoctoral researchers and in the past this 'training' was considered to be all that was needed to keep the continuum of science moving forward. The IPY provided the opportunity and the encouragement for enhancing the role early career professionals play in research and gave them a mechanism through which they could gain the additional skills needed for successful careers. The mentoring from senior polar professionals to the thousands of young researchers involved in IPY was a major contributing factor to the success of these programmes.

IPY undoubtedly stimulated students and youth around the world to pursue science careers. A sustained effort will be necessary to retain the young scientists that were involved in the IPY and provide resources for future researchers to develop their careers. Efforts, such as the activities, events, collaborations, conferences and exchanges, highlighted in this chapter should be sustained and further developed to continue the international and interdisciplinary momentum of IPY (Fig. 4.3-4).

The authors of this chapter encourage other research disciplines and programmes to follow the lead of the polar community in developing the careers of young researchers.

Acknowledgements

The sheer volume of activities for young researchers during IPY, which we only touch on in this chapter, were made possible mostly by talented young researchers who volunteered their time to help each other. We thank them and their advisors for being patient as they worked to become well-rounded professionals, focused on not only their research, but also on service to their community. All of these activities also show the engagement of senior researchers and polar professionals in fostering the next generation of polar researchers. We thank the, literally, hundreds of more established colleagues for helping nurture the brilliant young researchers that were part of the fourth IPY.

There are many individuals and organizations whose support and encouragement went above and beyond to help establish APECS and to incorporate young researchers into science planning.

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Fig. 4.3-4. During IPY early career researchers were engaged in numerous activities including (a,b) outreach in school classrooms, (c) field courses, and (d) conferences.
(Photos: courtesy APECS)

PART FIVE

The Legacies of IPY 2007–2008 and Future of Polar Research

Coordinating Editors: Igor Krupnik and Volker Rachold
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Introduction

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The five major sections of the JC IPY Summary are structured to provide detailed answers to a set of strategic questions related to the organization and implementation of IPY 2007–2008. Part 1 explains why IPY was launched, and how it was designed and implemented. Part 2 examines what has been learned in IPY by reviewing its key science activities in major fields and disciplines, and Part 3 explores how this was achieved via the multitude of IPY observational and data-management efforts. Part 4 explains how this new knowledge was disseminated to the polar science community, educators and students, and the general public, and how the next generation of polar researchers was involved in IPY.

Part 5, the concluding section, addresses two more strategic questions related to IPY, namely, **"Who learned it"** and **"What is next?"**. It explores the broader scientific and societal legacies of IPY 2007–2008 and the impact it has had or may eventually have upon various stakeholders – scientists and students, polar residents, national research planners, science managers, policy-makers and public at large.

Securing IPY 2007–2008 Legacies – The JC Perspective

Each previous IPY/IGY created a monumental legacy that outlived its planners and participants, often by many decades. The main legacy of the first IPY of 1882–1883 was the realization of Carl Weyprecht's proposal for concerted, if not fully coordinated observational programs by several nations to address common goals with common methods across the polar regions (Elzinga, 2010a; *Chapter 1.1*). The main legacy of the Second IPY in 1932–1933, besides its many scientific, observational and technological achievements, was to solidify the 'International Polar Year' as a multi-disciplinary collaborative program to be successfully replicated every 50 (or 25) years (Elzinga, 2010b). The International Geophysical Year of 1957–1958 was a much larger endeavour and much more convincingly bipolar. It left several lasting legacies, including the creation of the first permanent research stations in Antarctica (the 'peopling' of the last continent); the establishment of the World Data Centers; the beginning of the space research era and the use of satellites, as well as a greater appreciation of the upper atmospheric structure; and the new regime of science partnership that eventually led to the establishment of the Antarctic Treaty (Table 5.0-1, see summaries in Berguño and Elzinga, 2010; Dodds et al., 2010; Elzinga, 2009; Summerhayes, 2008; *Chapter 1.1*). Furthermore, IGY stimulated the development of a whole range of long-term daughter programs – not an obvious legacy from the first two IPYs (Summerhayes, 2008; *Chapter 1.1*)

These and other legacies of the previous IPY initiatives were clearly on the mind of the organizers of IPY 2007–2008 since the very start of the planning process in 2003–2004. It is no accident that the first Science Outline for IPY 2007–2008 produced in 2004 (*Chapter 1.3*) used the term 'legacy' more than 20 times (Rapley et al., 2004). At that early stage, IPY 2007–2008 was aimed to pave the way to:

- A new era of scientific progress in knowledge and understanding of the polar regions
- Vital legacy of sustained observing systems
- Increased international research coordination and collaboration
- Stronger links between researchers across different disciplinary fields
- Reference datasets for comparison with the future and the past
- Development of a new generation of enthused polar researchers
- Full engagement and understanding of the public and decision-makers worldwide in the purpose and value of polar research
- Increased participation of Arctic residents, including indigenous peoples, in polar science at all levels to enable future research to make maximum use of indigenous knowledge and for indigenous

communities to benefit from scientific advances (Rapley et al., 2004).

In 2006, upon completing the review of the proposals for prospective IPY projects, the IPY Joint Committee at its third meeting in Cambridge, U.K., identified key anticipated long-lasting 'successes' of IPY 2007–2008 as follows (JC-3 Minutes, 20-22 April 2006, p. 18, Table 5.0-1):

- A new regime for access to the Arctic
- Integration of local communities and social sciences
- (New) Observing systems in the Polar Regions
- Changing the data management and data center culture
- A new understanding of the operation of the polar climate.

The Joint Committee continued to discuss the IPY legacies at each of its subsequent meetings, most notably at JC-5 (March 2007, Paris), JC-6 (October 2007, Quebec; Carlson, 2007), JC-8 (February 2009, Geneva – Allison et. al, 2009), JC-9 (June 2010, Oslo), as well as at the IPY Opening Ceremony in Paris (March 2007)[1] and the IPY 'Celebration' in Geneva (February 2009). Also, several other groups and bodies involved in IPY, such as the Arctic Council, ATCM, SCAR, IASC, HAIS (Heads of the Arctic/Antarctic IPY Secretariats) and others have addressed the issue of the IPY legacy (or

IGY 1957–1958 achievements (JC-3, 2006; Summerhayes 2008)	**JC-3, 2006: expected results** (JC-3 Minutes, p.17)	**JC-8: planned results** (State of Polar Research, p.8-10)	**JC-9: Achievements by June 2010**
Discovery of Van Allen belts *(science)*	New understanding of the operation of polar climate *(science)*		Major science advances in many disciplinary and six integrative IPY themes *(science – Chapter 5.1; Part 2)*
"Peopling of the Antarctic" *(broad science advance)*	Integration of local communities and social sciences *(broad science advance)*	Cross-disciplinary collaboration, synthesis, and integration *(broad science advance)*	New integrative framework for polar research, global connections, cross-disciplinarity, social issues and biodiversity *(broad science advance – Chapter 5.2)*
Use of satellites and rockets for polar research *(observations, science technology)*	Observing systems at the Poles *(observations)*	Observational systems, facilities and infrastructure *(observations)*	New long-term observing systems targeted to many stakeholders *(observations – Part 3)*
The establishment of data centers *(data management)*	Changing data management and data center culture *(data management)*	Reference data *(data and data management)*	New strategic approaches to data and information management, including creation of the Polar Information Commons *(Chapter 3.11)*
The eventual establishment of the Antarctic Treaty system *(political cooperation)*	New regimes for access to the Arctic *(political cooperation)*	Scientific and political cooperation *(cooperation)*	Development of new 'bipolar' vision, partnerships, and institutions *(cooperation, science vision – Chapter 5.5)*
Establishment of SCAR *(science structure)*		New generation of polar scientists and engineers *(societal implications)*	New mechanism (APECS) to advance recruitment in polar research and to ensure the launch of the next IPY in 25 or 50 years *(science structure – Chapter 4.2)*
		Broad public interest and participation *(societal implications)*	Education and outreach networks to disseminate IPY results established *(societal implications – Chapter 4.1)*
		Engaging Arctic residents, including indigenous people *(societal implications)*	Bringing new stakeholders, i.e., polar residents, indigenous people, non-polar nations to polar research, science planning, and data management *(societal implications – Chapter 5.4)*

Table 5.0-1. Changing Vision on Major IPY 2007 –2008 'Achievements' (Legacies): 2006 –2010

'legacies') starting as early as 2006. As a result, scores of articles and discussion papers were produced in assessing various aspects of post-IPY legacy, IPY science synthesis and integration (Arctic Council, 2008; Baeseman, 2008; Dickson, 2009; Goodison, 2008; Hik, 2007; Hik and Church, 2007; Hik and Kraft Sloan, 2007; Kraft Sloan, 2006; Krupnik, 2009; LeDrew et al., 2008; Sarukhanian, 2008; Kraft Sloan and Hik, 2008; Summerhayes, 2007; 2008 Summerhayes and Rachold, 2007). The most recent assessment of the prospective IPY legacies was produced in July 2010 following the joint AC-ATCM workshop conducted during the Oslo IPY Science Conference (Winther and Njåstad 2010). In addition, the 2008 OECD Global Science Forum released an earlier report assessing IPY 2007–2008 in the context of international scientific cooperation and the specific need to consider IPY termination and legacy issues (Stirling, 2007).[2]

Nonetheless, a special memorandum developed by the HAIS group (Heads of Arctic/Antarctic IPY Secretariats) as early as February 2007 argued that **"the IPY JC should take a leadership role in the efforts to discuss and secure the IPY legacies"** (Rogne; 2007; emphasis ours – IK). That message resonated with the emerging vision that the JC role in IPY should expand to include the evaluation of the key IPY achievements and the stewardship of the IPY legacy. In fulfilling these responsibilities, the JC dedicated substantial effort to formulate its vision on the legacies on IPY 2007–2008 in its two major publications, *Scope of Science for the International Polar Year 2007–2008* (Allison et al., 2007) and *State of Polar Research* (Allison et al., 2009). A large section of the latter document was dedicated to the examination of possible future IPY legacies. It stated that "[the] rapid pace of scientific advance and our increasing awareness of humankind's impact on the Earth system as a whole suggest that research and data from IPY 2007–2008 will leave a lasting legacy in many fields of science, particularly in providing a clearer picture of what future changes may occur and what effects they may have" (Allison et al., 2009). Other major legacies of IPY 2007–2008 (besides its major science achievements) were identified as follows:

- Observational systems, facilities and infrastructure
- Scientific and political cooperation
- Cross-disciplinary collaboration, synthesis and integration
- Reference data
- A new generation of polar scientists and engineers
- Broad public interest and participation
- Engagement of Arctic residents, including indigenous peoples.

Some of those legacies of IPY 2007–2008 outlined by the JC have already been covered in earlier chapters of the volume, such as IPY observational initiatives and reference data (*Part 3*), new generation of polar scientists (*Chapter 4.3*), and the engagement of the general public (*Chapter 4.1*). This concluding section explores other key IPY legacies in greater detail, starting with *Chapter 5.1*, which overviews major science outcomes of IPY, particularly the development of the new integrative vision on polar processes and their global linkages. *Chapter 5.2* dwells on the role of IPY in broadening the cross-disciplinary and societal scope of the new generation of polar research. *Chapter 5.3* evaluates the growing role of non-polar nations, particularly the members of the Asian Forum for Polar Sciences (AFoPS) in polar studies. *Chapter 5.4* addresses the role of the new stakeholders in polar research, such as polar residents and, especially, Arctic indigenous people, as well as the societal benefits of sharing data and knowledge with local communities and new approaches to polar science education.

Chapter 5.5 examines many new partnerships forged during the IPY 2007–2008 era and, particularly, the new vision for unified 'bipolar' (Arctic-Antarctic) science planning and collaboration by major polar bodies, such as IASC, SCAR, Arctic Council, and ATCM, as well as the two IPY sponsors, ICSU and WMO. Lastly, *Chapter 5.6* explores how the momentum created by IPY 2007–2008 may be expanded beyond the timeframe on the fourth IPY, from the Oslo Science Conference in June 2010 toward the planning of the next (and final) major IPY-related Polar Conference in Montreal (April 2012), and into what may eventually become 'The International Polar Decade.'

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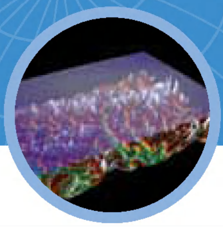
Notes

[1] Presentation by Ian Allison, JC Co-Chair (1 March 2007) explored *three* major aspects of the IPY legacy – scientific, collaborative, and human (i.e. societal).

[2] The most recent development in assessing the IPY legacies was a special workshop at the Oslo Science Conference in June 2010 and the subsequent scoping report (Winther and Njåstad 2010) produced under a proposal endorsed jointly by the Arctic Council and the Antarctic Treaty Consultative Meeting.



5.1 Early Science Outcomes of IPY 2007–2008

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Introduction: Reflecting on IPY Planning Themes

During the planning phase of IPY 2007–2008, a number of major themes emerged from the community-based consultation planning. In 2004, the ICSU Planning Group identified six major research themes outlined in the "Framework" document (Rapley et al., 2004; *Chapter 1.3*). These major IPY research themes were:

(1) To determine the present environmental status of the polar regions by quantifying their spatial and temporal variability.
(2) To quantify and understand past and present environmental and human change in the polar regions in order to improve predictions.
(3) To advance our understanding of polar-global teleconnections on all scales and of the processes controlling these interactions.
(4) To investigate the unknowns at the frontiers of science in the polar regions.
(5) To use the unique vantage point of the polar regions to develop and enhance observatories studying the Earth's inner core, the Earth's magnetic field, geospace, the Sun and beyond.
(6) To investigate the cultural, historical and social processes, which shape the resilience and sustainability of circumpolar human societies, and to identify their unique contributions to global cultural diversity and citizenship.

This summary reviews the early ideas and findings from each of the themes. Our objective is to take stock of what the IPY scientific community has learned to date, that is, by the official closing of IPY 2007–2008 at the IPY Open Science Conference in Oslo in June 2010 (*Chapter 5.6*). The previous chapters outlined what happened during IPY. Here, we will focus on the general achievements of the IPY science program. This summary is deliberately written to avoid referring to individual IPY projects, program names or specific activities that have been amply covered in other sections of this volume (*Part 2; Part 3; Chapters 5.2, 5.3,* and *5.4*). As is known from previous IPY/IGY efforts (*Chapter 1.1*), the major insights will take a substantial time to emerge. Given the initial stage of analysis and interpretation of much of the IPY data, this summary is neither comprehensive nor complete. Also, it uses a limited number of references, since the main literature based on the IPY results has not emerged yet. Many preliminary results (at the time of this writing) were only available from the abstracts of papers presented at the Oslo IPY Science Conference in June 2010 (e.g., Bell et al., 2010a; Ferracioli et al., 2010; Wiens et al., 2010).[1] Nonetheless, this chapter should be viewed as a first glimpse of the advances in our inter-disciplinary (and often, cross-disciplinary) understanding of the processes and linkages in the polar regions. For decades, the data collected during IPY 2007–2008 will support new scientific insights and advances.

Theme 1: Present Environmental Status of the Poles

The aim of the 'status' theme was to determine the present environmental status of the polar regions by quantifying their spatial and temporal variability. During the planning process it was envisioned that the main outcome would be a synoptic set of multidisciplinary observations to establish the status of the polar environments during the 'IPY era' that would become a baseline for measuring future change. The status theme specifically included polar issues related to biodiversity and to polar residents, their health, and social and economic well-being. The examples advanced during the planning process included establishing the status of the high latitude ocean circulation and composition, documenting polar ecosystem structure and function variability through space and identifying the contemporary factors of social cohesion and values for polar societies.

The IPY benchmark measurements produced new baselines of polar environmental conditions, biodiversity and ecosystem processes, status of the polar oceans, uniquely coordinated satellite observations of the polar environments and new measurements of the polar permafrost and the polar atmosphere. Determining spatial and temporal status of the environmental change, understanding the connections between the change and human impacts and understanding polar-global linkages – cannot possibly be addressed with two years of data. Understanding these complex connections will require sustained, global monitoring integrated across a wide range of disciplines.

IPY 2007–2008 built on the wealth of new scientific discoveries that catalyzed the development of sustained observing systems. For example, because of IPY, atmospheric observations are now taken at a consortium of research stations, employing standardized measurement techniques to monitor meteorological parameters, greenhouse gases, atmospheric radiation, clouds, pollutants, chemistry, aerosols and surface energy balances (*Chapters 3.4* and *3.5*). Similarly, the oceanographic community has effectively used IPY projects to address some of the major gaps in global ocean monitoring systems, to develop novel polar technologies as the core of efforts in the Arctic and Southern Oceans, and to link different monitoring systems run by individual agencies or nations into much more extensive and coordinated network (Bates and Alverson, 2010; Figs. 5.1-1 and 5.1-2).

Early insights are emerging from IPY baseline measurements. For example, IPY baseline permafrost observations were based on borehole temperature measurements (*Chapter 2.7*). The analysis of the permafrost temperature data in the borehole network improved during IPY demonstrated that the evolution of the permafrost temperatures is spatially variable and that the signs of warming of the upper permafrost differ in magnitude regionally. Simultaneously, new observing systems, particularly in biological sciences, have begun. Integrated, systematic observations of key species and habitats as part of long-term circumpolar monitoring programs are beginning to take shape and will be increasingly required to underpin management of ecosystem health and services in the face of the combined future impacts of climatic change and economic development in the polar regions.

IPY 2007–2008 was organized at a critical time. The Arctic and Antarctic Peninsula are known to be warming much faster than the rest of the globe (IPCC, 2007). Many impacts are already affecting biodiversity and ecosystem processes, some of which are likely to have global consequences. The international science community documented changes, deepened understanding of their causes, established baselines against which future changes can be measured, and projected future scenarios including local and global impact (*Chapter 5.2*; Dahl-Jensen et al., 2009; SWIPA, 2009; Turner et al., 2009a). Key to establishing these ecological benchmarks were biodiversity monitoring, data management and reporting through the development of integrated, ecosystem-based monitoring plans, coordinated, web-based data management products and targeted reporting tools (e.g. development of biodiversity indicators and indices). One important result is the intensified discussions on the urgent need for ongoing international, integrated monitoring systems of the Polar systems.

The facilities and instruments were improved at significant number of meteorological polar stations during IPY to provide basic meteorological variables and more reliable aerosol, chemistry, pollutant, greenhouse gases, fluxes, radiation, cosmic rays, ozone and carbon cycle measurements. Fluxes of charged particles observed in the atmosphere are the evidence to unusually profound and long-lasting solar activity minimum (Kotlyakov et al., 2010). To improve the data coverage in Antarctica, the meteorological observing network was extended by deploying new automatic weather stations at the location of the former manned stations, closed a long time ago, and by establishing new manned stations, such as Princess Elisabeth (Fig 5.1-3). New experiments during IPY enhanced the understanding of the high latitude atmospheric dynamics and demonstrated the importance of Arctic and Antarctic observations for the improvement and validation of local, regional and global numerical weather prediction models and weather forecasting. The large atmospheric measurement campaigns conducted in the Arctic have captured the dynamics, chemistry and microphysical processes within the polar vortices during IPY, providing an excellent reference for detecting future atmospheric changes. It has also been demonstrated that turbidity characteristics of the Arctic atmosphere are due to the emission of anthropogenic pollutants, as well as from agriculture, desert dust plumes and forest fires. The characterization of Antarctic aerosols has documented the strong differences between the coastal and the High Plateau aerosol particles (*Chapter 3.5*). IPY data on the polar stratospheric clouds as well as the ozone loss in the Arctic and the Antarctic have provided a coherent and complete picture of the stratospheric ozone depletion at its likely maximal development. These benchmark data sets will improve ozone loss models (Montoux et al., 2009; *Chapter 3.5*).

The status of the polar oceans was documented during IPY in an unprecedented way, due to intensified coordination and improved technology. A "snapshot" of the physical characteristics of the global ocean was obtained over a considerably shorter period than that made during the World Ocean Circulation Experiment (WOCE) of 1990–1997 (*Chapter 2.3*). Coordination increased the detection of regional variability by simultaneous cruises to different areas and provided key interdisciplinary contexts by combining

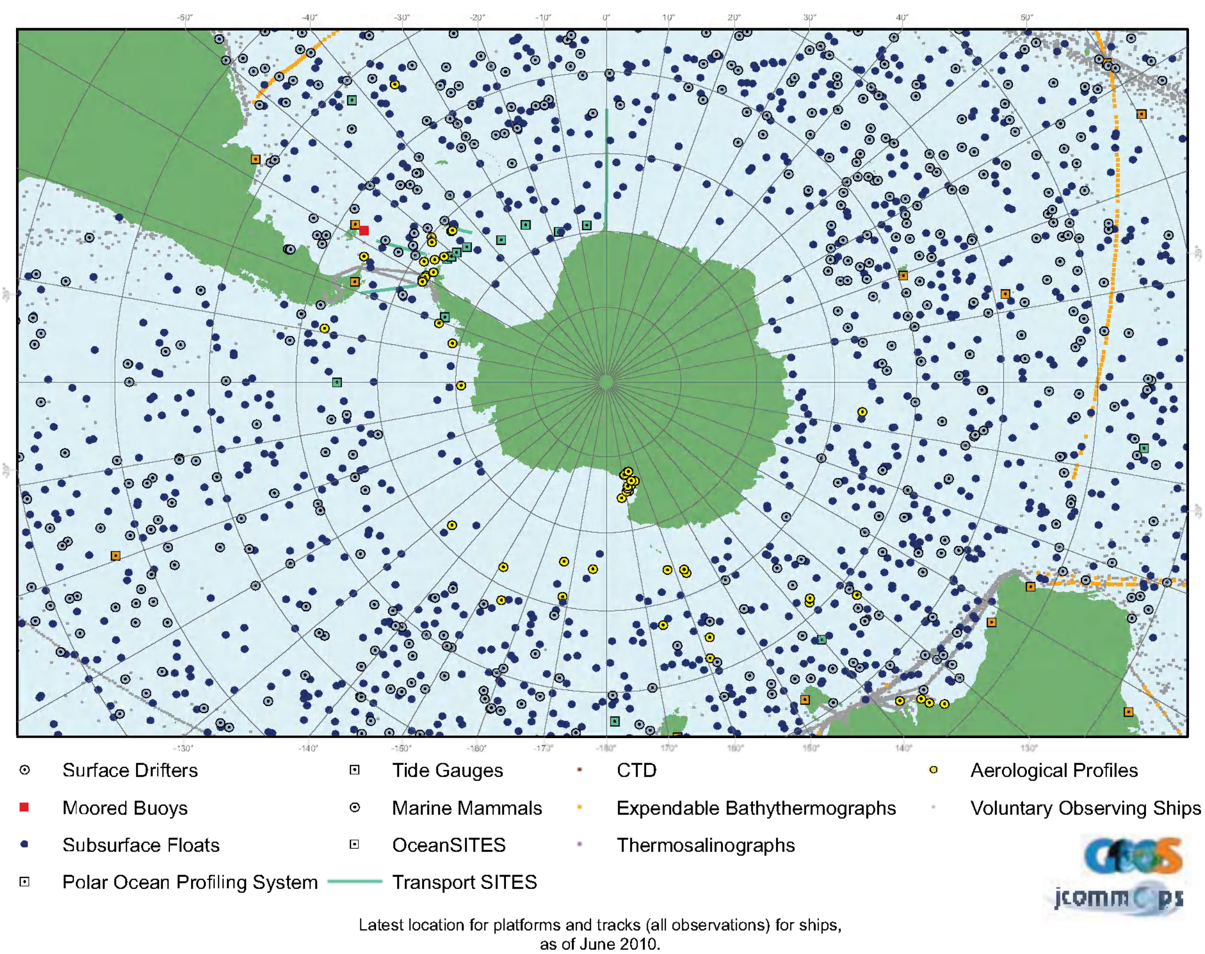

Fig. 5.1-1 *In situ* platforms, including drifting and moored buoys, subsurface floats and profilers, tide gauges, ship based measurements, and sensors on marine mammals, that reported data in June 2010 as part of the existing Global Ocean Observing System in the Southern Ocean. (Source: IOC-WMO JCOMM-OPS operational support center)

multidisciplinary measurements by different cruises to the same area (*Chapter 3.3*). The operational use of autonomous sampling or observation systems either freely floating in the water column, drifting on the sea ice, being carried by animals or on submersible vehicles opened vast regions to intense observations that previously were inaccessible. The high resolution and high quality measurements in combination with those from pre-IPY activities allow the present status to be seen in the context of variability over a wide range of time scales, from the seasonal to the multidecadal fluctuations, that are part of natural variability.

During IPY, space-borne instruments captured unique benchmark data sets of sea ice, polar oceans, ice sheets, polar atmosphere and seasonal snow. The minimal extent of the Arctic sea ice over the whole period of remote sensing was observed in September 2007 (with two less pronounced Arctic summer ice minimums also recorded in 2008 and 2009). For ocean studies, future scientists will be able to use IPY measurements of sea ice extent and thickness in the Arctic and Southern Ocean. While for ice sheets, IPY-coordinated efforts produced numerous key benchmark products including ice sheet wide digital elevation models and velocity measurements; multi-frequency, high-resolution imagery; maps of ice shelf extent and change; detailed images and digital elevation models of small ice caps, ice shelves and critical outlet glaciers around the coastlines of Greenland and Antarctica; time-variable series of gravity variability for estimating ice sheet mass balance and mass variability change. Space-borne measurements also provided key benchmarks of polar atmospheric composition and baseline, cloud distribution, cloud properties and upper level wind fields. Terrestial ice and seasonal snow and terrestial

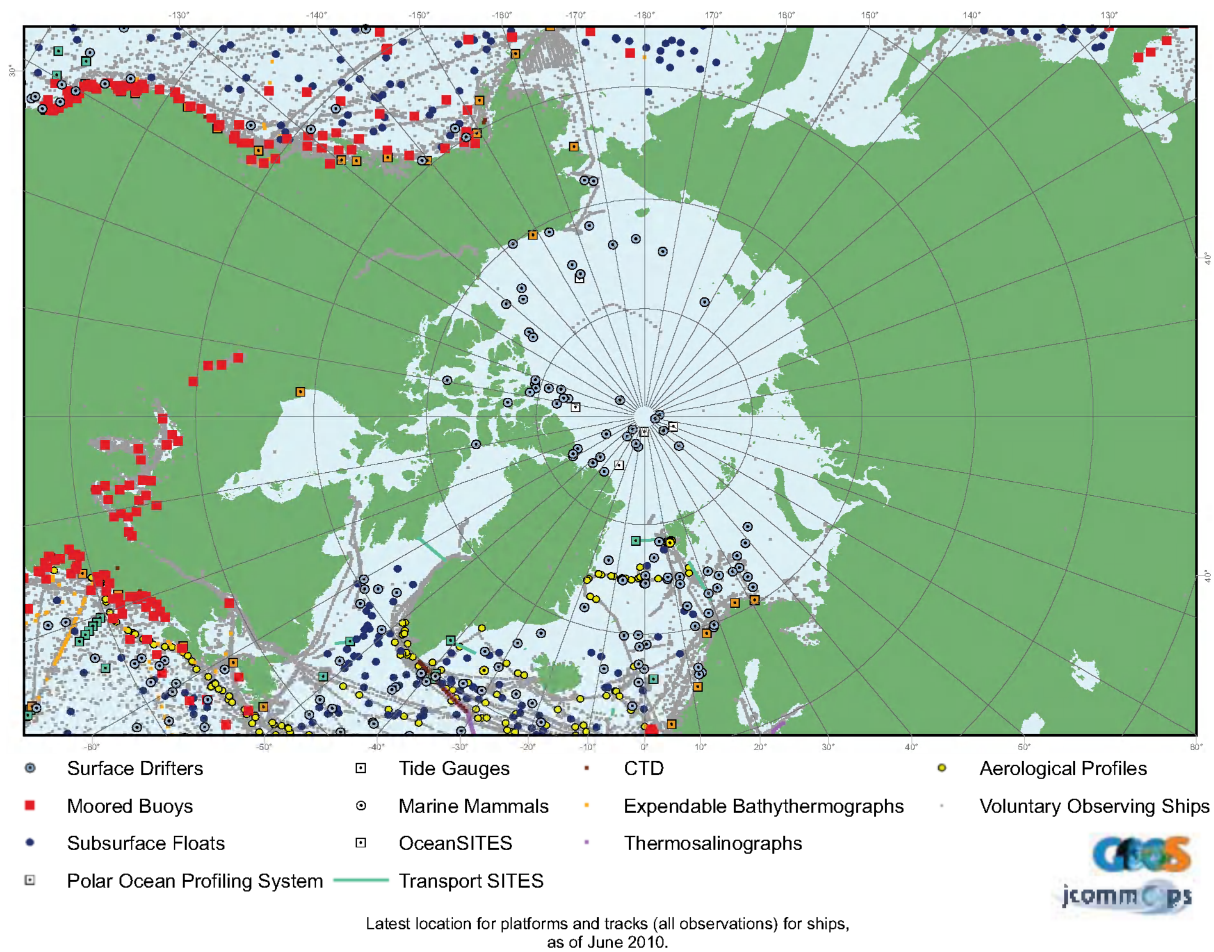

Fig. 5.1-2 *In situ* platforms, including drifting and moored buoys, subsurface floats and profilers, tide gauges, ship based measurements, and sensors on marine mammals, that reported data in June 2010 as part of the existing Global Ocean Observing System in the Arctic Ocean.

(Source: "Why Monitor the Arctic Ocean? Services to society from a sustained ocean observing system", IOC/UNESCO 2010)

Fig. 5.1-3 Antarctic Station Princess Elisabeth, Belgium, located at 71°57′ S 23°20′ E.
(Photo: René Robert, courtesy International Polar Foundation)

ice benchmarks included circumpolar optical imagery for mapping thermokarst and permafrost terrain characteristics, circumpolar snow areal extent of snow cover, snow water equivalent, and the timing of formation and break up of lake and river ice. Space-based measurements also produced observations of the distributions of surface albedo and surface temperature. A challenge will be to coordinate all of these results as the basis for developing the next generation of measurements (see several chapters in *Part 2* and *Part 3*).

In the human health field, current status data sets were collected and connected. Some recent accomplishments include an expansion of health monitoring scope to include tuberculosis, an effort to integrate health data collection for northern regions of the Russian Federation and the establishment of circumpolar working groups to focus on research aspects of viral hepatitis, diseases caused by *Helicobacter* pylor and sexually transmitted infections (*Chapter 2.11*). In the social science field, a major circumpolar overview of available 'status' data called the *Arctic Human Development Report* (AHDR, 2004) was just completed before IPY. Following this approach, almost every major IPY project in this field produced data to assess the status of polar societies and social processes. New 'baseline' datasets were generated on community development; industrial exploitation of polar resources; status of indigenous languages and knowledge systems; cultural heritage; and community use of local resources.

Theme 2: Quantifying and Understanding Change

The second theme focused most explicitly on change. It aimed to quantify and understand, past and present environmental and human change in the polar regions in order to improve predictions. Several approaches were proposed to monitor and predict environmental change, including recovering key paleo-climatic records, documenting the physical factors controlling past climate change, enhancing modeling capability, and developing long-term observation systems. Examples of specific questions to be answered included: how are climate, environment and ecosystems in the polar regions changing, how has polar diversity responded to long-term changes in climate, and how has the planet responded to multiple glacial cycles.

Insights into past climate change can be obtained by analysis of sediment cores and by ice sheet modeling. A frequent question has often been whether the West Antarctic ice sheet collapsed in the past. Sediments in the Ross Sea Antarctica, near McMurdo Station documented repeated cycles of ice sheet collapse and growth and some new IPY studies provide direct evidence for orbitally induced oscillations in the West Antarctic Ice Sheet (Naish et al., 2009). This large marine ice sheet appears to have collapsed and reformed during the interval between 3 and 5 million years ago when the planetary temperatures were 3°C warmer than today and the atmospheric CO_2 concentrations reached values as high as 400 ppm. Parallel IPY modeling efforts indicate that during periods with elevated temperatures and atmospheric CO_2, the West Antarctic ice sheet can collapse repeatedly producing ~5m of global sea level rise (Pollard and DeConto, 2009).

The general trend at the landscape level across the Arctic is that the most rapid decadal changes have occurred where there are fine-grained soils, strong natural and anthropogenic disturbance regimes, and relatively ample water and nutrients (Fig. 5.1-4). Nevertheless, not all changes are caused by climate shifts. For example, in Barrow, Alaska, some of the vegetation changes may have been caused by residents changing the hydrological system. Similarly some of the wetlands changes may have been caused by increased goose populations and their effect on eutrophication. Again, shrub and tree abundance shifts in some areas may be related to changes in herbivory. Identification of clear causes of ecosystem changes will require post-IPY investigations. Changes in ecosystems are relatively easy to document, but clear simple attribution to specific causes is often difficult.

Change has to be addressed by projecting IPY observations onto the background of past observations and by considering a wide range of natural variability from interannual to multidecadal time scales. Sea ice extent is a popular indicator of change, although attribution of its change can be globally as well as regionally controversial. The drastic changes in the Arctic Ocean are evidenced by the record minimum summer sea ice extent in 2007, which was followed by a slight recovery later during the IPY period. Over the longer-term a clear trend of decreasing ice extent and thinning has continued. In the Arctic Ocean the mobility of sea ice increased to the extent that the transpolar ice drift accelerated by a factor of two. In contrast, the sea ice cover extent in the Southern Ocean has tended to increase slightly each year and has shown a slight hemispheric increase of about 1% by decade over 30 years (Turner et al., 2009b) Superimposed on this overall trend there are marked regional differences. There has been a diminishing sea ice cover west of the Antarctic Peninsula (Amundsen and Bellingshausen seas) and an increase in the eastern Weddell Sea and the Ross Sea. There have also been changes to the annual persistence of Antarctic sea ice in some regions (*Chapter 2.3*).

The surface air temperature over the Antarctic continent seems to have increased by around 0.5ºC between 1957 and 2006, although there are substantial local differences and the trend is not significantly different from zero at the 95% confidence level (Steig et al., 2009). This result changes the previous accepted vision of the general cooling over the same period (Thompson and Solomon, 2002). The studies carried out during IPY have highlighted the potential of satellite observations together with in situ measurements to contribute to monitoring of weather and climate over the polar areas (*Chapter 3.1*).

During IPY, studies in the snow and firn from Devon Island in the Canadian Arctic allowed tracing human impacts in the Arctic over several millennia. Data back to 4,000 BP show that lead contamination in the High Arctic pre-dated the use of leaded gasoline additives and the Industrial Revolution. Several lead peaks linked to human activity ~3,100 years ago correspond to the Roman period and late 19th-20th centuries. Although the decrease in the use of leaded gasoline diminished the Pb in precipitation in the studied area, Pb isotope data show that at least 90% of the Pb in the High Arctic is still from anthropogenic sources (*Chapter 2.1*).

The Southern Ocean is warming and freshening throughout most of the ocean depth, although significant regional differences exist. Major currents are shifting to the south, causing regional changes in sea-level and supplying additional heat to melt ice around the rim of Antarctica (*Chapter 2.3*). The future of the Southern Ocean carbon sink is under debate. In the north, shifts in exchanges between the Arctic and Atlantic via subarctic seas are impacting the Arctic Ocean. The changing poleward ocean heat flux is central to determining the present and future of the perennial Arctic sea-ice. Changes in atmospheric conditions caused by warming have affected ocean stratification and circulation. Increased heat gain by

5.1-4 IPY studies of exchanges of carbon dioxide, energy and water between the sub-arctic mountain birch forest and the atmosphere required heavy equipment to be taken by helicopter to areas of forest near Abisko, Sweden with different history of insect pest outbreaks.
(Photo: Michal Heliasz)

the ocean introduces the potential for rapid further decrease of the sea ice cover. Indications of the effect of changing physical conditions on biogeochemical cycles and the distribution and development of marine organisms are evident in both the Southern and Arctic Oceans.

Preliminary results indicate mass loss from the Greenland and Antarctic ice sheets has increased in recent years. The satellite observations along with the IPY improved network of polar geophysical observatories are providing accurate measurements of future changes. The advance that occurred during IPY in the deployment of GPS, seismic, magnetic, gravity, tide-gauge and other geodetic stations, especially in Greenland and Antarctica, built an excellent base for such studies. The data will be useful to study geodynamic processes, subglacial environments and bedrock, ice sheets flow and evolution, and atmosphere characteristics, among other issues. Initial results are promising but some of such observations need longer periods to be representative.

Studies of polar atmospheric change focused on ozone depletion and air pollution phenomena. Intensified ozone observations carried out during IPY in polar regions together with observations in other parts of the globe have determined that the average total ozone values in 2006–2008 have remained at the same level for the past decade, about 3.5% below the 1964–1980 global averages (WMO/UNEP, 2010; *Chapter 3.5*). The ozone loss in Arctic winter and spring between 2007 and 2010 has been variable, but has remained in a range comparable to the values prevailing since the early 1990s. The Antarctic ozone hole continued to appear each spring from 2006 to 2008. During IPY the amount of ozone depleting substances has been nearly constant indicating that the depth and magnitude of the ozone hole are controlled by variations in temperature and dynamics. The October mean column ozone within the polar vortex has been about 40% below 1980 values. The Antarctic ozone hole appears to be influencing the surface climate in the Southern Hemisphere. Climate models also suggest that the ozone hole is the dominant driver of the observed austral summer changes in surface winds over the Southern Hemisphere mid and high latitudes. These changes have contributed to the observed warming over the Antarctic Peninsula and the cooling over the high plateau noted by Thompson and Solomon (2002). The changes in the winds have also been linked to regional changes in precipitation, increases in sea ice around Antarctica, warming of the Southern Ocean and a local decrease in the ocean sink of CO_2.

Efforts to study polar air pollution during IPY have yielded two preliminary conclusions. Firstly, the increased level of pollution in the Arctic atmosphere in recent years has an anthropogenic origin and has been generated by both agricultural activities and forest fires in Russia and Kazakhstan. In contrast, there is clear evidence that the atmosphere in the Antarctic remains uncontaminated by any anthropogenic aerosol through IPY 2007–2008.

In the social/human field, the 'change' theme was addressed by many projects, including those that investigated the growing impact of oil and gas development on polar people, their local economies and subsistence activities. Special efforts were made to document the impact of both environmental and social processes on community integration and well-being, as well as the new emerging threats to the continuity of indigenous economies, languages and knowledge systems. Several IPY projects in history and archaeology explored past changes in the polar regions, including former government relocation policies, and the impacts of early forms of commercial exploitation of polar resources, such as whaling, seal-hunting and mining. Arctic social change was documented via longitudinal comparative studies of migrations and the creation of long-term datasets on regional development, population movement, education and community dynamics (*Chapter 2.10*).

Theme 3: Polar Linkages to Global Processes

The third theme focused on how the polar regions are linked to global processes. It sought to advance the basic understanding of polar-global teleconnections on all scales and of the processes controlling these interactions. This theme aimed to address questions such as: the role the polar regions play in the global carbon cycle and the interactions between the polar regions and lower latitudes, including linkages through climatic, social, ecological and hydrological processes.

IPY efforts have clearly documented some of the key connections between the poles and the global processes. Changes in Arctic Ocean conditions are transmitted through subarctic seas on either side of Greenland, modulating the Atlantic thermohaline conveyor (*Chapter 2.2*). Evidence of fast propagation of anomalous atmospheric conditions to the mid latitudes demonstrated unprecedented large-scale interactions leading to a warm Arctic and colder conditions in mid latitudes. Continuing loss from the West Antarctic and Greenland ice sheets represents a key threat of abrupt increase in the global sea level.

Global paleo-environmental conditions and their changes can only be understood from information about paleogeography and processes that occurred around the poles. The evolution of submarine basins and ridges affected the oceanic bottom currents and produced deviations of the main current branches along the Earth history. During IPY, campaigns in different polar straits improved our understanding of the role of plate tectonics in establishing the main polar corridors for oceanic circulation. This information is also relevant to understanding past glaciation phases at both poles as well as changes in global climate. A new tectonic map of Antarctica is being compiled as a result of IPY research.

In the past, Arctic ecosystems have generally acted as a negative feedback to climate warming, sequestering the greenhouse gas CO_2, storing large quantities of organic carbon in cold soils and reflecting solar thermal radiation away from the snow-covered Arctic land surface. The decrease in the sea ice as well as the decrease in snow and land ice coverage lowers the albedo and introducing a key positive feedback capable of accelerating Arctic water and air temperature increases. The IPY research has contributed to better understanding in soils suffering permafrost degradation of both the microbiological processes and greenhouse gas liberation to the atmosphere. The advances in this field and the improvement of the boreholes network will permit monitoring future changes of these processes that can have global consequences. In both polar regions, biological systems were found to be more closely linked to each other than expected. This is supported by the identification of more than 1000 previously unknown marine animal species of which

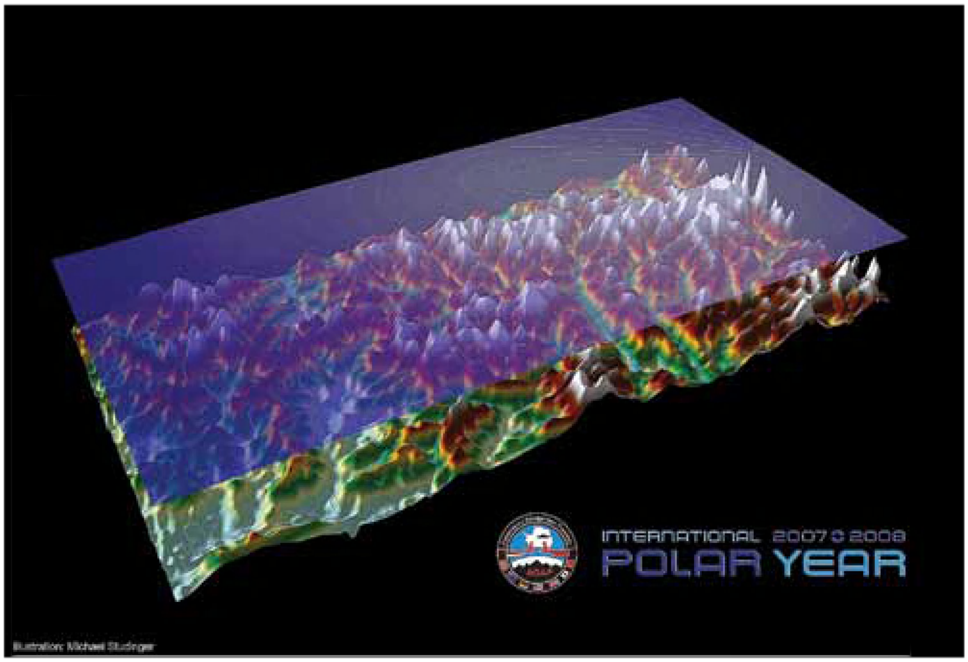

Fig. 5.1-5. 3D view of the subglacial Gamburtsev Mountains relief from inverted airborne gravity data. (Courtesy: M. Studinger)

250 were identified to be common to both poles and the remarkable similarity of the microbial systems between the poles.

Major outcomes from IPY social science and humanities research included the multi-level and adaptive nature of governance of the 'international spaces,' such as Antarctica, the Central Arctic Basin, High Seas and Outer Space (Shadian and Tennberg, 2009). This outcome originated in large part from the historical studies of IGY 1957-1958 and previous IPYs (Barr and Lüdecke, 2010; Elzinga, 2009; Launius et al., 2010); the celebration of the 50th anniversary of the Antarctic Treaty and the new role of the United Nations Convention on the Law of the Sea (UNCLOS) in the Arctic Policy debate.

The IPY efforts fostered the recognition of complex relationships among various drivers of change through the inclusion of local communities, their voices and perspectives in the interdisciplinary studies of climate change. Often more immediate challenges stem from the many social agents, such as local system of governance, economic development, break-up in community support networks and culture shifts. In certain areas in the Arctic, the purported 'threat' of climate change masks or distorts the impact of more immediate factors, such as the alienation of property rights, appropriation of land, disempowerment of indigenous communities and more restricted resource management regimes (Konstantinov, 2010). Climate change, environmental change or global warming should be considered an *added* stressor to the already challenging local conditions.

Theme 4: Frontiers of Science in the Polar Regions

The fourth theme sought to investigate the unknowns at the frontiers of science in the polar regions. While few geographic frontiers remain on the earth's surface, scientific frontiers aimed to be investigated during IPY exist beneath the polar ice sheets and under the ice-covered oceans, as well as at the intersections of science disciplines. Targets proposed during the planning process included: characterizing of the sub-ice and deep ocean polar ecosystems, determining the pattern and structure of polar marine and terrestrial biodiversity, at all trophic levels, and elucidating the nature of earth's crust beneath the polar ice cover. A number of these frontier questions were addressed during IPY.

During IGY 1957–1958 a large mountain range, the Gamburtsev Mountains, was discovered by the Russian Antarctic Expedition beneath Dome A, the highest part of the East Antarctic ice sheet. No systematic study of this enigmatic mountain range has been undertaken during the ensuing 50 years. The first results of the major Gamburtsev Mountain range under IPY 2007–2008 program are now emerging (Ferracioli et al., 2010; Wiens et al., 2010) (Fig. 5.1-5). The mountains are carved by a deep fluvial network indicating that they are older than the ice sheet. Both seismic and gravity measurements provide evidence of thickened crust beneath the mountains, indicating that they are old even though the topography may be geologically young (~35Ma). The thickened crust points to a very unusual evolution of this part of the Antarctic continent.

Several new studies just before IPY 2007–2008 revealed that the base of the Antarctic ice sheet contains an active subglacial hydrologic system including lakes that drained over the course of months (*Chapter 2.6*). Geophysical investigations during IPY showed this also occurred at Dome A and have provided evidences on the important role of subglacial water in ice sheet movement, stability and mass balance. Evidence of water in the deep valleys beneath Dome A indicated an active subglacial hydrologic system including widespread freezing of water from these systems onto the base of the ice sheet (Bell et al., 2010a). Generally the accumulation of snow on the surface of ice sheets is the main mechanism for ice sheet growth, but beneath the Dome, frozen-on ice occurs under almost one quarter of the ice sheet base. In some places up to half the ice thickness is a result of this novel freeze-on process (*Chapters 2.5* and *2.6*).

The focus of previous IPYs was primarily on geosciences and the physical world. The advent of modern genomic techniques opened the door to a microbial level frontier as one of the targets of IPY 2007–2008. One of the projects discovered polar microorganisms with surprising diversity, essential ecological functions and environmental roles as global warming sentinels. This has resulted in a major leap forward in our understanding of the microbial diversity of polar ecosystems and has contributed fundamental insights into arctic habitats, their communities and climate impacts. Striking microbial communities were found in the perennial cold springs in the Canadian High Arctic. Grey-coloured microbial streamers form there during winter in snow-covered regions but disappear during the Arctic summer. The streamers are uniquely dominated by sulfur-oxidizing species (Vincent et al., 2009). This finding broadens our knowledge of the physico-chemical limits for life on Earth.

Several High Arctic microbe taxa were >99% similar to Antarctic and alpine sequences, including to the ones previously considered to be endemic to Antarctica. One High Arctic gene sequence was 99.8% similar to *Leptolyngbya antarctica* sequenced from the Larsemann Hills, Antarctica and many of the Arctic taxa were highly dissimilar to those from warmer environments (*Chapter 2.9*). These results imply a global distribution of low-temperature cyanobacterial ecotypes, or cold-adaptive endemic species, throughout the cold terrestrial biosphere.

Mid-ocean ridges have been the focus of much study since their discovery during IGY. Beneath the Arctic Ocean, the Gakkel Ridge is the slowest spreading mid-ocean ridge on the planet and was targeted for IPY studies. This ultra-slow spreading ridge is often assumed to be relatively inactive. During IPY 2007–2008, evidence for explosive volcanism was discovered on the Gakkel Ridge (Sohn et al., 2008). The first-ever evidence for explosive volcanism on a mid-ocean ridge was documented with images of the ocean floor blanketed in an extensive frozen frothy lava including fragments of a bubble wall. This discovery raises questions about the accumulation of volatiles and gases in the magma chambers beneath slow spreading ridges during the long time between eruptions; little is currently known about the dynamics of magma chambers on these ridges.

Some of the basic discovery during IPY 2007–2008 resulted from collaborative work at both poles looking at the inventory of carbon stored in the permafrost layer. Permafrost is the ground, soil or rock and associated ice and organic material, which remains at or below 0°C for at least two consecutive years. More than 20% of the terrestrial part of the surface of the northern hemisphere consists of permafrost. If permafrost thaws, these large pools of previously frozen organic carbon within it may be remobilized releasing large amounts of greenhouse gases. These can contribute to a positive feedback loop in the climate system as the additional warming resulting from the release of the permafrost greenhouse gases will trigger more permafrost thawing. The new IPY estimate of total below ground soil carbon stored in permafrost regions (ca. 1672 PgC) is more than twice the previous value. It is more than double the present atmospheric pool (ca. 750 PgC) and three times larger than the total global forest biomass (ca. 450 PgC) (*Chapter 2.7*).

Multiple IPY studies solidified the basis for improved assimilation of satellite data in numerical weather models for regional polar prediction. Particular emphasis was put on improving the representation in models of surface processes, high-latitude clouds, cloud/radiation interactions and other key energy exchanges in the Arctic. These atmospheric models are now being run at increased resolution and are able to reproduce several processes that are essential for high-impact weather prediction. The newly incorporated processes include the role of local and middle latitude flow distortions caused by steep orographic changes, for example that in Greenland, and mesoscale phenomena referred to as "polar bombs".

In the social/human field, by far the most important frontier theme explored in IPY 2007–2008, was the relationship between indigenous perspectives developed via generations of shared knowledge and observations, and the data and interpretations generated through thematic scholarly research. The field that compares such perspective did not exist prior to the late 1990s. Several IPY projects contributed to our increased understanding of how indigenous knowledge could be matched with instrumental data in monitoring the changes in Arctic ice, snow and vegetation condition, marine mammal and caribou/reindeer migrations, behavioral patterns of polar animals and fishes. Another 'frontier' area in IPY social science studies centers on making polar research culturally and socially relevant to local residents by collaborating with new groups of stakeholders on research planning in their home areas (*Chapter 5.4*). As more attention is being paid to local concerns and community observations, the new research goals are set through dialogue with local communities (*Chapters 2.10, 3.10* and *5.4*).

The preservation of the polar environments from possible impacts has been revealed as an important issue connected with the increasing human impacts. The introduction of non-native species in the isolated Antarctic environment has been studied during IPY and opens a way for future protection actions.

Yet another frontier area pioneered in IPY 2007–2008 is the comparative study of northern-southern hemisphere processes under the concept of 'fringe environments' (Hacquebord and Avango 2009); this concept is relevant to both hemispheres. In the social sciences and humanities field, it focuses on the history of polar explorations, commercial use of local resources, polar governance, tourism and heritage preservation (*Chapter 2.10*).

Theme 5: Unique Vantage Point of the Polar Regions

The fifth theme sought to leverage the polar regions as unique sites for investigating distant realms. The vantage point theme aimed to use the unique location and conditions of the polar regions to develop and enhance observatories studying the Earth's inner core, the Earth's magnetic field, geospace, the Sun and beyond. The questions advanced ranged from what is the influence of solar processes at the polar regions on earth's climate to what is the state of the earth's magnetic dipole.

During IPY, astronomers continued leveraging the unique observing conditions offered by the polar regions to conduct a range of astronomical studies. Polar sites from South Pole, Dome C, Dome A, Dome F and Ridge A on the East Antarctic ice sheet to Arctic sites in Ellesmere Island and Greenland were evaluated as sites for new observatories (http://mcba11.phys.unsw.edu.au/~plato/). Places with already existing observatories, such as South Pole (Amundsen Scott Station) and Dome C (Concordia Station), have been broadly recognized as key places with great potential for astronomical observations and have been improved during IPY. Measurements of the atmospheric water vapor above Dome A during IPY showed it to be the driest location on Earth, with a vapor column as low as 25 microns of precipitable water for days at a time. With this dry atmosphere, the Antarctic plateau sites are the only locations on our planet from where routine astronomical observations in the terahertz spectrum (10^{12} Hz) are possible. During IPY, astronomers detected a previously unknown class of galaxy clusters by studies of the Cosmic Microwave

Background with the South Pole Telescope. These galaxy clusters are more numerous and appeared earlier in the evolution of the universe than previously expected (Staniszewski et al., 2009).

Links between the behavior of the sun and earth climate have long been advanced and discussed primarily through variations in the amount of energy put out by the sun, i.e. via solar irradiance changes. During IPY, scientists deployed instruments designed to measure the electrical flux through the polar atmosphere in an effort to examine whether there are additional couplings between the sun and earth's climate. These investigations suggest that small day-to-day atmospheric pressure variations in the Arctic and Antarctic are associated with a proxy for the output of the meteorological generators (thunderstorms and strongly electrified clouds) of the global atmospheric circuit. This proxy is derived from vertical electric field measurements made at the Vostok Station on the Antarctic ice plateau. Proportionate pressure variations on the Antarctic plateau are correlated with atmospheric circuit changes due to solar wind interactions in the polar regions. This result provides experimental evidence that a small portion of the global surface pressure variations is due to the influence of the global atmospheric circuit. The pressure response to the solar wind variations is an example of 'sun-weather' coupling via a different mechanism than solar irradiance changes (Burns et al., 2008).

Measurements in polar regions have potential for improving the seismic and tomographic models of the Earth interior. These regions are also unique vantage points for studying the structure and improving understanding of the evolution of the Earth's inner core and new studies will provide insights into core dynamics with implications for the Earth's magnetic field. Only seismic phases traveling along polar paths can map seismic anisotropy in the core, generally aligned parallel to Earth's rotation axis, which may be due to convection patterns in the core (Leykam et al., 2010).

Lake Vostok is frequently compared to the ice covered moons of Saturn and Jupiter, and the environments in the Antarctic Dry Valleys are viewed as the habitat on Earth most similar to that on Mars. During this IPY scientists used the same technology that was used on the Mars Landers to measure environmental conditions in the Dry Valleys of Antarctica. IPY scientists identified microbial biota in this extreme environment that may be typical of the types of biota that once inhabited Mars.

The idea that polar regions offer unique insight into global processes also resonates in the social science and humanities research, due to the amplification of many societal phenomena at the local scale. Also, Arctic regions often feature well developed long-term data sets, thanks to the long established tradition of community and human-environmental studies. During IPY, substantial efforts were made to place the circumpolar regions into wider global context, including the development of policies for managing 'common spaces', commercial resource exploitation of the economic 'frontier' zones, population exchange between Arctic and mid-latitudes; and the search for broadly applicable indicators of sustainability and community well-being (Larsen et al., 2010).

An internal 'vantage point' in the Arctic is the stock of knowledge about polar environments accumulated by local residents and, especially, by indigenous people. Many social scientists and indigenous experts believe that both of the vantage points offered by the two ways of knowing, academic knowledge and local/indigenous knowledge, are needed for a comprehensive understanding of the polar regions and processes.

Theme 6: Cultural, Historical and Social Processes (Human Dimension)

While the goal of IPY was to be fully interdisciplinary across all the themes, the ICSU IPY Planning Group added the sixth theme to address various issues related to human activities (e.g. cultural, economic, health, political) in the polar regions (Rapley et al., 2004). This sixth theme ensured that social sciences and the humanities, as well as polar indigenous people were a more visible part of the planning and implementation. The projects developed under this theme sought to investigate the cultural, historical and social processes that shape the resilience and sustainability of circumpolar human societies, and to identify their unique contributions to global cultural diversity.

In the years prior to IPY, the dichotomy between the northern and southern regions went far beyond the basic biological and physical differences exemplified by the northern polar bear and the southern penguin, or ocean ringed by continents in the north and continent surrounded by ocean in the south. Antarctic social sciences seemed to be an oxymoron; there were 'no people' in Antarctica. During IPY 2007–2008, this perception has changed dramatically and fully-fledged 'Antarctic social sciences' are emerging (*Chapter 2.10*); there is an explosion of interest in social issues that are *common* to both polar regions. These common social issues include the history of science, early economic exploration and commercial exploitation, sustainable economies, governance and political regimes, tourism, heritage preservation and engagement of local constituencies. Some areas are unique to the North including indigenous people, small-community studies and traditional knowledge. On other fronts progress is being made through IPY enhanced contacts and professional interactions between 'northern' and 'southern' social scientists.

Prior to IPY, the prevailing way of modeling complex linkages under the impacts of climate change, was to place "humans" at the margins of the chain-like charts illustrating connections within the ecosystem. The underlying assumption was that people would respond to the projected impacts predicted by computer-based scenarios such as warmer climates, shorter ice season or thawing permafrost. Social scientists were tasked with emphasizing the "human dimension". During IPY, a new approach moved communities to the center of the study of change and impacts. The new approach called *community-based vulnerability assessment* starts with the observations of change within local communities and proceeds bottom-up to identify potential future exposures, specifically new conditions or risks that communities may face or are already facing (Hovelsrud and Smit, 2010). This new approach places people and communities in the center of climate-impact studies. It operates with many more parameters of change, both physical and socio-cultural, and it puts much greater emphasis on what may be seen as *future* risks, sensitivities and adaptive strategies, as the current adaptation mechanisms are researched and understood.

The multiple perspectives approach developed during IPY requires that each process or phenomena should be viewed from many different perspectives (e.g. those of different disciplines or 'stakeholders') and that putting them together increases our power of understanding. In social sciences this approach is widely associated with the use of knowledge and perspectives of local people, but it is broader than that, since the objects to which the paradigm of 'multiple perspectives' may be applied range across many disciplines. The sea ice, for example, is viewed differently by ice scientists, climate modelers, oceanographers, local subsistence users and anthropologists who study ice-using cultures (Krupnik et al., 2010). Each group can learn from knowing other perspectives and the common resulting knowledge is more than the sum of its individual parts. The goal is to 'broaden the table,' which was one of the purposes of this IPY, and IPY research has successfully changed the dynamics in the relationship and status of data and knowledge used by various groups of polar stakeholders.

Concluding Remarks

IPY 2007–2008 led to a greatly enhanced polar research effort and a general spike in public attention to the Earth's polar regions for almost a full decade. During the formal two-year duration of IPY, the direct funding for polar science, excluding logistics and other support costs, increased by at least 30%. More importantly, the new collaborations formed between research groups, between nations and across disciplines enabling much larger and more integrated polar research challenges to be tackled by IPY projects than would otherwise have been feasible (Bell et al., 2010b). Research cooperation, shared logistics and the support from national space agencies in targeting optimized polar coverage during IPY enabled polar data to be collected systematically over larger geographic areas. IPY 2007–2008 brought in nations and scientists that had not previously worked in the Arctic or Antarctic (*Chapter 5.3*); new techniques, technologies and enhanced data sharing; and improved appreciation from policy makers and the public of the importance to the global community of supporting research in polar regions.

The IPY science outcomes presented in this overview are partial and preliminary. Detailed scientific results and insights can be expected to flow from IPY data and initiatives for the next decade or so. The scope and scale of IPY projects indicate the broad achievements already made against the planned IPY objectives. Nonetheless, more than fifty years after IGY 1957–1958, there remain hidden science frontiers that are in, or can be observed from the polar regions. Revealing these requires increasingly sophisticated planning and technology, and adequate lead time. In IPY 2007–2008, there was relatively little time between formulation of the program vision and initiation of field activities. A lesson for the next IPY organizers is that the most technologically challenging projects would benefit from greater lead time than was available for IPY 2007–2008. It is expected that some of the more important scientific advances that will emerge from IPY 2007–2008 will only result from synthesis of results and data across disciplines and projects. As was the case after IGY 1957–1958, it will probably take at least several years. More immediate scientific legacies of IPY 2007–2008 will be the ongoing measurements from new polar observational systems initiated during IPY (*Part 3*).

IPY 2007–2008 has also contributed to the improvement in the polar data management by advancing the progress in policy and philosophy beyond technical progress, an important issue that will have major impact in the future of polar research. New polar research directions and initiatives will undoubtedly arise that are guided by data and results from the many projects undertaken between March 2007 and March 2009 (and beyond). Future polar science will also benefit from IPY efforts to establish new links between scientists and between scientific organizations, as well as to develop the next generation of polar researchers.

We confidently expect that polar research institutions like the International Arctic Science Committee (IASC) and the Scientific Committee on Antarctic Research (SCAR) will strive to ensure the success of the IPY legacy especially in terms of the further development of multinational interdisciplinary science programmes on scales larger than individual nations can manage; the nurturing and enhancement of observing systems to underpin science requirements and operational needs; the sharing of polar data to enhance its value (on the principle of "capture once, use many times"); and the nurturing of the pool of talent available to ensure that the best science gets done with the resources available. It is also expected that the Arctic Council and the Antarctic Treaty Parties will continue to support SCAR and IASC in these endeavors (*Chapter 5.5*). Political will and national funding are essential aids to scientific success in support of societal needs.

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Notes

[1] All paper abstracts from the Oslo IPY Conference (June 2010) are available on the conference website http://ipy-osc.no/osc_programme. They may be searched and accessed by titles, their authors' last names and/or key words in the titles.

5.2 Broadening the Cross-Disciplinary Impact of IPY Research

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Cross-disciplinary collaboration, synthesis and integration

The science scope of this IPY was remarkably different from that of its predecessors and other large-scale science programs in polar research. Dedicated efforts were made to include cross-disciplinary studies and projects exploring the human dimension, ecological diversity, and community and ecosystem health. For the first time in an IPY–IGY setting, physical, natural, social and humanistic scientists and local community-based experts worked together under a common multidisciplinary science programme. This new form of cross-disciplinary collaboration is widely perceived as a lasting achievement of IPY 2007–2008. It marks an extraordinary advance in our perception of the complexities of the polar regions and of the importance of synthesis, knowledge integration and data sharing in the understanding of processes that affect our planet.

(The State of Polar Research, 2009, p. 9)

As impressive a venture as IPY 2007–2008 has been, with more than 228 international projects engaging some 50,000 scientists from 60 nations, it was not the *only* major polar science initiative between 2004 and 2010. Nor did IPY introduce the template of a 'mega-program' involving experts from many disciplines and funding from several nations. Some of those 'mega-programs' started prior to the main thrust for IPY 2007–2008 and were completed and published in parallel with the emerging IPY network. *Arctic Climate Impact Assessment* report (ACIA, 2005), *Arctic Human Development Report* (AHDR, 2004) and *Arctic Research: A Global Responsibility* (ICARP II, 2005) are among the few examples from those years. In other cases, national operators decided to re-label as 'IPY' what they would likely have been doing anyway. Although in development independently and prior to IPY, these programs experienced their full advancement during the IPY years and were taken by their originators as contributions to the goals of IPY 2007–2008 and its science program. Arctic Human Health Initiative (AHHI, IPY no. 167 – *Chapter 2.11*), U.S. *Study of Environmental Arctic Change* (SEARCH) and its international version, *International Study of Arctic Change* (ISAC, IPY no. 48), *Developing Arctic Modeling and Observing Capabilities* (DAMOCLES, IPY no. 40), *Arctic Social Indicators* (ASI – IPY no. 462), ArcticNet - Network of Centres of Excellence of Canada and several others are good examples of such major multi-disciplinary programs that became the building blocks of IPY.

In yet other instances, new research was indeed started due to the IPY-triggered 'pulse' and funded with the new money generated under IPY. For example, the development of the Arctic Ocean and Southern Ocean Observing Systems (*Chapters 3.2 and 3.3*) was a topic of ongoing concern for several years and the preparation for both had already been started. The arrival of IPY added the needed urgency to the process; it enabled many groups and scientists to develop their ideas as IPY proposals, which helped bring the wider community together and get things moving faster. Having the IPY label was a great boost for many science programs that would or might have happened anyway. As IPY illustrated, it makes a difference when you can see that what you are doing will contribute to a much larger global effort. For example, the five major new science programs approved by SCAR in 2004 all submitted major IPY proposals that, once approved by the JC and awarded their IPY project numbers, constituted special two-year observing periods within their longer-lived programs. These major SCAR programs were: Subglacial Lake Exploration (IPY no. 42); Antarctic Climate Evolution (no. 54); Interhemispheric Conjugacy Effects in Solar-Terrestrial and Aeronomy Research (ICESTAR no. 63); Antarctic in the Global Climate System (no. 180); and the Evolution and Biodiversity in the Antarctic program (EBA no. 137). Other ongoing SCAR programs with special observing periods as IPY programs included, the Census of Antarctic Marine Life (CAML no. 53); the Marine Biodiversity Network (MarBIN no. 83); the SCAR-WCRP Cryosphere Observing System program (no. 105); and the SCAR Antarctic Sea Ice Processes and Climate program (no. 141).

There were also several initiatives that were not formally submitted to the IPY process and thus have not been reviewed and endorsed by the Joint Committee in 2005–2006 based upon the 'IPY criteria,' such as inter-disciplinarity, international team, data-management policy, and education and outreach program (*Chapter 1.5*). Nonetheless, their ties to IPY 2007–2008 are indisputable and are proudly acknowledged by the organizers. These programs also influenced the overall IPY development and planning process and its approach to the extent that they may be decisively named 'IPY-era projects.'

This chapter highlights three of many of the initiatives of the past decade that bear the hallmark of what may be called the 'IPY science.' The first is the SCAR's *Antarctic Climate Change and the Environment* (ACCE) review, which was developed following the model of the Arctic Climate Impact Assessment (ACIA) published in full in 2005. The ACCE review was initiated in 2005 and was designed to produce a balance from the south (Antarctic) to the northern (Arctic) review. Since its work was carried out during the IPY years, the ACCE review was always seen by its originators as a designated contribution to IPY 2007–2008. The work was sped up in comparison to what would have happened without IPY; an element of urgency was added by the advent of IPY.

The second illustration, the *Snow, Water, Ice, Permafrost in the Arctic* (SWIPA) project, initiated by the Arctic Council, also developed during the IPY years, but would have followed the *ACIA* Report of 2005 for obvious reasons. Climate change and shifts in many environmental parameters in the polar regions have been advancing with such an alarming speed that periodic updates are urgently needed, as in the IPCC process. Again, the IPY momentum contributed that element of urgency. Another factor of IPY 'nature,' was the focus on the impacts those changes are having upon local stakeholders, particularly upon Arctic residents and indigenous people.

The third project featured here as an example of 'IPY-influenced science,' *Sea Ice for Walrus Outlook* (SIWO), was launched after the IPY main observational period. It grew 'on the shoulders' of several IPY 2007–2008 activities, like *Sea Ice Outlook* (*Chapter 3.6*) and SIKU and SIZONet projects (*Chapter 3.10*), but even more so, it sprung up from the new spirit of collaboration among scientists from different fields and polar residents promoted by IPY. Though SIWO is a pilot initiative with a limited time frame and with a particular regional scope, it perfectly illustrates many of the same influences that IPY science is already having over dozens of new polar initiatives, large and small.

Antarctic Climate Change and the Environment (ACCE) – A SCAR contribution to IPY 2007–2008

Colin Summerhayes

One of the key requirements of IPY 2007–2008 was to assess the state of the polar environments. In the case of the Arctic, this had to a large extent been done immediately before IPY in the "Arctic Climate Impact Assessment" (ACIA), produced by the Arctic Council and the International Arctic Science Committee (IASC), and published by Cambridge University Press in 2005 (www.acia.uaf.edu/pages/scientific.html). In July 2005, the SCAR Executive Committee, meeting in Sofia, Bulgaria agreed that a companion volume on Antarctic climate change should be produced for the guidance of policy makers in the Antarctic Treaty System and to inform the public. The ACCE review was designated by SCAR as a contribution to IPY 2007–2008 (www.scar.org/publications/occasionals/

acce.html).

The plan for the review was fleshed out at the first SCAR Cross-Linkages Workshop in Amsterdam (15-17 November, 2005). Initial results were presented to policy-makers at the Antarctic Treaty Consultative Meeting (ATCM) in New Delhi (30 April to 11 May 2007) (www.scar.org/treaty/atcmxxx/Atcm30_ip005_e.pdf) and published in 2009 (Mayewski et al., 2009). Phase II incorporated biology and chemistry. Preliminary results were presented to the ATCM in Kiev (2-13 June 2008) (www.scar.org/treaty/atcmxxxi/ATCM31_IP62_ACCE.pdf) with final results being delivered to ATCM in Baltimore (6-17 April 2009) (www.scar.org/treaty/atcmxxxii/Atcm32_ip005_e.pdf). The completed ACCE book (Turner et al., 2009 Fig. 5.2-1) was printed in October 2009 and copied to national delegations to the 15th Conference of the Parties to the UN Framework Convention on Climate Change (UNFCCC) meeting in Copenhagen in December. Talks on ACCE were given during the UNFCCC meeting and a summary paper was published in *Antarctic Science* in December 2009.

The ACCE review contributes to the goals of the World Climate Research Programme (WCRP) and, in particular, to its Climate and Cryosphere programme (CliC) of which SCAR is a co-sponsor. It will be copied to the Intergovernmental Panel on Climate Change.

The report of 560 pages has 100 authors from 13 countries; it was reviewed by around 200 scientists and was edited by a team of nine led by John Turner of the British Antarctic Survey. It is available on the SCAR web site so as to encourage its widespread use as a research and teaching resource (www.scar.org/publications/occasionals/acce.html). The volume is an eventual outcome of the work begun by the SCAR Group of Specialists on Antarctic Climate Research, which was formed in 1980 to plan the Antarctic contribution to the WCRP (then about to be formed) (Allison, 1983) and SCAR Steering Committee for the newly formed International Geosphere-Biosphere Program (IGBP) (SCAR, 1989, 1992).

The ACCE volume provides a comprehensive, up-to-date account of how the physical and biological environment of the Antarctic continent and Southern Ocean has changed over the past 100 million years or so until the present day, and how that environment may change over the next century in a warming world.

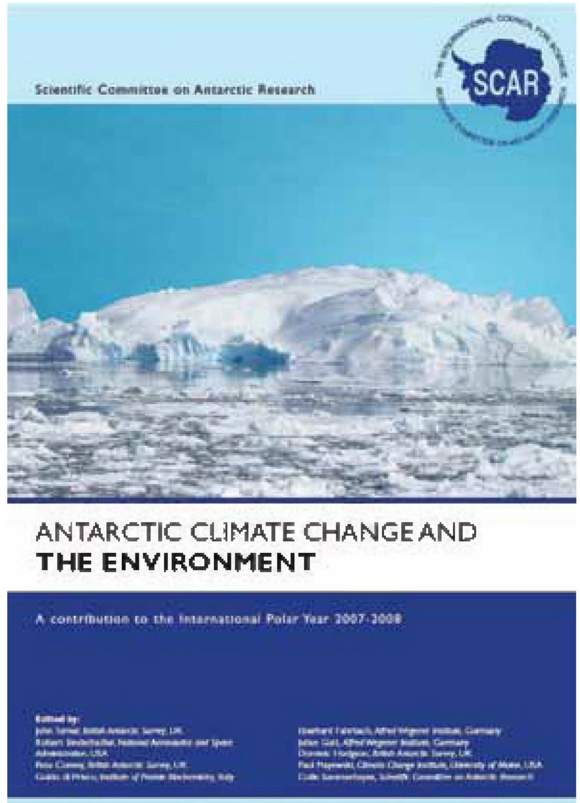

Fig.5.2-1. Antarctic Climate Change and the Environment (2009) – SCAR contribution to IPY 2007 –2008 science program.

Climate Change and the Cryosphere: Snow, Water, Ice and Permafrost in the Arctic (SWIPA)

Morten Skovgård Olsen, Lars-Otto Reiersen, and Volker Rachold

"Climate Change and the Cryosphere: Snow, Water, Ice and Permafrost in the Arctic (SWIPA)" is one of the key assessment projects of the Arctic Council that was designed, approved and advanced during the IPY 2007–2008 era.

At their 5th meeting in Salekhard in October 2006, the Arctic Council Ministers urged Arctic Council working groups to continue supporting, analyzing and synthesizing Arctic climate research, particularly in the follow-up to the *Arctic Climate Impact Assessment* (ACIA, 2005) and the ACIA Policy Document. It was suggested that the Arctic Monitoring and Assessment Program (AMAP), in cooperation with other AC working groups and relevant scientific bodies, would continue to review needs and gaps in climate monitoring in the Arctic. The *Salekhard Declaration,* which also endorsed

IPY 2007–2008 (*Chapter 5.5*), requested that the AC Working Groups continue their collaboration with relevant IPY projects so that data and information from IPY 2007–2008 could be included in the work of the Arctic Council.

A joint statement by Norway, Denmark and Sweden at the Salekhard Meeting concerning their common objectives for the period of their respective chairmanships of the Arctic Council (2006-2012 – see http://arctic-council.org/article/2007/11/common_priorities) expressed strong commitment to "continuing to follow up on the findings of the ACIA report" with an emphasis on the Arctic Council efforts to provide high quality information on climate change, particularly on the consequences and challenges posed by climate change in the Arctic to the member states and the Arctic residents. During its Chairmanship of the Council (2006-2009) Norway proposed a concept for an Arctic 'Cryosphere Project' to the Senior Arctic Officials (SAO) meeting in April 2007. The *Climate Change and the Cryosphere: Snow, Water, Ice, and Permafrost in the Arctic (SWIPA)* was formally approved by SAOs at their meeting in Svolvær, Norway in April 2008 and was officially named an "Arctic Council 'Cryosphere Project' in Cooperation with IASC, CliC and IPY."

As stated in the preamble to the preliminary SWIPA Overview Document (SWIPA, 2009)"… The International Polar Year (IPY) represents a considerable basis for accelerated progress in understanding. The proposed SWIPA reports provide an opportunity to synthesize new information from the IPY and provide a bridge between the IPY, Arctic Council and future IPCC activity. Strong coordination between the *Climate Change and Cryosphere Project* and the IPY, and other ongoing relevant national and international activities, is central to the *Climate Change and Cryosphere Project* concept."

The SWIPA project is being coordinated by the Arctic Monitoring and Assessment Programme

Fig.5.2-2. Cover image of the SWIPA Project (from SWIPA brochure - www.amap.no/swipa/).

(AMAP), a program working group of the Arctic Council in cooperation with the International Arctic Science Committee (IASC), the World Climate Research Programme/Climate and Cryosphere Project (WCRP/CliC), the International Polar Year International Programme Office (IPY IPO) and the International Arctic Social Sciences Association (IASSA) – see Fig. 5.2-2. The project brings together Arctic scientists from a broad range of disciplines in order to compile and evaluate information from Arctic monitoring networks and recent international research activities, such as those carried out during IPY 2007–2008 to better quantify and understand the recent changes to the cryosphere and their impacts since 2005 (i.e. the year when the ACIA report was published).

Overall coordination of the project is conducted by the SWIPA Integration Team (IT), composed of authors and representatives of the sponsoring organizations (i.e. AMAP, IASC, WCRP/CliC, IASSA and IPY IPO). The AMAP Secretariat serves as the secretariat for SWIPA, convening meetings and organizing the overall activities. The SWIPA implementation plan, the draft table of contents and timetable are available at the SWIPA website at www.amap.no/swipa.

SWIPA will produce a number of reports and other products over the course of its lifetime (2008–2011). Its first report, *The Greenland Ice Sheet in a Changing Climate* (Dahl-Jensen et al., 2009, Fig. 5.2-3), together with two short films, was introduced as the Arctic Council's contribution to the 15th Conference of Parties (COP15) under the UN Framework Convention on Climate Change (UNFCCC), in December 2009 in Copenhagen (*Chapter 2.4*).

The final SWIPA science report will be presented to the Arctic Council in spring 2011 and will serve as an Arctic contribution to the Fifth Assessment Report of the UN Intergovernmental Panel on Climate Change (IPCC), scheduled for completion in 2013–2014. The SWIPA report is subject to a thorough scientific peer review, as well as a national review by Arctic countries prior to publication. The final structure of the main SWIPA Report, which is going to be a document of approximately 500 pages (Fig. 5.2-4) was defined at the SWIPA Cross-Fertilization Workshop held in Potsdam, Germany on 12-15 January 2010.

An approximately 50-page summary report in layman language containing the key findings of the SWIPA project and recommendations based on the science report will be written by a science writer in close cooperation with the lead authors of the SWIPA report, the SWIPA IT and the AMAP working group; one or more films conveying the messages of SWIPA are also foreseen. The summary report and the film(s) will also be released at the time of the Arctic Council ministerial meeting .

The SWIPA Project is being conducted according to three main Arctic cryosphere components: sea ice, the Greenland Ice Sheet and the terrestrial cryosphere, composed of snow, permafrost, mountain glaciers and ice caps, and lake and river ice. In addition to assessing the physical and environmental changes occurring in the cryosphere, the project considers the consequences of such changes on the socio-economics, culture and lifestyles of Arctic residents, including indigenous peoples, as well as some global implications. The most critical is the last section of the report called 'Integrated synthesis.' It will be prepared by a special team of several SWIPA scientists, according to their fields of expertise. This is a clear projection of the template developed and advanced during IPY 2007–2008, with increased focus on cross-disciplinary

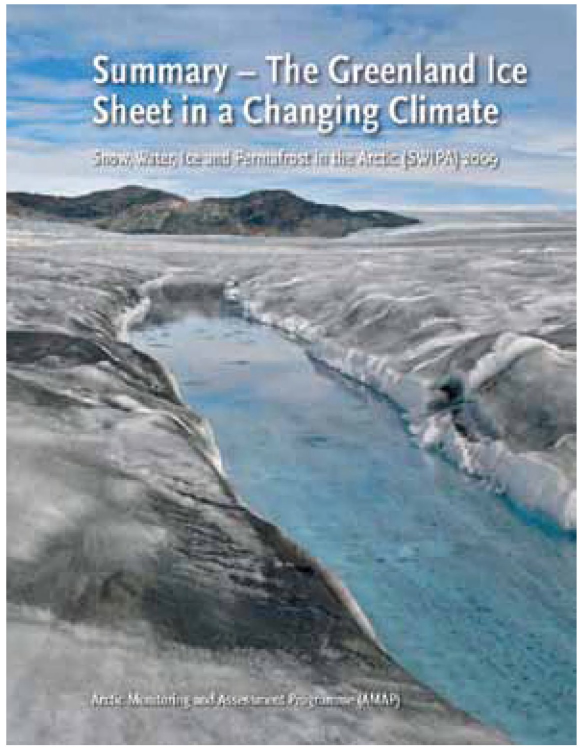

Fig.5.2-3. The Greenland Ice-Sheet in a Changing Climate (GRIS) report, 2009.

collaboration, science integration and appeal to local stakeholders, including polar indigenous people. Also, several among these lead authors have been heading individual IPY project teams and during the preparation of the SWIPA, major effort have been devoted to track down and ensure the inclusion of IPY projects relevant to the project.

The preliminary findings of the SWIPA Project, as well as of many IPY 2007–2008 teams, demonstrate that all of the components of the Arctic cryosphere have changed dramatically over the past decade (2000–2010). These changes have multiple (and yet poorly known) feedback and cascading effects. This rapidly changing polar environment affects people in the Arctic and beyond. Understanding the results of these interactions is a major scientific challenge and a key SWIPA activity. Some of the many topics and questions under study in the SWIPA are:

- What will be the effects of cryospheric change on individuals, communities and regions in the Arctic, and how will those effects vary by location and economic sector?
- What will be the effects for global society from rising sea level and increasing climate change resulting from a changing Arctic cryosphere?
- Given that many changes under way will not easily be halted or reversed, what adaptations are possible in the Arctic and beyond?
- How will the increased flow of freshwater from the melting of the Greenland Ice Sheet, mountain glaciers and small ice caps in the Arctic influence ocean circulation, marine food webs and the people who depend on them?
- What is the total effect of cryosphere changes on climate through changes in reflection of solar energy, release of greenhouse gases and other feedbacks?
- What additional monitoring and observations are needed around the Arctic to better track cryospheric change and its many implications?
- Given that many changes under way will not easily be halted or reversed, what adaptations are possible in the Arctic and beyond?

The findings of the SWIPA project will be disseminated via many scientific and public channels during 2010–2011 and will be available in full by the time of the next major (post) IPY 2007–2008 Conference in Montreal in April 2012. Information on SWIPA and its products may be found on www.AMAP.no/swipa .

Figure 1: Structure of the SWIPA Science Report.

Fig.5.2-4. Proposed structure of the main SWIPA science report (as of January 2010).

Sea Ice for Walrus Outloook (SIWO)

Hajo Eicken, Gary Hufford, Vera Metcalf, Sue Moore, James Overland and Helen Wiggins

Reviewers: Igor Krupnik and G. Carleton Ray

The 'Sea Ice for Walrus Outlook' (SIWO), an activity growing out of the SEARCH IPY *Sea Ice Outlook* project (*Chapter 3.6*), is a new web-based resource for Alaska Native subsistence hunters, coastal communities and other stakeholders interested in sea ice dynamics and walrus subsistence hunting and management in the Bering and Chukchi Seas. Though chronologically launched after the official completion of the IPY observational period in March 2009, the SIWO descends from two IPY projects, Sea Ice Knowledge and Use (*SIKU* no. 166 – *Chapter 3.10*) and *Seasonal Ice Zone Network (SIZONet)* sponsored by the U.S. National Science Foundation's IPY program. Most importantly, it builds upon many years of partnership among sea ice and walrus scientists, subsistence users, local indigenous communities, weather forecasting and game protection agencies, anthropologists and heritage documentation specialists (Eicken et al., 2009; Oozeva et al., 2004; Krupnik and Ray, 2007; Metcalf and Krupnik, 2003; Ray and Hufford, 1989).

The SIWO project was formally discussed with representatives from Bering Straits communities for the first time in January 2010 at a meeting supported by the Eskimo Walrus Commission in Nome, Alaska (www.kawerak.org/servicedivisions/nrd/ewc/index.html) and the National Science Foundation. The template and the plan of work were quickly developed and the first weekly sea ice and walrus distribution assessment went online on the newly launched SIWO website on 2 April 2010.

The SIWO is a pilot initiative (2010–2011) aiming to develop consumer-focused ice- and weather-forecasting capabilities that address practical needs of hunters in Alaskan indigenous communities as well as game managers and marine biologists. For the first time, it created a formal alliance among the U.S. National Oceanic and Atmospheric Administration; the National Weather Service, the University of Alaska Fairbanks; the National Science Foundation and its SEARCH program, which generated the *Sea Ice Outlook* initiative (*Chapter 3.6*); the Arctic Research Consortium of the United States, which administers the SIWO website; and the Eskimo Walrus Commission, an organization of 19 indigenous communities in Western and Northern Alaska.

The SIWO produces improved local weather forecasts and detailed assessments of local sea ice conditions relevant to walrus distribution and migration in the Northern Bering Sea and southern Chukchi Sea region adjacent to northwestern Alaska and northeastern Russia (Chukchi Peninsula). SIWO updates have been released weekly for the period

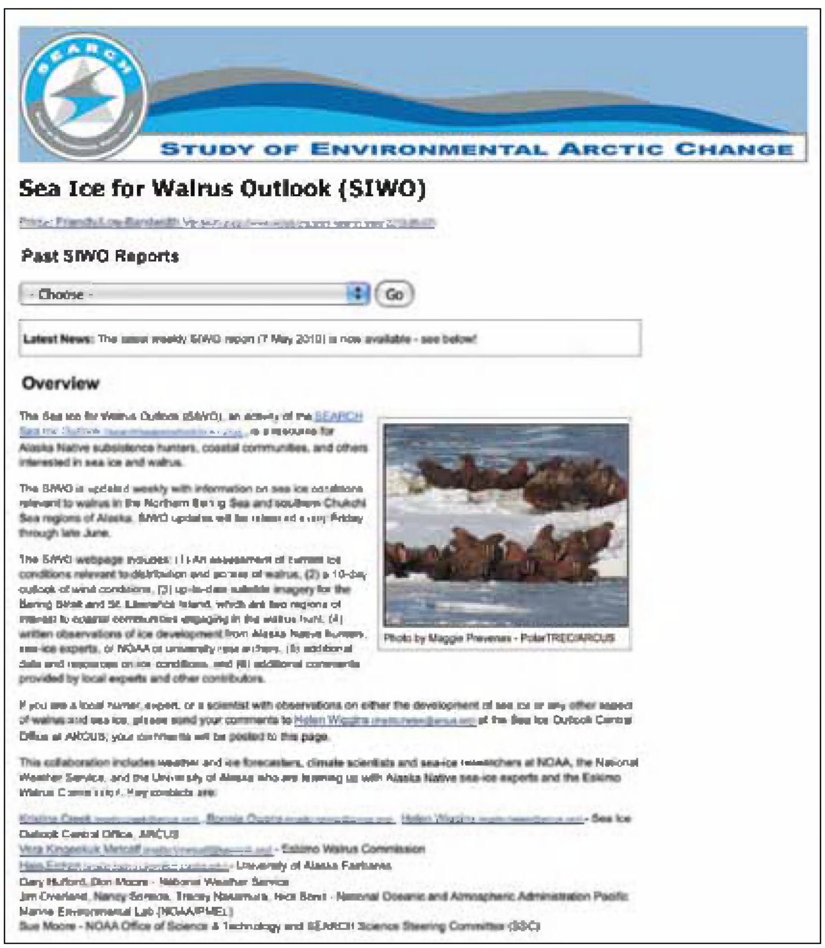

Fig.5.2-5. Opening page of SIWO service website www.arcus.org/search/siwo/.

from April 2010 through mid-June 2010. This period was selected to match the interest of local Alaskan stakeholders who hunt walrus primarily during the peak of the spring migration during break-up and northward retreat of ice in the Bering and Chukchi Seas (Metcalf and Robards, 2008).

Each weekly analysis on the SIWO webpage (www.arcus.org/search/siwo - see Fig. 5.2-5) included: (1) an assessment of the current ice conditions relevant to distribution and access to walrus, (2) a 10-day outlook of wind conditions (speed and direction), (3) up-to-date satellite imagery for the Bering Strait and St. Lawrence Island, which are two regions of the most interest to coastal indigenous communities engaging in the walrus hunt (Fig. 5.2-6), (4) written observations of ice development from Alaska Native hunters, sea-ice experts, NOAA/NWS and university researchers, (5) additional data and resources on ice conditions, and (6) additional comments provided by local experts and other contributors, local hunters and academic specialists alike. Indigenous observers from four Alaskan communities, Wales, Shishmaref, Gambell and Nome are contributing to the assessments, together with scientists and observers on ships at sea, at the Alaska NWS headquarters in Anchorage and at the University of Alaska Fairbanks, who are using satellite imagery, coastal radars and airborne observations.

A key aim of the SIWO activities is to improve research and operational products for assessment and forecasting of weather and ice conditions in Arctic coastal environments. Thus the NWS, in collaboration with the National Center for Environmental Prediction (NCEP), is generating high-resolution long-term weather forecasts (requiring dedicated model runs) for the region. Feedback from local experts on the accuracy and relevance of this product in turn can help improve model performance. Here, input by local partners, like Winton Weyapuk Jr. in Wales, Paul Apangalook and Merle Apassingok in Gambell, who provided updates on ice conditions and deployed supplemental drift sensors proved of critical importance. Similarly, remote sensing products, such as high-resolution visible-range imagery and synthetic aperture radar (SAR) scenes, are interpreted and discussed by both sea-ice geophysicists and local hunters. Both the type of imagery provided and the mode of delivery have been modified from original plans based on comments and input from coastal communities. For example, the Alaska Satellite Facility (ASF) was able to provide short-term access to high-resolution, weather-independent

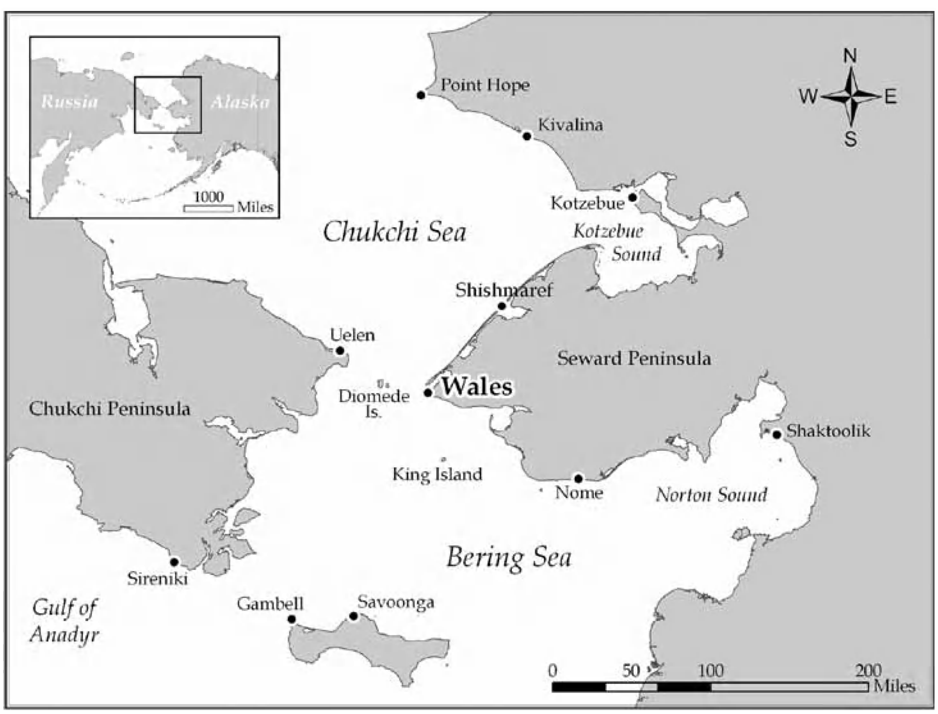

Fig.5.2-6. Area covered by the SIWO pilot initiative in the northern Bering Sea and southern Chukchi Sea (from SIWO website www.arcus.org/search/siwo/).

SAR imagery provided by a Japanese satellite down-linked at ASF in Fairbanks.

A project such as SIWO also requires retrospective analysis to ensure that both scientific findings, e.g. with respect to downscaling of model output and remote sensing data to the local scale and assessment of operational products, lead to significant progress. Such activities benefit greatly from having the SIWO partnership embedded in a larger, U.S. interagency program (SEARCH), which can draw on broader expertise and resources from the scientific community, government agencies and local organizations. Support from outside experts, such as Carleton Ray and Igor Krupnik, who have provided critical input and support to this effort, also help ensure that such local or regional activities can be translated to a larger pan-Arctic scale.

Though designed as a small pilot project, SIWO carries on the legacy of IPY 2007–2008 in terms of making polar research relevant and valuable to the growing number of local stakeholders. It solidifies partnerships across science disciplines (ocean and ice studies, atmospheric science, marine biology, anthropology and subsistence research) and between scientists and indigenous organizations that were forged during the IPY era. SIWO may eventually become a prototype of a much broader observational service network that would incorporate indigenous ice and weather observations into the existing agency-supported weather and ice monitoring and forecasting. Such integration could significantly augment and improve the design and implementation of an Arctic observing system from broad to local spatial and temporal scales (Eicken et al., in press). If such incorporation occurs, what started as pilot efforts by a few IPY 2007–2008 projects may eventually become a permanent fixture of the agency-run polar 'services' for years and decades ahead.

Conclusion

The impact of IPY in polar science was several-fold. It encouraged the submission of new research programs from the wider community and the merger of many smaller projects with larger ones, so as to make them more interdisciplinary and increase their potential impact. It triggered new and growing efforts within SCAR and IASC to submit aspects of their work as IPY projects and the speeding up of programs in the works, like ACCE and SWIPA. It led to the development of programs that had been called for in the IPY planning documents, but not submitted by the research community (e.g. SCAR developed the SOOS proposal outside the formal IPY structure when it was clear that no research proposal had addressed this need). Lastly, it encouraged the re-labeling of some planned work by the national operational agencies as IPY. All of these efforts contributed to the mass of outputs begun or delivered during the IPY years. In that respect, IPY was a great catalyst for action, adding urgency and impetus to activities that might otherwise never have begun or would have been much delayed in execution.

There was also a definite impact of the IPY process, in terms of planning, language and ideology on many other initiatives of the 'IPY era.' Firstly, IPY 2007–2008 solidified the transition to more *societal-relevant* science and pushed polar research to be more attuned to the needs and interests of multiple stakeholders, such as polar residents, policy-makers, environmental groups, science educators and the like. Secondly, IPY embedded a new format of polar research with a much broader ('across-the-range') spectrum of disciplines than had been common for earlier multidisciplinary studies and infused more input from social sciences and local knowledge of polar residents, at least in the Arctic. That transition is obvious for ISAC, SAON, DAMOCLES and other primarily physical research and observational initiatives in IPY, but it generated similar transitions in many other IPY-era programs. Several teams are known to have altered their work plans to make them adhere more overtly to the IPY goals in order to contribute to the IPY outcomes, or even to be seen to be doing so.

These activities, like ACCE, SWIPA, SIWO (reviewed here) and others of their ilk can all be viewed as IPY-adopted or IPY-inspired. The contribution of such 'IPY-inspired' projects to achieving the goals of IPY has been considerable. They all advance the same interdisciplinary approach that addresses status and change in the polar regions and that explores societal and ecosystem impacts of the geophysical processes, so fitted very well with the ethos of IPY.

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5.3 Engaging Asian Nations in IPY: Asian Forum for Polar Sciences (AFoPS)

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One of the principal aims of IPY 2007–2008 was to engage worldwide resources to create a pulse of activities focused on the polar regions. The IPY early planning document (Rapley et al., 2004) was completed during 2004 by a group of experts drawn from all regions of the world, including Asia,[1] and it underscored the importance of including in IPY "nations not traditionally involved in polar research." Recognizing the importance of international cooperation, aiming to serve the common interests between Asian countries in polar sciences, and anticipating the coming IPY, the *Asian Forum for Polar Sciences* (AFoPS) was established in September 2004. Its main declared objectives were to provide a foundation for cooperative research activities, to present Asian achievements to the international polar communities and to encourage Asian countries' involvement in polar research.

Participation of the Asian nations in international polar programs goes back to the early 1900s (for Japan) and to IPY-2, in which China, India, Indonesia, Japan, the Philippines, Syria and Turkey took part (*Chapter 1.1, Box 3*).[2] Fifteen Asian nations—Burma, Ceylon, Republic of China (Taipei), India, Indonesia, Iran, Israel, Japan, Republic of Korea, Malaya, Mongolia, Philippines, Thailand, and both the Republic of Vietnam (South Vietnam) and Democratic Republic of Vietnam (North Vietnam) participated in IGY 1957–1958 (*Chapter 1.1, Box 4*), though, primarily via conducting geophysical and meteorological observations on their national territories. Japan maintained active research program in Antarctica since 1957 and was one of the 12 original signatories of the Antarctic Treaty in 1959. Four other Asian nations joined the Antarctic Treaty as Consultative Parties – China (PRC, in 1983), India (1983), Republic of Korea (1986), Democratic People's Republic of Korea (North Korea, 1987); and Turkey is the Acceding State (since 1996). China, India, Japan, Republic of Korea and Malaysia are also Full Members of SCAR and Pakistan is its Associate Member.

The role of the Asian nations in polar research has increased dramatically over the past decades, due to their economic, political and scientific power. Among 63 nations with scientists involved in IPY 2007–2008, 14 countries (China, India, Indonesia, Israel, Japan, Kazakhstan, Kyrgyzstan, Malaysia, Mongolia, Philippines, Republic of Korea, Turkey, Uzbekistan and Vietnam) are within the Asian region. Five of them—China, India, Japan, Malaysia and Republic of Korea—established their national IPY committees and set national IPY programs (*Appendix 7*). This chapter reviews the contribution by those five nations to the IPY 2007–2008 activities and to international collaboration in polar research.

Demand for practical cooperation among Asian nations in polar science and logistics has been ever increasing. China, Japan and the Republic of Korea, which are the Asian members of the Council of Managers of National Antarctic Programs (COMNAP), had informal communication on this matter for years. At the COMNAP Meeting in Brest in 2003, Korea and Japan agreed to establish a regional 'East Asian group' and China agreed to join by on-line communication.

Directors of the national polar research institutes from China, Japan and Korea held their first joint meeting in Shanghai on 25 May, 2004 to build the framework of AFoPS. At the second AFoPS Meeting on 10 September, 2004 in Jeju Island, Korea, the organization was officially inaugurated, with its Secretariat currently located at the National Institute for Polar Research in Tokyo, Japan. At the 3rd AFoPS meeting in Kunming, China (April 2005), India and Malaysia joined the organization (www.AFoPS.org).

The period of IPY, March 2007 to March 2009, was a time of significant scientific accomplishment in polar science by the AFoPS countries. Even more, this period marked new international involvement in science by the Asian nations and scientists. Many Asian countries increased their participation in international polar science or policy organizations, such as SCAR, IASC (in which Japan has membership since 1991, China since 1996 and Korea since 2001); the Pacific Arctic Group that now includes institutions and scientists from China, Japan and Korea (www.pagscience.org/), and the Arctic Council, to which China, Japan, and the Republic of Korea have applied for an observer status.[3] Interest by Asian nations in the Arctic Council is particularly noteworthy as this is the only intergovernmental group focused on the Arctic. The involvement in the Council by non-Arctic countries, especially Asian countries with no Arctic tradition, speaks loudly to the perceived role of the Arctic in many global issues such as climate change, maritime transportation, tourism and resource exploitation. Antarctic science also accelerated in Asia during IPY 2007–2008 with new stations and new programs launched by several Asian nations.

China

Antarctic Activities (Summary by John Calder). China has been a major player in polar research for the past 30 years. The Chinese Antarctic Administration (since renamed Arctic and Antarctic Administration) of the State Antarctic Research Committee, a Beijing-based agency of the PRC State Oceanic Administration, was established in 1981. Chinese scientists first participated in Antarctic research with Australian expeditions in the austral summer of 1980–81 and over the following winter. Over the next several years Chinese scientists continued collaboration in Antarctic research with other nations. China established the first of two year-round research stations in Antarctica (Great Wall Station on King George Island) in February 1985, and the second (Zhongshan in East Antarctica) was opened in February 1989. China also has a research station in Svalbard in the Arctic (Yellow River Station).

In 2006, just one year before the launch of IPY, the Chinese government significantly boosted its commitment to polar science by allocating additional $70 million in funding to the Polar Research Institute of China and the Chinese Arctic and Antarctic Administration: a spectacular figure by any international measure.

From this investment, some $4 million was earmarked to directly boost scientific research funding during IPY; $25 million was spent on the renovation of China's polar research and logistics vessel, the *Xuelong* (Snow Dragon); $19 million was spent on refurbishing and expanding facilities of the Polar Research Institute of China in Shanghai; and $22 million was earmarked to modernize the Great Wall and Zhongshan stations in Antarctica. This boost in funding strengthened the platforms from which China has and will launch a series of highly ambitious polar research campaigns and international collaborations. First among these the so-called PANDA project (The Prydz Bay, Amery Ice Shelf and Dome A Observatories, IPY no. 313), the Chinese key international program for IPY. It addresses questions relating to global climate change and, specifically, the role of the Lambert Glacier Basin, the largest glacier system in East Antarctica.

China and other key partners, including Australia, Japan, the U.S.A., Germany, France and the U.K., hope that PANDA will help to better understand how the East Antarctic ice sheet, the largest ice sheet in Antarctica (*Chapter 2.5*) has fluctuated in the past, and how it might respond to ongoing regional and global climatic changes. With the East Antarctic Ice Sheet estimated to contain enough ice to contribute about 50 meters to global sea level rise, it is easy to grasp the importance and relevance of this effort.

As part of the PANDA project a succession of traverses from Zhongshan Station on the coast of East Antarctica, to Dome A (Dome Argus), the highest point on the East Antarctic Ice Sheet, was conducted. Building on the experience gained during the first Zhongshan to Dome A traverse in 2004-05, these traverses supported diverse observations in glaciology, atmospheric science and physical geography, as well as deploying a series of four automatic weather stations (in collaboration with Australia) along the Zhongshan-Dome A transect. Chinese scientists conducted research on past climate and environmental change in the Grove Mountains protruding out of the East Antarctic Ice Sheet, and the Xuelong icebreaker took part in an integrated marine observation program covering the edge of the Amery ice shelf, the Prydz Bay region and the South Indian Ocean.

In addition, the Dome A region and Gamburtsev mountain range that lies beneath it under the ice sheet were surveyed by both surface and aerial methods in collaboration with the U.S.A., U.K. and Australia (*Chapter 2.5*). One aim of this survey was to find the most scientifically valuable location for future drilling of an ice core that will provide a climate record of more than one million years.

Looking beyond IPY 2007–2008, China's flagship ambition is to build a permanent station at Dome A, one of the remotest, coldest and most physically testing places on Earth. The 2007 and 2008 PANDA traverses lay the groundwork for a multi-year program set to start after 2010 and construction of the new station at Dome A, named Kunlun, commenced during IPY. Kunlun Station, formally opened in January 2009, will push back the boundaries of Antarctic science in a manner reminiscent of the most important and lasting contributions from IGY 1957–1958. The ice at Dome A is up to 3070 meters thick, and precipitation levels are estimated to be the lowest on the continent. When completed, Kunlun Station will be the jewel of China polar research program, and possibly the platform for an international drilling program set on recovering the world's oldest ice record in excess of one million years, perhaps going back to 1.2 million years.

Dome A is also thought to be the world's best location for astronomical research. Thanks to its altitude (4087 meters), the clarity of its skies, the stillness and relative thinness of its atmosphere, the absence of light pollution and the length of its polar night, Dome A will provide astronomers with the possibility to scour space with a greater clarity than anywhere else on Earth - even surpassing Dome C and the South Pole where a 10-meter telescope has been deployed in 2007. In order to seize and build on this opportunity, an autonomous astronomical site-testing observatory, called PLATO, was deployed at Dome A. The PANDA traverse successfully delivered PLATO to Dome A in January 2008. A large international team has contributed to PLATO and its instruments, with Iridium satellite communication being provided by the U.S. Antarctic Program. The instruments include a 15-centimeter telescope, operated by China, and there are plans to follow with the deployment of a 50-centimeter and even larger telescope in years and decades to come.

Arctic Activities (by Jinping Zhao). During IPY, China planned to conduct two cruises to the Arctic Ocean in 2008 and in 2009, however, the cruise in 2009 was postponed to summer 2010. The scientific focus of the 2008 cruise was Arctic change and its influence on China's climate. The cruise covered the Bering Sea, the Chukchi Sea, the Beaufort Sea and the central area of the Arctic Ocean. It enabled both Chinese and international researchers from France, Korea, Finland and Japan to study ocean-sea ice-atmosphere interactions and variations (Figs. 5.3-1 and 5.3.2). The main fieldwork was focused on the coupling variation of the air-ice-sea system, the response of the ocean to the changing ice and atmospheric condition, changes in the Arctic system, carbon and biogeochemical cycling, micro biological resources, paleooceanography and paleoclimate, influence of Arctic change on the climate of China. The data obtained on this cruise will shed light on the cause and effect relationships between global and regional Arctic changes and processes, and should provide precious insight into how climate change in the Arctic will impact China and the rest of the world.

The second Chinese Arctic cruise during IPY postponed to 2010 (1 July–23 September, 2010) was focused on the ice melting process in the Arctic. A 12-day ice station was set in the Canadian Basin to observe the physical processes related to ice melting. Another topic of the 2010 cruise was the evolution of the Arctic system. The cruise, an extension of Chinese IPY program, was launched to observe the response to rapid changes in the Arctic (see http://adsabs.harvard.edu/abs/2010AGUFM.C53B.07A).

The ongoing project at the Yellow River Station on

Fig.5.3-1. Routine CTD profiling during the Chinese Arctic cruise, 2008. The system includes CTD, rosette samplers and lowered ADCP. After CTD deployment, an 120 m profile for water optics were conducted for all daytime stations.
(Photo: Jinping Zhao)

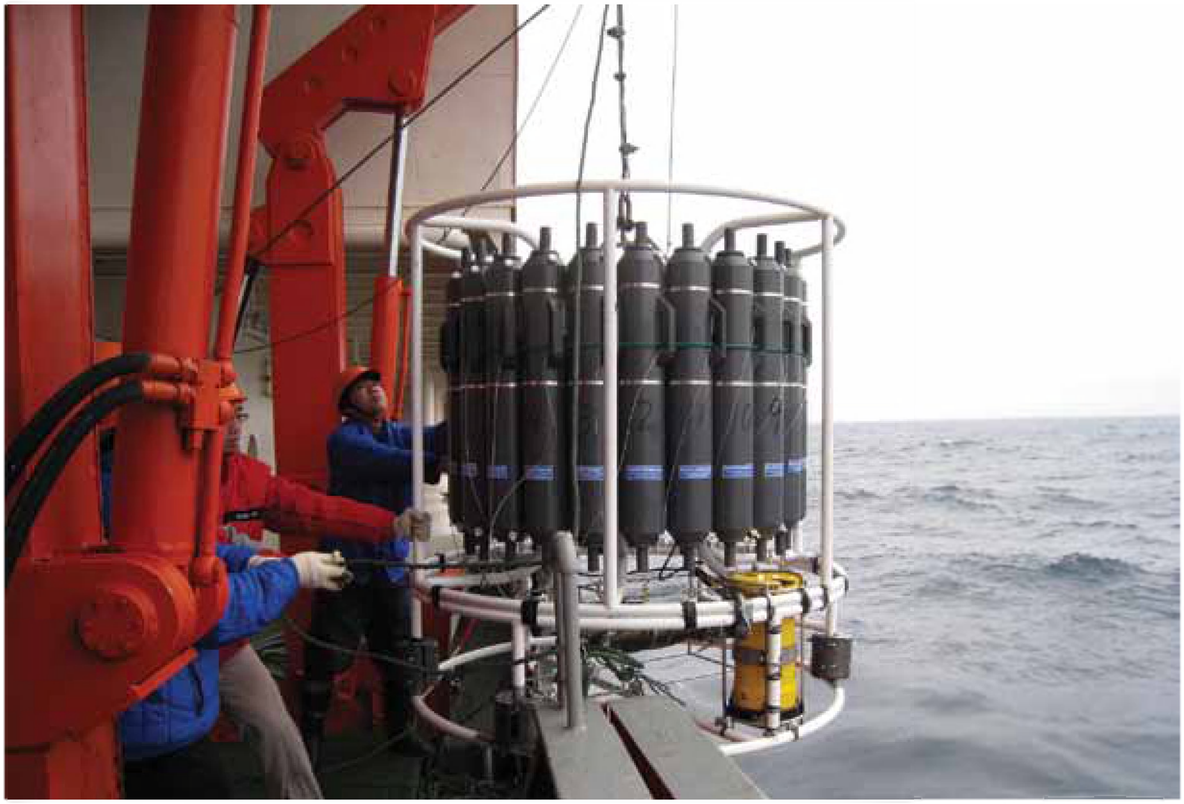


Fig.5.3-2. Optical experiment for sea ice in the summer Arctic. For comparing with winter results, an optical experiment with natural light and artificial light was undertaken during the 2008 summer cruise of Xue Long. A large area must be covered by thick black cloth for the artificial light experiment.
(Photo: Jinping Zhao)

Fig.5.3-3. Water optics observation in northern Bering Sea conducted from the U.S. icebreaker *Healy*.
(Photo: Jinping Zhao)

Fig.5.3-4. Artificial light experiment in dark Arctic. This was the first attempt to measure the optical property of first year sea ice with an artificial lamp in winter Arctic. This work was conducted on the Canadian icebreaker *Louis St. S. Laurent*.
(Photo: Jinping Zhao)

Svalbard, Norway was also a part of the Chinese IPY program, and involved long-term observations for space physics and space environment. Also during the summer 2008, a group of scientists conducted observations in biology, glacier, geology and microbiomass.

By participating in other countries' cruises during IPY, Chinese scientists were involved as international collaborators to conduct certain field observations. Chinese scientists took part in three U.S. icebreaker *Healy* cruises in 2007, 2008 and 2009, to explore ice-covered Bering Sea in spring to study optics in both water and sea ice (Fig. 5.3-3). During the winter of 2007–08, a group of Chinese scientists was aboard the Canadian icebreaker *Amundsen* for three months. During the through-winter cruise, they conducted artificial light experiment on sea ice in dark condition (Fig. 5.3-4). Two groups of scientists were aboard the Canadian icebreaker, *Louis S. St. Laurent*, to observe water optics in central Canada Basin in 2006 and 2009. By these international collaborative activities, Chinese scientists involve themselves in Arctic science frontiers and extended their research to a wider area.

Thanks to China emerging data-sharing plan, this data will be also analyzed alongside findings obtained by other large-scale IPY Arctic projects, such as the European DAMOCLES program, thus contributing to a complex and uniquely detailed perspective on Arctic processes. By 2012, China intends to launch a new icebreaker, so that it can conduct both Arctic and Antarctic research more effectively, and mount expeditions to both poles in the same year more frequently.

India

The National Center for Antarctic and Ocean Research (NCAOR) is a nodal Indian agency for Southern Ocean research and for launching Indian scientific expeditions to the Antarctic and the Arctic. Since 1981, 29 expeditions have been launched to Antarctica. India joined the Antarctic Treaty System in 1983 and operates a permanent station Maitri in Antarctica (70°45′57″S, 11°44′09″E), which was established during 1988–1989 at Schirmacher Oasis. During research expeditions, data are being collected in many fields, including glaciology, earth sciences, upper atmosphere and astronomy, meteorology, geomagnetism and biology. Other studies relate to cold region engineering, communication, human physiology and medicine. In addition, NCAOR houses Antarctic lake studies, Antarctic and global change research, and the National Antarctic Data Centre (NADC).

During IPY, India initiated the process for construction of its second station, Bharati at Larseman Hills at Ingrid Christensen Coast that will be completed by 2012. This state-of-art station will be located at 69°S, 76°E. Upon its completion, India will join the exclusive group of nine nations having multiple stations south of the Antarctic Circle. The new research base is planned to have a life span of 25 years. It shall accommodate 25 people during summer and 15 people during the wintertime. The Bharati Station will advance research in meteorology and atmospheric studies; earth sciences; oceanography; biology and environmental assessment.

During IPY India also expanded its polar interests to include research on Svalbard in the Arctic. In August 2007, a pilot expedition was organized and in early 2008, a second phase of Arctic research was initiated. Research was conducted on snowpack production of carbon monoxide and its diurnal variability; sea ice microbial communities; carbon cycling in the near-shore environments of Kongsfjorden; and understanding the links between the Arctic and tropical Indian Ocean climatic variations. In July 2008, India established a new research station *Himadri* in Ny Ålesund on Svalbard, about 1200 km from the North Pole through a Memorandum of Understanding with the Norwegian Polar Institute. The station is managed by NCAOR and research at *Himadri* will take place year-round with a special emphasis on climate change.

For the IPY science program, India contributed two projects of NCAOR that were endorsed by the IPY Joint Committee:

Monitoring of the upper ocean circulation, transport and water masses between Africa and Antarctica (IPY no. 70, Alvarinho J. Luis, PI – Fig. 5.3-5). Profiling of density structure in the upper 1 km of the Southern Ocean was carried out from January 2007 through summer 2009 by launching expendable CTD probes from a cruising ship between South Africa and Antarctica, chartered under the Indian Antarctic program (Fig. 5.3-6). The hydrographic data so collected have been analyzed for quantifying the changes in the vertical density structure by comparing with historical data, identification of water masses, changes in the heat content, understanding the circulation, geostrophic currents and Ekman components (Fig. 5.3-7).

Land Based Anthropogenic Impact of Coarse Particles on Antarctic Shelf (IPY no. 129, Anoop Tiwari, PI). Carbon content of air samples was recorded along the ship course starting from Cape Town, South Africa to the India Bay in Antarctica (70°45.94'S and 11°44.13'E) and further en route to the site of India's third station at Larsemann Hills (69°24'S and 76°10'E). Aerosol observations and carbon content of air samples at Larsemann Hills were also analyzed for impact assessment studies, prior to the construction of new station Bharati.

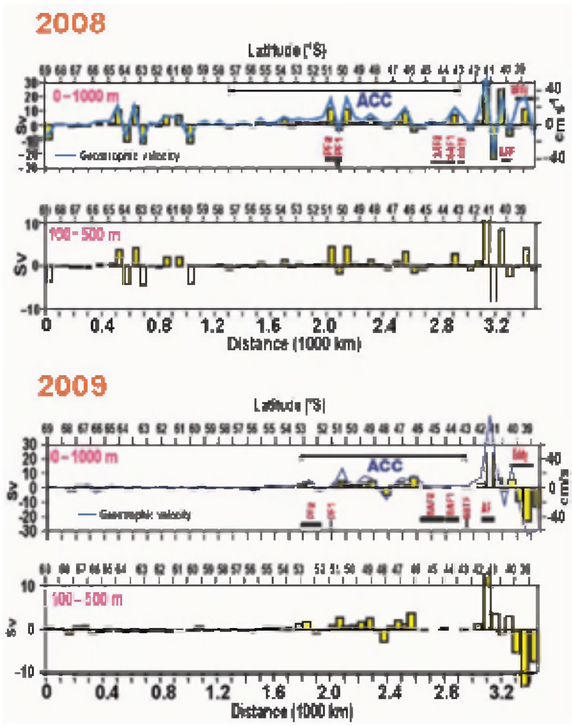
An in-house study of the short-term Holocene climate variability in Antarctica and the Southern latitudes used sediment cores collected from the South Indian Ocean. Researchers also analyzed sediment cores taken from the periglacial lakes and the shallow Antarctic ice-cores. Several articles have been published to disseminate the information regarding IPY themes and papers were presented at various international conferences.

NCAOR was also actively involved in outreach activities by generating public awareness about the causes and impact of climate change with reference to Polar regions. NCAOR sponsored the visit of two college students to Antarctica during the 25th Indian Antarctic Expedition under the "Students Participation

Fig.5.3-5. The data collection campaign for IPY project no. 70 launched in austral summer 2007. Project PI, Alvarinho J. Luis launches an XCTD probe in the Southern Ocean.
(Photo: Luis Alvarinho)

Fig.5.3-6. Weather parameters were recorded along the ship track by using an Automatic Weather Station installed on onboard MV *Emerald Sea* during the 26th Indian Scientific Expedition to Antarctica (2006–2007) for IPY project no. 70.
(Photo: Luis Alvarinho)

Fig.5.3-7. Comparison of geostrophic transport in 0-1000 m layer and 100-500 m layer during austral summer of 2008 and 2009 for the ship track between Cape Town and India Bay, Antarctica sampled under IPY project no. 70. The abbreviations are as follows: PF1 and PF2: north and south Polar Front; SAF1 and SAF2: north and south Subantarctic Front; SSTF: southern Subtropical Front; ARF: Agulhas Retroflection Front; ACC: Antarctic Circumpolar Current.
(Courtesy: Luis Alvarinho)



Programme". A series of lectures were delivered at more than 20 schools and colleges and students from several schools and colleges and scientists/visitors from Indian institutions and foreign countries visited NCAOR to get first-hand experience of Indian polar research.

Competitions on poster and model making, stamp designing, petition writing, etc., for school students were held during 2007–2009. Prizes were distributed on the *Earth Day* in 2007 and the winner of the model making competition was taken on a trip to Antarctica during the 28th Indian Antarctic Expedition (2008–2009) sponsored by NCAOR. Under the aegis of IPY, a 14-year old Indian student was selected by the Canadian organization, *Students on Ice,* for its annual Arctic expedition, 2–17 August 2007. NCAOR also supplied audio-visual and printed material on Polar Science to Nehru Science Centre (a unit of the National Council of Science Museums, Ministry of Culture) that organized an exhibition, "The Story of Poles" focused on geography, environment, flora, fauna, people and importance of the poles for the issues like ozone hole, global warming, at Mumbai. NCAOR has also participated and financially supported the "4th Science-Expo" organized by the Nehru Science Centre at Mumbai on 11–15 January 2008 that was attended by 18,000 visitors. Lectures were given by NCAOR Scientists highlighting the efforts of Indian researchers in unraveling the mysteries of the past using ice cores and other anthropogenic problems faced by the Antarctic environment.

Japan

Japanese engagement in polar research goes back to the early 1900s (Shirase's expedition to Antarctica in 1910–1912) and Japan maintained the ongoing presence in Antarctica since 1957. In response to the call from ICSU and WMO, Japanese scientists promptly joined IPY 2007–2008. Japan established its national committee for IPY (http://polaris.nipr.ac.jp/~ipy/index.htm; in Japanese) under the Science Council of Japan, SCJ in 2004 (Chair, Natsuo Sato, National Institute of Polar Research, SCJ: www.scj.go.jp/en/index.html). The Committee helped organize, promote and support research plans proposed by polar scientists in universities and institutes across Japan prior to and during the IPY period. A total of 63 projects endorsed by the IPY Joint Committee have been planned with the Japanese participation (Fig. 5.3-8). One project, the Microbiological and Ecological Responses to Global Environmental Changes in Polar Regions (MERGE, IPY no. 58) was organized by a Japanese scientist, collaborating with partners from 16 nations, including non-Antarctic Treaty parties. It will continue to serve as a coordinating platform for post-IPY activities. In the Science Meta-Data Base (SMDB) at the National Institute of Polar Research, Japan (NIPR), a total of 148 metadata sets were accumulated so far with regard to IPY. Brief summaries for several major projects (both endorsed and non-endorsed by the JC) are presented below.

A kick-off event and several symposia and education-outreach activities for younger generations were held in association with IPY "The Polar Open Forum for Junior High and High School Students" was started in 2004 as part of the IPY outreach program by the SCJ and the NIPR to broaden interest in polar sciences among the next generation. This five-year (2004–2009) outreach campaign will be continued as a legacy of IPY to facilitate future recruitment of polar scientists in Japan (Fig 5.3-9).

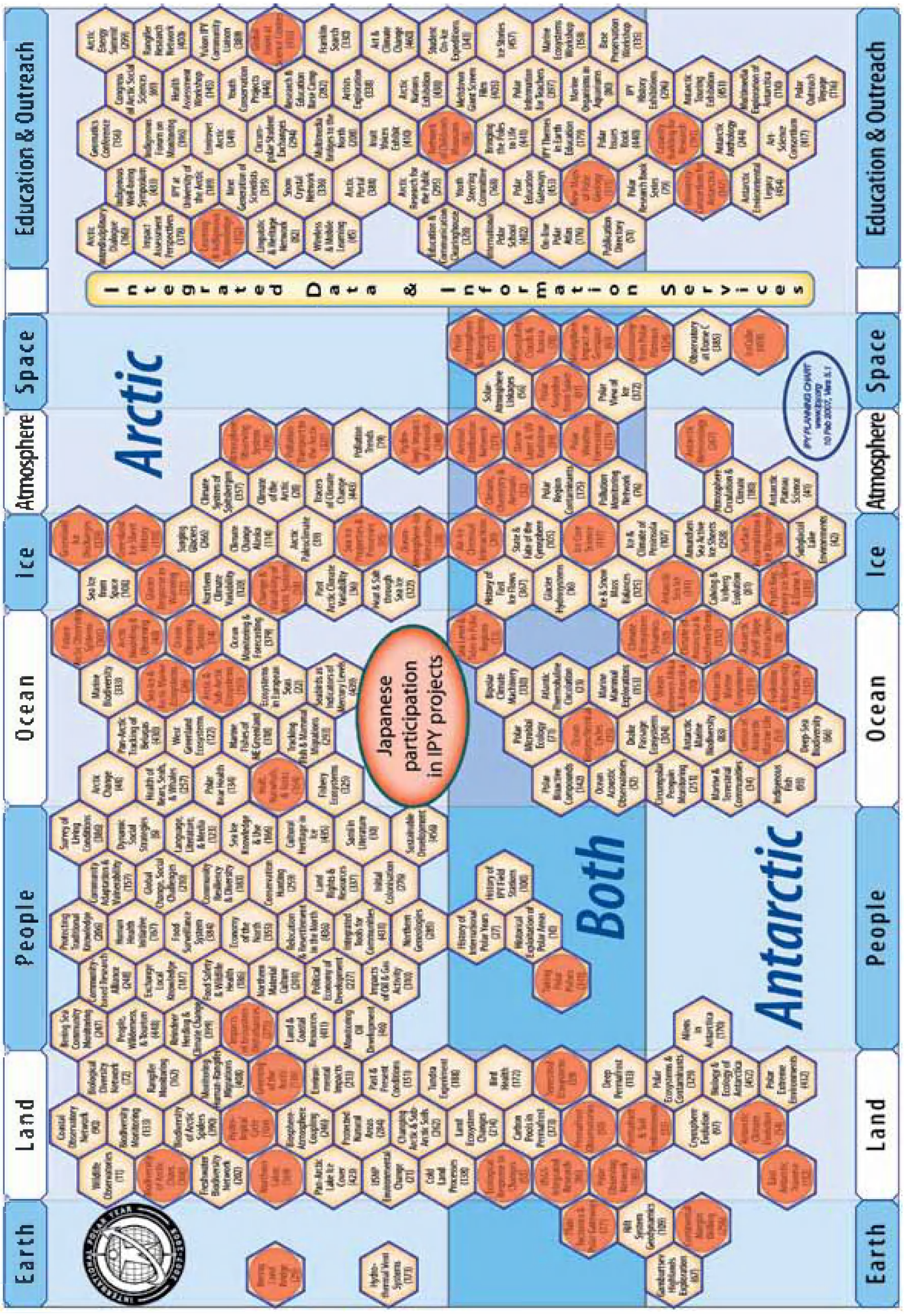


Fig.5.3-8. IPY project chart featuring IPY proposals with Japanese participation.

During IPY period Japan has advanced in the development of coordination structure and information exchange within the Japanese polar research community and internationally. An *ad hoc* group initiated regular Arctic Sessions at the Japan Geophysical Union Meetings since 2007, held in May every year at Makuhari-Messe, Chiba, Japan. The same group initiated the International Symposium on Arctic Research (ISAR) with sub-title "Drastic Change in the Arctic", gathering nearly 200 national and foreign scientists, in November 2008. Second Symposium took place 7–9 December 2010 in Tokyo. Such activities advanced the cooperation among Japanese polar scientists and also international collaboration.

Major Japanese Contributions to IPY Science Program

Comprehensive Ozone Layer Observation at Syowa Station, Antarctica (IPY no. 99). After the opening of the Japanese Syowa Station in 1957 in East Antarctica (69°00'S, 39°35'E), several observations have continued at the station, including upper atmosphere, middle atmosphere, meteorology, glaciology, geology and biology. Among them, the discovery of ozone hole in the Antarctic in 1982 by the 23rd Japanese Antarctic Research Expedition (JARE23) was one of the most remarkable JARE contributions to the earth science.[4] Since 2007, several comprehensive measurements related to ozone depletion have been conducted. These include high-resolution Fourier Transform Infrared (FTIR) spectroscopy measurements for minor species, low-resolution FTIR measurements for polar stratospheric cloud (PSC) characterization, ozonesonde campaign measurements and aerosolsonde measurements for PSCs. The Japanese activity was a part of the project called "ORACLE-O3: Ozone layer and UV radiation in a changing climate evaluated during IPY" (IPY no. 99) headed by Alfred Wegener Institute in Germany (Fig. 5.3-10).

IPY research cruise in the Indian Sector of the Antarctic Ocean by RV Umitaka Maru. Collaborative oceanographic/marine biological studies in the Indian sector of the Antarctic Ocean were conducted during the southern hemisphere summer of 2008 (January-February 2008) by a research cruise using the RV *Umitaka Maru.* Main survey areas were off Lutzow-Holm Bay and off Terre Adélie and George V Land (www.caml.aq/voyages/umitaka-maru-200708/index.html). The investigation at the former area was conducted as a part of the STAGE (STudies on Antarctic ocean Global Environment) program of the Japanese Antarctic Research Expedition and inter-annual variation of ecosystem in marginal ice zone were studied comparing with the previous results from 2003–2004 and 2004–2005 cruises. The biodiversity studies were conducted at the latter areas as a Japanese-Australian-French collaboration program (Collaborative East Antarctic Marine Census: CEAMARC) which was a part of the Census for Antarctic Marine Life (CAML, IPY no. 53).

Japanese-Swedish Antarctic Expedition, East Antarctica (IPY no. 152). Linking glaciological data spatially between the two deep ice-core drilling sites at EPICA-DML and Dome Fuji was successfully done during the Japanese-Swedish Antarctic Expedition 2007–2008 (JASE – Fig. 5.3-11). JASE was part of the project TASTE-IDEA (IPY no. 152). Data show a geographic variability in boundary conditions of the ice sheet such as surface mass balance, meteorological conditions, physical processes in firn and chemical and biological inclusions in snow. Data also show spatial variations of internal conditions of the ice sheet such as 3D structures and subglacial environment. These data suggest that climate proxies of deep ice cores are linked to the spatial gradients of the environment in the Antarctic plateau. Between November 2007 and February 2008 the area between these sites was surveyed by two groups. The spatial variability in snow layering in shallow

Fig.5.3-9. Participants of the IPY kick-off symposium ("Asian Collaboration in IPY 2007–2008"), 1 March 2007, Tokyo.
(Photo: Japanese IPY Committee)

Fig.5.3-10. Ozonesonde launch at Syowa Station, Antarctica on 5 June 2007. This was the opening flight of ozonesonde match campaign under IPY no. 99, ORACLE-O3, in which nine Antarctic stations from seven countries participated (Photo: Japanese IPY Committee)

depths was observed by subsurface radars, indicating no change in spatial distribution in accumulation during the Holocene. Radar reflections from deeper ice imply no major changes in ice dynamics over time. The basal conditions were mapped in detail at sites where there were indications of existing subglacial lakes or basal melting conditions near the ridge and Dome Fuji. Snow surface conditions showed a variation in snow properties linked to temperature, wind speed and accumulation ratio. Aerosol measurements were carried out along the route and snow samples was collected to link snow and atmospheric conditions.

Linkages between Low Pressure Systems over the Northwestern Pacific and Arctic Regions during Winter T-PARC. For the purpose of improvement of one to 14-day high impact weather forecast, the wintertime THORPEX Pacific-Asia Regional Campaign (Winter T-PARC) was carried out by the U.S. National Oceanic and Atmospheric Administration (NOAA) in January and February 2009. Main observation platform was NOAA G-IV for drop-sonde soundings. The NOAA G-IV was located at Yokota AB near Tokyo during Winter T-PARC. National Institute of Polar Research (NIPR) supported Winter T-PARC as a part of Japanese IPY activity.

Joint Pacific Arctic Ocean Climate Studies and iAOOS (IPY no. 345 and no. 14). The pattern of the recent sea ice reduction is not spatially uniform and is disproportionately large in the Pacific sector of Arctic Ocean. This regionality implies that the Pacific Ocean inflow has significant impact on the Arctic change. To understand mechanisms of past, recent and future changes in the Arctic Ocean, R/V *Mirai* International Polar Year cruise was conducted in 2008 as the first Japanese cruise that covered the full span of the southern Canada Basin and southeastern Makarov Basin jointly with other IPY cruises. The multidisciplinary research during that cruise consisted of ocean hydrography, mooring observations on major pathways of Pacific inflow into the Canada Basin, water sampling, plankton samplings, bio-optical observations, underway upper ocean and meteorological observations, and piston core samplings for Paleoceanographic reconstructions. Results of this cruise, such as changes between sea ice reduction and upper ocean structure, were included

Fig.5.3-11. Japanese-Swedish Antarctic Expedition in East Antarctica (IPY no. 152). The meeting of two teams.

(Photo: Japanese IPY Committee)

in the report by the Arctic Ocean Science Board titled "Observing our Northern Seas during IPY" (http://ipy-osc.no/abstract/376015).

Terrestrial biology. During IPY years, the integrated program, ''Microbiological and ecological responses to global environmental changes in Polar Regions'' (MERGE, IPY no. 55) was performed in both polar regions. MERGE is the proposal formed by scientists from 30 nations as a core coordinating proposal led by Takeshi Naganuma (Hiroshima University). MERGE selected three key questions to produce scientific achievements. Prokaryotic and eukaryotic organisms in terrestrial, lacustrine, and supraglacial habitats were targeted according to diversity and biogeography; food webs and ecosystem evolution; and linkages between biological, chemical, and physical processes in the supraglacial biome. Japanese national component of MERGE was focused on the spore-forming halophiles as most stress-resistant microbes exploring sites in Svalbard and Greenland. Research for the project, "Response of Arctic tundra ecosystem and carbon cycle to climate change" (TUNDRACYCLE, EoI no. 794) was focused on plant physiology, microbial ecology, remote sensing and carbon flows and pools on a glacier foreland in Ny-Ålesund, Svalbard and in Oobloyah Valley, Ellesmere Island, Canadian Arctic.

Satellite application: JAXA's activities during IPY. Japan Aerospace Exploration Agency (JAXA) promotes Arctic research in collaboration with the International Arctic Research Center (IARC) at the University of Alaska Fairbanks through conducting terrestrial and ocean studies (Fig.5.3-12). The terrestrial team evaluated comprehensive impact of wildfires in Alaska in 2004 upon vegetation and permafrost. The ocean research team promoted an integrative approach (Ship Survey-Satellite Remote Sensing-Ice-Ocean-Ecosystem Modeling), to elucidate the linkage of ice/ocean/ecosystem in the Arctic Ocean and Subarctic seas, especially ice melting/formation dynamics and its impacts on primary production. Our main target area is the Bering/Chukchi Sea where we can conduct ship surveys and where rapid changes are ongoing. JAXA-supported research activities such as Japanese R/V *Oshoro-maru* 2008 cruise, R/V *Mirai* 2008 cruise (Fig. 5.3-13) and Chinese Arctic Expedition 2008 by sending sea ice extent information derived from passive microwave satellite (AMSR-E) data of the Arctic Ocean to the researchers on the vessels in near real-time for ship navigation and observation planning. The near real-time AMSR-E data were found to be very effective for research cruises. JAXA will continue supporting summer research cruises after the IPY period. Also, image datasets of the Arctic and Antarctic regions were made using the data of PALSAR onboard the ALOS satellite. The satellite images of AMSR-E and PALSAR are available at the respective web sites. In particular, the data of the Arctic Sea-Ice monitor by AMSR-E cover the recent drastic changes of the Arctic sea-ice and now capture huge attention of general people and researchers.[5]

Conjugacy of the Ionospheric and Magnetospheric Penomena as seen from the both Polar Regions (IPY no. 63). Space and Atmospheric Sciences Group of NIPR extended observation network in Antarctica by deploying unmanned magnetometers and promoting collaborations with other Antarctic stations. This effort and direction will continue after IPY. The conjugacy of auroral phenomena using Syowa Station-Iceland conjugate pair stations has been studied. This study will be extended not only in the auroral zone, but also in the cusp and polar-cap region with the aid of the extended observation network.

IPY data management

Metadata related to Japanese IPY projects, together with other Japanese and international projects, have been compiled at the IPY Portal in the GCMD (Global Change Master Directory) (http://gcmd.gsfc.nasa.gov/KeywordSearch/Home.do?Portal=ipy&MetadataType=0) in NASA (National Aeronautics and Space Administration). In the Portal of GCMD, a total number of metadata descriptions (DIFs: Directory Interchange Format) is more than 90.

In the Science Meta-Data Base at the National Institute of Polar Research, Japan (SMDB/NIPR), a total of 148 metadata sets were accumulated so far. The format of metadata is original one, but it includes the items listed in DIFs of AMD (Antarctic Master Directory). There are also links to the corresponding metadata in the AMD for each metadata of the SMDB/NIPR.

Science Outreach and Communication

Scientific symposia. The IPY kick-off symposium, "Asian Collaboration in IPY 2007–2008", was held on 1 March 2007 at the SCJ, Tokyo with 117 participants from 14 countries (http://polaris.nipr.ac.jp/~ipy/usr/sympo/). The IPY closing Symposium, "Global Change and Polar Science," to summarize first scientific results and make adequate orientation to the post-IPY generation was held on 1 March 2010 at the SCJ.

Other symposia include:

- 1st International Symposium on the Arctic Research (ISIRA-1: www.jamstec.go.jp/iorgc/sympo/isar1/index.html), organized jointly by the Japanese National Committee for IASC and the SCJ in November 2008 at the National Museum of Emerging Science and Innovation (Miraikan), Tokyo and
- The International Symposium, "Fifty Years after IGY – Modern Information Technologies and Earth and Solar Sciences" (http://wdc2.kugi.kyoto-u.ac.jp/igy50), in November 2008 at the National Institute of

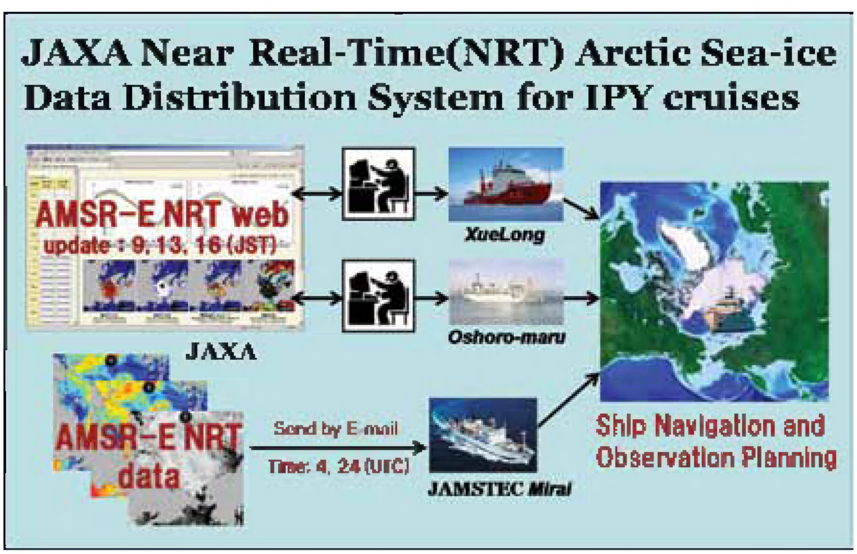


Fig.5.3-12. JAXA's Arctic Sea-ice Data Distribution System for IPY cruises using Near Real-Time AQUA/AMSR-E data.
(Photo: Japanese IPY Committee)

Advanced Industrial Science and Technology (AIST), Tsukuba with 160 participants that was sponsored jointly by several National Committees on IPY, eGY (electronic Geophysical Year), IYPE (International Year of Planet Earth) and IHY (International Heliophysical Year).

Education-outreach activities

Polar Open Forum for Junior High and High School Students. The Polar Open Forum for Junior High and High School Students was started in 2004 as an outreach program by the SCJ and the NIPR to broaden interest in polar sciences among the next generation. The catchphrase of the forum was "Arctic and Antarctic Proposals from School Students." The forum had been held annually for five years. Implementation of the proposal was carried out by the Japanese Antarctic Research Expeditions (JAREs) overwintering at Syowa Station. The results of the experiments were reported to the students through an Intelsat TV conference system from Syowa, Antarctica, while the expedition members enjoyed conducting the experiment.

After review, it was decided to continue the forum as a legacy of IPY for the recruitment of polar scientists, under the new title, "Contest on Antarctic and Arctic Science for Junior High and High School Students." A total of 128 proposals were submitted and a research proposal to study dreams of Antarctic expedition personnel won the first prize. The forum was held in November 2009 at the NIPR in Tokyo with 120 participants, including 70 students.

IPY Junior Summit. An outreach event titled the "IPY Junior Summit" was held at the National Science Museum in Tokyo on 1 March 2009. Students who had won prizes in the first to fifth forums described above were invited to give talks on the theme "Polar Research in 2057–2058," i.e. during the period when the next IPY will be launched. More than 100 participants, many of them quite young, listened to the talks. A retired professor, a member of the Japanese IGY re-

Fig.5.3-13. Memorial photo after the last science station in the Bering Strait. Total of 600+ hydrographic stations were made jointly with CCGS Loius S.St-Laurent (blue: Mirai, red: *Loius S.St-Laurent.* The area covered the full span of the Canada Basin and eastern Makarov Basin.
(Courtesy: Japanese IPY Committee)

Fig.5.3-14. Korean Antarctic station King Sejong on King George Island, Barton Peninsula.
(Photo: Dongmin Jin)

search team, who overwintered at Syowa in 1957, was invited as a guest panellist. He introduced the early years of JARE, stretching the Summit time focus from 1957 till 2057.

Korea (Republic of Korea)

Formation of KOPRI

Korea began its Antarctic Expeditions in November 1985 with two teams. The mountaineering team became the fifth to reach the summit of the Vinson Massif (4897 meters), the highest mountain in Antarctica on 29 November 1985. The second team set up tents at the coast of the Fildes Peninsula on King George Island in the South Shetland Islands, and researched the island environment. The team also visited foreign stations and collected information on their construction and life at the station.

Korea joined the Antarctic Treaty as the 33rd nation on 28 November 1986. Korea was not a UN member state at that time, and was only able to become a signatory state on the Antarctic Treaty with the endorsement from all Antarctic Treaty Consultative Parties. In 1987 the Korean Ministry of Foreign Affairs made a report on the access to the Antarctic Treaty System as part of its new year's task, which resulted in the construction and opening of the Korean Antarctic station "King Sejong" on 17 February 1988 (Fig. 5.3-14). Since then, Korea has dispatched annually the overwintering parties and summer expedition teams. In 2010, the overwintering party consists of 17 members at the station. Every austral summer season witnesses approximately 100 scientists from research institutes and universities visiting the station. Korea strengthened its polar program in the Arctic by establishing the Dasan Station in Ny-Alesund, Svalbard in 2002 and also by joining International Arctic Science Committee (IASC) in 2002.

To implement its polar science program, a Polar Research Laboratory was established at the Korea Ocean Research and Development Institute (KORDI) in 1987. The Lab was expanded to the Polar Research Center (1990) and enlarged again as the Korea Polar Research Institute (KOPRI) in 2003. KOPRI was developed into an autonomous research institute in 2004 and moved its campus to Incheon in 2006. KOPRI is one of the 13 government supported research institutes under the auspices of Korea Research Council of Fundamental Science and Technology (www.kopri.re.kr/index_eng.jsp).

The construction of the ARAON

The construction of the first Korean ice-breaking research vessel *ARAON* (Fig. 5.3-15) was implemented by KOPRI as a part of the national polar infrastructure development in accordance with the Korean government 'Polar Science and Technology Development Plan.' *ARAON* is a Korean compound word that combines "ARA," which means "sea," and "ON," which means "all," in the archaic Korean language. As named, *ARAON* embraces a wish to be free to explore all of the oceans in the world.

The *Araon* displaces 7487-tons and is designed for operation in one-meter-thick-annual ice condition (KR PL-10) with 3 knot speed per hour. She can accommodate up to 85 persons (25 crews + 60 researchers), load up to 31 TEU (20 ft container). Her endurance is around 70 days (20,000 nautical miles) without re-supply (Fig. 5.3-16).

The major missions of the *Araon* are to provide logistical support to the Antarctic King Sejong Station and the Arctic Dasan Station, and to conduct scientific research in ice-covered seas. To perform world-class scientific activities, state-of-the-art scientific instruments, like the Multibeam echo sounder, LIDAR, and Dynamic Positioning System were installed on the ship.

Construction began in January 2008 and the ship was launched in June 2009. After delivery to KOPRI in November 2009, *Araon* sailed to the Antarctic Ocean for her maiden voyage and ice-breaking test. KOPRI plans to conduct an Arctic expedition in the summer season of 2010, which will include international collaborative work. KOPRI intends that *Araon* will do a scientific cruise to both the Antarctic and Arctic each year.

Research at the Dasan Station and initiation of a long-term research based on the use of Araon. Since the inauguration of Dasan Station in Ny Ålesund, studies by Korean scientists included atmospheric research, ocean science, biology and geosciences. Especially KOPRI has investigated the relation of Arctic atmosphere variability and climate in East Asia. Energy and CO_2 fluxes have been observed at polar stations using an eddy covariance flux measurement tower. A Cloud Condensation Nuclei (CCN) counter was installed

Fig.5.3-15. New Korean ice breaking research vessel *Araon*. (Photo: Dongmin Jin)

at the Zeppelin Station, Ny Ålesund to investigate long-short term variation of aerosol activation into cloud droplet size. The collaborative research between KOPRI and the Zeppelin aerosol research team from the University of Stockholm, Sweden has expanded by adding atmospheric particle number concentration monitoring at the Corbel Station in Ny Ålesund in August 2006.

Studies on the biodiversity and adaptation mechanism of the Arctic organisms, investigation on the fauna and flora inhabiting various environments around the Korean Arctic Research Station and sampling of marine plants and sea water have been made. Physiological characteristics and extracellular polymer-degrading enzyme activities will be assessed from the collected samples to understand adaptation in polar environment and nutrient cycle.

In summer 2010, *Araon* made her first voyage to the Bering Sea and the Arctic Ocean to target the rapid melting of the Arctic sea ice and its effect on the ecosystem. Through annual cruises, long term monitoring of the primary production patterns in the Western Arctic will be conducted. *Araon* will contribute to the Antarctic research in areas such as the responses of carbon flow and biological productivity to the rapid retreat of sea ice in western Antarctic area, and monitoring on the ice-shelves and adaptation of living creatures beneath them.

Expansion of the Antarctic science

In 2006 the Korean government announced a plan to build a new research station in Antarctica to enhance Korean scientific capabilities and promote collaboration for the development of Antarctic sciences. Two key areas were identified according to scientific interest: Cape Burks in Marie Byrd Land and Terra Nova Bay, Northern Victoria Land. An intensive field survey was conducted by 22 scientists, onboard *Araon* from 12 January to 18 February 2010 in both areas. According to the study, the Terra Nova Bay is considered the most suited for the new station. Terra Nova Bay is expected to provide an ideal platform for research on climate change over the Pacific Ocean side of Antarctica. The winter-over research program will contribute to the understanding of rapid climate change in the region. With the new research station, Korea is expected to make significant contribution to the international collaboration and the effective management and conservation of the Antarctic environment.

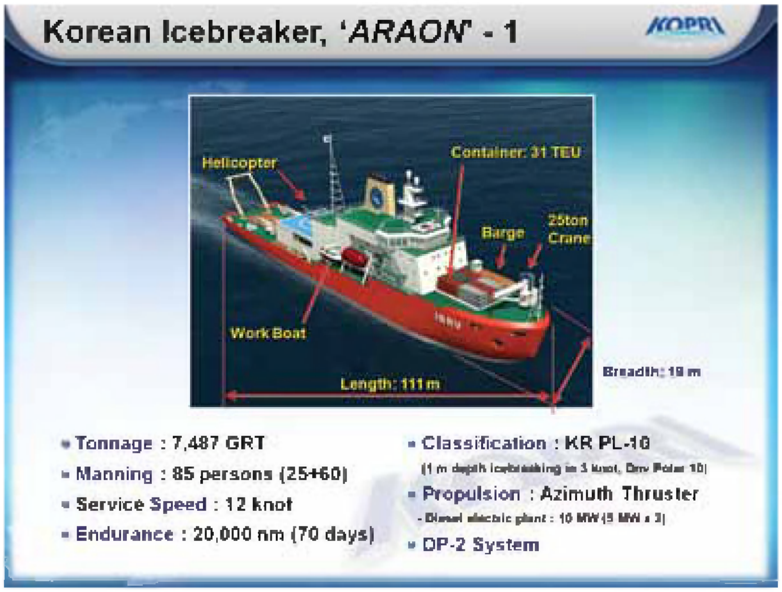


Fig.5.3-16. Major technical and research parameters of *Araon*.
(Photo: Dongmin Jin)

Malaysia

Development of Malaysian Antarctic Science Program

Malaysia's interest in Antarctica started in 1983. In 1985 the Academy of Sciences of Malaysia encouraged Malaysian scientists to embark on Antarctic research; but funding and interest was then insufficient to launch a national Antarctic program. The breakthrough came in 1997, when New Zealand offered the use of its Scott Base Station in Antarctica to Malaysian scientists to undertake polar studies. The first Malaysian field research in the Antarctic with the focus on climate change and biodiversity was undertaken in October 1999, at the Scott Base Station.

Since 1999, the Malaysia Antarctic Research Program (MARP – www.myantarctica.com.my/aboutMARP.htm#marp) undertook a number of initiatives to develop and sustain Malaysian scientific research in Antarctica. Under the leadership of MARP, the number of research projects grew from the initial four in 2000 to the current 15, covering the fields of atmospheric sciences, remote sensing, upper atmospheric and solar terrestrial connection, and biological sciences. To date, more than 40 scientists and postgraduate students from various universities in Malaysia are involved in Antarctic research. In order to coordinate and archive MARP activities, the National Antarctic Research Centre was established in cooperation with the University of Malaya in 2002. This is also the physical location of the Malaysian data server under its obligation as a member of Joint Committee on Antarctic Data Management and IPY.

Since the first scientific fieldwork, MARP has established scientific collaboration with a growing list of national polar research centers, such as the British Antarctic Survey, Australian Antarctic Division, Korean Polar Research Institute, Institut Antarctico Chile, Institut Antarctico Ecuador, Institut Antarctico Argentine, Byrd Polar Research Institute, the Japanese National Institute of Polar Research and other Japanese institutions. Malaysian scientists are presently conducting research in Antarctic Peninsula, Ross Ice Shelf, Queen Maud Land and Wilkes Land. They are also working on the sub-Antarctic Marion Island in cooperation with South African partners and recently visited the Korean research station in Ny Ålesund to collect samples for biological research, under the MoU with the Korean Polar Research Institute (KOPRI).

Malaysian IPY initiatives

In 2004–2005, MARP encouraged Malaysian scientists to submit their proposals for future IPY activities, resulting in 14 EoIs by Malaysian researchers; some of them were later merged into endorsed full proposals (IPY nos. 53, 55, 63, 180). The majority of Malaysian biological research was conducted under the 'Microbiological & Ecological Responses to Global Environmental changes in polar regions' project (MERGE, IPY no. 55). A number of Malaysian biology studies were also integrated with the SCAR *Evolutionary Biology of Antarctica* program. The geophysical group has also been invited to participate in the *Interhemispheric Conjugacy Effects in Solar-Terrestrial and Aeronomy Research* (ICESTAR) program of SCAR contributing their Global Positioning System (GPS) network to study solar terrestrial interaction. An international seminar on Antarctic Research was held at the University of Malaya in Kuala Lumpur in June 2005 in the build-up to IPY.

As a part of the outreach, education and capacity building of the IPY program, under the leadership of University of Tasmania, a multi-institutional International Antarctic Institute (IAI) was established and accepted as an IPY program (www.iai.utas.edu.au/ - *Chapter 5.4*). In acknowledgement of Malaysian active polar research, the University of Malaya (UM) and the University Science Malaysia (USM) were invited to join the IAI. In addition, the MARP is an active member of the 'Sixth Continent Initiative,' an IPY program proposed by the International Polar Foundation to encourage non-traditional polar countries' research in Antarctica.

During IPY, 45 Malaysian scientists participated in 21 field trips to Antarctica and the Arctic (Fig. 5.3-17). Most of the Malaysian IPY research was conducted in Antarctica: at the Scott Base Station (with New Zealand colleagues), also on Antarctic Peninsula (on collaborative projects with the British Antarctic Survey, the Ecuador Institute of Antarctic Research and Chile Institute of Antarctic Research), at the Signy and Casey Antarctic stations (in collaboration with British and Australian colleagues). Several trips were made to the islands in the Southern Ocean, such as South Shetland Islands, King George Island and Marion Island. Most Malaysian Antarctic research is in the field of biology, remote sensing, atmospheric studies and geology (Figs. 5.3-17, 5.3-18).

In January-February 2007, one Malaysian biologist took part in the Japanese research cruise in the Bering and Chukchi Seas organized jointly by the National Institute of Polar Research, Japan and Hokkaido University. In July 2008, two Malaysian biologists worked at the German research station in the Arctic managed by the Alfred Wegener Institute (Fig. 5.3-19). Thus, IPY made a breakthrough for Malaysian researchers in their entry to the Arctic.

Fig.5.3-17. Malaysian biologist Cheah Yoke Queen collects samples at a penguin rockery on the South Shetland Islands (2007).
(Courtsey: Malaysian National Antarctic Research Centre)

Science Dissemination and Outreach

Malaysia has placed significant emphasis on communicating the results of its polar science. The *3rd Malaysian International Seminar on Antarctica (MISA3): From the Tropics to the Poles* was held in Kota Kinabalu, Sabah on 20-23 March 2007 in conjunction with the launch of IPY 2007–2008. It was followed by Outreach Program and an ICSU-SCAR Forum. The theme of the seminar, "From the Tropics to the Poles" followed the science program of IPY that argues that the polar regions are integral components of the complex Earth systems. Increasingly, there is also a need to engage scientists from nontraditional polar research countries and from other regions (such as the tropics). The Outreach Program was held to generate interest in Antarctica among the general public and schoolchildren, together with the Forum on "Understanding the Implications of Rapid Warming in the Polar Regions to Earth systems" organized jointly by the ICSU Regional Office for Asia and the Pacific (ROAP) and SCAR.

Following the formal conclusion of IPY, the *4th Malaysian International Seminar on Antarctic - Legacy of IPY to the Tropics* (MISA-4), with 102 participants was held in Petaling Jaya, Selangor, 1–2 April 2009. In conjunction with MISA-4, two workshops,

Fig.5.3-18. Installing Malaysian Antarctic research program automated weather station (AWS) at McKay, 2007.
(Courtesy: Malaysian National Antarctic Research Centre)

Recent Antarctic Climate Change and Its Implications on the Marine and Terrestrial Biota; and *Molecular Markers Techniques for the Identification of the Transport Pathways of Organic Pollutants in Extreme Environment* have been organized on 3–4 April 2009 (www.myantarctica.com.my/misa4/misa4.html). The first workshop engaged several leading Malaysian and foreign climate change experts. The second workshop was held at the Faculty of Environmental Sciences, University of Putra Malaysia. The workshop provided a platform for local scientists to get involved in hydrocarbon pollution research, learn the latest developments in research, and to establish an international link with foreign experts in the field.

Students on Ice. In February 2009, one Malaysian postgraduate student and one undergraduate student from the University of Malaya participated in the Canadian-funded trip to Antarctica on the *Students on Ice* project. The two students together with 69 other students and 18 researchers from around the world completed a two-week trip on board the *MV Ushuaia.* During the cruise, they participated in lectures, workshop and hands-on activities related to polar environment and wildlife. This expedition was endorsed as an IPY event (www.studentsonice.com/ipy/).

International Polar Week with the theme "What happens to the Poles Affects Us All" was organized on 5–9 October 2009 at the University of Malaya, in conjunction with IPY (*Chapter 4.1*). Talks were given by experts and postgraduate students from across the country and poster exhibition was one of the key activities. This event provided the information about Malaysian scientific activities in Antarctica and the Arctic, as well as about the IPY studies across the polar regions.

Conclusion

The five Asian nations, members of the AFoPS, with a combined population of more than 2.7B, used IPY 2007–2008 as an opportunity to increase their polar science capabilities and their role in the global science community. Not only was significant new national funding (the "pulse") directed to polar research, but also new infrastructure was constructed or committed that will ensure continuing efforts at an enhanced level for decades to come (the "legacy"). Outreach efforts aimed at college and high-school students throughout the Asian nations will add to the lasting legacy of IPY in this region. Of major importance is also the growing presence of China, Japan and Korea in the Arctic Ocean and in the northern polar region, in addition to their earlier involvement in Antarctic research going back to the IGY and post-IGY years.

Fig.5.3-19. Malaysian Arctic sampling program in Ny-Alesund, Svalbard (featuring Wong Chiew Yen), June 2008.
(Courtesy: Malaysian National Antarctic Research Centre)

Another IPY focus was on international cooperation, and the AFoPS member countries increased their participation in international scientific activities during IPY. Many endorsed IPY projects were led or participated in by Asian scientists. Asian-funded field projects were joined by international partners and guests, and several international science organizations held major meetings in Asia, that were crucial in launching IPY 2007–2008, such as the SCAR 26th meeting in Tokyo in July 2000; SCAR 27th Meeting in Shanghai in July 2002, the World Climate Research Programme (WCRP) session in Beijing in October 2002; the Arctic Science Summit Week in April 2005 in Kunming, China; and the official endorsement of IPY 2007–2008 by the 28th ICSU General Assembly in October 2005 in Suzhou, China (*Chapters 1.2, 1.3, 1.5 and 1.6*)[6]. A significant number of scientific papers co-authored by Asian and non-Asian scientists should result from these collaborative efforts. Some of these collaborations can be expected to endure, leading to future insight and the growing role of Asian nations in polar research as the legacy of IPY 2007–2008.

Notes

1 Drs. Prem Chand Pandey from India (National Centre for Antarctic and Ocean Research) and Zhanhai Zhang, from China (Polar Research Institute of China) were members of the ICSU Planning Group in 2003–2004, and two scientists from the Asian nations, Qin Dahe from China and Yoshiyuki Fujii from Japan, were nominated to the ICSU-WMO Joint Committee in 2004.

2 Most of these countries participated by conducting meteorological observations on their territories, with no special activities in the polar regions.

3 Both Korea and Japan had representatives at the AC 'deputy ministers' meeting held in May 2010 in Copenhagen. The AC members have stated that they would come to a decision on the observer countries at the next Ministerial meeting, scheduled for May 2011.

4 Observations of depleted Antarctic ozone were noticed at Halley Station in the late 1970s; but their significance was not recognized until later. The U.S.A., Japan, and the U.K. all obtained ozone data in the early 1980s, and a Japanese scientist, Chubachi Shigeru was first to publish it in 1983. But the British Antarctic Survey announced their "discovery" of the ozone hole in 1985 and received credit in the western press (editor's note).

5 See: Arctic Sea-Ice monitor by AMSR-E www.ijis.iarc.uaf.edu/cgi-bin/seaice-monitor.cgi?lang=e; IPY Dataset by ALOS/PALSAR www.eorc.jaxa.jp/ALOS/en/ipy/ipy_index.htm.

6 Two most recent events underscoring the role of AFoPS nations in international polar year research were the 17th International Symposium on Polar Science, 26–28 May 2010, at the Korea Polar Research Institute, in Incheon, and the International conference on Cryospheric Change and its Influences – Cryospheric Issues in Regional Sustainable Development, organized jointly by CliC and IASC in Lijiang, China, 12–14 August 2010.

5.4 Connecting to New Stakeholders in Polar Research

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Engagement of Arctic residents, including indigenous peoples:
IPY has advanced the participation of Arctic residents, including indigenous peoples, in large-scale interdisciplinary science in their own region. For the first time, Arctic residents and their organizations have acted as full partners and leaders in international projects involving scholars from many nations and disciplines, research planning, data collection, management, analysis and outreach. The contributions, observations and knowledge of Arctic residents have proven key to the success of several IPY studies on the dynamics of sea ice, weather, changes in habitat and wildlife distribution, the sustainability of local economies, public health and community well-being. This legacy of partnership has built a solid foundation for the engagement of Arctic residents and indigenous peoples in future large-scale science projects.

(The State of the Polar Research, 2009, p.10)

Introduction

Igor Krupnik

The inclusion of "human dimension' in IPY 2007–2008 was not merely a symbolic break with the previous model of pure (or primarily) geophysical program of the early IPY/IGY. Nor was it a pragmatic response to the new requirement of 'societal impacts' coming from the international science organizations and many national funding agencies. The many reasons for that historic change in the IPY design and for the emergence of the new vision of 'polar research' have been addressed in detail in other sections (*Chapters 1.3, 1.5, 2.10, 3.10*). What it meant in practice in 2004 –2005, when the IPY science program was being formed via the submission of Expressions of Intent (EoI) and 'full proposals,' was the urgent need to reach out to new prospective 'stakeholders.' Those new stakeholders—future project participants, proposal writers, research teams and ground-supporters—were coming from the fields that have either marginal institutional memory of the early IPYs and IGY, such as social and human health scientists, or no institutional memory at all, like polar residents and, particularly, polar Indigenous people.

Unlike older scientific organizations and Science Unions, associations (NGOs) of local polar residents are relatively new phenomenon. All of them appeared long after the completion of IGY 1957–1958 and their activities have always been focused primarily on self-determination, land and resource rights, support for indigenous languages and cultures, and community well-being. Of course, polar residents have a long experience of interaction with polar researchers, and not only with anthropologists, but also with natural and physical scientists from many disciplines. These relationships had their own uneasy history and generally varied from pragmatic partnership to alienation and utmost resistance, as in the case of certain types of archaeological excavations, wildlife and human blood sampling, and genetic research.

To reach out to these new constituencies and to bring them to the IPY 'big tent' required new approaches never tested in the previous IPY/IGY. This chapter covers three of those new models (out of many) that were used successfully to bring polar residents to IPY. The first opportunity came from the emergence of vocal and active *indigenous organizations* that now have many fora to increase their role via major intergovernmental organizations, like the Arctic Council or umbrella NGOs (like the International Work Group on Indigenous Affairs, IWGIA or Survival International), in which they participate. The other model, first explored in IPY 2007–2008, was to engage local and indigenous stakeholders through various *knowledge and data sharing networks.* That latter channel was of crucial importance, since none of the previous IPY/IGY had any policy of *sharing data* with people in whose native areas IPY science teams made their observations, collected samples and drilled holes. Yet another new model was to engage local educational institutions in the polar regions, such as local universities, community colleges, even high schools, in support of IPY research. We were fortunate to rely upon many such partners that did not exist during earlier IPY/IGY, that took the lead in bringing its constituent institutions into IPY 2007–2008 (Box 1).

Of course, the individual stories presented in this chapter are mere snapshots of the diversity of approaches and of new stakeholders that emerged in IPY. Nonetheless, they illustrate how the organizers' dreams of an IPY with a 'human dimension' evolved into practical mechanisms contributing to the success of IPY.

Engaging Arctic Indigenous Organizations in IPY 2007–2008

Victoria Gofman and Cindy Dickson

Reviewers: Jens Dahl, Shari Gearheard and Igor Krupnik

IPY 2007–2008 has received unparalleled support from the scientific community, governments and the public. This support was born, in part, out of sheer necessity to respond to the rapid climate and other environmental changes, most notably in the Arctic. What used to be an exclusive realm of physical science became "the social pole" (Monastersky, 2009). The inclusion of "human dimensions" in IPY 2007–2008 program took it to the next level, but the vision of the IPY organizers eventually expanded the notion of inclusiveness to the range never experienced in the previous 'polar years.' Arctic residents, especially indigenous peoples, were recognized as important stakeholders, collaborators and drivers of new research, and, for the first time, were explicitly called upon to participate in IPY science (*Chapters 1.3, 2.10, 3.10*).

One of the most symbolical events of IPY 2007–2008 was the launch ceremony for the 'Indigenous Peoples' International Polar Year' in the northern Norwegian town of Kautokeino/Guovdageaidnu on 14 February, 2007 organized jointly by the Nordic Sámi Institute, International Centre for Reindeer Husbandry and other local institutions (http://arcticportal.org/en/icr/ealat; www.polararet.no/artikler/2007/IP_IPY Fig. 5.4-1). By holding such an event two weeks prior to the official launch of the IPY 2007–2008 on 1 March, 2007 these organizations of Arctic indigenous peoples made a concerted effort to raise their profile in IPY and to demonstrate their full support to this multi-national program.[1]

The energy culminated in IPY 2007–2008 was a result of many years of an uphill battle for recognizing indigenous, local and traditional knowledge as invaluable components in understanding of physical, natural and social environments in the Arctic. Indigenous and local participation in IPY 2007–2008 was also a result of political changes that occurred in the last few decades. The process of indigenous land settlement claims that began in the 1970s in Alaska and was followed by a similar movement in Canada resulted in the establishment of indigenous government bodies. That led, among other things, to the increase in capacities of local indigenous organizations and to new government regulations requiring consultations and sometimes approval of research planned on indigenous lands. The full list of scientists, indigenous leaders, and various organizations and government agencies that contributed to the inclusion of Arctic residents in IPY 2007–2008 is too long for this short section to cover. Nevertheless, two events leading up to IPY played an especially significant role and deserve to be mentioned: the formation of the Arctic Council and the Arctic Climate Impact Assessment report (ACIA, 2005).

In 1996, eight Arctic states established the Arctic Council (*Chapter 1.4*), an international body as *"…a means for promoting cooperation, coordination and interaction among the Arctic States, with the involvement of the Arctic indigenous communities…"*[2] From the very onset, the Arctic Council laid ground for the inclusion of indigenous peoples in all of its endeavours by *"Recognizing the traditional knowledge of the indigenous people of the Arctic … and taking* *note of its importance … to the collective understanding of the circumpolar Arctic…"*[2] The Inuit Circumpolar Council (previously called the Inuit Circumpolar Conference, ICC), the Saami Council and the Russian Association of Indigenous Peoples of the North, Siberia and the Far East (RAIPON) played an important role in the development of the Arctic Council and establishing the category of "Permanent Participants" for indigenous organizations *"to provide for active participation and full consultation with the Arctic indigenous representatives within the Arctic Council."*[2]

Currently, six indigenous organizations are admitted as Permanent Participants: the Aleut International Association (www.aleut-international.org), the Arctic Athabaskan Council (www.arcticathabaskancouncil.com), the Gwich'in Council International (www.gwichin.org), the Inuit Circumpolar Council (www.inuit.org), Saami Council (www.saamicouncil.net) and the Russian Association of Indigenous Peoples of the North, Siberia and the Far East (wwww.raipon.org) (*Chapter 1.4*) (Gofman, 2008).

The Arctic Council provides one of the few fora where indigenous organizations have a unique role in discussing and shaping policies and research leading to sustainable development, protection of the environment and, in more recent times, also related to Arctic governance. The fact that indigenous organizations share a negotiation table with ambassadors and Foreign Ministers of Arctic States is a remarkable act of recognition. For example, there are no other organizations or fora that would provide a mechanism for the direct participation of indigenous organizations in international scientific assessments of the magnitude of the *Arctic Climate Impact Assessment* report (2005).

The *Arctic Climate Impact Assessment* (ACIA 2005) highlighted the changes expected to occur in the Arctic as a result of climate change over the next decade and throughout the 21st century. It also showed that these changes have already begun and will have significant environmental, economic, social and cultural effects in the Arctic. A key ACIA recommendation for future Arctic research was the improvement of long-term monitoring, extending it to year-round record collection and expanding it spatially.

ACIA was also one of the first major scientific

Fig. 5.4-1. Website for the 'Indigenous People's IPY Opening event in the Norwegian Sámi town of Kautokeino (Guovdageaidnu), February 14, 2007 at *www.ip-ipy.org*. The site is now owned by the EALÁT project (IPY no. 399) administered by the Sámi University College-Nordic Sámi Institute at http://arcticportal.org/en/icr/ealat.

reports that included observations of local indigenous peoples, as case studies, to support and extend scientific findings, and to give a human face to some of the impacts of climate change (Huntington and Fox, 2005). A striking convergence of community-based observations with scientific data helped validate local observations and elevated them from "anecdotal evidence", a term commonly applied to identifying this type of information in scientific research, to an invaluable building block of a holistic understanding of the Arctic environment. Nevertheless, case studies can only convey personal perspectives. They may provide the basis for discussion and scientific inquiry, but they do not provide aggregate statistics or general trends (Huntington and Fox, 2005).

The recognition of the validity of local observations coupled with the need for on-going monitoring created a perfect opportunity for a surge in interest in various forms of community-based monitoring. This was amplified by the opportunity presented by IPY 2007–2008.

The Arctic Council Permanent Participants often cannot fully realize the opportunities afforded by the Arctic Council, such as a meaningful participation in its projects, due to many problems. Some are financial and others are rooted in lack of experience and expertise in permanent participants' organizations. Lack of core funding prevents permanent participants from hiring needed experts. Since most of the obstacles are financial, they act as a *de facto* filter preventing Permanent Participants from full engagement in research projects initiated by the Arctic Council and in the development of research policy and recommendations.

IPY 2007–2008 generated much needed opportunities for funding and those Permanent Participant organizations that had portfolios of research ideas and proposals were in a position to reap the benefits. For example, the Aleut International Association (AIA) saw these opportunities in as early as 2004 and realized that the experience gained while working on ACIA in cooperation with many renowned scientists gave AIA a competitive edge in the development of its research programs. ACIA findings clearly indicated the need for broad-based efforts for monitoring of environmental changes. AIA was also among the first applicants from the social and human studies field that responded to the call for IPY 2007–2008 projects in winter 2004 and had submitted its concept for an IPY activity ("International Network of Arctic Indigenous Community-Based Environmental Monitoring & Information Stations"). That concept was included in the 'Initial Outline Science Plan' for IPY in April 2004 (ICSU Planning Group, 2004) and was received with great interest (*Chapter 1.3*). Those early contacts were important in the further development of the full proposal for the Bering Sea Sub-Network: International Community-Based Environmental Observation Alliance (BSSN, IPY no. 247) that became an endorsed IPY project (*Chapter 3.10*).

BSSN was funded by the U.S. National Science Foundation (NSF), first as a pilot under the Arctic Observing Network (AON) funding initiative. The pilot phase started in 2007 and demonstrated that an international network of indigenous communities could be organized to produce usable local observation data sets (*Chapter 3.10*). In 2009, the project received additional funding for five more years and will be operational until 2014 (Fig. 5.4-2).

Another good example of stakeholder involvement was a partnership of indigenous organizations that was formed in Canada for participation in IPY 2007–2008. The Council of Yukon First Nations (CYFN), Canada involvement in IPY 2007–2008 began with the participation in the Canadian National Committee in 2005. The release of the ACIA focused attention on climate change and IPY was viewed as an opportunity to further research and explore the potential effects of global warming in the Arctic and help determine what that would mean for Arctic peoples. The potential challenge was that northern communities did not fully trust researchers and many of them were expected to come north for IPY research. To mitigate this issue, northern communities decided to get involved in IPY 2007–2008 from the beginning. The Canadian IPY 2007–2008 Program focused on two priority areas for northern science and policy development: 1) Climate change impacts and adaptation; and 2) The health and well-being of northern communities. CYFN's interest was in the "human dimensions" of the IPY Program ("to investigate the cultural, historical and social processes that shape the sustainability of circumpolar human societies, and to identify their unique contributions to global cultural diversity and citizenship"). CYFN was looking for an opportunity to develop its research agenda that would capture the two priority areas identified as part of the Canadian IPY Program, climate change impacts, and community health and well-being. Similarly, other Canadian northern indigenous organizations were also looking to develop their research agendas and CYFN took the initiative to develop such a partnership. Eventually, CYFN, Gwich'in Council International, Arctic Athabaskan Council, Inuit Circumpolar Council, Inuit Tapiriit Kanatami and Dene Nation formed a committee that enabled them to identify their priorities. They identified community resilience as a priority research focus in their IPY-related efforts, with the aim to build capacity for Arctic community health and sustainability.

This partnership, for example, helped develop a project titled 'Arctic Peoples, Culture, Resilience and Caribou' (ACRC). Central to this study was the assumption that change is dynamic, uneven and unpredictable. Long-term socio-ecological health and well-being for Arctic communities means having the ability to adapt to change by accessing a range of strategies to respond to a variety of potential conditions. The project is currently in its final year.

It will be a while before Arctic communities realize the full significance of IPY 2007–2008 research results in the Canadian Arctic. The legacy that will be left behind will be determined through arctic eyes. Yet, they hope that IPY 2007–2008 momentum will continue and that it will adapt for the long-term support of health and well- being of northern communities.

Overall, out of more than 160 IPY research projects that were implemented, 12 projects were led by indigenous researchers or indigenous organizations

Fig. 5.4-2. BSSN workshop participants, Anchorage, 2008. Seated Left to Right: Victoria Gofman (AIA), Lyudmila Kulchitskya (Kanchalan, Russia), Arlene Gundersen (Sand Point, Alaska), Molly Chythlook (Dillingham, Alaska), Helen Chythlook (Dillingham, Alaska) Standing Left to Right: Moses Kritz (Togiak, Alaska), Iver Campbell (Gambell, Alaska), Marty Waters (Anchorage, Alaska), Ivan Vozhikov (Nikolskoye, Russia), Natalya Tatarenkova (Nikolskoye, Russia), Svetlana Petrosyan (Tymlat, Russia), Jim Gamble (AIA). (Photo: Aleut International Association)

while additional 25 projects had indigenous partners (*Chapters 2.10* and *3.10*)[3]. Many of these projects had a substantial community-based monitoring component (*Chapters 3.10* and below – Fig. 5.4-3). Community-based monitoring (CBM), a term used mostly in North America, is a complex research field that is becoming an essential and often required component in academic research and natural resource management (Gofman et al., in press). CBM enables researchers to reach beyond "Western" science by using the best available knowledge, be it academic, indigenous, traditional or local. Such holistic approach improves understanding of ecological systems and how they interrelate with human societies. Many IPY projects incorporated elements of CBM or traditional knowledge (*Chapter 3.10*) in a similar way ACIA did. Few, however, attempted to generate statistical data and trends based on information gathered solely from and by local residents. BSSN (IPY no. 247) was one of such projects.

In general, IPY projects that claimed leadership or participation by indigenous and other local organizations and residents can be organized in three groups: 1) Research led by academia focused on indigenous communities (e.g. CAVIAR, no. 157; SIKU no. 166, Narwhal no. 164, ELOKA no. 187, NOMAD no. 408, MODIL-NAO no. 46); 2) Research led by a partnership of indigenous organizations and academia (EALÁT no. 399 – see Fig. 5.4-4); 3) Research led by an indigenous organization and managing it as a project fiscal agent (e.g. BSSN, no. 247, no. 186). The last two groups represent a measurable increase in the involvement of indigenous and local stakeholders in polar research and management. This growth is a reflection of a growing political influence, financial and human capacities of indigenous and tribal governments, corporations (in North America), legislative bodies, and non-profit organizations in addition to the opportunities presented by IPY 2007–2008.

For the first time, representatives of indigenous organizations were invited to participate in the organizational and management bodies of an IPY. Many national committees included such representation: in Canada – Duane Smith of ICC and Cindy Dickson of the Council of Yukon First Nations, in Russia – Larisa Abryutina and Rodion Sulyandziga of RAIPON, in Sweden – Susanne Spik of Sirkas Same Village, and in the U.S – Richard Glenn of the Arctic Slope Regional Corporation (source: http://classic.ipy.org/national/committee.htm). Several representatives of indigenous organizations served on the IPY 2007–2009 subcommittees (Lene Kielsen Holm,

Fig. 5.4-3. Community meeting organized by the EALAT Project team near the town of Khralovo, Yamal-Nents Area, West Siberia for the Nenets, Komi, Khanty and Sami reindeer herders participating in the EALAT project.
(Photo: Svein Mathiesen)

Fig.5.4-4. The IPY EALAT consortium meeting in Kautokeino, Norway, 13 January 2009
(Photo: Philip Burgess, EALAT International Reindeer Center)

Greenland, on the Subcommittee on Observations; Birget Kleist Pedersen from the University of Greenland and Rodion Sulyandziga from RAIPON, Russia on the Education and Outreach Subcommittee). Ole Henrik Magga, the first President of the Norwegian Saami Parliament in 1989–1997 and the PI on the EALÁT project (IPY no. 399 – *Chapter 3.10*) addressed the IPY Open Science Conference in June 2010 as one of its plenary speakers (Fig. 5.4-5). Unfortunately, no member of polar indigenous organizations was invited to serve on the IPY Joint Committee. This will be one more peak to climb in the next International Polar Year.

Success of IPY 2007–2008 cannot be measured solely by the number of involved stakeholders. The main question is whether these initiatives can make significant contributions to the understanding of polar systems. Some projects were designed and funded to be implemented during 2007–2009 (SIKU, no. 166). Other projects used IPY 2007–2008 as a test drive for new ideas and those who demonstrated success have launched full-scale research after IPY, like BSSN (no. 247) and ELOKA (no. 187). The full results of projects will be available in a few years, but the fact of their existence and their longevity is a true IPY 2007–2008 triumph.

The experience gained in IPY 2007–2008 by many indigenous groups and academic institutions can help them better understand the difficulties inherent to integrating non-academic and academic research. The IPY experience also led to new developments in data management, research methods and funding processes, and to improving future research efforts to actively engage local stakeholders. More importantly, this experience opened doors to the next stage in collaborative polar research. The Arctic is a theatre where indigenous organizations are actors rather than props and it is time for them to play leading roles in polar research. IPY 2007–2008 was a baby step in that direction, but it was a giant baby step.

Exchanging and Sharing Knowledge with Local Stakeholders – ELOKA

Shari Gearheard, Henry Huntington, Mark Parsons, Chris McNeave and Peter Pulsifer
Reviewers: Claudio Aporta and Igor Krupnik

> *"I believe it is time for the harpoon and the computer to work together"*
> - Peter Kattuk, Sanikiluaq, Nunavut

Over the last decade, Arctic residents and indigenous peoples have been increasingly involved in polar research. Through Local and Traditional Knowledge (LTK) research and community-based monitoring (CBM), Arctic residents have made, and continue to make, significant contributions to understanding recent environmental change in the polar regions (e.g.

Fig.5.4-5. Ole Henrik Magga, Grete Hovelsrud and Svein Mathiesen at the Opening Ceremony for IPY 2007 –2008 in Paris, 1 March 2007. (Photo: Igor Krupnik)

Krupnik and Jolly, 2002; Huntington and Fox, 2005; Riewe and Oakes, 2006; Krupnik et al., 2010). Arctic residents' participation in IPY 2007–2008 and their critical role in many IPY projects in social and human health fields, marine and terrestrial biology, and environmental monitoring (*Chapters 2.10, 2.11, 3.10*) are commonly viewed as one of the key accomplishments of IPY 2007–2008. Nevertheless, this momentum in Arctic residents' participation in science research created by IPY has to be preserved and extended to become a lasting legacy of IPY. To achieve this goal, IPY scientists, collaborating northern communities and Arctic indigenous peoples' organization are developing new means to strengthen their partnership through a local and indigenous knowledge exchange network beyond the IPY 2007–2008 era.

ELOKA (the "Exchange for Local Observations and Knowledge of the Arctic"), one of IPY 2007–2008 projects (no. 187, *http://eloka-arctic.org*) launched in 2006 with funding from the Arctic Observing Network (AON) (National Science Foundation, U.S.) may become a prime vehicle in such a post-IPY partnership. It received continuation funding for 2009–2012, also from the NSF AON program, and will be processing, sharing and preserving data collected via several collaborative IPY and associated projects during the post-IPY decade. The main goal of ELOKA is to play a role in the creation of a post-IPY *network* to facilitate the collection, preservation, exchange and use of local observations and knowledge of the Arctic by providing assistance in data management and user support services. Such an emerging network will serve a wide range of people, from local citizens in small Arctic communities, to scientists in universities and educators in K-12 schools. In particular, it seeks to connect local and traditional knowledge of Arctic residents with science, and local experts with scientists, to further the collective understanding of the Arctic.

A key challenge of local and traditional knowledge research and community-based monitoring is having an effective and appropriate means of recording, storing and managing data and information. Another challenge is to find an effective means of making such data available to Arctic residents and researchers, as well as to other interested groups such as teachers, students and decision-makers. Without a viable network and operational data management system to support LTK and community-based research, a number of problems have arisen, such as misplacement or loss of extremely precious data from Elders who have passed away; lack of awareness of previous studies causing repetition of research and wasted resources occurring in the same communities; and a reluctance or inability to initiate or maintain community-based research without an available data management system. Thus there is an urgent need for effective and appropriate means of recording, preserving and sharing the information collected in Arctic communities. The momentum started in the IPY and spearheaded by the ELOKA project aims to fill this gap.

Building a Knowledge Exchange

At the heart of ELOKA is the **development** and **implementation** of the tools and services needed to manage, protect, communicate and share LTK and CBM information. In order to achieve this, ELOKA began its efforts during the IPY years with two case study projects: the *Sanikiluaq Sea Ice Project (Nunavut, Canada) and Narwhal Tusk Research* ('Studies of Narwhal Teeth', IPY no. 164). The community of Sanikiluaq has been active for many years in researching and monitoring the local environment from both Inuit and scientific perspectives. ELOKA partnered with Sanikiluaq to provide data management for a small subset of their work: documenting local observations and knowledge of recent sea ice change.

The Sanikiluaq data consists of videotaped interviews with Inuit hunters and map overlays that hunters used to draw their observations of sea ice change. These data are typical of many LTK projects that often use video, audio and mapping techniques. The tools developed to manage this information include a video player and maps created by professional cartographers in collaboration with community members. Together these tools provide a unique and customized means to store and present Sanikiluaq's LTK research (see Fig. 5.4-6).

Narwhal Tusk Research was an IPY 2007–2008 project (no. 164) launched in collaboration with the Inuit hunters and elders from Nunavut, Canada and Northwest Greenland (see www.narwhal.org/; http://classic.ipy.org/development/eoi/proposal-details.php?id=164). Hunters and elders from several communities on Baffin Island and Greenland have provided key information on changes in hunting strategies for narwhal, observations of narwhal behavior including feeding and migration patterns, and task-related behavior.

ELOKA is developing a website for Narwhal Tusk Research that presents over 30 interviews conducted with Inuit hunters and elders, along with complete, transcribed translations (Fig. 5.4-7). This allows one to view entire, unfiltered interviews in the context in which they were given, or new search tools being developed will allow for more direct access to desired information. Along with the interviews, the sub-site provides information on the science and laboratory work completed in the project and summary information about narwhals.

The Sanikiluaq Sea Ice Project and Narwhal Tusk Research are the first two case studies advanced during the IPY years. Work on sub-sites for other projects is underway as similar and complementary tools are being developed by other projects and organizations that have partnered with ELOKA to develop a network of services for local knowledge and community-based monitoring information. For example, significant research is being carried out in the area of web-based mapping and Geographic Information Systems (GIS) for LTK by research groups such as the Geomatics and Cartographic Research Centre at Carleton University, Ottawa, Canada. Other partners in a growing list working with ELOKA on building a support network include the Sea Ice Knowledge and Use (SIKU, IPY no. 166) project, Department of Fisheries and Oceans Canada, Nasivvik Centre for Inuit Health and Changing Environments, Aleut International Association (AIA), Inuit Tapiriit Kanatami (ITK), Inuit Knowledge Centre (IKC), Sustaining Arctic Observing Networks (SAON), Yukon River Inter-Tribal Watershed Council, Earth Institute (Columbia University), International Polar Year Federal Program Office Canada, SIZONet (Seasonal Ice Zone Observing Network, University of Alaska Fairbanks), Circumpolar Biodiversity Monitoring Program (CBMP), Alaska Native Science Commission and the SnowChange Cooperative, an international group based in northern Finland that is documenting indigenous knowledge about Arctic climate change.

Fig. 5.4-6. Part of the Sanikiluaq Sea Ice Project subsite on ELOKA showing LTK maps and video player featuring an interview with Peter Kattuk, a Sanikiluaq hunter.

Fig. 5.4-7. Presented in an on-line video/ translation player, Cornelius Nutarak of Pond Inlet, Nunavut, discusses his life-long experiences observing and hunting narwhal.

Meeting the Challenges of Local Knowledge and Data Management in the post-IPY Era

The unique interdisciplinary approach of IPY 2007–2008 and the experience of exchanging and sharing knowledge generated by Arctic residents (via ELOKA and other IPY projects) have highlighted critical needs to ensure data are well preserved and useful to a broad community. Many of these needs reach across all types of data and information, but LTK and CBM present unique challenges as well. The Arctic Council has determined community-based research to be a priority. For this research to be effective it needs to be supported with robust data management.

All data collection efforts, be they satellite missions or the gathering of oral interviews, require advanced planning to ensure the data collected are well documented, secure and useful. Professional data management should be an explicit requirement of any data collection effort. With LTK collection efforts, additional training may be necessary to ensure ethical and effective data collection practices that capture the broad context necessary to understand the information.

Data archiving is a critical need. Agencies must support new repositories and resource centres (e.g. Inuit Tapiriit Kanatami in Canada, RAIPON in Russia) for LTK and for CBM data where appropriate archives do not exist. These archives need to collaborate with similar organizations in other countries. ELOKA can facilitate this collaboration, but ultimately there needs to be an internationally supported network of organizations providing LTK and CBM data. SAON, another IPY 2007–2008 initiative (*Chapter 3.8*), provides a logical focal point for this collaboration. There is an acute need for more research and publication on best practices on LTK data organization and presentation that captures necessary context to convey richer knowledge. Funding agencies also need to consider how open data policies can be best applied to LTK through fair but simple intellectual property agreements.

Finally, it is essential to continue and expand community-based research and collaboration. Agencies should support projects and workshops that bring together scientific researchers and community members to identify and explore integrative science questions. ELOKA work with the community of Sanikiluaq revealed several critical science questions and potential hypotheses about the Hudson Bay water cycle and food web is just one example of the potential.

Summary of Prospective Services to Northern Communities in the post-IPY Era

We understand that the development of a circumpolar network and data management services for Arctic local and traditional knowledge and community-based observations will take time, collaboration and input from many sources. Our hope is that the work begun during IPY 2007–2008 has built a strong foundation for the development of such a network and, in particular, that the work will continue. The momentum generated by ELOKA and related IPY projects has the potential to fulfill an existing need in Arctic research and to support northern communities in diverse research and heritage efforts. It has the potential to make a strong contribution to many of the IPY 2007–2008 legacy initiatives, such as SAON and ISAC (International Study of Arctic Change) as well as to facilitate connections between local and international researchers.

Among the services to be provided to local communities in the post-IPY era, the ELOKA team has identified several activities with potentially the most tangible benefits, such as: (1) data preservation and archiving for local and traditional knowledge and community monitoring; (2) facilitation of data discovery and data distribution; (3) dynamic data presentation that seeks to maintain relevant context around the information; (4) digital mapping and community-contributed mapping and GIS; (5) assistance in developing data management plans, data collection protocols, documentation and data organization; (6) connections between local and community-based information with scientific data, including research and data products that draw on both; and (7) 'match-making' between scientists and Arctic communities based on research needs, interests and questions as well as facilitation and support of research collaborations.

The key condition to achieve these and other related goals in managing and sharing data from the local knowledge and community observational projects is to expand the post-IPY network of polar communities, science agencies and individual researchers. Partnerships with Arctic residents and research around knowledge and observation data sharing has made important progress, particularly, thanks to IPY. In order to become a lasting legacy, the network of community-based projects initiated in IPY 2007–2008 needs support with building collaborations across the Arctic, especially by organizations like the Arctic Council, indigenous peoples' organizations and science funding agencies (NSF, ESF, SSHRC and others).

The University of the Arctic and the International Polar Year

Lars Kullerud and Outi Snellman
Reviewer: Volker Rachold

IPY - an opportunity, a reality and a hope?

The Board of Governors of the University of the Arctic (UArctic) decided as early as 2005 to propose the UArctic as an IPY project. From the perspective of Northern institutions, this was not an obvious choice as many were skeptical about a "southern"

Fig. 5.4-8. EALAT Reindeer Herders Workshop, Kautokeino, Norway, March 24, 2010. (Photo: Svein Mathiesen)

driven (i.e. proposed as IGY+50 – eds.) IPY 2007–2008 that could run over the interest, needs and focus of the people of the North. UArctic was also a young institution, established in 2001, as an outcome of an Arctic Council initiated process (see www.uarctic.org/compactArticles.aspx?m=75). Nonetheless, at its annual meeting in Oulu, May 2005 the Council representative forum of all UArctic member institutions voted in favour of joining the IPY program. This was due to a great extent to a convincing presentation given by Cynan Ellis-Evans on behalf of the IPY team, who explained the work towards including the human dimension into IPY 2007–2008 science program.

Already in January 2005, the UArctic submitted an Expression of Intent (EoI no. 404, *Higher Education in the International Polar Year*) to the IPO aimed to include the University as a whole as a project under the IPY program. In September 2005, a proposal "The University of the Arctic: Providing Higher Education and Outreach Programs for the International Polar Year" was submitted and shortly after it became an endorsed IPY project (no. 189). After completion, it is fair to state that being in the IPY has been a success in engaging public interest about polar regions and in focusing research investment in polar issues.

In the years leading to the next IPY, we may assume that this IPY will be remembered for the strategic decision to include social sciences, for recognizing indigenous and traditional forms of knowledge, and for enabling the creation of strong networks. While 'interdisciplinary' may have been more a buzzword in many projects than a reality, this IPY also shows some outstanding examples (i.e. the EALAT project – *Chapter 3.10*; Fig. 5.4-8), where social and natural sciences as well as indigenous perspectives are fully integrated.

The UArctic has been the lead agent for IPY Higher Education in the Arctic. Even if its effort under the Project no. 189 constituted a minor portfolio among IPY activities, it is a crucial part of the IPY Legacy. Higher education is the tool to foster development of scientists and northern experts and leadership for the future, including future polar years. We therefore are proud that UArctic has grown during the IPY years into a unique and complete network of higher education institutions in the North (Fig. 5.4-9), with more than 100 members, including practically all of the universities and colleges in the Circumpolar North and several important research institutions and indigenous organizations. Totaling over 650,000 students and some 50,000 academic staff, the UArctic provides a research network built by its members (see Table 5.4-1) and, with support from governments is ready to take on a leadership role in bringing the energy from IPY 2007–2008 into a new level and into a new era (Fig. 5.4-10).

Higher education in the North during International Polar Year

UArctic has grown steadily since its establishment in 2001. Our growth has coincided with many other important processes effecting the North. The IPY, the evolution of the Arctic Council and its working groups, the renewed geopolitical focus on the North, emerging new forms of self-governance, strengthened indigenous organizations, the emerging Arctic implementation of the UN Law of the Sea, as well as the media hype have helped UArctic and other initiatives thrive. It is, however, important to remember that this increased focus on the polar regions is fundamentally driven by many external factors like energy demand, climate change, globalization of local economies and the like.

UArctic established an IPY Coordination Office in 2007, hosted by the University of Alaska, Fairbanks to ensure that Higher Education proposals generated outside UArctic were supported. This office, in cooperation with the UArctic Field School Office at UNIS on Svalbard, contributed significantly to national and international work of the IPY Education and Outreach Subcommittee. UArctic is particularly happy to observe the establishment of the Association of Polar Early Career Scientists, APECS (*Chapter 4.3*). As an offspring of this work by IPY and UArctic have funded and run specialized IPY field courses for International students as part of this work. UArctic also encourages the development of the International Antarctic Institute, which may over time develop into a strong sister organization of the UArctic (see below).

An important goal for IPY was to ensure increased global awareness and support to polar issues and polar research. UArctic established in 2007 the GoNorth program (www.uarctic.org/SingleArticle.aspx?m=777&amid=8836) which is a collective effort among our members to market northern study

Fig. 5.4-9. The University of the Arctic is a cooperative network of universities, colleges and other organizations committed to higher education and research in the North.

opportunities for students from outside the Arctic.

Partly influenced by our work with IPY, UArctic is now developing more focused strategies for relating to institutions in more southern latitudes. Whereas formerly UArctic's membership was only open to organizations in the Arctic eight countries, the new Associate Member category created in 2010 will enable members from outside the Arctic region to join as long as they have an interest in enhancing collaboration and fully subscribe to UArctic's values and goals. As we grow, it is important to create mechanisms that ensure that we ourselves stay true to our values: circumpolar, diverse and holistic. One of these mechanisms is UArctic's newly created post of Vice-President Indigenous Affairs.

Post-IPY Era: Ways ahead

When it comes to access to education, the North is still "the periphery" in most countries, with a gravity of education opportunities, research, development as well as business and job opportunities located mainly further south. Recent socioeconomic and resource statistics (Glomsrød and Aslaksen, 2008) demonstrates that the North contributes more to the GNP per capita than other regions of most arctic states. IPY has done a tremendous job in increasing respect for, understanding of and interest in northern issues in the south. It remains a challenge to modify the "images of the North" so that they become something beyond "the frontier".

The UArctic was created before IPY 2007–2008 with the purpose to take the lead to provide stewardship for a sustainable long-term legacy in higher education and research cooperation in the Circumpolar North. We strongly believe that a well-educated northern population and strong northern research networks will foster leadership for the next IPY. Further, UArctic is committed to ensuring that the northern universities and colleges become key players in the development of research and sharing knowledge in and about the North, and that such knowledge is based on indigenous and local traditional approaches as well in modern science.

UArctic would like to do this in close cooperation with the global polar research community, in particular with major polar science organizations like IASSA, IASC and SCAR. This is another legacy of many new partnerships built during the IPY years.

Fig. 5.4-10. UArctic member institutions have been extensively involved in projects of the International Polar Year. This map shows the relative number of projects each member is involved in.

IPY 2007–2008 grassroots approach to define key projects and research issues demonstrated an impressive openness within the science community. Governments and science organizations have also had ample opportunity to influence the priorities of IPY. People living in the Arctic, both indigenous as well as other northerners and their leaders, were rarely informed of the IPY process during its early formative years, 2002–2004, and generally have not been engaged to formulate its research priorities. It remains a challenge for the Arctic science organizations, including IASC and IASSA, as well as UArctic to ensure that the science community will not monopolize the right to define research agenda in the North for the next IPY.

The biggest disappointment of this IPY may be the lack of coordination between various funding agencies. Even if there have been some well meant attempts, the general picture is that funding is nationally prioritized and is only modestly linked to the implementation of projects across the national borders. UArctic view, shared clearly by key actors such as the Nordic Council of Ministers, IASC and IASSA is that this problem can best be addressed through a concerted collaboration of the Ministries responsible for the funding of science and education in the either Arctic Countries.

Nevertheless, as we wait for the circumpolar funding instruments to be in place for the next IPY, we have also learned other lessons about the funding instrument during this IPY. As funders tend to focus the bulk of the funding on large programs and huge projects it has become harder and harder for smaller partners—and often the Higher Education Institutions in the North are small—to find their place at the table. The necessary step is the wish to be inclusive. If diversity, balance in representation and inclusiveness are seen as important aspects of quality, these adjustments will also become obvious requirements to future polar research as we plan for the post-IPY era and for the future IPY.

Table 5.4-1: UArctic Members and Students' Participation in IPY Projects, by major Arctic nation.

	Number of partners to IPY projects	Number of UArctic members among the partners	UArctic members (%)	UArctic members part of national total higher education student mass	UArctic members relative popularity as IPY project partner	Part of UArctic members in each country that do have IPY participation	Part of UArctic members self identify as Indigenous with IPY participation
Canada	513	95	19	18.7 %	1.0	32 %	25 %
Denmark	235	16	7	3.7 %	1.8	75 %	100 %
Finland	101	47	47	34.2 %	1.4	40 %	50 %
Iceland	42	8	19	29.9 %	0.6	80 %	
Norway	365	101	28	8.9 %	3.1	35 %	50 %
Russia	303	16	5	1.3 %	4.1	19 %	17 %
Sweden	191	85	45	22.3 %	2.0	100 %	
U.S.A.	804	141	18	.009 %	194.9	38 %	0 %
International	36	9	25			50 %	100 %

Number of IPY partners by country based on the IPY IPO database of almost 3800 partners in 172 IPY endorsed projects that have Arctic or bipolar focus (Antarctic excluded) and partial or substantial funding. The popularity of UArctic members relative to all universities and colleges in the country is estimated based on total number of university level students in the country (UNESCO, 2007 data) and the number of students as reported by the UArctic members in the UArctic annual survey. The factor indicates that UArctic members are more active in IPY projects than average in most of the Arctic eight countries. In spite of this, in most countries less than half of UArctic members have partnership in any IPY project. UArctic members that self identify as Indigenous (often small organizations) seem to have same popularity as IPY partners as other members. It must be noted that these statistics do not indicate anything about size of the engagement, only whether a researcher from an institution is listed as a partner in the IPY project database.

The International Antarctic Institute and the International Polar Year

Patti Virtue

History of our partnership with IPY

At the very beginning, during our 'dreamtime' in late 2004, it was proposed that IPY would be the platform upon which to launch the International Antarctic Institute (IAI) (Fig. 5.4-11). We were indeed launched upon this wonderful platform and, with the help and guidance of many organizations, we came into being in 2006 with our constitution adopted in 2008. IPY was an opportunity to establish the IAI and to build a legacy for Antarctic education into the future. The IPY Joint Committee endorsed our proposal to establish the IAI (EoI no. 415) and, together with the University of the Arctic, we were identified as potential lead players in Education and Outreach. This gave us great impetus to grow and evolve as we continue to do so in the footsteps of the University of the Arctic. We may not have been a big player in IPY, but IPY was a big part of us, and will continue to be through the collaborations, connections and friends we made throughout 2007–2008.

The need for international training in polar research

By international agreement, the Antarctic continent has been set aside for peace and scientific collaboration. As has been seen over the past half-century, and as evidenced through IPY, international cooperation is the key to the success of large-scale research programs in Antarctica and the Southern Ocean. With climate change now accepted as being a result of human influence, the importance of understanding the role of polar regions on climate mechanisms needs to be part of global education. The delivery of knowledge and information to the next generation of researchers and policy-makers needs to address sustainable resource management, climate impacts and other global environmental and social issues associated with Antarctica and the Southern Ocean. In addition to traditional disciplines, it is important to provide opportunities for students during their formal training to look beyond their home borders. We need to educate our students to be open and receptive to different ways of thinking, of researching and of viewing the world.

The International Antarctic Institute was established during IPY as an educational and research platform for all nations, facilitating cooperation and collaboration among member institutes. This platform was built on existing international research and educational programs concerning Antarctica and the Southern Ocean, using recognized skills and expertise within the IAI network. The IAI is governed by a council comprising a person appointed by each participating Institution. The main focus of the IAI is to enhance interdisciplinary studies in relation to Antarctica, the Southern Ocean ecosystem and global climate understanding. Our aim is to cross-credit study programs, develop joint curricula, and share teaching, educational, and other resources and facilities. Together we offer multi-disciplinary and multi-institute courses and units of study. A certain number of places in these courses are allocated for IAI students from partner universities with no associated tuition fees. Students maintain enrolment at their home university and can undertake either course work or research projects at other IAI member universities.

Our Goals

The goals of the IAI, now a consortium of 20 institutes representing 13 countries[4] are to:

- Develop and provide students with international opportunities in Antarctic education that will enable them to become expertly trained scientists and social scientists with international experience and skills in research and its application.
- Deliver the knowledge and information needed by the next generation of researchers and policy-makers to address sustainable resource management, climate impacts and other global environmental and social issues associated with Antarctica and the Southern Ocean.
- Facilitate the engagement of the international scientific community in Antarctic and Southern Ocean education.
- Extend existing national teaching bases in Antarctic education into the international arena.

IAI activities during IPY 2007–2008

Throughout IPY, we focused on developing new and innovative Antarctic courses, developing effective ways to share teaching resources among partner universities and developing clear articulation of pathways between degrees to encourage student and staff mobility. We have developed and implemented programs and activities in three key areas: courses and units of study, Masters degree programs, and field opportunities for students. Recently, new Masters programs were developed with a focus on Polar Marine Biology, Chemistry and Glaciology. We have facilitated student exchanges both to undertake courses and research. Some of the exchanges have allowed students to carry out research on the Antarctic continent and participate in Southern Ocean oceanographic research expeditions.

During IPY we developed a UNESCO/Cousteau Chair under the IAI umbrella organization. Through graduate student training programs and global research programs, the Chair hopes to facilitate the bringing together of nations, including countries with strong Antarctic research programs and non-traditional Antarctic research countries. The Chair will serve to bridge scientific and social disciplines to facilitate a better understanding of global issues that affect the Antarctic region.

Post-IPY: Future Development for IAI

Key priorities for the IAI in the coming years include expanding our course offerings to cover physical and geosciences. We are currently developing courses focused on the social sciences, such Antarctic law and policy, as well as multidisciplinary on-line modules in Antarctic Science offered as a distance option to partner universities. Under the UNESCO/Cousteau Chair we hope to encourage non-traditional Antarctic research countries to join the IAI which will require concerted effort and substantial funding. As we continue to foster the next generation of polar researchers through international collaboration, we hope to work more closely with APECS and UArctic. The goals of our organisations are complementary and this was recognized through the signing of a joint MOU during the Oslo conference. Together the IAI, APECS and UArctic as partners, have enormous synergistic potential, yet to be realised.

Fig. 5.4-11. Inaugural IAI meeting in Hobart, 2004.
(Courtesy: Patti Virtue)

'Dreamtime'

The 'dreamtime' forms a part of Australian aboriginal history, although a complex philosophy, it is a special time when birds got their colours (except the bad tempered crow)[5], when sacred places were created, when law and custom were developed. It is a period of fashioning, organising and moulding the past to the present and into the future (Dean, 1996). Perhaps IPY 2007–2008 was our 'dreamtime', when the sciences danced with humanities, when the research community embraced education for the future of the Arctic and Antarctica.

Box 1 International Ocean Institute (IOI) promotes objectives of IPY 2007–2008

Iouri Oliounine

Since the announcement of IPY 2007–2008, the International Ocean Institute (IOI – www.ioinst.org/), a non-governmental organization located in Gibra, Malta, demonstrated its interest in supporting the IPY objectives, particularly via information sharing, training and educating new constituencies. The IOI was founded in 1972 by Prof. Elisabeth Mann Borgese, as an international knowledge-based institution, devoted to the sustainable governance and peaceful use of the oceans. In 2004, Yuri Olyunin, former IOI Director, was invited to share with the IPY organizers his experience in coordinating the International Year of the Oceans held in 1998. In March 2005, the IOI representative took part in the first IPY Open Consultative Forum in Paris. IOI expressed its readiness to provide its network, experience and knowledge for contributing to the IPY efforts.

IOI's main contribution to IPY was via hosting the *Pacem in Maribus* Conference (PIM) in 2007 in Malta under the title "Waves of Change: Women, Youth and the Sea, Partnering for the Protection of the Marine Environment and the Sustainable use of its resources." A group of experts on polar issues, including David Carlson, Eduard Sarukhanian, Angelika Renner and Claudia Halsband-Lenk, gave presentation at the special session dedicated to the issues relevant to IPY.

Training programs on ocean governance organized by IOI in Canada and in Malta in 2007–2009 were enriched by the series of lectures dedicated to IPY. IOI annual *Ocean Year Book* volumes 23 (2009) and 22 (2008) featured several chapters on change, biodiversity, fishing and legal aspects of governance in the polar regions. These and other IOI activities relevant to IPY provide a good example of the NGO potential in promoting a multi-faceted global science program.

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Notes

1 The town of Kautokeino in the heart of the Sámi territory had a special role in IPY history as the site of one of the first IPY observation stations in 1882–1883 (*Chapter 1.1, 2.10*).

2 1996, Ottawa, Declaration on the Establishment of the Arctic Council.

3 Based upon recent count from the IPY project chart.

4 www.iai.utas.edu.au

5 www.okulture.com/Black%20Opal/index-19.html

5.5 IPY and Expanding Partnerships in Coordination of Polar Research

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IPY Legacies: Scientific and political cooperation

Owing to the common interest in polar science during IPY, the links between science and the political frameworks provided by the Antarctic Treaty System and the Arctic Council have been strengthened. The heightened level of political attention and financial support has enhanced opportunities for direct international scientific collaboration, facilitated polar access and effective international sharing of polar logistical assets and infrastructure, accelerated the exchange of technological information and improved reporting from nationally supported operational networks. It has also increased connections and collaboration among polar science organizations, such as SCAR and IASC, as well as with non-polar science organizations. As a result, the findings of IPY science have attracted both the interest and the support of the Antarctic Treaty nations and the Arctic Council.

(The State of Polar Research, 2009, p.8-9)

One important outcome of IPY 2007–2008 was the advancement of existing partnerships and the development of new ones. The cornerstone for IPY was the partnership between its two main sponsors, the International Council for Science (ICSU) and the World Meteorological Organization (WMO) that started more than 50 years ago with the implementation of the International Geophysical Year 1957–1958. The collaboration between ICSU and WMO, again, emerged as the main driving factor in the planning and organization for this IPY (*Chapters 1.2, 1.3, 1.5*).

Nonetheless, the new IPY was born and implemented thanks to the collective efforts of many organizations, including the Scientific Committee on Antarctic Research (SCAR), International Arctic Science Committee (IASC), Intergovernmental Oceanographic Commission (IOC), Arctic Ocean Sciences Board (AOSB), World Climate Research Programme (WCRP), European Polar Board (EPB), Arctic Council (AC), Antarctic Treaty Consultative Meeting, International Arctic Social Sciences Association (IASSA) and many more (*Chapter 1.4*). These networks of new relations or of strengthened established ones will define the future of polar research for decades to come and may serve the model for the future planners of the next IPY.

This Chapter covers only a fraction of these new or advanced partnerships forged during IPY as an important element of the legacy of IPY. The first part deals with linkages between and among the key scientific bodies that were instrumental to IPY and will almost certainly define its legacy in the post-IPY era, i.e. ICSU, WMO, SCAR and IASC. IPY 2007–2008 was clearly a major peak in ICSU-WMO relationship and it ushered in a totally new level of collaboration between the two major polar science organizations, the Scientific Committee on Antarctic Research (SCAR) and the International Arctic Science Committee (IASC). The second part of this chapter deals with the science/policy interface, first and foremost, with the AC and the AT/ATCM collaboration. Due to the heightened level of political attention to the role of polar science in climate research during IPY (and, generally, over the past decade), the awareness of the need for scientific input to underpin political deliberations in the framework of the Antarctic Treaty System (ATCM) and the Arctic

Council (AC) increased significantly. Some prospects of this more active engagement of intergovernmental political bodies in science and science planning, particularly with regard to the next major post-IPY Conference (*From Knowledge to Action*) in 2012, will be covered in more detail in *Chapter 5.6.*

Future ICSU and WMO Engagement in Polar Research

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International Council for Science (ICSU)

ICSU is a strategic organization that works on international science cooperation, universality of science and the science-to-policy interface. ICSU acts on behalf of its members[1] through the international, interdisciplinary programmes it plans and (co)sponsors. IPY 2007–2008 was one such program; now that IPY is over, this is how ICSU envisions its continued engagement in polar research.

The starting point is to emphasize that IPY is not the only program with polar dimensions that ICSU sponsors. The Scientific Committee on Antarctic Research (SCAR) is another example, as is the World Climate Research Programme (WCRP) with its Climate and Cryosphere (CliC) project. ICSU has among its members the International Union of Geodesy and Geophysics with its International Association on Cryospheric Sciences. Furthermore, the International Arctic Science Committee (IASC) is a Scientific Associate of ICSU.

These and other ICSU-related entities were boosted by IPY 2007–2008 and all will engage in the future of polar research. The challenge is to do so efficiently and effectively. The planning and implementation of IPY certainly helped with this challenge; IPY fuelled, for example, development of cooperative agreements among the aforementioned groups as well as new joint initiatives like the SCAR-IASC bipolar action group (see below). More fundamentally, IPY illustrated the benefit of international cooperation in polar research and highlighted the value of multidisciplinary approaches, and of inspiring and engaging educators, communicators and early career scientists. These lessons are being captured in ICSU through the ongoing work of polar-related organizations in the ICSU network and by involvement of IPY "veterans" on new, related ICSU initiatives. In the remainder of this section, we describe two such major initiatives that should add to the momentum IPY 2007–2008 generated for international polar research.

Polar Research as Integral to ICSU Earth System Research Agenda

A theme of IPY 2007–2008 and the 2010 IPY Oslo Science Conference was "Polar Science: Global Impact." One needs to look no further than the array of IPY science in this volume to appreciate this global impact and to be reminded that polar research is a fundamental component of Earth system research, which has a long history within ICSU. Yet, it is probably fair to say that ICSU-sponsored polar bodies have not been as directly engaged as they could or should have been with the four ICSU-sponsored Global Environmental Change programmes.[2]

In October 2008, ICSU initiated a "Visioning Process" (www.icsu-visioning.org/) for Earth system research that was motivated by the urgencies of global environmental change and the need for a holistic research strategy among the multitude of international programs, projects and partnerships. By contributing to the Visioning Process and the Earth system research agenda that should follow, the polar research community influences and engages in ICSU's major thrust in Earth system research over the next decade. The onus is on ICSU to create and highlight opportunities for engagement in this process and its outcome. Taking a lesson from IPY on engagement of early career scientists, ICSU asked the IPY-initiated Association of Polar Early Career Scientists to nominate a participant for the initial "visioning" workshop in September 2009 and ensured that roughly one third of workshop participants were early-career scientists. An equal responsibility lies with the polar research community and its organizations (whether ICSU-affiliated or not) to be proactive in this Visioning Process and subsequently to take ownership of relevant elements of this new initiative that will emphasize the research needed to address the grand challenges of global sustainability.

Polar Research Underpinned by Effective Data Management

IPY 2007–2008 tested the ICSU-sponsored World Data Centers and found them, and many other facets of the data management process, wanting (*Chapter*

3.11). In October 2008, ICSU launched the World Data System (WDS) to begin to improve this situation that also prevails beyond polar data circles. Lessons and ideas from the IPY are influencing the development of WDS; improving polar data archiving is one of the early WDS implementation actions.

ICSU overall strategy toward polar data is further supported by its seed grant to a number of ICSU-affiliated polar organizations investigating the Polar Information Commons (PIC). In parallel, ICSU is examining the role of the "Commons" approach in data management in general; this study will both learn from and highlight PIC's work.

ICSU Outlook

Strategic development of Earth system research and data management is by no means the only ICSU focus that should benefit polar research in the long term. One could, for example, mention ICSU's sponsorship of global observing systems or ICSU's role in promoting the principle of Universality of Science that underpins the conduct of all science (see www.icsu.org/Gestion/img/ICSU_DOC_DOWNLOAD/3245_DD_FILE_Polar_Universality_statement.pdf). One could also note ICSU sponsorship of the 2012 IPY Montreal "From Knowledge to Action" conference (*Chapter 5.6*).

Nevertheless, listing activities distracts from the simple message ICSU wishes to convey in this Summary: ICSU foresees strong ongoing engagement with the polar research community, particularly in the context of Earth system research. This will be built on the shoulders of the polar organizations invigorated by IPY and in collaboration with many partners in its implementation, especially WMO. For its part, ICSU will regularly assess progress and opportunities for enhancement. In addition, ICSU will work on key pillars that support polar science, including international data management, universality, observing systems, international coordination of funding, and public and policymaker awareness of science. For their part, polar researchers and their organizations should test and push ICSU on these many fronts—raising ideas, opportunities and challenges with ICSU's planning and decision-making organs—so that polar science continues to push the envelope on international, interdisciplinary science cooperation after IPY 2007–2008 is completed and at this critical juncture in the evolution of the Earth system.

World Meteorological Organization (WMO)

WMO is an intergovernmental organization that initiates and supports international research to enhance the ability of its Members[3] and their National Meteorological and Hydrological Services (NMHS) to improve observations of weather, climate, water and environment, and, as a result, improve prediction, service delivery, and scientific assessments of regional and global environmental conditions. In order to ensure the best policies to protect the ozone layer, reduce the effects of the long-range transport of air pollution, and to cope with climate change and variability, the WMO-sponsored research and scientific assessments provide support to relevant international environmental conventions and related protocols concerning, *inter alia,* ozone-reducing substances, climate change, desertification and combating drought. The WMO Commission for Atmospheric Sciences (CAS), the WMO Commission for Climatology (CCl), the Joint WMO/IOC Commission for Oceanography and Marine Meteorology, and the Joint Scientific Committee for the WCRP assist Members' research through the CAS World Weather Research Programme (WWRP), including The Observing System Research and Predictability Experiment (THORPEX), the Global Atmosphere Watch Programme on atmosphere chemistry (GAW), the CCl Climate Information and Prediction Services (CLIPS) project and through WCRP-affiliated major projects (GEWEX, CLIVAR, CliC and SPARC).

IPY 2007–2008 is a highlight of WMO research leadership and partnership. Indeed, WMO, through the NMHSs and its Commissions, substantially contributed to the IPY research and observations in the areas of polar meteorology, oceanography, glaciology and hydrology. Ultimately, the intensive campaign of internationally coordinated IPY scientific research and observations has significantly contributed to the enhancement of the WMO observational networks in Polar Regions: a better understanding of physical processes; improvements in the use of observations, modelling and prediction in Polar Regions; and better knowledge of the role of environmental changes in sustainability and well-being of Arctic communities. To coordinate WMO activities in Polar Regions in post-IPY era, the Executive Council established in June 2008 the Panel on Polar Observations, Research and Services (EC-PORS; see www.wmo.int/pages/prog/www/Antarctica/antarctic.html).

Development of polar prediction system

WMO recognizes that the needs of users for weather, climate, hydrological and other environmental services are constantly increasing in changing polar environments, and that services will be in great demand for users including shipping and navigation industries, platforms, search and rescue and other emergency response operations, infrastructure development, overland transportation, hydro-power production and polar science logistics management. To meet these requirements, an important task for WMO in the near future will be to design and develop polar prediction system based on IPY scientific advances. This will require effective collaboration across the NMHSs and relevant WMO Commissions as well as with other partners. The CAS at its fifteenth session (November 2009) recommended the establishment of a THORPEX Polar Research project to improve understanding of the impact of polar processes on polar weather, assimilation of data in Polar Regions and prediction of high-impact weather over Polar Regions (www.wmo.int/pages/prog/arep/cas/index_en.html). At its first session (October 2009) the EC-PORS recommended that efforts be made to advance prediction for polar weather and climate and to extend efforts to snow, ice, carbon and ecosystem modelling and analysis. This would also require the involvement of relevant WMO Commissions and Programs as well as WCRP.

Working towards Climate Outlook Forums for Polar Regions

Despite the interest in and increasing need for long-range forecasts (months to several years) and climate prediction (beyond two years), there is not the same level of predictability in the polar regions as is realized in temperate and tropical latitudes. WMO recognizes the need to determine user requirements for forecasts and prediction, and to develop the requisite prediction capabilities to meet the needs for short and longer term products in the Polar Regions. Considering the extent and rapidity of climate and environmental changes with a profound effect on polar (and indeed global) peoples, WMO, in collaboration with WCRP, is working to extend the Climate Information and Prediction Services (CLIPS) concept to Polar Regions by establishment of Polar Climate Outlook Forums (PCOF). This idea was proposed by the WMO/WCRP/IPY Workshop on CLIPS in Polar Regions held in St. Petersburg in September 2008 (www.wmo.int/pages/prog/wcp/wcasp/polarclips.html) and supported by EC-PORS-1 and CCl-XV (February 2010). PORS-1 recognized the role of PCOF as a core mechanism for promotion of climate products and services to users within the Global Framework for Climate Services established by countries and agencies at the World Climate Conference-3 (September 2009), and recommended: (i) a survey to assess user requirements and (ii) development of polar climate "statements" by the PCOF. Polar Climate Outlook Forums could be considered to accompany the Trans-Regional Climate Centre evolution currently being developed in WMO, providing a regular international collaboration between climate service providers and user representatives with interests in the Polar Regions, to share currently available information, to respond to user requirements for climate information, products, and services, and to engage in awareness and technical training of climate providers and users. The PCOF concept has been recognized as a WMO legacy of IPY 2007–2008 and as a potential contributing mechanism to the WMO Global Cryosphere Watch (GCW) that represents a third stream of WMO future activities related to polar research (a detailed description of GCW initiative is given in *Chapter 3.7*)

WMO Outlook

The outcomes of IPY 2007–2008 offer benefits to all WMO Programs by generating comprehensive datasets and authoritative scientific knowledge to ensure the further development of environmental monitoring and forecasting systems, including severe weather prediction and the assessment of climate change and its impacts on polar environment and circumpolar communities. Beside the aforementioned WMO scientific initiatives, other WMO projects focused on polar research, such as studies of atmospheric chemistry, ozone depletion, and hydrology and water resources that will continue in the next years. Consequently, the WMO Executive Council at its sixtieth session (June 2008) recognized the unique opportunity for WMO, in consultation with ICSU and other international organizations, to consider the launch of

Fig. 5.5-1. From left, Thomas Rosswall (then ICSU Executive Director), Albert II, Prince of Monaco and Michel Jarraud (WMO Secretary-General) at the IPY Opening Ceremony, March 2007.
(Photo: Palais de la decouverie / C. Rousselin)

an International Polar Decade as a long-term process of research and observation in the Polar Regions to meet requirements for climate change studies and prediction in order to address societal needs (*Chapter 5.6*).

Strengthening ICSU and WMO partnership in polar research in the post-IPY era

The story of ICSU and WMO partnership began more than 50 years ago when both organizations successfully implemented International Geophysical Year 1957–1958 (*Chapter 1.1*). A subsequent collaboration was the successful realization of the First Global Atmosphere Research Program (GARP) Global Experiment in 1979 and, as a consequence, the establishment in 1980 of WCRP (the IOC joined later as the third sponsor of WCRP – *Chapter 1.4*). A new era of active partnership between ICSU and WMO began in the 1980s after the decision of the Second World Climate Conference (1979) to establish the Global Climate Observing Systems (GCOS), Global Ocean Observing System (GOOS) and Global Climate Terrestrial System (GTOS). All of these systems continue today and are co-sponsored by ICSU and WMO as well as, for some of them, IOC, FAO and UNEP.

The foundation of ICSU-WMO cooperation that has accumulated over the last 50 years ensured a strong collaboration on IPY 2007–2008 (see Fig. 5.5-1). In the post-IPY era, and in addition to the many activities described above, both organizations will continue their joint efforts towards development of intensive polar research through co-sponsorship of programs like WCRP which, through its projects, contributes to work on polar climate predictability, climate model development and prediction, ozone in the stratosphere, cryospheric and hydrological processes in the terrestrial Arctic, and sea-ice observations and research. Regarding the global observing systems, the analysis of their existing capabilities and of the observational advances made during IPY 2007–2008 suggests a possibility of greatly improving the availability of observational data on the state of the atmosphere, ocean, hydrosphere and cryosphere in Polar Regions in coming years. The development and maintenance of the IPY legacy observing initiatives (*Part 3*) would lead to reinforcement of existing global observing systems to fill gaps in coverage.

Many new and ongoing partnerships will be needed among IPY 2007–2008 legacy observing initiatives and international organizations to: (i) reinforce observations of the polar atmosphere and hydrological cycle by development of SAON and an Antarctic meteorological network; (ii) fill gaps in polar oceans observations through iAOOS and SOOS development; (iii) provide substantial input to further development of GOOS (sea ice observations) and GTOS (hydrological cycle, permafrost, ice sheets, glaciers) through the establishment of the GCW; and (iv) provide better services to many new stakeholders invigorated by IPY 2007–2008, including Arctic residents and indigenous communities across the polar regions and beyond.

New Partnership between SCAR and IASC

Volker Rachold and Colin Summerhayes

Background to the Partnership

The SCAR Executive Committee meeting in Brest, France on 11-15 July 2003 (*SCAR Bulletin 152, 2004*) recognized the importance of the Arctic Science Summit Weeks and the interest of having a formal SCAR representation at such meetings. It was decided to approach IASC to request formal representation at their meetings, with a reciprocal invitation to IASC to be represented at SCAR meetings.

At the next SCAR Executive Committee meeting, in Bremerhaven, on 21 January 2004 (*SCAR Bulletin 154, 2004*) it was proposed that an outline document for a program on the cryosphere and the polar regions including potential links with IASC be developed. A first meeting to take these links forward was held between the SCAR Executive Director and IASC Executive Secretary in the margins of the IPY Joint Committee Meeting (JC-1) in Paris in March 2005. A draft agreement between SCAR and IASC was discussed at the SCAR Executive Meeting in Sofia, Bulgaria, 11-13 July 2005. The SCAR Executive Committee approved the idea of creating a partnership with IASC (*SCAR Bulletin 159, 2005*) and encouraged participation of an IASC representative in the SCAR Open Science Conference and Delegates Meeting in Hobart in 2006.

Discussions between SCAR and IASC were developed with a view to improve collaboration in areas of common interest, hold a joint SCAR-IASC forum in association with SCAR's proposed 2008 meeting in St Petersburg and consider the implications of IPY. Given that both bodies have polar interests and both are associated closely with ICSU (SCAR as one of ICSU's Interdisciplinary Bodies and IASC as an International Scientific Associate of ICSU), there were strong grounds for supposing that a closer linkage between the two organizations should bring benefits to both parties, not least in an exchange of views and experience on important scientific topics. A SCAR and IASC Letter of Agreement was developed and duly signed in July 2006 (www.scar.org/about/partnerships/iasc, *IASC Bulletin 06/07*). Through it, SCAR and IASC agreed to combine their efforts in selected fields and activities (to be decided by mutual agreement) so as to raise the level of impact of both organizations in terms of making scientific advances and of advising policy-makers (e.g. of the likelihood and likely effects of climate change) as well as to avoid duplication. The IPY event was an important driver for the two organizations coming together, though not the only one. The partnership would have developed anyway, but the arrival of IPY provided added impetus and the desire to accomplish something within the IPY time frame. It also 'forced' SCAR and IASC to address what to do about the IPY legacy that they would together inherit as the existing polar science infrastructure organizations.

Under the Letter of Agreement, SCAR and IASC agreed:

(i) To invite each other to attend the meetings of their major bodies (SCAR Delegates' Meeting and IASC Council).
(ii) To encourage appropriate linkages between the relevant existing SCAR and IASC scientific projects.
(iii) To encourage their scientific communities to develop joint bipolar projects and approaches in appropriate fields.
(iv) To work together in arranging workshops, conferences and reports on topics of mutual scientific interest.
(v) To exchange ideas on best practices in data and information management.
(vi) To exchange newsletters and advertise each other's newsletters and web sites on their own web sites.
(vii) To develop combined approaches to communicating with the wider community on the significance of polar research to find solutions of societal issues, including their respective experience in giving advice to the Arctic Council and Antarctic Treaty Consultative Meeting.

Since then, SCAR has regularly attended IASC Council meetings and Arctic Science Summit Weeks, and IASC has attended SCAR Executive Committee and Delegates meetings as well as meetings of SCAR's Cross-Linkages Group.

Key developments during IPY

In January 2008, SCAR and IASC created a joint Bipolar Action Group (BipAG) charged with advising SCAR and IASC management bodies on further possible linkages, and developing and managing the IPY Legacy (see below). SCAR and IASC began to co-sponsor the biennial High Latitude Climate meetings that take place every two years or so (the first jointly sponsored workshop was held in Seattle, U.S.A. October 2007). SCAR and IASC also co-sponsored an ice-sheet modelling workshop in St Petersburg (July 2008) and, with funding from ICSU and NSF, subsequently co-sponsored its follow up, an ice sheet modelling summer school (Portland, Oregon, August 2009).

From July 2008, SCAR and IASC both co-sponsored with WCRP the Climate and Cryosphere programme (CliC) and in July 2008 they also co-signed a Letter of Agreement with the new International Association of Cryospheric Sciences (IACS). In March 2009, they co-signed a Letter of Agreement with the International Permafrost Association (IPA). These agreements effectively bind together the five main polar bodies of ICSU (*IASC Bulletin* 07/08, *IASC Bulletin* 08/09).

IASC continues to participate in the process towards Sustaining Arctic Observing Networks (SAON) and SCAR is observing this process to develop something along the lines of a "Pan-Antarctic Observing System". If SAON and "PAntOS" can be made to develop as intended and attract funds, together they will provide an observing system legacy for the IPY. Both organizations are encouraging the development of the ocean observing systems called for by IPY (an international Arctic Ocean Observing System (iAOOS) and a Southern Ocean Observing System (SOOS) – *Chapters 3.2 and 3.3*. These will be either stand-alone systems or parts of SAON and "PAntOS". The polar ocean observing systems will make complementary contributions in the post-IPY era and are considered essential operational requirements by WMO.

SCAR and IASC worked closely together as members (*ex officio*) of the IPY Joint Committee (2005–2010). The two organizations jointly sponsored the Open Science Conference in St Petersburg, Russia (8-11 July 2008), which was adopted and co-sponsored by ICSU and WMO as the 1st IPY conference (see Figs. 5.5.2-4). The full program and the summary report of the meeting are available (Klepikov 2008; www.scar-iasc-ipy2008.org/; http://icestories.exploratorium.edu/dispatches/welcome-to-the-scariasc-ipy-open-science-conference/). As a contribution to the development of a data and information management policy for IPY, the Chief Officer of SCAR's Data and Information Management Committee, Taco de Bruin, served as Co-Chair of the IPY Data Subcommittee. Independently, data management had been on the agenda of SCAR and COMNAP (Council of Managers of National Antarctic Programs)

Fig.5.5-2. Joint SCAR-IASC IPY 'Open Science' Conference, St. Petersburg, July 2009. From left to right: Khotso Mokhele (ICSU Vice President), Eduard Sarukhanian (WMO), Kristján Kristjánsson (then IASC President), Chris Rapley (then SCAR President) and Artur Chilingarov (Russian Duma, Co-Chair of the Russian national IPY committee). (Photo: Alexander Klepikov)

Fig.5.5-3. In the hallways of the SCAR-IASC conference in St. Petersburg, July 2008. Left to right: Kristján Kristjánsson (then IASC President), Chuck Kennicutt (newly elected SCAR President) and Jenny Baeseman (APECS Executive Director). (Photo: Alexander Klepikov)

and in 2004, SCAR had recognised the need to develop a Data and Information Management Strategy for the Antarctic, seeing this as an essential first step to managing the IPY data legacy in the southern hemisphere. The strategy was approved by SCAR Delegates at their meeting in St Petersburg (2008) and an Implementation Plan is now being developed. SCAR is advising IASC on the development of approaches to data and information management to enable both organisations to contribute to managing the IPY data legacy.

The Joint IASC/SCAR Bipolar Action Group (BipAG)

BipAG was created for two years in January 2008. It met in St Petersburg on 8 July 2008 and in Oslo, on 15-16 October 2009. Members include Heinz Miller (Germany – glaciology, (Chairman), Nick Owens (U.K. – oceanography), Bryan Storey (NZ – geology), Wayne Pollard (Canada – permafrost and geomorphology), Fridtjof Mehlum (Norway – terrestrial biology), Huigen Yang (China – upper atmosphere physics), Elena Andreeva (Russia – social sciences), Sue Moore (U.S.A. – marine mammals), Chris Rapley (SCAR EXCOM rep), Volker Rachold (IASC Secretariat), Colin Summerhayes (SCAR Secretariat) and Jenny Baeseman (APECS)
BipAG has two main terms of reference:

(i) To advise the SCAR and IASC Executive Committees on the development of instruments such as workshops, programs and networks to address bipolar issues (i.e. the first priority is to see how and where we could work more closely together).
(ii) To advise the SCAR and IASC Executive Committees on the development of mechanisms to nurture the IPY 2007–2008 legacy, with a special focus on the roles of IASC and SCAR.

The reports of the BipAG meetings are available on SCAR´s IASC partnership website (www.scar.org/about/partnerships/iasc/bipag.html). In 2010, SCAR and IASC will consider whether or not to continue BipAG and, if so, in what form.

IPY Legacy Developments

As the existing polar coordination structures, SCAR and IASC are positioning themselves to take a prominent role in ensuring the IPY legacy. SCAR and IASC have focused on four key aspects: (i) scientific cooperation; (ii) development of observing systems; (iii) data and information management; and (iv) development of early career scientists (the next generation).

SCAR's data and information management system will ensure better management and more effective exchange of data and information. As part of post-IPY data management, ICSU, through a coalition led by CODATA and including SCAR, IASC, IPY IPO and IUGG, is developing a new approach to data and information management: the Polar Information Commons (PIC). In addition, Kim Finney (new Chief Officer of SCAR's Standing Committee on Data and Information Management or SCADM) is a member of ICSU's Strategic Coordination Committee on Information and Data, which looks strategically at data issues across all ICSU-sponsored activities. Her participation should help ensure that SCAR's data management developments, ICSU's PIC and broader developments with the emerging ICSU World Data System remain connected. There are sensitivities across national boundaries in the Arctic that do not exist within the Antarctic Treaty area. Thus, so far, a similar data management system for the Arctic does not exist. Nevertheless, together with the Arctic Council and WMO, IASC is developing the Sustaining Arctic Observing Networks initiative (SAON, *Chapter 3.8*), which includes pan-Arctic data sharing systems.

IASC and SCAR are already co-sponsoring the development of early-career scientists and hence provide a natural home for the Association of Polar Early Career Scientists (APECS), an offshoot of IPY.

In addition, SCAR and IASC are working together to ensure a higher profile for the polar science in the post-IPY world. Main examples are as follows:

(i) SCAR and IASC wish to obtain a higher profile at ICSU General Assemblies, where recently, polar matters have only been considered under the heading IPY, which itself will disappear when the ICSU-WMO IPY Joint Committee comes to an end (summer 2010).

(ii) SCAR and IASC have a common interest in having a higher profile within ICSU's global environmental change programs (Earth System Science Partnership – ESSP and International Geosphere-Biosphere Program – IGBP), which previously have largely ignored the polar realms. This is currently the subject (among others) of an ICSU consultation (see below). It should be noted that SCAR and IASC do have a high profile within the World Climate Research Programme, of which ICSU is a co-sponsor.

(iii) SCAR and IASC continue to work together as co-sponsors (with others) of the second IPY science conference (Oslo, June 2010) and have begun to work in a similar fashion in relation to the third IPY conference (Montreal, 2012). After these conferences, there will be scope to consider holding another joint SCAR-IASC Open Science Conference in 2014 (or later) provided it is located in the northern hemisphere.

(iv) To ensure closer linkage to the climate community, SCAR and IASC intend to seek representation as observers at IPCC. As a start, SCAR and IASC have obtained permission from ICSU to attend IPCC meetings as part of the ICSU delegation. SCAR has also gained observer status with the UNFCCC, and attended the recent Copenhagen meeting. This may provide leverage to obtaining observer status with IPCC.

Fig.5.5-4. Volker Rachold, IASC Executive Secretary and Colin Summerhayes, SCAR Executive Director, acting as moderators for the opening session of the SCAR-IASC IPY Conference in St Petersburg, July 2008.
(Photo: Alexander Klepikov)

New Role of the Arctic Council in Polar Research

Helena Ödmark

Reviewers: Volker Rachold and Colin Summerhayes

The fifth Arctic Council Meeting of Foreign Ministers in Salekhard, Russia, in October 2006 (see Figs. 5.5-5 and 5.5-6), adopted a Declaration that welcomed "the expansion of the IPY to include *the human dimension*", which the AC considered to be an important new feature of IPY 2007–2008. Many IPY projects in the socio-economic and human sciences were closely linked to ongoing AC work aimed at improving living conditions in the Arctic and will continue after IPY.

A prominent example is the coordinating efforts on scientific research on human health performed by the Arctic Human Health Initiative (IPY no. 167) during IPY. That has inspired the AC working group on sustainable development (SDWG) to form a dedicated Arctic Human Health Expert Group to support and promote further integration and collaboration between scientists and health practitioners striving to improve the health of all Arctic residents and, in particular, indigenous peoples.

The Arctic Social Indicators project (IPY no. 462), a collaborative effort between scientists and local communities that attempts to identify indicators to enable comparative monitoring of social and other important welfare conditions in Arctic communities, also built on previous AC work and will continue after IPY within the AC framework.

In Salekhard, the Ministers further emphasized "the importance of *climate change* in the context of the IPY, and to achieve a legacy of *enhanced capacity of Arctic peoples to adapt to environmental, economic and social changes* in their regions, and enabling Arctic peoples to *participate in and benefit from scientific research*".

They urged "Member States and other entities to strengthen monitoring and research efforts needed to comprehensively address Arctic change and to promote the establishment of a *circumpolar Arctic observing network of monitoring stations with coordinated data handling and information exchange for scientific data, statistics and traditional knowledge* as a lasting legacy of IPY (and as the evolving Arctic component of the Global Earth Observing System of Systems, (GEOSS)".

As these extracts from the 2006 Declaration show, the AC had identified two distinct legacies that it anticipated as lasting results of the IPY:

i) Arctic science would be conducted in a manner that would provide benefits to the people who live in the Arctic.
ii) Establishment of transparent and coordinated observations, monitoring, data handling and information exchange structures.

The importance of IPY legacies in these two areas was reiterated in the Declaration adopted by the sixth AC Meeting of Foreign Ministers in Tromsø, Norway in April 2009, which expressed support for "continued international coordination to maximize the legacy of [the] IPY within the following areas: observations, data access and management, access to study areas and infrastructure, education, recruitment and funding, outreach, communication and assessment for societal benefits, and benefits to local and indigenous peoples".

The Tromsø Declaration also called "for consultations involving national funding and operational agencies to create a basis for internationally coordinated funding and shared infrastructure and enhance the recruitment of young scientists into polar science" and encouraged "the exploration of ways to continue the innovative forms for IPY outreach and the presentation of outcomes of the IPY, including the use of scientific data and traditional knowledge in future assessments".

During IPY, contacts increased between the AC working groups and scientists, even when the scientists had no previous links to AC work. That active interaction illustrates the role of the AC as a body that is well-placed to articulate the needs for information from the science community to underpin policy-making on Arctic issues. A major task for the AC working groups is to review issues that matter to policy-makers and regularly prepare assessments on, for example, specific contaminants, individual species or certain economic activities, and to present their findings in reports on status and trends.

Another task is to inform policy-makers on new, complex developments that require scientific explanation and analysis. The 2004 *Arctic Climate Impact Assessment* (ACIA) report was based on a comprehensive review of available scientific knowledge on impacts of climate change in the Arctic combined with traditional knowledge from indigenous peoples and other Arctic

Fig. 5.5-5. AC Ministerial Meeting venue in Salekhard, Russia.
(Photo: Helena Ödmark)

residents. That synthesis report proved to be very valuable to policy-makers. IPY provided a major boost to this kind of synthesis work. In 2009, the AC released a follow-up report, the *Arctic Marine Shipping Assessment* (AMSA).

During the IPY era, the AC working groups also identified many new partners in the international Arctic science community. New interdisciplinary networks were created. The AC and its working groups will continue to develop and expand these cooperative formats. Cooperation and collaboration with IASC and the International Arctic Social Sciences Association (IASSA) in particular, has increased and deepened as a result of various creative joint activities during IPY.

Two new major synthesis reports are under preparation in the AC, the *"Snow, Water, Ice and Permafrost Assessment",* SWIPA, (*Chapter 5.2*) scheduled for completion before the next AC Ministerial Meeting in April 2011 and the *"Arctic Biodiversity Assessment",* ABA, expected to be presented in 2013.

The *Sustaining Arctic Observing Networks* initiative, SAON (*Chapter 3.8*), was identified by the AC Ministerial Meeting already in Reykjavik in 2004 as a potential major legacy of IPY. In the Tromsø Declaration, the AC decided to "consider ways to develop an institutional framework to support circum-Arctic observing". Even though the SAON process has turned out to be quite complex, the AC continues to believe that substantial improvements in monitoring and observations is critical to future scientific research on impacts of climate change and other types of change in the Arctic. New methodology for community-based monitoring developed during IPY should be seen as a useful complement to more advanced technology solutions such as space observations.

Another IPY project, the *Arctic Portal* (IPY no. 388) that was built on an earlier AC project, has been selected as the gateway home for the IPY IPO website to ensure continued easy access to all IPO web-based material after the end of IPY. The Arctic Portal also hosts the websites of the AC and its working groups as well as those of IASC, IASSA and other activities (e.g. the SAON process, www.arcticportal.org). Some of the successful outreach and education work during IPY might be pursued under the auspices of the AC in cooperation with IASC, IASSA and others.

In the Tromsø Declaration the AC decided "to consider the proposal to arrange an international polar decade". This and other proposals for contributions to the potentially quite substantial legacy of IPY will need continued attention by SAOs during the Danish AC chairmanship 2009-2011 to ensure that the intergovernmental AC cooperation can take full advantage of experiences gained during IPY and contribute to increased support for scientific research.

Fig. 5.5-6. Ice sculptures of national emblems of AC Member States, Russia and United States.
(Photo: Helena Ödmark)

AC and ATCM Collaboration

Helena Ödmark, Manfred Reinke and Colin Summerhayes
Reviewers: David Hik, Igor Krupnik and Jerónimo López-Martínez

There are many similarities between the two polar regions, but there are also some remarkable differences between the Arctic and Antarctic with respect to geographical, legal and political realities, which need to be kept in mind. Antarctica is an uninhabited continent surrounded by the Southern Ocean. The Arctic is a circumpolar range of lands that have been populated for several thousand years and that surround a North Pole deep under the Arctic Ocean.

In the midst of the Cold War, the Antarctic Treaty was negotiated as a *binding security policy instrument* on the basis of the cooperative arrangements that were agreed upon for scientific activities during the International Geophysical Year (1957-58). Since its establishment, the Treaty has accommodated the different existing positions on sovereignty over territory in Antarctica by putting aside any claim or right to claim and by stipulating a set of agreed upon rules on joint governance and management that devote the land and sea areas south of 60°S to peace and science. The Antarctic Treaty Consultative Meeting, ATCM, is currently a yearly two-week long *meeting of the parties* to the Antarctic Treaty and exists only for the duration of each meeting. A permanent secretariat located in Buenos Aires has existed since 2005 (*Chapter 1.4*).

The Arctic Council, AC, was established through a *Political Declaration* signed by the Foreign Ministers of the eight Arctic States at a meeting in 1996 in Iqaluit, Canada (*Chapter 1.4*). The Declaration focuses on sustainable development and environmental protection. The AC was set up as a *forum for intergovernmental cooperation* on all issues, except military, and for consultations with Arctic indigenous peoples. The Arctic land territories and the peoples that live there belong to sovereign states. The applicable legal framework is a combination of national and international law. The UN Convention on the Law of the Sea, UNCLOS, constitutes the basis for governance in Arctic marine areas, even though not yet ratified by the U.S.A., as its main provisions form part of international customary law.

Due to the distinct differences in applicable legal framework for the two polar regions, the contexts for international and, in particular, intergovernmental co-operation on Arctic and Antarctic issues, respectively, are consequently very different.

There was no notable collaboration between the AC and the ATCM prior to IPY 2007–2008. Nevertheless, that does not mean that governments believed that there were no lessons to be learned from intergovernmental cooperation on issues related to the other pole.

On the contrary, in many cases the policy objectives that governments pursue in the AC and at the ATCMs are the same (e.g. reducing conflicts of interest, creation of multi-national fora to discuss issues relevant to many nations, mitigation of, and adaptation to climate change, maritime safety and security, integrated ecosystem-based management, environmental protection, access to research sites, conservation and sustainable use of living resources, establishment of protected areas, science-based regulation of fisheries, energy efficiency etc.). A widely held view is that legitimate activities in the Arctic as well as in the Antarctic should meet the highest environmental and safety standards. They should take into account the specific conditions that are unique to the polar regions and be based upon the fundamental scientific knowledge generated through sound and multi-disciplinary research. This is where yet another line of similarities comes to mind between ATCM working with its scientific arm, SCAR, and AC, for which IASC plays similar role (see above).

There are many examples of ATCM deliberations being informed by discussions on similar issues in the AC context, and vice versa, which is quite natural since seven of the eight AC member states and all the AC observer states are Parties to the Antarctic Treaty.

Several issues that are addressed by the intergovernmental community at the global level are also of specific concern in the polar regions. In such cases, deliberations in the AC and/or at the ATCM can inform and facilitate discussions in other forums. One example is international shipping, where regulations need to be adopted by the International Maritime Organization, IMO, in order to be binding on all flag states. The AC has endorsed a set of detailed recommendations in its 2009 "Arctic Marine Shipping Assessment". The ATCM has adopted a number of measures on many of the same issues. Negotiations are now ongoing under the auspices of the IMO on a binding "Polar Code" that seems to enjoy very wide support.

A different approach is required for biological prospecting. Biological material in the Arctic falls under national law and the UN Convention on Biological Diversity. Specific rules are needed for areas outside national jurisdiction and are currently under deliberation in the UN General Assembly. In that situation, it is up to the ATCM to take corresponding action in order to protect Antarctic biodiversity from excessive exploitation.

New Forms of AC-ATCM Collaboration

The first formal cooperative activity involving the member states of the AC together with the Antarctic Treaty Consultative Parties, ATCPs, took place in the margins of the 32nd ATCM in Baltimore 2009, when representatives of the AC and the ATCPs were invited at ministerial level for their first ever Joint Meeting, in Washington DC on 6 April to mark the 50th anniversary of the Antarctic Treaty and the successful conclusion of IPY 2007–2008. The Joint Meeting was Co-Chaired by Hillary Rodham Clinton, U.S. Secretary of State, for the U.S. chairmanship of the ATCM, and Jonas Gahr Störe, Norwegian Minister of Foreign Affairs, then chairman of the AC. The Declaration was adopted at that meeting (*Box 1*).

The AC Ministerial Meeting in Tromsø in late April 2009 welcomed "the Washington Ministerial Declaration highlighting IPY 2007–2008, an internationally coordinated scientific research and observation campaign in polar regions, which, for the first time, considered the human dimension and concerns of local and indigenous peoples and engaged Arctic residents".

Other Forms of Cooperation

A workshop on "The Legacy of the International Polar Year", coordinated by the Norwegian Polar Institute and supported by the AC and the ATCM, took place in Oslo in June 2010 in conjunction with the IPY Science Conference.

In 2005, stimulated by the attention accorded to the ACIA report, SCAR began developing a southern hemisphere equivalent, which resulted in the report

Fig.5.5-7. Website for the 50th Antarctic Treaty Summit meeting, Washington, DC, 30 November – 3 December, 2009, www.atsummit50.aq.

on "Antarctic Climate Change and the Environment", ACCE, published in November 2009 (*Chapter 5.2*). The ACCE report forms part of SCAR's annual provision of scientific advice to the ATCM. At the 29th ATCM in Edinburgh in 2006, the attention of the ATCM was drawn to the activities of the AC, in particular the preparation of the ACIA report, through a presentation by the ACIA team leader Dr Robert Corell.

Ongoing work in the ATCM context on improved observations and monitoring in the Antarctic Treaty Area has been inspired by corresponding work on coordination and integration of observations and monitoring in the Arctic within the SAON process under the auspices of the AC (*Chapter 3.8*).

Some Academics and other expert commentators argue in favor of more parallel treatment of the Arctic and Antarctic regions. They point to the 50 years of successful implementation of the Antarctic Treaty to reinforce their argument and, at times, also suggest that a similar legal instrument be negotiated for the Arctic region as a legacy of IPY 2007–2008. That message was reiterated at the *Antarctic Treaty Summit: Science-Policy Interactions in International Governance* four-day meeting dedicated to the 50th anniversary of the Antarctic Treaty, which was held at the Smithsonian Institution in Washington, DC from 30 November – 3 December 2009 (see Figs. 5.5-7, 5.5-8 and 5.5-9). The meeting celebrated "the development and resilience of the Antarctic Treaty on the 50th anniversary of its signature day", but was also focused on the "lessons learned from the first fifty years of international governance of Antarctica" that may be applied to other domains and areas, i.e., the Arctic. The meeting, attended by over 200 participants, was one of the IPY endorsed projects (IPY no. 342) in the 'Education and Outreach' field. Its organizers, keynote

Fig.5.5-8. Paul Berkman, Chair of the ATSM 50 Meeting presents Antarctic Treaty Summit Medal to HSH Prince Albert II of Monaco (December 2009, Washington, DC).
(Courtesy: Paul Berkmany)

Fig.5.5-9. Speakers at the "Building Bridges: Communicating Science with Policy-Makers" luncheon dialogue organized by APECS at the conclusion of the 50th Antarctic Treaty Summit Meeting (Washington, DC, December 2009). Left to right: Olav Orheim (Former Chair - Committee on Environmental Protection), Dr. Marie Jacobsson (Member, United Nations International Law Commission; International Counsel, Swedish Ministry for Foreign Affairs; Member, International Board for the Antarctic Treaty Summit); Prof. Oran Young (University of California Santa Barbara; Member, International Board for the Antarctic Treaty Summit); and Dr. Yeadong Kim (Former Director, Korean Polar Research Institute; Member, International Board for the Antarctic Treaty Summit).
(Photo: Paul Markman)

Box 1 Antarctic Treaty Consultative Meeting, Baltimore, U.S.A., April 6-17, 2009
Antarctic Treaty-Arctic Council Joint Meeting
Washington Declaration on the International Polar Year and Polar Science

On the occasion of the conclusion of the fourth International Polar Year (IPY), the Member States of the Arctic Council and the Consultative Parties to the Antarctic Treaty,

Observing that the IPY occurred against a backdrop of rapid and significant climate and environmental change in the polar regions,

Acknowledging the unique scientific importance of the polar regions, both as actors and barometers of these changes, which are vital to the functioning of the earth's terrestrial, biological, climate, ocean and atmosphere systems,

Recognising the need to improve he modelling and prediction of change on a regional basis,

Recognising the significant work of the Intergovernmental panel on Climate Change in assessing documented and predicted changes in polar regions and in relating them to larger global systems,

Affirming the importance of the IPY's findings to the scientific community, Arctic residents, including indigenous peoples, and to humanity as a whole,

Observing the success of participants in forming IPY collaborations that integrate the human, physical, and biological aspects of their research to achieve system-scale knowledge,

Recognising the vital contributions toward understanding the characteristics and dynamics of polar regions and their roles for the world's ecosystems made by scientists and other participants from over sixty countries,

Noting the extensive efforts of the International Council for Science (ICSU), the World Meteorological Organisation (WMO), the many IPY National Committees, and the scientists and other participants around the globe whose research made IPY a great success,

Recalling the goals for the IPY set forth in the 2006 Edinburgh Antarctic Declaration on the International Polar Year 2007–2008, and the strong support for IPY expressed by the Arctic Council in the 2006 Salekhard Declaration,

Expecting that the legacy of the IPY will continue well beyond its formal conclusion,

Hereby:

1. Urge states, national and international scientific bodies, and other interested parties to cooperate to deliver a lasting legacy from the IPY, and to support appropriate infrastructures to achieve this;

2. Commit themselves to reviewing key issues related to scientific cooperation and recent scientific findings at the biennial Ministerial Meetings of the Arctic Council and annual Antarctic Treaty Consultative Meetings, and further commit to using science to help inform the cooperative development of measures to address the threats to the polar regions;

3. Call upon IPY participants to continue to make data collected under IPY 2007–2008 and its legacy programs available in an open and timely manner, recall the obligations related to exchange of scientific information to this effect in the Antarctic Treaty, and encourage the same spirit of scientific openness among Arctic researchers;

4. Endorse the goal of strengthening international cooperation at all levels in polar regions among States, scientists, Arctic residents, including indigenous peoples, and their institutions in areas such as educational outreach, human and ecosystem health, environmental protection, and scholarships or young scientists;

5. Encourage the development of coordinated research and scientific observations at both poles to compare the current dynamics of polar areas and their contributions to the Earth's processes and changes;

6. Recommend that governments continue their support for efforts initiated during IPY to create and link observational systems in order to improve the modelling and prediction of climate change on both regional and temporal scales;

7. Encourage states and international bodies to use the scientific understandings derived from IPY research to support the development of concrete steps to protect the environment in the polar regions;

8. Support the analysis and use of scientific data and information collected from the polar regions as a result of IPY to contribute to future assessments by the Intergovernmental Panel on Climate Change, as well as other efforts to address climate change, and future Arctic Council assessments;

9. Call upon states, organisations, scientists, and other stakeholders to continue to engage with young people to cultivate the next generation of polar scientists, and to communicate with the general public to develop an awareness of the importance of polar research for life in all regions of the world; and

10. Affirm the value of collaboration and coordination between states and Arctic residents, including indigenous peoples, for the benefit of polar research.

Adopted at Washington, April 6, 2009.

speakers and panellists included many distinguished scholars, science managers, policy specialists and young scientists representing APECS from both the Antarctic and the Arctic fields (see www.atsummit50.aq/about_summit/speakers.php

Nevertheless, the governments of the eight Arctic States have made it clear that they believe that continued peace and stability in the Arctic can best be achieved by continuing to strengthen and develop the present intergovernmental cooperation structures with full respect for existing legal and political realities. Within that framework, there is scope for more lessons to be learned and more experiences to be shared on how to address similar issues in the two polar regions. Joint action between the AC and the ATCM could be contemplated to highlight matters of common concern such as the need for improved hydrographic charts, adequate satellite coverage and increased funding for polar research.

Conclusions

New or advanced partnerships in support of coordination of polar research – Arctic, Antarctic as well as bipolar – can be considered a main outcome of IPY. The corresponding central achievements of IGY were in the Antarctic domain. The frameworks for scientific and political cooperation in the Arctic, i.e. IASC and AC, were only established in the early 1990s. IPY succeeded in both fully integrating the relatively young Arctic components and strengthening bipolar scientific activities and collaboration. The linkages between the political frameworks provided by the ATCM and the AC as well as the collaboration between and among the key scientific bodies, i.e. ICSU, WMO, SCAR and IASC, have been strengthened and will continue. This emergence of a bipolar cooperative approach to polar research that did not exist prior to IPY will certainly influence how the next IPY will be organized.

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Notes

[1] See www.icsu.org. The members include 121 National Scientific Bodies (mostly national academies of science) covering 141 countries, 30 International Scientific Unions, and 21 International Scientific Associates.

[2] WCRP, International Geosphere-Biosphere Programme, International Human Dimensions Programme, DIVERSITAS, and their Earth System Science Partnership.

[3] See www.wmo.int WMO has a membership of 189 Member States and Territories (as of 30 April 2010).

5.6 Shaping the Future

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Broadening and Sustaining the IPY Momentum

David Hik and Karen Kraft Sloan

Background for Broadening the Legacy of IPY

One important role of science and research is to assist governments, and therefore society, in effectively discharging their responsibilities and mandates. In the polar regions, these mandates are necessarily far reaching, diverse and include a broad range of disciplines, from the natural sciences, the human behavioral, social and historical sciences, medical sciences, engineering and applied sciences, and research in the managerial, economic, and legal fields. Polar research is characterized by an abundance of cross-cutting issues that require interdisciplinary or multidisciplinary approaches, and the knowledge provided by research must address questions on a wide range of scales from local to global, and from immediate to long-term. In the Arctic, it is also recognized that advanced technological knowledge and fundamental or theoretical research must be combined with the holistic observations and knowledge of indigenous northern peoples.

From the very beginning of IPY there was a discussion of its potential legacies, and promotion of the notion that IPY could be a "catalyst" for sustaining future Arctic and Antarctic research efforts (Kraft Sloan and Hik, 2008). For example, the word 'legacy' was used 14 times in the IPY Framework publication (Rapley et al., 2004). History would suggest this outcome is possible and even likely, but what continuing efforts are required to secure a legacy of sustained interest and investment in Arctic and Antarctic research? Even at the conclusion of IPY 2007–2008, there is still a need to define and pursue the next steps in securing a broad legacy for IPY, as envisioned by so many of the scientific and governmental participants.

In 2005 we began a dialogue about IPY legacies that we called 'Broadening the Legacy.' There were several elements to our approach including:

1. Making the IPY legacy part of the IPY process itself;
2. Identifying partners in order to link with and build upon other initiatives, through Arctic Council and other organizations, including national governments;
3. Learning from other efforts to formalise international polar science cooperation, especially from the implementation of the Antarctic Treaty System and from the first fifteen years of the evolution of the Arctic Council;
4. Being opportunistic and identifying fora to engage governments and other potential partners and supporters;
5. Identifying champions and providing them with resources to promote the global and local value of enhancing polar science, research, and knowledge capacity.

This initiative was presented at the Arctic Science Summit Week and ARCUS in 2006, and at meetings with the Commission on Sustainable Development, the OECD Global Science Forum, the Heads of Arctic and Antarctic IPY Secretariats (*Chapter 1.7*), among others. In retrospect it is likely that our efforts in 2006 were premature. The IPY planning process was still in its early stages, and many countries had not yet allocated funding or resources to support the substantial interest in IPY. A discussion of 'legacy' could not find much time on the agenda. However, these ideas still resonate at the conclusion of IPY and are relevant to successfully implementing and sustaining diverse IPY legacies. Indeed, legacy has become a major consideration for Arctic Council, IASC, SCAR, Arctic Parliamentarians, WMO, ICSU and many other sponsors of IPY, including the governments and agencies that funded IPY activities.

Approach for Broadening the Legacy

International scientific assessments and reports involving thousands of scientific and research contributors have detailed the urgent and accelerating global environmental crisis, which create headline news for a few days and then usually seem to go unnoticed by both the public and politicians. Examples include the *Arctic Climate Impact Assessment* (2005); *Millennium Ecosystem Assessment* (2005); *The Stern Review: On the Economics of Climate Change* (2006); *Global Footprint-Living Planet Report* (2010); and so on. New approaches to encourage meaningful follow-up to scientific discovery and assessments need to be explored. To strengthen appropriate policy responses to the scientific outcomes of IPY, the Broadening the Legacy dialogue sought to engage decision-makers in relevant IPY processes early on. Decision-maker participation throughout IPY could assist them to better understand both the substantive outcomes of IPY and the conditions that are required to sustain international support for polar science.

The scientific legacies of International Polar Year would occur, regardless of what action was taken to broaden the legacy of IPY. However, in order to heighten decision-makers' understanding of polar scientific issues and to encourage acceptance of their responsibility for on-going support of polar science, their engagement at the beginning of the IPY process was important. IPY presented an interesting opportunity to build links amongst the science communities, Arctic residents, the public at large, the private sector and governments to ensure that the impact of IPY would be lasting and substantive.

The opportunity to 'use' IPY as a catalyst for something new did not pass unnoticed by the IPY Joint Committee, IPY participants and other observers. Previous Polar Years in 1882-83 and 1932-33 contributed to the development of international polar science programs, and the International Geophysical Year of 1957-58 also left a political legacy in the form of the Antarctic Treaty System, which set aside an entire continent for the peaceful study of science. However, no such coordinating mechanism or instrument formally exists for the Arctic, as highlighted in an editorial in the journal *Nature* in May 2006:

> *"In contrast with Antarctica, there is no political framework for collaboration on Arctic research. Despite the stark findings of the 2004 climate assessment, the eight nations with territory north of the Arctic Circle — Russia, Canada, the United States, Denmark (on behalf of Greenland), Iceland, Finland, Norway and Sweden — remain*

Fig. 5.6-1. Presidents of SCAR (Chuck Kennicutt) and IASC (David Hik) met at the Olso IPY Conference in June 2010 to discuss collaborative efforts to promote IPY legacy activities.
(Photo: Jerónimo López-Martínez)

too passive in their approach to coordinating polar research. Their benign neglect has led to the gradual deterioration of parts of the network of meteorological stations in the Arctic. Better baseline support for such monitoring would cost little, but would make a huge difference to Arctic researchers of all disciplines." (*Nature*, 11 May 2006, Vol. 441, no. 7090)

The Broadening the Legacy approach attempted to set the stage for political and policy discussions on polar issues after IPY by creating a forum where science and policy could converge in a broad, inclusive dialogue that would operate at all levels of scale (international, national, regional and local). Polar years have set the precedent for international cooperation in science and research; emphasized the need to make sense of disparate data and methods of data management, and ensure access for scientists, communities and others; assisted policy-makers understand the impact of research through mechanisms for translating scientific data and creating science into policy communications; and contributed to the development and evolution of new institutional forms to ensure the on-going investment and interest, the "glue" to sustain international cooperation in polar research.

It is already apparent that IPY 2007–2008 has raised some critical polar and global issues and created momentum for political action and policy responses, but the many outcomes may not be immediate. For example, it was the scientific community in the 1960s and 1970s that first focused international attention on the threats imposed by global climate change. Even though it took many years before international governance and policy mechanisms were created to enable national governments to seriously respond, the mounting scientific evidence and the profile that these scientific conferences provided was a major contribution to raising the issue of climate change internationally.

Evidence for Broadening the Legacy

As IPY 2007-2008 formally comes to a close, it is fair to ask if there is evidence of sustained momentum for the international cooperation, collaboration and institution-building that will be necessary to support IPY legacies in the future? So far, these responsibilities seem to lay with the primary sponsors of IPY (WMO and ICSU), the scientific organizations at the forefront of polar research (SCAR and IASC), and the political organizations in the Arctic (Arctic Council) and Antarctic (the ATCM). These organizations have recognized the need to provide institutional commitment and solutions for sustaining polar research, and discussions regarding the IPY legacy are now an important agenda item within these bodies, including the two polar science organizations, SCAR and IASC (Fig. 5.6-1; *Chapter 5.5*). Importantly, IPY was a catalyst for these organizations to initiate several new international observing initiatives focused on gathering and sharing information about change in the polar regions (*Part 3*).

The conditions necessary to sustain IPY legacy outcomes will also require engagement with other international processes and partnership with the wider global research and policy community, and with other elements of civil society. Outside of the polar regions there are some good examples of institution-building approaches for furthering the science – policy nexus, including the Intergovernmental Science – Policy Platform on Biodiversity and Ecosystem Service (IPBES - www.ipbes.net). IPBES is not restricted to the Arctic region, but its goal of providing "scientifically sound, uniform and consistent framework for tackling changes to biodiversity and ecosystem services" is highly relevant. Similarly, the Global Earth Observation System of Systems (GEOSS) program was launched as a response to requests from the 2002 World Summit on Sustainable Development and by the G8 (Group of Eight) leading industrialized countries for greater international collaboration to make better use of Earth observations to support decision making (www.earthobservations.org). To maximize the global impact of IPY, these sorts of international programs and approaches will have to be encouraged to participate in the IPY Montreal Conference, "From Knowledge to Action" in April 2012 (see below).

Observations about engaging society, policy makers and governments in polar science may not surprise many of the participants in IPY 2007-2008. Indeed, there is increasing evidence of interest from other groups in participating in the dialogue about approaches for gathering and sharing knowledge about the polar regions, models of openness, interdisciplinarity and collaboration that IPY promoted since its very early planning stages (*Chapter 1.2, Chapter 1.3*). Some authors (e.g. Brock, 2010) have suggested that the observed gap between research and policy in the Arctic may reflect poorly calibrated expectations about the conditions under which research is relevant to public policy. Others have concluded that the primary challenge is to develop a "holistic and integrating international plan" to steward and govern the Arctic environment in a sustainable manner (Aspen Institute, 2011). There is also a growing interest in reconciling the influence and rights of Arctic residents within the existing governmental and scientific framework (Kraft Sloan and Hik, 2008; Bravo, 2009; Brock, 2010; Aspen Institute, 2011). So while there are still many challenges, we are increasingly confident that efforts to 'Broaden the Legacy' of IPY will succeed.

The combined pages of this IPY Summary show that IPY has already succeeded in inspiring a discussion about the future of polar research. The polar research and polar policy agendas has been dynamic and full over the past several years, with a number of parallel processes occurring that collectively have provided space for exploring the future of these regions. Some barriers to international cooperation require simple technical or scientific solutions. Others are multi-dimensional, systemic and deep rooted. These require institutional and/or political responses, and therefore must involve governments. Still others may need a combination of approaches. For example, utilization of scientific data may reflect a simple management problem, solvable with technical remedies such as standardization (*Chapter 3.11*). However, access to data could be limited by political or systemic barriers, thus requiring different strategies to resolve (e.g. Carlson, 2011). Solutions to these and other issues will only be found by continuing to broaden the discussion of IPY legacy.

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The Next Generation of Polar Researchers

Jenny Baeseman and Hugues Lantuit

The International Polar Year 2007–2008 was an immense success on many levels. Born in the mind of a few enlightened researchers, the IPY grew to become more than a science event. It involved thousands of researchers in its multifaceted scientific endeavors and provided global awareness for polar regions to date. But it also did more than just that: It changed the way we do science, emphasizing international and interdisciplinary collaboration, open scientific practices and involving residents of high latitudes. Its legacies are many and will provide a lasting basis upon which polar research will build to drive its next ventures. Young researchers involved in IPY must capitalize on the legacies of IPY and help shape the future of polar research.

The high-quality science stemming from the IPY effort has demonstrated the benefits of an enhanced level of support for polar research into the future. The direct impact of changes at higher latitudes on southern regions has made this greater involvement more acutely needed. Without significant investment in sustaining research activities, but also global data stewardship and recruitment and training of promising young researchers, the basic requirements of polar science to answer pressing scientific questions can not be correctly met. IPY has indeed brought out a series of research challenges that have great societal relevance and urgency beyond IPY, but that can only be comprehended in a long-term scientific observing framework.

The greater level of collaboration during IPY has also emphasized the need and the benefits of working cross-disciplines and cross-borders. Far from being a placeholder concept, international and interdisciplinary partnerships have led to very substantial results that could not have been attained without the added value of the forum that IPY provided. It is, then, necessary to promote and develop programs that go far beyond discipline and national borders and that integrate climate, ecosystem and socio-economic prognoses. National borders and scientific disciplines will certainly remain both in the geopolitical and scientific arena as the pillars of polar research, but polar research should strive to go beyond these very real yet environmentally abstract borders to solve scientific issues in a very targeted manner.

Polar science is very special in that it requires a different approach to space, people and time. IPY has done considerable groundwork in publicizing this message among decision-makers. What it needs to do now, is to work further to secure the full engagement and understanding of decision-makers worldwide in its purpose and value.

With the remarkable accomplishments of this IPY, it is essential now to focus on the IPY legacy, display and explore the richness of IPY data, and to chart future directions for sustainable long-term polar observing systems. Reminding the science community, national funding agencies, data providers and most importantly the new generation of polar researchers should be one of the driving principles of polar science over the years to come. Initiatives, such as the Polar Information Commons should be supported to provide a rewarding mechanism for researchers to release their data, but still needs much more attention (*Chapter 3.11*).

Observing systems for monitoring change are essential for validating and improving predictions, especially of future global warming. A unrewarding job for many, the coordination of observations at the regional level is in itself a challenge, but it holds vast promises in polar regions, for the level of remoteness in these areas requires to coordinate and standardize observations to understand the driving processes behind the evolution of the environment, whether those deal with ice, ocean, atmosphere, coastal or land observations. The coordination of observations is a matter to all polar research stakeholders and should be acknowledged and supported as such, as it matters to both science and society. Parallel to this, polar research will have to strengthen international collaboration at large. That includes international funding mechanisms, transnational field site access and use of internet-based technologies. While such efforts are often regarded as difficult, if not idealistic, they proved necessary to the conduction of science in polar regions.

The Paradox of IPY

The paradox of IPY is that it created a vast range of opportunities, fostered the involvement of national states in polar regions, but added a thick layer of complexity to the conduct of research in polar regions. Polar researchers are scientists, managers, logisticians, and diplomats at once, and that in an area of the world where access and infrastructure are arranged fundamentally differently from other regions. This results in challenging work conditions for researchers, which can only be addressed by improving the system on the administrative side, making it faster, more efficient, and more consolidated. That applies to the peer-review of applications, but also on licensing, dialogue with local stakeholders and logistics preparation and implementation. With expected improvements to infrastructure and access in the polar regions, an increase of the number of researchers can be expected. This increase needs to be mitigated by strong environmental requirements, coordination and consolidation of logistics, and not by bureaucracy, which would be detrimental to the conduction of science and dialogue with local stakeholders.

IPY 2007–2008 has provided a solid foundation for the engagement of Arctic residents and indigenous peoples in future large-scale science projects. Future scientific endeavors will without a doubt, consider research in the Arctic very differently and elaborate an added number of projects in partnership with northern residents. With its global relevance, though, the Arctic has traditionally be the focus of scientific investigations from countries from all over the globe. The range of cultural approaches in the research landscape is probably just as large as the range of cultural understandings of the environment in arctic communities, and researchers coming to the Arctic will have to proactively seek to apprehend, understand and acknowledge the cultural differences and richness of northern communities. This dialogue is an exciting challenge and is relevant to all: large scale institutions, communities, indigenous peoples organizations, and, above all, individuals.

IPY has created a large influx of new energetic, enthusiastic and talented young researchers interested in helping to better understand the Arctic and Antarctic systems. Through the addition of grassroots initiatives and generous mentoring from senior scientists, these early career scientists have progressively benefited from a comprehensive and coherent training system at the international level, focused on soft skills and international collaboration. This incredible success needs to be sustained beyond IPY and mechanisms need to be created to retain these young researchers that began Polar Research during IPY and keep them involved.

Naturally this includes more positions at research institutions, but it also needs to include more positions for science communication, logistics coordinators, data managers, programme managers, industry positions, and other positions that are important to the full spectrum of science, outreach, and policy making in polar regions. It is, in 2010, hardly realistic to match the expectations of the general public in terms of research and involvement in polar regions without increasing personnel and finding successors to the baby-boomers.

The polar researcher's job has evolved with time and IPY strongly showed both the interest and the need to offer a comprehensive training framework to young researchers to rapidly train and involve them in international activities and outreach activities. Polar research will have to grab this opportunity and provide better career development training on and international and interdisciplinary level, such as the organization of field schools; participation in international conferences; a dedicated mentorship programme; career development workshops and virtual poster sessions. Finally, international organizations will have to encourage early career people to take on leadership roles in organizations and committees to provide a continuum of leadership in polar science.

Enhancing investment in polar research for the benefit of all can only be achieved through the political will that comes from greater public understanding. The polar researchers of the twenty-first century will be asked to be more than researchers and devote part of their time to outreach efforts. Following up on the extraordinary and multifaceted outreach initiatives of IPY, polar researchers will explicitly embed education and outreach components in their research projects that will feed into high-quality educational, outreach and communication initiatives and networks. These networks, which were created during IPY 2007–2008 will need to be supported to help researchers in producing publications, exhibitions, films, web pages and lectures around science. Only then, will polar research reach out to society and play an important role in involving communities in the continuing analysis and assessment of IPY outcomes and impacts.

The IPY Oslo Science Conference, 8–12 June, 2010

Olav Orheim

The initial process

Following the JC-3 meeting in April 2006, the Joint Committee for IPY issued a call in August 2006, asking for proposals to host a global conference that would present the science results from IPY 2007–2008 (*Chapter 1.5*). Norway had already a Secretariat for IPY established at the Research Council of Norway (RCN) led by Olav Orheim, which quickly took the initiative to develop such a proposal. The elements of the plan to hold the main IPY Science Conference in Oslo were pieced together and presented to the JC at the JC-4 meeting on 27-28 September 2006 in Longyearbyen, Svalbard. In its proposal the RCN took as a given premise that the Conference might be attended by at least 3000 participants, and that it should take place in the summer of 2010. The venue location would be the Norway Trade Fair Centre at Lillestrøm, outside Oslo (Fig.5.6-2). This proposal was enthusiastically approved by the JC.

In September 2007, Olav Orheim met with Michel Béland (Co-Chair of JC) and prepared a detailed outline for the organization of the conference. It was discussed at the JC-6 meeting the following month in Québec. Planning for the conference started in full in January 2008, following the approval by the JC of overarching plans and organising structure for the conference.

An international Steering Committee (SC) was established with representatives from relevant organisations. It was led by Orheim, and had its first meeting on 16 May 2008, and its sixteenth and final meeting on 11 June 2010. SC established the programme, appointed scientific committees, selected plenary speakers, and considered all other matters related to the content of the conference. RCN had the economic and organisational responsibility, but SC was updated on and discussed major decisions related to RCN's responsibility, such as inspection of localities, determination of registration fees, etc

The committee had the following composition:

- Susan Barr, Oslo, nominated by Norwegian National Committee for Polar Research
- David Carlson, Cambridge, head of IPO
- Paul Cutler, Paris, JC Member nominated by ICSU
- Øystein Hov, Oslo, nominated by Norwegian IPY Committee
- Kriss Rokkan Iversen, Tromsø, nominated by APECS
- Jerónimo López-Martínez, Madrid, JC Member
- Olav Orheim, Oslo, representing RCN
- Margarete Pauls, Bremerhaven, representing IPY EOC subcommittee
- Volker Rachold, Potsdam, JC Member, nominated by IASC
- Eduard Sarukhanian, Geneva, JC Member, nominated by WMO
- Colin Summerhayes, Cambridge, JC Member, nominated by SCAR

The SC had unchanged composition through the period, with the exception of APECS' representative, who was later replaced by Hugues Lantuit, Potsdam.

APECS Executive Director Jenny Baeseman attended regularly as an observer. It turned out to be difficult to obtain a nomination of a representative from Arctic indigenous communities, as no single person could represent all these. It was resolved that IPS (Indigenous Peoples' Secretariat) in Copenhagen sent an observer, from SC fifth meeting onward. At that meeting Kathleen Fischer, Executive Director, Government of Canada Program for IPY, also joined the SC, to ensure the link to the next major IPY-related conference to be held in Montreal in 2012. The SC had an executive group which made decisions between meetings on items requiring a more immediate response; it consisted of Carlson, Orheim, Rachold and Summerhayes.

In parallel with the international work, RCN established a project Secretariat, consisting of Olav Orheim as project leader, Asgeir Knudsen, project coordinator, and Kristen Ulstein, responsible for communications. All of these members took part in the SC meetings, as did others from RCN at times. Congress Conference, Oslo, was also hired at an early stage as PCO (Professional Conference Organiser).

Information on the conference was distributed by electronic means, which included three circulars. Nevertheless, the main conference website www.ipy-osc.no was the most important communication channel both before and during the conference. Up to August 2010, the web page has had 42,000 unique visitors.

The first Conference Circular was issued in June 2008. The main message was an invitation to submit proposals for sessions, with a deadline of 24 October 2008. The second Circular came out in November 2009. It presented the complete programme with listed themes and sessions, and established the deadline for abstracts, 20 January 2010. The third Circular was a brochure about the conference which was distributed digitally in February 2010.

The program

The SC decided that the conference should be organised under six separate themes, with international committees established for each theme (Chairs' names are given in parenthesis; the full committee membership is listed on http://ipy-osc.no/article/2009/1233092078.8):

- T1: Linkages between Polar Regions and global systems (Harald Loeng, Norway)
- T2: Past, present and future changes in Polar Regions (Valérie Masson-Delmotte, France)
- T3: Polar ecosystems and biodiversity (David Hik, Canada)
- T4: Human dimensions of change: health, society and resources (Sverker Sörlin, Sweden)
- T5: New frontiers, data practices, and directions in polar research (Chuck Kennicutt, U.S.A.)
- T6: Polar science education, outreach and communication (Louise Huffman, New Zealand).

IPY participants were invited to send proposals for sessions under these themes. The secretariat received about 120 different proposals by the end of 2008. It took many months to combine them in such a way that the total number of sessions was manageable, with not too much overlap, so that it would be clear where a submission could find its home, and all IPY-related activities were covered. For each session a team of usually three scientists was selected as conveners. The composition of the session conveners (about 150 altogether) was balanced by geography, gender, and age. It should be noted that SC decided very early in the process that each session team should include a representative for young researchers in the respective field.

There was much engagement in these issues, and as a result the SC and Science Committee added three more sessions to include subjects that were not well enough covered in the original programme. In the end 41 sessions were approved (Box 1).

Fig.5.6-2. The IPY Oslo Science Conference 2010 required the largest conference center in the country, Norway Trade Fair in Lillestrøm. Two Saami tents (lavvu) were erected by the Saami participants from Kautokeino in front of the Conference Hall. (Photo: Jostein Fossnes)

By the end of January 2010, 2650 abstracts had been submitted from 2200 persons. During the next few weeks all abstracts were evaluated individually by the conveners, and based on total scores the abstracts were designated to oral or poster presentation. The Committee used a system from Elsevier that functioned without problems. Eventually 2200 abstracts were accepted, from persons from 49 different nations.

The Secretariat worked in parallel to produce a programme. Originally it was planned for 15 simultaneous sessions. The large number of abstracts led to the decision to have sessions in 17 lecture halls. Even so it was only possible that about 40% of the submissions could be scheduled as oral presentations, each for 15 min.

Eventually the conference was attended by 2323 persons, from 53 nations (Fig.5.6-3). After Norway, which exceeded 500 including support staff, the countries with the largest number of participants were as follows:

Country	# of Participants
United States	331
Canada	270
Russian Federation	130
Germany	120
United Kingdom	110
Poland	71
Sweden	67
France	57
Denmark	46
Spain	43
Italy	41
Japan	36
Finland	34
China	32
Netherlands	28
New Zealand	28
Australia	27
Belgium	27
Brazil	19
Switzerland	13

The conference activities

The main activity at the conference was the presentation of results of individual and collective research during IPY 2007–2008. During the five days there were altogether 1,054 oral talks and about 1000 poster presentations. Much of the presented material is available online. All plenary lectures were web-streamed, and archives can be viewed on the conference website at http://ipy-osc.no/live. The conference program and all conference abstracts are also available at http://ipy-osc.no/osc_programme. Most of the results are published in the regular scientific journals. However, there were also book launches connected with sessions, and the journal "Polar Research" is producing a special issue presenting key papers from the conference.

In addition there were a large number of other events. These started prior to the conference, when the University of Oslo offered space for two related activities on 6 and 7 June 2010. An early career professional development workshop was organized by the Association of Polar Early Career Scientists (APECS) for about 120 young researchers. An international Polar Teachers conference collected a similar number

Fig. 5.6-3. Inside the Lillestrøm Centre during the conference days. The main mingling area was named 'The Polar Street' for a week. (Photo: Jon-Petter Reinertsen)

of teachers from 20 countries under the theme "How to use polar science in your classroom". Here the IPY EOC subcommittee also launched its new resource book for polar teaching (*Chapter 4.1*). The day before the opening of the conference the IPY JC held its last meeting (JC-9) in the RCN, just five years and three months after its first meeting (JC-1) (*Chapter 1.5*).

The conference was opened on the morning of 8 June by HRH Crown Prince Haakon of Norway (Fig. 5.6-4). The other speakers at the colourful opening ceremony were Minister of Research Tora Aasland, Executive Director of ICSU Deliang Chen, WMO Secretary-General Michel Jarraud (by video link), Indian Minister of Research Prithviraj Chavan, Special

Box 1 Oslo Science Conference Program

Theme 1:Linkages between Polar Regions and global systems

- T1-1 Polar Oceans and their importance for global ocean circulation
- T1-2 Plate tectonics and polar gateways in earth history
- T1-3 Chemical exchanges between snow, ice, atmosphere and ocean in Polar Regions
- T1-4 Polar climate feedbacks, amplification, and teleconnections, including impacts on mid-latitudes
- T1-5 Polar contribution to sea level rise
- T1-6 Arctic and Antarctic marine chemistry: The role of the polar oceans in global carbon cycling and acidification
- T1-7 Polar/global atmospheric linking processes: Polar aerosols - sources and impacts

Theme 2: Past, present and future changes in Polar Regions

- T2-1 Climate and paleoclimate dynamics and processes
- T2-2 Troposphere and stratosphere dynamics and processes and their links with climate
- T2-3 Snow and ice dynamics and processes
- T2-4 Permafrost on a warming planet
- T2-5 From land to ocean: Hydrological, coastal, near shore and upper shelf processes in Polar Regions
- T2-6 Ocean physical and geochemical dynamics and processes
- T2-7 Solid earth geophysical and geochemical processes
- T2-8 Heliosphere impact on geospace

Theme 3: Polar ecosystems and biodiversity

- T3-1 Chemosynthetic eco-systems in polar waters
- T3-2 Invasive and introduced species in polar environments
- T3-3 Arctic-subArctic connections: Ecosystems and bio-diversity
- T3-4 Processes in polar deep-sea benthic biodiversity
- T3-5 Arctic and Antarctic freshwater ecoystems
- T3-6 Impact of climate change on polar terrestrial ecosystems
- T3-7 Integrated processes in leads and polynyas
- T3-8 Ecosystems of the Southern Ocean

Theme 4: Human dimensions of change: health, society and resources

- T4-1 Human health and well-being in the Polar Regions
- T4-2 Natural resource exploration and utilisation
- T4-3 History of polar exploration, cooperation, research and logistics
- T4-4 Communities and change
- T4-5 Polar lessons: Arctic and Antarctic governance and economics
- T4-6 Human impacts in the Arctic and Antarctic: Environmental and management implications

Theme 5: New frontiers, data practices, and directions in polar research

- T5-1 New frontiers and directions in biology, ecology and biodiversity
- T5-2 New frontiers and directions in observing and technologies
- T5-3 New frontiers and directions in subglacial exploration
- T5-4 Data and other cross-cutting issues for future polar research

Theme 6: Polar science education, outreach and communication

- T6-1 Learning together: The impacts of integrating education, outreach and research in IPY
- T6-2 Incorporating polar science into formal education
- T6-3 Adventures in the field: Impacts of field programs for students, teachers, artists, writers and others
- T6-4 Global learning: The impact of the media
- T6-5 Informal initiatives and polar inspiration: IPY in museums, art, films, books and drama
- T6-6 PolarCINEMA

Fig.5.6-4. Crown Prince Haakon of Norway greets Mr. Klemet Erland Hætta, the Mayor of Kautokeino Municipality at the Saami cultural 'booth' set during the Oslo Conference among over 25 organizational thematic exhibits (booths) at the main Polar Expo Centre. (Photo: Jon-Petter Reinertsen)

Fig. 5.6-5. Sergey Kharyuchi, the President of the Russian Association of the Indigenous Peoples of the North (RAIPON) speaks at one of the sessions under the Theme 'Communities and Change' that took place inside the Saami lavvu tent. (Photo: Jon-Petter Reinertsen)

Representative of President of Russian Federation Artur Chilingarov, and RCN's Managing Director Arvid Hallén. Other community leaders that spoke during the conference included HSH Prince Albert II of Monaco, Chuck Strahl, Canadian Minister of Indian Affairs and Northern Development, and Sergey Kharyuchi, the President of the Russian Association of Indigenous Peoples of the North (RAIPON – Fig.5.6-5).

Plenary ceremonies during the conference included the award of Martha T. Muse-price of U.S. $ 100 000 to Prof. Steven Chown (by the Tinker Foundation/ SCAR), and the award of the IASC medal to Prof. Patrick Webber (by IASC).

Various groups with polar interests held side events in conjunction with the conference. A workshop on the IPY legacy was organized by AC and ATCM; it was chaired by Jan-Gunnar Winther, Director of the Norwegian Polar Institute. The workshop was attended by more than 70 representatives of IPY-JC, SCAR, IASC, AMAP and many national polar scientific and indigenous organizations. The workshop participants agreed that it would be critical to maintain the momentum of the IPY legacy process, and that the organizations, such as IASC, SCAR, University of the Arctic, IAI, APECS, ICSU/CODATA that have the capacity and mandate to further advance the IPY legacy would be provided with the necessary means and resources to do so (Winther, 2010). The workshop also recommended that continued focus on scientific research in the polar regions in the coming decades should be supported and that the initiative of the WMO Executive Council for an International Polar Decade (IPD) should be further explored and supported as appropriate (see below). Considerations should be given to find the mechanisms for working together with the AC and the ATCM to develop a strategy to sustain polar research, including the concept of an IPD. National funding agencies should be encouraged to commit to such long-term efforts.

Education, Outreach and Communication (EOC) activities played large part in the Oslo conference program, just as they had during IPY 2007–2008. A special EOC-committee was established to supervise such activities in Oslo, in part based on the IPY-EOC subcommittee, and chaired by Margarete Pauls, Germany (media), and Sandy Zicus, Australia (education). The committee had several meetings and developed a great variety of public and educational events that were implemented during the week of 7-12 June 2010 (Fig.5.6-6).

A total of 90 films from 17 countries were nominated to be shown at the PolarCINEMA. Selection was by four juries (in Malaysia, Alaska, Netherlands and Norway). A total of 69 productions were shown, with a total of 40

Fig. 5.6-6 The inclusion of early career scientists, teachers, and others involved in outreach was one of the major achievements of IPY-OSC 2010. Here some of them are enjoying themselves on a cruise on The Oslo Fjord.
(Photo: Jon-Petter Reinertsen)

hours of show time.

BBC science journalist Sue Nelson led three afternoon science talk shows termed PolarEXCHANGE, which were all web cast, with the aim of promoting polar science to a wider audience than the conference participants alone.

To meet the public in Oslo the EOC-committee developed the concept PolarFESTIVAL, which took place in front of the Town Hall over two days. Here seven Norwegian institutions participated, together with three research vessels (*G.O. Sars*, the Polish research vessel *Oceania* and KV *Aalesund*).

The Joint Committee was responsible for the plenary which formally closed IPY on 12 June 2010, the final day of the conference. This ceremony was opened by Gerlis Fugmann, President of APECS. Prof. Jerónimo López-Martínez presented the JC summary perspective on IPY, and pointed to a surge in multidisciplinary polar scientific activities, extensive new circumpolar data baselines and improved observing systems, enhanced international collaboration and stronger links between the Arctic and Antarctic science communities, an enthusiastic new generation of polar scientists, the active engagement of Arctic residents in IPY activities, and the unprecedented involvement of educators and increased public awareness about polar regions.

Fig.5.6-7 Dr. Elena Manaenkova, Assistant Secretary General of WMO, speaks at the closing of IPY 2007–2008. (Photo: Jon-Petter Reinertsen)

"IPY was founded on the ideas and energy of thousands of scientists, educators, technicians and many more," said Elena Manaenkova, Assistant Secretary General of WMO. "As co-sponsors of IPY, we would like to express our most sincere thanks to all the participants and the organisers who have made this venture one of the biggest internationally coordinated research programmes ever undertaken." (Fig. 5.6-7).

Dr. Deliang Chen, Executive Director of ICSU, added, "IPY has paved the way for a sound understanding of the polar regions at a critical time for society's relationship with the Earth. The collaboration among many nations and among many scientific disciplines has been critical to the success of IPY, and it is crucial that the energy and partnerships that came together for IPY are sustained in the long-term."

"I have the honour to officially close the IPY 2007–2008," announced Dr. Manaenkova, before López-Martínez, on behalf of the Joint Committee, handed over the IPY flag to Gerlis Fugmann, as a symbol that the next generation of researchers must take responsibility for continuing the momentum of IPY and polar research. Web casts were made from 21 plenary sessions, and 30 interviews, and edited versions were quickly available for on-demand download. Making all presentations available in this manner was, unfortunately, outside realistic budgets. From the start of the conference to the end of August the web cast and the web-TV-page had 13,000 visitors from 75 countries. With its multitude of presentations and other activities the Oslo Science Conference was a fitting tribute to the many people who invested large portions of their careers in the International Polar Year.

The importance of the IPY Oslo Science Conference is hard to overestimate. At the first IPY Science Conference in St. Petersburg, in June 2008 most of the presentations were based primarily on the results of the previous polar studies, since by the time of that Conference the IPY research and observational phase had been running for only a little more than a year. At the Oslo Conference in 2010, the majority of the presentations introduced scientific advances achieved during the three-year period of IPY 2007–

2008 implementation. Altogether, over 2000 oral talks and posters presented a monumental and multi-faceted snapshot of the natural and social conditions in the polar regions and major ongoing changes. It provided the scientific community with new ideas and knowledge that can be used in the future development of polar science and will serve as a fundamental baseline for prediction of the future state of polar regions and of the planet as whole.

The Oslo Conference was formally closed later on 12 June by Jonas Gahr Støre, Norwegian Minister of Foreign Affairs. At the closing ceremony, Olav Orheim handed over the baton from IPY-OSC to Dr. Peter Harrison, Chair of the Montreal IPY "From Knowledge to Action" conference to be held in Canada in April 2012.

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Montreal 2012: From Knowledge to Action

Kathleen Fischer

The IPY 2012 Conference *From Knowledge to Action* will be the final major conference for International Polar Year 2007–2008. Building on the results of the IPY St. Petersburg Conference in 2008 and the IPY Oslo Science Conference in 2010, the focus of this conference is to apply the findings and knowledge gained from IPY to policies, programs, and practices and other actions. The idea of the 2012 'post-IPY' conference was first discussed at the JC-6 meeting in Québec, Canada, at which the Joint Committee held several sessions jointly with the members of the Canadian IPY Committee and National Secretariat (*Chapter 1.5*). The Canadian proposal for hosting the final IPY conference in Montreal in April 2012 was discussed at several subsequent JC meetings and at the closing ceremony of the IPY Oslo Science Conference on 12 June, 2010, the IPY "torch" was symbolically passed from Norway to Canada as the future host of the next major IPY meeting (Fig. 5.6-8).

The objectives of the Montreal 2012 IPY international and interdisciplinary science-to-action conference include (www.ipy2012montreal.ca/050_program_e.

Fig.5.6-8. Olav Orheim, Chair of the IPY-OSC 2010 Steering Committee, handed over a Norwegian traditional "budstikke" (baton) to Peter Harrison, Co-Chair of Motreal 2012 'From Knowledge to Action' IPY Conference.
(Photo: Jon-Petter Reinertsen)

shtml):

- Demonstrating and applying the findings and new knowledge gained through IPY research
- Assessing and synthesizing IPY scientific findings about polar regions and global systems
- Defining and addressing the key issues facing polar regions and identifying appropriate responses
- Using a common platform for scientists, policy-makers and Arctic peoples to discuss the implications of changing conditions in their regions and issues important to their health and well-being
- Conveying knowledge from IPY research effectively to key stakeholders
- Seeking opportunities to increase the application of polar research to benefit, not only the Poles, but the planet

This upcoming international forum of some 3000 participants, on 22–27 April 2012 will be a valuable opportunity to demonstrate and apply the latest findings of polar research on a broad range of topics from oceans and sea ice, to permafrost, vegetation and wildlife, to changes in Arctic communities and beyond (Fig. 5.6-9). The *From Knowledge to Action* Conference will present the highlights of IPY 2007–2008 and the recent polar science assessments that are advancing our knowledge of the polar regions. The Conference will draw on examples and best practices of the application of this knowledge to policies, programs and education, as well as to observation systems and networks and other actions. It is to bring together internationally-renowned polar researchers with policy makers, analysts, community members, industry representatives, non-governmental organizations and other interested groups to discuss the results of IPY 2007–2008, the largest-ever coordinated program of multi-disciplinary research in the earth's polar regions. In addition to presenting the current state and key changes in the polar regions and identifying actions that will be important in a global context, the Conference is also tasked with sharing results and providing the opportunity for participants to plan the future directions for polar science.

The 2012 Conference is being organized around *four* main areas:

1. *Highlight the latest polar science findings:* The Conference will be an opportunity for international researchers to present interdisciplinary research and indigenous knowledge from the polar regions, as well as the highlights of the IPY research.

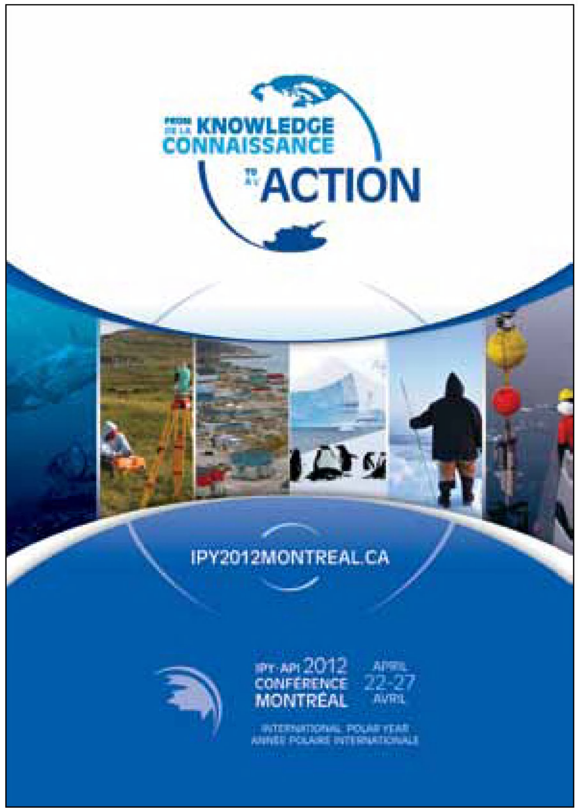

Fig. 5.6-9. Poster for the IPY 2012 'Knowledge to Action' Conference. 2010 (www.ipy2012montreal.ca/docs-pdf/IPY2012-poster.pdf)

2. *Synthesize knowledge and results into system-scale understandings:* The Conference will draw on IPY and other polar research along with recent assessments to provide a synthesis of knowledge in areas critical to the polar environments and the well-being of circumpolar and indigenous communities at different scales.
3. *Link knowledge to action:* The Conference will provide an opportunity for scientists, northern communities, policy-makers, industry and other stakeholders to discuss the application of the scientific results to issues facing the polar regions. Global change, community and ecosystem adaptation, resource development and conservation - what actions are required? The Conference will bring together those interested in the application of the latest polar science to address future actions and needs.
4. *Advance public engagement to further action on polar issues:* Engaging various audiences on polar science through communication, outreach,

capacity building, and education initiatives creates an informed citizenry with a deeper understanding of the importance of the polar regions and their role in global systems. Drawing on the expertise from other fields, sessions will be held on how polar science can enhance the flow of information between researchers and those interested in applying the new knowledge and information. A special emphasis will be placed under this area of the conference on communicating science to support the use and application of research results.

The planning for the Montreal 2012 Conference is being led by the Conference Steering Committee chaired by Dr. Peter Harrison, Stauffer-Dunning Chair and Director of the School of Policy Studies, Queen's University, Kingston, Ontario, Canada and Co-Chaired by Dr. Karl Erb, Director, U. S. National Science Foundation, Office of Polar Programs. The Conference Steering Committee of 12 members includes representatives from the World Meteorological Organization, International Council for Science, International Arctic Science Committee, Scientific Committee on Antarctic Research, International Arctic Social Sciences Association, International Union for Circumpolar Health, U.S. National Science Foundation, Association of Polar Early Career Scientists, Inuit Circumpolar Council, Forum for Arctic Research Operators, and the Council of Managers of National Antarctic Programs. The IPY 2012 Conference Secretariat has been set up within the Northern Affairs Organization, Department of Indian and Northern Affairs, Canada with responsibility for the daily organization, planning and coordination of the IPY 2012 Conference, in partnership with the National Research Council of Canada.

The Conference Steering Committee has held several meetings in 2010 in preparing the draft of the Conference program. Keynote speakers, numerous plenary, concurrent and poster sessions, as well as panel discussions and special events are being planned. In addition, workshops, interactive presentations, and roundtables will provide conference participants with the opportunity to discuss the application of the IPY research findings, the policy implications and how to take the polar science advances during IPY 2007–2008 from knowledge to action (www.ipy2012montreal.ca/001_welcome_e.shtml).

The 2012 Montreal Conference will be the largest concluding event associated with IPY 2007–2008 (Fig.5.6-10). By the time of the conference, major results of IPY and polar science, observational, and other activities will be circulating within the international science community. The conference will then become the major next step in making those IPY writings, data and records relevant to policy-makers, polar communities and indigenous residents, science managers, educators, and public at large.

Fig.5.6.-10. The IPY 2012 Conference will be hosted in the vibrant, cosmopolitan city of Montréal at the Palais des Congrès in downtown Montréal. (Courtesy: Palais des Congrès, Montreal)

International Polar Decade[1]

Eduard Sarukhanian and Odd Rogne

Reviewer:

Anders Karlqvist

Introduction

The idea to launch an International Polar Decade (IPD), based on scientific advances and lessons learned during IPY 2007–2008, was first discussed at and supported by the 60th session of the WMO Executive Council in June 2008 (WMO, 2008).

The Council recognized the success of IPY's first year; the large investments made by governments to this international campaign and the growing requirements of the scientific and local communities to continue sustained observations and research in the polar regions beyond IPY 2007–2008. Consequently, the Council proposed that WMO, in consultation with ICSU and other international organizations, consider the launch of an International Polar Decade as a long-term program for research and observations in polar regions.

The IPD idea was subsequently discussed at several international fora, including the conference, *The Arctic: Observing the Environmental Changes and Facing their Challenges* organized by the European Union (Monaco, November 2008); the Conference on the IPY Legacy organized by UNESCO (Monaco, March 2009); and the workshop, *Space and the Arctic* sponsored by the European Commission, European Space Agency (ESA) and EUMETSAT (The European Organisation for the Exploitation of Meteorological Satellites, Stockholm, October 2009).

The IPD initiative was also considered by IASC (Bergen, March 2009) and by the Sixth Ministerial Meeting of the Arctic Council (Tromsø, April 2009), where Ministers representing the eight Arctic States "welcomed commitments to deliver a lasting legacy from the IPY and decided to consider the proposal to arrange an International Polar Decade" (Tromsø Declaration, 2009). Two weeks earlier, the Antarctic Treaty Consultative Meeting (April 2009) called on members to "work with SCAR and COMNAP to maintain, extend and develop long-term scientific monitoring and scientific observations in Antarctica and the surrounding Southern Ocean" (Resolution 9-ATCM XXXII).

Noting the general positive response to the IPD initiative expressed by the international polar community, the 61st session of the WMO Executive Council (June 2009) requested its Panel on Polar Observations, Research and Services (EC-PORS) to consider modalities and plans for the IPD, focusing on decadal needs and issues of long-term character in order to make recommendations to the Council. The first session of EC-PORS, held in Ottawa, Canada in October 2009, was very supportive of launching the IPD. The session participants recognized the need to engage a broad spectrum of partners, including those outside the physical science community (social sciences, human health research, etc.). They also noted the significant contribution that space agencies made to IPY 2007–2008. The next session of EC-PORS, held in Hobart, Australia in October 2010, was charged with considering this broader IPD concept based on communications with interested parties.

IPD scientific requirements

The IPD concept can be developed using the major findings and conclusions of IPY 2007–2008 as outlined in the Joint Committee's Statement (Allison et al., 2009) and expanded in this Summary Report. The starting point is recognizing that the polar regions are an integral and rapidly changing part of the Earth system and have an influence on the rest of the globe. Preliminary IPY findings reveal new evidence of the widespread effects of global warming in the polar regions *inter alia:*

- Greenland and Antarctic ice sheets are losing mass, contributing to the sea level rise.
- The minimum extent of year-round sea ice in the Arctic decreased during summer 2007 to its lowest level since satellite records began 30 years ago; an unprecedented rate of sea-ice drift was observed.
- Large pools of carbon are stored as methane in permafrost. Thawing permafrost threatens to destabilize the stored methane, an active greenhouse gas, and send it into the atmosphere. Substantial

emissions of methane from ocean sediments were observed along the Siberian Arctic coast.

- The types and extent of vegetation in the Arctic have shifted, affecting grazing animals and local economies based on hunting and reindeer-herding.
- The Southern Ocean, particularly the southern flank of the Antarctic Circumpolar Current, has warmed more rapidly than the global ocean average, and a freshening of the bottom water near the Antarctic continent is consistent with the increased ice melt that could affect ocean circulation.

These phenomena were discovered during a relatively short period of time during IPY 2007–2008, which resulted in a valuable snapshot of the polar environment. What environmental changes can we expect in the near future? Will people be prepared to meet those changes and secure a sustainable socio-economic development? To answer these and similar questions, it is necessary to develop proper techniques for climate change prediction. One main problem is the predictability of polar climate. Given that high latitudes are areas where decadal variability prevails, knowledge about polar climate change and its long-term variability could provide opportunities for developing reliable climate predictions for the polar regions that would also help assess global climate change. Polar predictability is one of the main drivers of IPD. IPD results would then help develop environmental prediction techniques that will be extremely important for industrial, social, cultural and other activities in the Arctic, such as life support, protection of the environment, transport, defence, resource exploration and extraction.

During IPY 2007–2008, significant emphasis was given, for the first time, to human and social issues, and to the concerns of local and indigenous peoples, such as requirements for sustainable development, impacts of globalization, human wellbeing, culture and health. Local communities have joined several IPY monitoring networks to collect and document changes in weather and climate, sea ice, biota and the ongoing community adaptation to these changes. The results of these activities during IPY (*Chapters 2.10, 3.10*) would form a basis for an IPD human and societal-oriented component.

IPD objectives

As a starting point for discussion, the main objectives of the International Polar Decade may be formulated as follows:

- To address critical long-term issues for developing and improving international cooperation in polar research and observation.
- To integrate observations through modern data assimilation systems, and use them in weather, climate and environmental prediction systems.
- To assess the ecological state of the polar environments and develop measures for reducing the negative impact of pollution on polar populations and ecosystems.
- To increase the level of science and education in the field of polar research and raise the awareness of the general public.
- To assess the consequences of polar climate change, in order to develop adaptive measures for growing industrial and social infrastructures and protection for resident populations in the polar regions.

IPD observing structure

IPY 2007–2008 has shown the feasibility of addressing key environmental and social issues in the polar regions, but their complex nature requires a systematic and sustained approach. This requirement is consistent with several major initiatives that form the core of the legacy of IPY observing systems. Detailed descriptions of these initiatives are provided in Part 3. It is proposed that these initiatives, in particular SAON (*Chapter 3.8*), IASOA (*Chapter 3.4*), iAOOS (*Chapter 3.2*), SOOS (*Chapter 3.3*), GCW (*Chapter 3.7*), Sea Ice Outlook (*Chapter 3.6*), CBMP (*Chapter 3.9*) and the Human-based observing systems (*Chapter 3.10*) should be considered as building blocks for the framework of observing systems to be developed during the IPD. Some long-term ongoing IPY projects should also be considered as possible candidates for including in this IPD framework.

IPD research criteria

As in IPY 2007–2008, a set of well-defined criteria is needed in order to select the most promising IPD activities that would complement each other. At this stage, it may be sufficient to list at least three critical features of the prospective IPD initiatives:

- cover decadal phenomena (e.g. climate variability);
- require international cooperation;
- address important societal needs.

Nevertheless, these (and other) criteria should be refined through coordinated findings and by the input from prospective stakeholders.

Organizational steps

To define the scientific concept of IPD and its prospective observing and organizational structure, it is necessary to engage those international organizations that have strong interest in polar research, such as WMO, ICSU, UNESCO and its programs, such as IOC, UNEP, among others. The Arctic Council and the Antarctic Treaty Parties with IASC and SCAR, should play the leading role in the organization and development of long-term strategies for polar research, monitoring and management. APECS, as important component of the IPY legacy, is another key group to take IPD forward.

A critical issue in IPY 2007–2008 was to secure internationally coordinated funding. Today, as many IPY activities are winding down, polar research is still primarily based on national government funding. Various national funding agencies have their own research priorities and procedures. A possible next step is to bring science funders and fund managers together to identify common themes that meet their priorities and to consider mechanisms for coordinated funding (a consortium). Similar to the beginning of IPY 2007–2008, a broad marketing effort would be needed for IPD, as well as for polar research in general. Therefore, it is highly desirable to involve the International Group of Funding Agencies for Global Change Research (IGFA) and the European Science Foundation in the IPD process, in addition to the individual national funding agencies.

To broaden the way the IPD is framed and to engage the broader community, it is proposed that a series of workshops, focused on the IPD program, be organized. Such workshops should include some key funders, not only from research funding agencies, but also from operational agencies that have the mandate to make sustained observations. These international organizations would also ensure connections with GCOS, GOOS and other global observing systems. As for polar research and prediction, the four global environmental change research programs would need to be engaged as should be various ICSU Scientific Unions and the WMO technical commissions.

The purpose of such planning workshops should be clear, as should be the overall purpose of IPD. It is thus desirable to develop a succinct and broadly supported statement outlining the IPD concept, what IPD aims to achieve and its potential benefits. An important outcome of these workshops would be to identify partners and stakeholders for IPD by forming a joint body that would develop a science and implementation plan for IPD and provide the oversight and guidance for its organization and funding. This is another valuable lesson of the planning and implementation of IPY 2007–2008 that will be carried into the future.

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Notes

[1] The status of the International Polar Decade proposal is discussed here as of June 2010 – ed.

Epilogue

Lead Authors:
Igor Krupnik with Rip Bulkeley, Colin Summerhayes and Eduard Sarukhanian

> *The polar regions are an integral and rapidly changing part of the Earth system. Humankind's future environment, well-being and sustainable development require that we comprehensively understand and observe polar systems and processes and the changes that are already upon us. The message of IPY is loud and clear: what happens in the polar regions affects the rest of the world and concerns us all.*
>
> (The State of Polar Research, 2009, p. 12)

A product of the 50-year cycle of its parent initiatives, IPY 2007–2008 could not have happened at a more opportune time. It was shaped by three developments during the preceding decade: (1) scientific and public anxiety about rapid climate and global environmental change, which was having a faster and larger effect in the polar regions than elsewhere; (2) the successful experiences of many multi-disciplinary science programs of the 1990s and early 2000s (WCRP, IGBP, ACIA and others); and (3) widespread longing for a seminal new initiative to re-energize the polar science community, international organizations, and agencies in charge of planning, funding, and capacity building in polar research 50 years after the very successful IGY 1957–1958. These and other factors conjoined in 2001–2002, at the very time when polar scientists started talking about how to celebrate the 50th anniversary of IGY 1957–1958. Those early talks about a commemorative 'IGY+50' event quickly evolved into planning for a new Polar Year. The rest is history.

IPY 2007–2008, whose actual chronology started in 2001–2002, developed into what some have called the largest internationally coordinated planetary research effort of the past 50 years. It marshaled the intellectual resources of thousands of scientists from an unprecedented number of fields and from more than sixty nations. It has already advanced our understanding of the complexities of the polar regions and of the range of global linkages, geophysical, biological, and societal, of polar processes. IPY 2007–2008 also generated a widely anticipated 'pulse' (momentum) in the form of substantial new funding for polar research and monitoring programs, new observational and analysis technologies, integrated system-level approaches, and a remarkably broadened circle of stakeholders in polar science. By the official closing date of June 2010, the field had been rejuvenated by almost a decade of planning, organization and implementation of IPY, as well as by the entry of many new players. Also, the general public had been kept much more abreast about the significance of polar scientific and environmental research than ever since the years of IGY 1957–1958. These and other developments were covered in the preceding chapters of this book.

Co-sponsored by ICSU and WMO, IPY 2007–2008 helped establish a set of new research and organizational paradigms that may have a lasting legacy of their own. It added powerful support to the societal need for polar science (public perception of rapid change in the polar regions) and showed the value of integrative polar studies. It solidified a new trans-disciplinary format for future research that now includes biology, social sciences, human health and community studies, in addition to meteorology, glaciology, oceanography, geophysics, geology and other classical polar research fields. Also, IPY helped restore a healthier geographical balance within the field of polar research that was once heavily dominated by Arctic explorations and was later skewed towards Antarctica in the IGY/post-IGY era. The most visible evidence for that is the strengthened collaboration between the leading regional players, such as SCAR and IASC, Arctic Council and ATCM, and the launch of many bipolar projects, conferences, and research activities by international and national polar programs.

An urgent need for further polar research

IPY 2007–2008 has demonstrated the benefits of an enhanced level of support for polar research into the future, as well as the need to establish and sustain comprehensive long-term polar observing systems for rapidly changing polar environments. The pressing need for further polar research continues to motivate strong public engagement in the issues related to the polar regions. This feeds into national and international commitments to funding and operational support for polar science, ongoing data stewardship and the recruitment of promising young researchers who are needed to carry the work forward.

As outlined in the earlier assessment produced by the IPY Joint Committee (*The State of Polar Research 2009*), the following research challenges will have great societal relevance and urgency beyond IPY 2007–2008 (Allison et al., 2009):

- Rapid climate change in the Arctic and in parts of the Antarctic
- Diminishing snow and ice worldwide (sea ice, glaciers, ice sheets, snow cover, permafrost)
- The contribution of the great ice sheets to sea-level rise and the role of subglacial environments in controlling ice-sheet dynamics
- Global climate impacts of changes to ocean circulation
- Loss of biodiversity and changing ecosystem patterns and ranges
- Methane release to the atmosphere from melting permafrost
- Improved projections and forecasts from integrated coupled climate and weather models
- Global transport of pollution and contamination to the polar regions and consequent impacts on environments, humans, and ecosystems
- Health and well-being of Arctic residents and Arctic communities.

These topics headed the agenda of IPY 2007–2008 and of many other contemporary initiatives of the 'IPY era.' They are certain to dominate polar research and public attention into the next decade and beyond.

Unfinished Tasks

From early 2005 and until summer 2010, the ICSU-WMO Joint Committee (JC) for IPY and the International Programme Office (IPO), in accordance with their Terms of Reference, acted as leaders in the IPY implementation process. They were widely viewed by the polar science community as stewards of the IPY collaborative spirit and legacy. That status was granted to them for a good reason. The JC served for five years as the key authority in steering the IPY program, as caretaker of the IPY scientific goals, and as the symbol of IPY inter-disciplinarity, openness, and international appeal. The IPO earned across-the-board acclaim for reaching out to national IPY committees and individual project teams, for relentless public promotion of IPY and for resolute support of the younger cohorts of polar researchers. In these and other regards, both bodies followed in the footsteps of their predecessors, the International Polar Commission in IPY-1, Commission for the Polar Year in IPY-2, and CSAGI and IGY Secretariat in IGY 1957–1958.

As early as 2006, and very actively since 2007, both JC and IPO addressed the questions of the legacy of IPY and how to secure the long-term impact of IPY research, data and public programs after the official IPY period of 2007–2009. Unfortunately, the JC was dissolved in June 2010 and the IPO was terminated in September 2010. Comparisons with early Polar Years are illuminating. The International Polar Commission, the steering body of IPY-1, remained in being for eight years after the observational period was completed in 1883. In IPY-2, the Commission for the Polar Year was fully active for six years after observations ended in 1933 and continued at a lower level during the first years of World War II. It was eventually succeeded by an IPY Liquidation Committee that worked for five more years, until 1950. After IGY 1957–1958, most of the observational activities were extended through 1959 as the 'International Geophysical Cooperation.' Various successor bodies (*Special Committee for Inter-Union Cooperation in Geophysics, Comité Internationale de Géophysique* (CIG), and CIG Terminating Group) worked for twelve years past the original term of IGY. No such luxury was granted to IPY 2007–2008, as the mandate of both the Joint Committee and the International Programme Office was limited to five years, from late 2004 till the end of 2009 (the two bodies were eventually extended by ICSU and WMO for additional six and 12 months, respectively).

Though no official successors to the JC and IPO have been nominated at the time of this writing, several bodies created before and during the IPY era are likely to continue some of the 'unfinished tasks' of the JC and IPO. In July 2008, WMO has established the Executive Council Panel on Polar Observations, Research, and Services, which has among its tasks to secure the IPY legacy in coordination with other international organizations. ICSU has initiated the Polar Information Commons to continue to improve the management of polar data. The international Group on Earth Observations has adopted the recommendations of SCAR, WCRP and the IPY cryosphere programme for a Cryosphere Observing System, which is now embedded within the Global Earth Observing System of Systems (GEOSS). The two polar bodies of ICSU, IASC and SCAR, have jointly established the Bipolar Action Group (BipAG) to consider how best to implement the legacies of IPY and are contributing to such activities

Table E-1: What Does It Take to Complete IPY? *(Numbers indicate years after the end of the official observational period)*

Tasks	IPY-1	IPY-2	IGY	IPY 2007–2008
Main steering body service after the end of observational period	+8	+9	+1	+1
Successor Group	No	+16 (Liquidation Committee)	+13 (CIG/Publication Group)	No ???
Summary Report	No	+26 (1959)	No	+2 (2011)
Final Event/Conference	+8 (Small-size meeting, 1891)	No	+5 (International symposium, 1963; several smaller venues)	+1 (2010 Oslo Science Conference, 2300 participants)
Publication of Proceedings and/ or Minutes	Yes	Yes (partly)	Yes	??? (Online; partly in the JC Report)
Centralized archive	Yes (St. Petersburg)	Yes (Copenhagen)	Yes (in several places)	Yes (SPRI, Cambridge)
Bibliography	No	+18	+13	??? (To be compiled by SPRI and AINA)
Publication Series	Yes (22 vols.)	No	Yes (Annals of IGY, 48 vols.)	Yes/Partly (Started by Springer in 2009, 4 vols. published, several planned)
Central Depository of Data/ Records	Yes (St. Petersburg)	Yes (Copenhagen)	Yes (Several World Data Centers)	???
Free Data Access	Yes (In published volumes)	Yes (Via main archives in Copenhagen)	Yes Via World Data Centers	??? (In progress)
Individual Project Reports	Yes (Via published national volumes)	No (Via individual publications only)	No	Yes (In monographs, papers, and submissions to the JC Report)
National Reports	Yes (Via published expedition volumes)	No (General bibliography only)	Yes (Individual nations only)	Yes/Partly Several already prepared; more activities still feasible

as the Sustaining Arctic Observing Network (SAON) and the Southern Ocean Observing System (SOOS). These and other bodies are working to secure certain components of IPY legacy. The continuous growth of APECS, now co-sponsored by SCAR and IASC is one key legacy of the IPY. On the horizon, though as yet only dimly perceived, is the possible implementation of an International Polar Decade (IPD). These various legacy initiatives will be inextricably linked to IPY 2007–2008, much as SCAR and the Antarctic Treaty System are linked to IGY 1957–1958.

Launching an IPY took six to seven years in the four known cases, IPY-1, IPY-2, IGY, and IPY 2007–2008 (*Part 1*). Completing an IPY and securing its legacy is a similarly extended process. It comprises several components and to judge from previous IPY's (Table E-1) it requires dedicated leadership and continuing effort over many years. The data collected have to be systematically processed and the results ideally need to be published under a *standardized template* (series, proceedings), as was done in IPY-1 and IGY, as well as in numerous individual publications. To ensure their lasting use, these publications should be monitored and thematically organized in an overall *IPY bibliography* (as in IPY-2 and IGY). Original data and documents related to IPY planning and implementation need to be stored in established *centralized depositories* or *archives* (as in IPY-1, IPY-2, and IGY) or, better, copied and made accessible through *data centers* (as in IGY). National activities need to be summarized in *national IPY reports* (as in IPY-1 and IGY), and major field and disciplinary advances need to be promoted via *summary overviews* (as in IGY). Such disciplinary summaries and major results of individual IPY efforts then have to be shared with the larger science community at high-profile *workshops* and *conferences* (as after IGY), and in *overview books* (as after IGY) that may be published years or even decades later (as in IPY-1 and IPY-2).

In IPY 2007–2008, the JC and IPO knew beforehand that that their days after 2009 would be numbered and took decisive actions early. The discussion about how the legacies of IPY 2007–2008 should be secured and by whom, was launched at the JC-6 meeting in October 2007. For the JC-7 meeting in July 2008, David Carlson, the IPO Director, prepared a 16-page road map, 'IPO IPY Planning Document – 2008 and Beyond.' It outlined prospective actions and partners in securing IPY legacies in science and science funding, data management, observations, logistics, international cooperation, the next generation of polar researchers, public and political networks and other critical fields. As the resources available to JC and IPO were very limited, it was agreed (at JC-7 and also at JC-8 in February 2009) that many of those responsibilities would be naturally taken over by other groups following the end of IPY, without centralized planning and oversight by the JC and IPO. At the JC-8 meeting in February 2009, it became clear that several important legacy tasks remained beyond the reach of JC and IPO. They included the launch of the JC-supervised *IPY Proceedings*/publication series, the collection of the final reports from 230 individual IPY projects, the enforcement of a uniform data-management and data-sharing policy for endorsed IPY projects, and the commission and compilation of the national IPY committees' overviews of their activities during 2005–2009.

With no prospect of the continuing oversight, the JC-8 meeting opted for three paths to be pursued in the remaining months: production of the JC 'summary' volume on IPY planning and operations during 2001–2010; preparation of an overview paper on IPY science achievements for major professional journal/s; and active contribution to the planning of the IPY 'Open Science Conference' in Oslo in June 2010. The latter was successfully accomplished in collaboration with the Norwegian Research Council and the Conference Secretariat, making the Oslo 2010 meeting the largest-ever gathering in the history of polar sciences. None of the early IPYs had enjoyed such a remarkable and highly visible closure event. By eventually embracing both an overview of IPY activities and 'science achievements' papers from many IPY fields, the present JC summary volume has also grown far beyond the initial scope envisioned in 2009. Of course, the full analysis of the material collected in IPY 2007–2008 will take several more years and the overall footprint of IPY may become more visible with time. Nevertheless, the Joint Committee views this current summary volume as its farewell input to the IPY process and as a symbolic 'passing of the baton' to those who will explore IPY legacies in the years ahead. It would be ideal if, as the sponsors of IPY 2007–2008, both ICSU and WMO, and their subsidiary bodies could develop some mechanism for regular reporting on progress with the implementation of the various aspects of the IPY legacy over the next several years. The forthcoming 2012 IPY Conference in Montreal may become a major milestone in this process.

Conclusion

We strongly believe that IPY 2007–2008 fulfilled the expectations of its organizers and its many enthusiastic participants and supporters. The envisioned two-year pulse in research and public activities from March 2007 to March 2009, both in the Arctic and Antarctic, became an exciting milestone in the history of polar science and once-in-a-lifetime experience for thousands of researchers, students, educators, polar residents and many more people worldwide. The overall time impact of IPY covers almost a full decade from 2001 to 2010 and is certain to continue as the IPY project data are processed, analyzed, published, and discussed at workshops and conferences. The prospective launch of the International Polar Decade may successfully extend the IPY momentum and create an entire 'IPY generation' in polar research, observation and science training.

IPY 2007–2008 advanced the ability of polar scientists to meet many of the major challenges of the polar regions—environmental, societal, educational—and contributed to the theoretical and organizational strengthening of polar research. It created a strong legacy in our understanding of polar processes and of their global linkages. As envisioned by IPY organizers, large-scale baseline data sets were established in many fields, against which future change can be assessed. Novel and enhanced observing systems were launched that will eventually produce long-term benefits to many stakeholders, including polar residents and indigenous people. Last, but not least, IPY 2007–2008 trained a new generation of scientists and leaders who are determined to carry this legacy into the future.

The IPY momentum helped bridge disciplines and fields, teamed scientists and polar residents in cooperative research, and related educators and the general public to the issues of polar regions – as had been long advocated. The broad international effort of IPY contributed to a new level of inter-disciplinarity and to multi-faceted visions of polar regions and processes. It increased cooperation between scientists, organizations, and nations in the generation of knowledge and lessons for the sustainable use of our planet. It will be for future generations to preserve these legacies of IPY 2007–2008 and to ensure their lasting contributions to polar science, to the study of Earth's polar regions and to society at large.

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Appendices

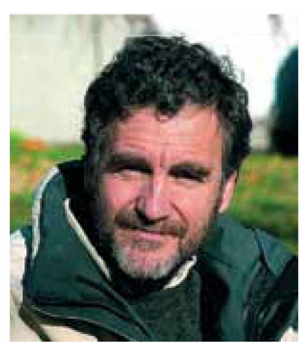
APPENDIX 1

IPY Joint Committee Members Biographies

Invited Members

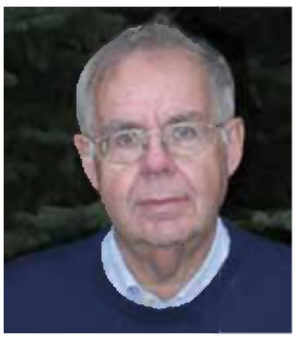
Ian Allison ***(JC Co-Chair, 2004–2009)*** is a research scientist and leader of the Ice, Ocean, Atmosphere and Climate Program of the Australian Antarctic Division (retired). He has studied the Antarctic for over 40 years, participated in or led more than 25 research expeditions to the Antarctic, and published over 100 papers on Antarctic science. His research interests include the interaction of sea ice with the atmosphere and ocean; the dynamics and mass budget of the East Antarctic ice sheet; melt, freezing, and ocean circulation beneath floating ice shelves; and Antarctic weather and climate (Australian Antarctic Division and Antarctic Climate Ecosystems Cooperative Research Centre, Hobart, Australia).

Michel Béland ***(JC Co-Chair, 2004–2010)*** is a meteorologist specializing in the field of atmospheric dynamics and numerical weather prediction. From January 1973 until his retirement in July 2008, he was with Environment Canada—first as a meteorologist, then as a research scientist in the field of predictability and global atmospheric modelling, and eventually as Director General, Atmospheric Science and Technology. He served in many leadership positions on the Commission of Atmospheric Sciences of the World Meteorological Organization and was re-elected as its President in November 2009. He is a past President (1995) of the Canadian Meteorological and Oceanographic Society. His interests are in the field of environmental prediction and seamless or integrated modelling (Science and Technology Branch Environment Canada, Montreal, Canada).



Jerónimo López-Martínez ***(JC Co-Chair, 2009–2010)*** is an Antarctic geologist and Professor of Geology at the Universidad Autónoma de Madrid. He has been involved in Antarctic research since 1989, and has participated in nine field expeditions. His current research interest is in the evolution of relief, linking neotectonics and geomorphology, as well as recent and active geological processes in the Antarctic Peninsula region. He is President of the Spanish National Committee for the Scientific Committee on Antarctic Research (SCAR). He served as Past Vice-President of SCAR and has occupied several positions in the European Polar Board, Council of Managers of National Antarctic Programs (COMNAP), and the Committee of Environmental Protection of the Antarctic Treaty (Faculty of Sciences, Universidad Autónoma de Madrid, Madrid, Spain).

Robin Bell is a Doherty Senior Research Scientist at Columbia University Lamont-Doherty Earth Observatory. She received her doctorate in marine geophysics from Columbia University. Bell has coordinated eight major aero-geophysical expeditions to Antarctica, studying what makes ice sheets collapse. Using data collected from small ski-equipped aircraft and satellite data she has discovered a volcano beneath the West Antarctic ice sheet. Working with colleagues from the National Aeronautics and Space Administration and the University of New Hampshire, she identified several new lakes. During IPY 2007–2008, she lead the Antarctica's Gamburtsev Province (AGAP) expedition to the Gamburtsev Mountains and the top of the East Antarctic ice sheet (Lamont-Doherty Earth Observatory, Columbia University, New York, U.S.A.).



Kjell Danell is an animal ecologist and professor at the Swedish University of Agricultural Sciences in Umeå. He has spent most of his life in the North with a great interest in the boreal forest and tundra ecosystems. His scientific focus is on plant-herbivore-human interactions, especially issues on conservation and sustainable use of forests, wildlife, and fish resources. He has done field research in Fennoscandia, the Canadian and Russian Arctic, Alaska and Kamchatka, and participated in international activities such as the Arctic Climate Impact Assessment and the Millennium Ecosystem Assessment (Department of Wildlife, Fish and Environmental Studies, Swedish University of Agricultural Sciences, Umeå, Sweden).

Eberhard Fahrbach is an oceanographer, head of the Observational Oceanography at the Alfred Wegener Institute, and scientific coordinator of RV *Polarstern*. He studied Physics at the University of Heidelberg and later Physical Oceanography in Kiel. After working in a programme on coastal and equatorial upwelling processes, he obtained his doctorate in 1984 with a thesis on the heat budget of the equatorial Atlantic. In 1986, Dr. Fahrbach moved to the Alfred Wegener Institute in Bremerhaven, Germany where he investigated circulation and water mass formation in polar oceans with many cruises to the Greenland and Weddell Seas (Alfred Wegener Institute, Bremerhaven, Germany).

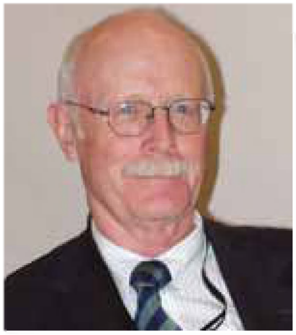
Edith Fanta *(1944–2008)* served as a member of the IPY Joint Committee from 2004 and until her death in May 2008. She was marine biologist specializing in fishes, and she was Chair of the Scientific Committee of the Commission for the Conservation of Antarctic Marine Living Resources. In 2005, she organised the 9th SCAR International Biology Symposium at the Universidade Federal do Paraná, the first such meeting in South America. In addition to her activities in various international committees, she led Working Group 5 of SCAR's Scientific Research Programme on Evolution and Biodiversity in the Antarctic, which deals with the impact of past, current, and predicted environmental change on biodiversity and ecosystem function (Universidade Federal do Paraná, Curitiba, Brazil).

Yoshiyuki Fujii is Director General of the National Institute of Polar Research, Japan and a climatologist with interest in changes in global climate and environment through ice core from Antarctica, Arctic and high mountains, including volcanic signals in ice cores, their effects on climate, and geochemical cycles in polar region. He has been the Head of Arctic Environment Research Center, National Institute of Polar Research (1997–2004) and the Science Adviser to the Japanese Ministry of Education, Culture, Sports, Science and Technology (in 2000–2006). He has worked on research projects in Antarctica, Siberia, Svalbard, Greenland, Nepal Himalyas, and Alaska. He served on the IPY Joint Committee in 2005–2006 (National Institute of Polar Research, Tokyo, Japan).

Grete Kaare Hovelsrud is an anthropologist and a senior researcher at the Center for International Climate and Environmental Research-Oslo (CICERO). She has worked in the Arctic for more than 25 years in a number of disciplines (quaternary geology, reindeer ecology, marine geology, and social anthropology). After a number of years as General Secretary to the North Atlantic Marine Mammal Commission, she began her research on the consequences of climate change on local communities in the Arctic. She is a member of the International Arctic Social Sciences Association (IASSA) Council, as well as the Norwegian IPY National Committee (Center for International Climate and Environmental Research, Oslo, Norway).

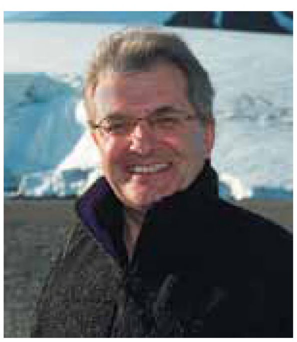
Vladimir Kotlyakov is Professor of Geography, Director of the Institute of Geography, and also a member of the Russian Academy of Sciences. He is polar glaciologist and geographer, and has studied icesheets, glaciers, sea ice, permafrost, and other elements of glaciology in the Arctic and the Antarctic for more than 50 years. He was a member of the Russian team during the International Geophysical Year 1957–1958 and has received numerous honours and honourary degrees in Russia and from international scientific academies and geographical societies. Professor Kotlyakov is honorary President of the Russian Geographical Society (Institute of Geography, Russian Academy of Sciences, Moscow, Russia).

Igor Krupnik is a a cultural anthropologist and curator of Arctic ethnological collections at the Smithsonian Institution in Washington, DC. Trained as physical geographer and ecological anthropologist, he conducted fieldwork in Alaska and along the Russian Arctic coast. His interests include traditional ecological knowledge, social systems, and cultural heritage of Arctic people; climate change and indigenous observations of the sea ice and ecosystem dynamics, primarily in the Western Arctic. He coordinated several projects on the impacts of climate change, preservation of cultural heritage, and ecological observations of Arctic people. He was a founding member of IASSA and served on the IASSA Council in 2004-2008 to foster IASSA's involvement in IPY (Arctic Studies Center, Smithsonian Institution, Washington, D.C., U.S.A.).



Tillmann Mohr is a mathematician, physicist, and meteorologist. He joined the Deutscher Wetterdienst in 1965 and was appointed its President in 1992. His involvement in satellite activities started in 1971 with the European Space Research Organisation, later with the European Space Agency as member and chairman of working groups and programme boards of the METEOSAT Programme. After the establishment of EUMETSAT in 1986, he headed the German delegation to the EUMETSAT Council and was the chairman of the Policy Advisory Committee of of EUMETSAT. In 1995–2004, he served as Director-General of EUMETSAT; then as Special Advisor to the Secretary-General of WMO on Satellite Matters, and in 2010, as Special Advisor on the Global Framework for Climate Services (European Organisation for the Exploitation of Meteorological Satellites, retired, Germany).

Dahe Qin specializes in physical processes and biogeochemistry in snow and ice. He developed his career by studying snow-firn-ice processes on glaciers and the Antarctic ice sheet. In 1995, he was elected as a Lead Author for the Intergovernmental Panel on Climate Change (IPCC) and, in 2002, was elected as Co-Chair of IPCC Working Group I for the Fourth Assessment Report (AR4). Dr. Qin has published ca. 250 papers and received many awards. He has been Director General of the Laboratory of Ice Core and Cold Regions Environment in the Chinese Academy of Sciences since 1992. In 2000, he became the Administrator of the China Meteorological Administration and the Permanent Representative of China to WMO (China Meteorological Administration, Beijing, China).



Chris Rapley is Director of the Science Museum London and Professor of Climate Science at University College London. This follows a decade as Director of the British Antarctic Survey, and four years as Executive Director of the International Geosphere-Biosphere Programme (IGBP) at the Royal Swedish Academy of Sciences in Stockholm. Prior to that, he was Professor of Remote Sensing at University College London. His interests are in climate change and Earth system science. He served as President of the Scientific Committee for Antarctic Research and as Chair of the ICSU Planning Group for International Polar Year in 2003-2004 He was awarded an honorary D.Sc. from the University of Bristol and received the 2008 Edinburgh Science Medal (The Science Museum, London, U.K.).

Takashi Yamanouchi is Vice-Director and Professor in atmospheric science and polar climatology at the National Institute of Polar Research. He is also a professor in the Department of Polar Science at the Graduate University for Advanced Studies. He has wintered in the Antarctic three times as a member of Japanese Antarctic expeditions, and is a leader of the 52nd Expedition in 2010-11. In addition, Dr. Yamanouchi has coordinated Arctic research observation projects such as the Arctic Study of Tropospheric Aerosol and Radiation. His research interests are in radiation, material cycling, atmospheric circulation, and cloud and sea ice climatology with satellite remote sensing. He is currently the Japanese Delegate to SCAR (National Institute of Polar Research, Tokyo, Japan).

Ex officio members:

Keith Alverson (IOC) is Director of the Global Ocean Observing System (GOOS) program office and head of ocean observations and services section at the Intergovernmental Oceanographic Commission (IOC) of UNESCO in Paris, France. He received his Ph.D. in Physical Oceanography from the Massachusetts Institute of Technology-Woods Hole Joint Program in 1995. Dr. Alverson has participated in several ocean field expeditions, including to the Arctic and Antarctic, and carried out modelling, statistical, and synthesis studies in physical oceanography and paleoclimatology. He was previously Director of the Past Global Changes project of IGBP (Intergovernmental Oceanographic Commission, Paris, France).

Paul Cutler (ICSU) is a geomorphologist, meteorologist, and Quaternary geologist and has conducted research in elevated and cold parts of Asia, North America, Europe, and Antarctica. As Science Officer with ICSU, he is responsible for scientific planning and review across the breadth of ICSU-sponsored activities and in particular for ICSU's engagement in IPY 2007–2008. He joined ICSU in 2007 from the U.S. National Academy of Sciences where he directed projects in polar, atmospheric, and Earth sciences. Dr. Cutler's earlier research in geology and geophysics involved numerical modelling of quaternary ice sheets and permafrost, sedimentology of glacial deposits, and climate-water-ice dynamics in modern glacial environments (International Council for Science, Paris, France).

Leah Goldfarb (ICSU) is an atmospheric scientist and a Science Officer with ICSU working on issues related to the environment and sustainable development. She coordinates among the ICSU environmental bodies, e.g. the Global Environmental Change Programmes, has represented the scientific and technological community at international fora, and liaises with the United Nations Environment Programme. Before joining ICSU in 2002, she performed atmospheric research in the U.S. and Europe. Dr. Goldfarb represented ICSU on the IPY Joint Committee in 2005-2006 (International Council for Science, Paris, France).

Mahlon C. (Chuck) Kennicutt II (SCAR) is Professor of Chemical Oceanography and Director (1997–2004) of the Geochemical and Environmental Research Group at Texas A&M University. He was to Antarctica six times, participated in six submersible dives, and has a project at McMurdo Station, Antarctica. He is the U.S. Delegate to SCAR and was elected as President of SCAR for 2008–2012. He has held various offices, including SCAR Vice President for Finance and Scientific Affairs, Chair of the Delegates Committee on Scientific Affairs, and Secretary of the SCAR Scientific Research Program on Subglacial Antarctic Lake Environments. He also served as a science advisor to the U.S. Department of State Antarctic Treaty Delegations since 2002 (Texas A&M University, College Station, TX, U.S.A.).

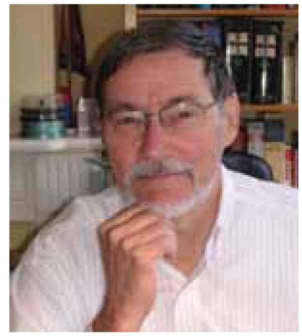
Volker Rachold (IASC) is a geochemist with a Ph.D from Göttingen University, Germany. From 1994 he worked at the Alfred Wegener Institute in Potsdam and Bremerhaven, Germany, and led eight land- and ship-based Russian-German expeditions. His research focused on land-ocean interactions in the Siberian Arctic. In 2006, he became Executive Secretary of the International Arctic Science Committee (IASC) (International Arctic Science Committee, Potsdam, Germany).

Eduard Sarukhanian (WMO) graduated from the State Marine Academy in Leningrad/St. Petersburg, Russia as an oceanographer. He started his polar career at the Arctic research observatory in Tiksi, Russia, and has continued studies of the polar regions at the Arctic and Antarctic Research Institute in St. Petersburg, as a research scientist at the ice-drifting station "North Pole-19" (1969-70), head of three Russian Arctic and Antarctic marine expeditions, and head of the Soviet-American expedition "Weddell Polynia" in 1981. In 1984, Dr. Sarukhanian moved to the WMO Secretariat in Geneva where he worked as chief of the Observing System division and Director of World Weather Watch–Applications Department. Since 2004, he served as Special Adviser to the WMO Secretary-General on IPY (World Meteorological Organization, Geneva, Switzerland).

Colin Summerhayes (SCAR) is an oceanographer and marine geologist and was the Executive Director of SCAR from 2004 to 2010. He is President of the Society for Underwater Technology, Vice President of the Geological Society of London, and an Emeritus Associate of the Scott Polar Research Institute of Cambridge University. Prior to his position with SCAR, Dr. Summerhayes worked in academia, government, and industry in several countries, and for UNESCO in Paris. He has served on many national and international scientific management committees, and is a past Member of the Steering Committee for the Global Climate Observing System (Scientific Committee on Antarctic Research, retired, Cambridge, U.K.).

Odd Rogne (IASC) came into polar research in 1979 as Deputy Director of the Norwegian Polar Institute (Norsk Polarinstitutt) in Tromsø, Norway, with a background in economics and naval operations. He served as the Institute Director in 1983–1991. He was one of the founders of COMNAP, FARO and he played crucial role in the creation of IASC in 1990. He served as the Executive Secretary of IASC from 1990 until 2006 and was also the Norwegian delegate to SCAR for several years. He represented IASC on the Joint Committee until 2006 and subsequently served as Senior Advisor to IPY IPO (Arctic Monitoring and Assessment Programme Secretariat, retired, Oslo, Norway).

Observers:



Johannes Huber (ATCM) was the Executive Secretary of the Antarctic Treaty Secretariat until 2009. After pursuing an educational career that led him from physics via political science to Chinese history, he joined the Netherlands Foreign Service in 1979. From 1997 to 2004 he was the Dutch representative in the Antarctic Treaty Consultative Meeting (ATCM) and the Arctic Council, and from 2004 and until his retirement in 2009 he served as the first Executive Secretary of the Antarctic Treaty Secretariat in Buenos Aires, Argentina. He served as the ATCM Observer on the JC in 2005–2008.

Helena Ödmark (AC) is a Swedish diplomat. After graduating from Stockholm School of Economics, she served in various positions at the Foreign Ministry and at diplomatic missions abroad, including as ambassador to Mozambique and Swaziland. In 2003, she was appointed "Senior Arctic Official" for Sweden in the Arctic Council. She also leads the Swedish delegations to the Antarctic Treaty Consultative Meetings and the Commission on the Conservation of Antarctic Marine Living Resources. Ambassador Ödmark chaired the Scientific Advisory Board for the Abisko Scientific Research Station of the Royal Swedish Academy of Sciences 2004-2008 and was a member of the Swedish national IPY committee. In 2007, she took over from ambassador Vitaly Churkin of Russia as the AC Observer on the JC (Ministry for Foreign Affairs, Stockholm, Sweden).

Manfred Reinke (ATCM) is Executive Secretary of the Antarctic Treaty Secretariat in Buenos Aires, Argentina (since April 2009). He has a Ph.D. in marine biology and started his polar career at the Institute for Polar Ecology in Kiel, Germany. He worked at the Alfred Wegener Institute for Polar and Marine Research (AWI), in Bremerhaven, Germany, in 1986–2009 and was one of the designers of the 'Publishing Network for Geoscientific and Environmental Data' (PANGAEA) used by the World Data Center for Marine Environmental Sciences as a repository. He was a member of the SCAR *ad hoc* Planning Group on Antarctic Data Management and later of the Joint Committee on Antarctic Data Management (JCADM) within SCAR; he also served on various European and international data management committees.

IPY Endorsed Projects as of May 2010

(231 in total, of which 3 have been withdrawn (those highlighted in red).

Activity ID	Title	Geographical Focus	Category
6	Dynamic Social Strategies in Arctic Environments: Long-term Perspectives on Movement and Communication	Arctic	people
8	Synoptic Antarctic Shelf-Slope Interactions Study	Antarctic	ocean
10	Large Scale Historical Industrial Exploitation of Polar Areas	Bipolar	people
11	Arctic Wildlife Observatories Linking Vulnerable EcoSystems	Arctic	land
13	Sea level and tidal science in the polar oceans	Bipolar	ocean
14	Integrated Arctic Ocean Observing System	Arctic	ocean
16	Hydro-sensor-FLOWS Arctic and antarctic glacier hydrosystems as natural sensors for recent climatic variations	Bipolar	ice
19	Metal pollution in Canadian High Arctic: Pollution trend reconstruction of noble metals (Pd and Pt)	Arctic	atmos
20	Air-Ice Chemical Interactions – IPY coordinated studies	Bipolar	ice
21	U.S. National Park Service. Understanding environmental change and its biological, physical, social, subsistence and cultural effects in national parks and protected areas of Alaska, Chukotka, and the Yukon, through research, monitoring, education and outreach	Arctic	land
22	POLARSTERN expedition "HERMES - the Nordic margin" in the framework of the EU funded Integrated Project HERMES (Hotspot Ecosystem Research on the Margins of European Seas)	Arctic	ocean
23	Bipolar Atlantic Thermohaline Circulation	Bipolar	ocean
26	The Pan Arctic cluster for Climate forcing of the Arctic Marine Ecosystem	Arctic	ocean
27	Changing Trends in Polar Research as Reflected in the History of the International Polar Years	Bipolar	people
28	Climate of the Arctic and its role for Europe/Arctic System Reanalysis	Arctic	atmos
29	The Bering Strait, Rapid Change, and Land Bridge Paleoecology	Arctic	land
30	Representations of Sami in Nineteenth Century Polar Literature: The Arctic 'Other'	Arctic	people
32	POLar study using Aircraft, Remote sensing, surface measurements and modelling of Climate, chemistry, Aerosols and Transport (POLARCAT)	Arctic	atmos
33	Antarctic and sub-Antarctic Permafrost, Periglacial and Soil Environments	Antarctic	land
34	Impact of CLImate induced glacial melting on marine and terrestric COastal communities on a gradient along the Western Antarctic PENinsula	Antarctic	ocean
35	International Polar Year GEOTRACES: An international study of the biogeochemical cycles of Trace Elements and Isotopes in the Arctic and Southern Oceans	Bipolar	ocean
36	ARCTIC OCEAN WARMING IN THE PAST	Arctic	ice
37	The dynamic response of Arctic glaciers to global warming	Arctic	ice
38	Ocean-Atmosphere-Sea Ice-Snowpack Interactions affecting Atmospheric Biogeochemistry and Ecosystems in the Arctic	Arctic	ice
39	Arctic Palaeoclimate and its EXtremes	Arctic	ice
40	Developing Arctic Modelling and Observing Capabilities for Long-term Environmental Studies	Arctic	ocean
41	Concordia, a new French-Italian facility for international and long-term scientific activities on the Antarctic Plateau	Antarctic	atmos

Activity ID	Title	Geographical Focus	Category
42	Subglacial Antarctic Lake Environments – Unified International Team for Exploration and Discovery	Antarctic	ice
45	POLAR: WMT Paving the way for Online Learning in Arctic Regions using Wireless & Mobile Technologies	Arctic	education
46	Traditional Indigenous Land Use Areas in the Nenets Autonomous Okrug, Northwest Russia	Arctic	people
48	International Study of Arctic Change	Arctic	ocean
49	International Polar Year (IPY) Data and Information Service (DIS) for Distributed Data Management	Bipolar	data
50	Permafrost Observatory Project: A Contribution to the Thermal State of Permafrost (TSP-125)	Bipolar	land
51	International Polar Year Publications Database	Bipolar	education
52	Antarctic Biological And Earthquake Science (ABES): Southern Ocean Broadband Seismo/ Acoustic Observatories	Antarctic	ocean
53	A Census of Antarctic Marine Life	Antarctic	ocean
54	Antarctic Climate Evolution	Antarctic	land
55	Microbiological and Ecological Responses to Global Environmental Changes in Polar Regions	Bipolar	land
56	Quantifying the relationship of solar variability with the atmosphere, weather and climate (particularly via the global electric circuit and ozone variability associated with solar activity)	Bipolar	space
58	Change and variability of Arctic Systems Nordaustlandet, Svalbard	Arctic	ice
59	Terrestrial ecosystems in ARctic and ANTarctic: Effects of UV Light, Liquefying ice, and Ascending temperatures	Bipolar	land
63	ICESTAR/IHY – Interhemispheric Conjugacy in Geospace Phenomena and their Heliospheric Drivers	Bipolar	space
66	ANDEEP – SYSTCO (ANtarctic benthic DEEP-sea biodiversity: colonisation history and recent community patterns – SYSTem COupling)	Bipolar	ocean
67	Origin, evolution and setting of the Gamburtsev subglacial highlands: Exploring an unknown Antarctic territory	Antarctic	land
69	International Congress of Arctic Social Sciences VI in Nuuk, 2007–2008.	Arctic	education
70	Monitoring of the upper ocean circulation, transport and water masses between Africa and Antarctica.	Antarctic	ocean
71	Polar Aquatic Microbial Ecology	Bipolar	ocean
72	Network for ARCtic Climate and Biological DIVersity Studies	Arctic	land
76	Atmospheric Monitoring Network for Antropogenic Pollution in Polar Regions	Bipolar	atmos
77	Plate Tectonics and Polar Gateways in Earth History	Bipolar	land
78	Synchronized observations of Polar Mesospheric Clouds (PMC), Aurora, and other large-scale polar phenomena from the International Space Station (ISS) and ground sites.	Bipolar	space
79	IPY book series on environmental research	Bipolar	education
80	Determining breeding and exposition conditions for selected Arctic and Antarctic marine organisms at the Gdynia Aquarium in Gdynia, Poland.	Bipolar	education
81	Collaborative Research into Antarctic Calving and ICeberg Evolution	Antarctic	ice
82	LICHEN: The Linguistic and Cultural Heritage Electronic Network	Arctic	education
83	SCAR-MarBIN: the information dimension of Antarctic Marine Biodiversity	Antarctic	ocean

Activity ID	Title	Geographical Focus	Category
86	U.S. Geological Survey participation in the International Polar Year	Bipolar	land
88	Antarctic Surface Accumulation and Ice Discharge (ASAID)	Antarctic	ice
90	Arctic Circum-Polar Coastal Observatory Network	Arctic	land
91	Global Inter-agency IPY Polar Snapshot Year (GIIPSY)	Bipolar	space
92	Integrated analyses of circumpolar Climate interactions and Ecosystem Dynamics in the Southern Ocean–International Polar Year	Antarctic	ocean
93	International Collaborative Expedition to collect and study Fish Indigenous to Sub-Antarctic Habitats, 2007	Antarctic	ocean
95	The state of the Arctic sea ice cover: Physical and biological properties and processes in a changing environment	Arctic	ice
96	Go Polar! An International Network of Children's Museums to Bring Polar Science to Children and Families	Bipolar	education
97	Investigating the Cryospheric Evolution of the Central Antarctic Plate (ICECAP): Internationally coordinated long-range aerogeophysics over Dome A, Dome C and the Aurora Subglacial Basin of East Antarctica	Antarctic	land
99	Ozone layer and UV radiation in a changing climate evaluated during IPY	Bipolar	atmos
100	'Polar Field Stations and IPY History: Culture, Heritage, Governance (1882-Present)'	Bipolar	people
104	The Arctic Hydrological Cycle Monitoring, Modelling and Assessment Program	Arctic	land
105	The State and Fate of the Cryosphere	Bipolar	ice
107	IPY in the Antarctic Peninsula – Ice and Climate [The APY, APICS, GLABENAP, and TRAPIS Expressions of Intent]	Antarctic	ice
108	Sea Ice from Space for IPY (EoI no. 921) Parent Activity: iAOOS (EoI no. 80)	Arctic	ice
109	Geodynamics of the West Antarctic Rift System (WARS) in Remote Ellsworth Land and its implications for the stability of the West Antarctic Ice Sheet	Antarctic	land
110	Antarctic Mission: multi-media exploration of the science of climate change in Antarctica	Antarctic	education
112	Circumpolar Center for Learning and Indigenous Knowledge Systems	Arctic	education
113	Understanding deep permafrost: Interdisciplinary studies related to understanding the structure, geology, microbiology, thermal state, physical properties, and fluid fluxes in thick permafrost leading to a long term observatory.	Arctic	land
114	Climate change in the Arctic with special emphasis on Alaska	Arctic	ice
116	The Royal Society of Victoria's Two INTernational Research Expedition Polar Inter-Disciplinary Voyages.	Antarctic	education
117	International Partnerships in Ice Core Science (IPICS)-International Polar Year Initiative	Bipolar	ice
118	The Greenland Ice Sheet; Stability, History and Evolution	Arctic	ice
120	Northern High Latitude Climate variability during the past 2000 years: implications for human settlement.	Arctic (sub)	ice
121	Improved numerical weather forecasting and climate simulations by exploitation of in-situ, airborne remote-sensing and satellite data, advanced modelling systems and basic research into polar processes and into polar-global interactions.	Primarily Arctic, but also Antarctic and western Pacific. The later is to investigate polar-global connections.	atmos
122	ECOSYSTEM WEST GREENLAND	Artic	ocean
123	Glocalization – Language, Literature and Media among Inuit and Sami people 1. Language Planning, 2. Computer Assisted Linguistics, 3. From Oral Tradition to Rap, 4. Citizenship, Consumerism and Media	Arctic	people

Activity ID	Title	Geographical Focus	Category
124	Astronomy from the Polar Plateaus	Bipolar	space
125	Ice and snow mass change of Arctic and Antarctic polar regions using GRACE satellite gravimetry	Bipolar	ice
130	Bipolar Climate Machinery - A study of the interplay of northern and southern polar processes in driving and amplifying global climate as recorded in paleoclimate archives and their significance for the generation of realistic estimates of future climate	Bipolar	ocean
131	Integrated circumpolar studies of Antarctic marine ecosystems to the conservation of living resources	Antarctic	ocean
132	Climate of Antarctica and the Southern Ocean – Ocean Circulation Cluster	Antarctic	ocean
133	Circumpolar Biodiversity Monitoring Program	Arctic	land
134	Polar bear (Ursus maritimus) circumpolar health assessment in relation to toxicants and climate change	Arctic	ocean
135	A multidisciplinary and international conference with presentations focussed on technical and administrative issues associated with the protection and preservation of historic scientific bases and in particular earlier IPY stations in polar regions and taking the form of a series of presentations and discussions that will ultimately be published for distribution in book and electronic form.	Bipolar	education
137	Evolution and Biodiversity in the Antarctic: the Response of Life to Change	Antarctic	ocean
138	Cold Land Processes in the Northern Hemisphere continents and their Coastal Zone: Regional and Global Climate and Societal-Ecosystem Linkages and Interactions	Arctic	land
139	GREENING OF THE ARCTIC: CIRCUMPOLAR BIOMASS:	Arctic	land
140	Hydrological Impact of Arctic Aerosols	Arctic	atmos
141	Antarctic Sea Ice in International Polar Year	Antarctic	ice
142	The development of a polar-based photobioreactor for the production of bioactive compounds by indigenous micro-algae and cyanobacteria.	Arctic	ocean
145	Workshop / Conference summarizing the results of the Arctic Monitoring and Assessment Program's Human Health Assessment Group (AMAP HHAG Research Program (2002 – 2008).	Arctic	education
147	International Antarctic Institute	Antarctic	education
151	Present day processes, Past changes, and Spatiotemporal variability of biotic, abiotic and socio-environmental conditions and resource components along and across the Arctic delimitation zone.	Arctic	land
152	Trans-Antarctic Scientific Traverses Expeditions – Ice Divide of East Antarctica	Antarctic	land
153	Marine Mammal Exploration of the Oceans Pole to Pole	Bipolar	ocean
155	Ecosystem Studies of Subarctic and Arctic Regions	Arctic	ocean
156	Geomatics for the North - Circumpolar Conference on Basic Geospatial Information for Northern Development	Arctic	education
157	Community Adaptation and Vulnerability in Arctic Regions	Arctic	people
158	Comparative Studies of Marine Arctic and Antarctic Ecosystems and the Potential Consequences of Climate Change	Bipolar	education
160	Arctic Change: An Interdisciplinary Dialog Between the Academy, Northern Peoples, and Policy Makers	Arctic	education
162	Starting the clock for the CARMA Network: Impacts on Human-Rangifer Systems in the Circumarctic.	Arctic	land
164	Inuit and Scientific Descriptions of the Narwhal, Connecting Parallel Perceptions: Inter-disciplinary Studies of the Narwhal with a Focus on Tusk Function.	Arctic	ocean

Activity ID	Title	Geographical Focus	Category
166	Sea Ice Knowledge and Use: Assessing Arctic Environmental and Social Change	Arctic	people
167	Arctic Human Health Initiative	Arctic	people
168	International Polar Year Youth Steering Committee (IPY YSC)	Bipolar	education
169	Network for present and future circumpolar freshwater lake research and data management	Arctic	land
170	Aliens in Antarctica	Antarctic	land
171	POLAR-AOD: a network to characterize the means, variability, and trends of the climate-forcing properties of aerosols in polar regions	Bipolar	atmos
172	Health of Arctic and Antarctic bird populations	Bipolar	land
173	Biogeography and Geological Diversity of Hydrothermal Venting on the Ultra-Slow Spreading Arctic Mid-Ocean Ridge	Arctic	land
175	Fate, uptake and effects of contaminants in the Arctic and Antarctic ecosystem	Bipolar	atmos
176	A Polar Atlas for Education and Outreach based on a Spatial Data Infrastructure Framework (extension of EoI 645)	Bipolar	education
179	Extending IPY Themes to the Undergraduate Earth System Science Education Community	Bipolar	education
180	Antarctic Climate and Atmospheric Circulation	Antarctic	atmos
183	Arctic Resiliency and Diversity: Community Response to Change.	Arctic	people
185	Polar Earth Observing Network	Bipolar	land
186	Engaging communities in the monitoring of zoonoses, country food safety and wildlife health.	Arctic	people
187	Exchange for Local Observations and Knowledge of the Arctic (formerly APOC (Arctic Peoples Observations Center), no. 358)	Arctic	people
188	International Tundra Experiment (ITEX): impacts of long-term experimental warming and climate variability on tundra ecosystems	Arctic	land
189	The University of the Arctic: Providing Higher Education and Outreach Programs for the International Polar Year	Arctic	education
191	The Sixth Continent Initiative - Capacity Building in Antarctic Scientific Research	Antarctic	education
196	International Arctic Systems for Observing the Atmosphere	Arctic	atmos
201	Northern Material Culture through International Polar Year Collections, Then and Now: In the Footsteps of Murdoch and Turner	Arctic	people
202	Arctic Freshwater Biodiversity Monitoring and Research Network	Arctic	land
206	Legal and Constitutional Frameworks for Protecting Traditional Ecological Knowledge in Northern Canada	Arctic	people
208	Remote Sensibility - a multimedia project exploring and reflecting the immaterial relationship global industrial culture has with the circumpolar north.	Arctic	education
210	Global Change - Social Challenges Processes of socio-economic changes in the Circumpolar North, with focus on gender and inter and intra-generational relations.	Arctic	people
213	Environmental baselines, processes, changes and Impacts on people in sub-arctic Sweden and the Nordic Arctic Regions	Arctic	land
214	Retrospective and Prospective Vegetation Change in the Polar Regions: Back to the Future	Bipolar	land
217	The Structure and Evolution of the Polar Stratosphere and Mesosphere and Links to the Troposphere during IPY.	Bipolar	space
227	The Political Economy of Northern Development	Arctic	people

Activity ID	Title	Geographical Focus	Category
244	Antarctic Anthology. A collaborative book incorporating literary, visual and scientific representations of the continent, to commemorate this IPY.	Antarctic	education
246	Arctic Biosphere-Atmosphere Coupling across multiple Scales	Arctic	land
247	Bering Sea Sub-Network of Community-Based Environmental Monitoring, Observation and Information Stations	Arctic	people
248	Arctic Indigenous Community-based Monitoring and Information Stations Network: Arctic Community-based Research Alliance	Arctic	people
251	Circumpolar monitoring of the biology of key-species in relation to environmental changes	Antarctic	ocean
256	Antarctic continental margin drilling to investigate Antarctica's role in global environmental change	Antarctic	land
257	Wildlife Health: Assessing the Cumulative Impacts of Multiple Stressors REVISION TO IPY FULL PROPOSAL no. 192	Arctic	ocean
258	Multidisciplinary Study of the Amundsen Sea Embayment	Antarctic	ice
259	Conservation Hunting in the Arctic: An Analysis of Constraints and Opportunities	Arctic	people
262	Response of Arctic and Subarctic soils in a changing Earth: dynamic and frontier studies	Arctic	land
266	Remote sensing monitoring and forecast of surging glaciers' evolution with the investigation of modern fluctuations of surging glaciers of the Alaska, Svalbard and high elevated Asia glaciers	Arctic	ice
267	Comprehensive Meteorological dataset of active IPY Antarctic measurement phase for Scientific and applied Studies	Antarctic	atmos
275	Polar Disturbance and Ecosystem Services: Links between Climate and Human Well-being	Arctic	people
276	itial Human Colonization of Arctic in Changing Palaeoenvironments	Arctic	people
282	The Nunavut Arctic Research and Educational Base Camp	Arctic	education
284	Development of a system of complex monitoring and elaboration of information-analytical system on protected natural areas of the Polar zone	Arctic	land
285	Northern Genealogies: Development of an ethnodemographic informational system on the peoples of Siberia and the Russian North	Arctic	people
293	Arctic Shelf Tracking and Physics Array	Arctic	ocean
294	International Polar Year Circumpolar Exchanges – proposed exchanges of students and young northern professionals from Canada and other circumpolar countries during International Polar Year 2007–2008	Arctic	education
295	Popularization of Northern Scholarly Articles for Public Interest (EOI 1057)	Bipolar	education
296	IPY Histories: International Polar Year Activities Past and Present, Museum and Virtual Exhibitions	Bipolar	education
299	International summit and working group conference on the development and deployment of energy resources in the arctic including remote and rural villages	Arctic	education
300	Arctic Biodiversity of Chars – Network for Monitoring and Research (revised)	Arctic	land
304	SEASonality of the DRAKE Passage pelagic ecosystem: BIOdiversity, food webs, environmental change and human impact. Present and Past	Antarctic	ocean
305	Consortium for coordination of Observation and Monitoring of the Arctic for Assessment and Research	Arctic	ocean
310	The Impacts of Oil and Gas Activity on Peoples in the Arctic Using a Multiple Securities Perspective	Arctic	people
313	The Prydz Bay, Amery Ice Shelf and Dome A Observatories – A Chinese Key International Program for IPY	Antarctic	ice

Activity ID	Title	Geographical Focus	Category
315	Tectonic Map of the Earth's Polar Regions	Bipolar	education
318	TUNU-Programme: MARINE FISHES OF NE GREENLAND – diversity and adaptation	Arctic	ocean
322	International Polar Year - A multitracer approach to study heat and salt fluxes through sea ice, pollutant transport and surface ocean hydrography	Arctic	ice
325	Marine and estuarine ecosystems in the eastern, central and western Canadian Arctic	Arctic	ocean
327	INterContinental Atmospheric Transport of Anthropogenic Pollutants to the Arctic	Arctic	atmos
328	Integrated Communication, Education and Evaluation	Bipolar	education
329	The Canadian Antarctic Research Program	Antarctic	land
330	International Polar Year: The search for the Franklin expedition: a new perspective based on Inuit oral tradition	Arctic	education
333	Arctic Ocean Diversity (ArcOD)	Arctic	ocean
336	IPY Global Snowflake Network (GSN)	Bipolar	education
337	Dynamics of Circumpolar Land Use and Ethnicity	Arctic	people
338	Arctic Quest - Northwest passage 100 Year Celebration	Arctic	education
339	Measurement and Attribution of recent Greenland Ice sheet chaNgeS (MARGINS)	Arctic	ice
341	Taking the Antarctic Arctic Polar Pulse-IPY 2007-8 Human Biology and Medicine Research	Bipolar	people
342	ANTARCTIC TREATY SUMMIT: SCIENCE-POLICY INTERACTIONS IN INTERNATIONAL GOVERNANCE	Antarctic	
343	Students on Ice - IPY Youth Expeditions to the Arctic and Antarctic	Bipolar	education
349	Course in Arctic Wildlife Medicine and Welfare	Arctic	education
355	The Economy of the North	Arctic	people
357	Spitsbergen Climate System Current Status – SCSCS.	Arctic	atmos
367	NEOGENE ICE STREAMS AND SEDIMENTARY PROCESSES ON HIGH-LATITUDE CONTINENTAL MARGINS	Bipolar	ice
372	Polar View: The Polar Information Centre	Bipolar	space
373	CARBON POOLS IN PERMAFROST REGIONS	Bipolar	land
378	Impact Assessment with Indigenous Perspectives	Arctic	education
379	IPY Operational Oceanography for the Arctic Ocean and adjacent seas	Arctic	ocean
384	Integrity of the Traditional Food System and Environmental Health in the Circumpolar North	Arctic	people
385	Towards an international astronomical observatory at Dome C in Antarctica	Antarctic	space
386	Survey of Living Conditions in the Arctic, SLiCA - Remote Access Analysis System	Arctic	people
388	ARCTIC PORTAL DEVELOPED BY ARCTIC COUNCIL AND AFFILIATES	Arctic	education
389	Yukon IPY Community Liaison	Arctic	education
390	Biodiversity and Climate Induced Lifecycle Changes of Arctic Spiders	Arctic	land
395	Building the next generation of polar scientists, engineers and logisticians by engaging youth from Nunavut and the Northwest Territories in International Polar Year activities	Arctic	education
396	Indigenous Peoples' Forum on Environmental Monitoring in the Arctic	Arctic	education
397	International Polar Year 2007–2008 @ Grand Valley State University	Bipolar	education
399	Reindeer Herders Vulnerability Network Study: Reindeer Pastoralism in a Changing Climate	Arctic	people
400	ANTLER Network Secretariat and Workshop Series	Arctic	education

Activity ID	Title	Geographical Focus	Category
402	International School Education on Polar issues	Bipolar	education
405	Meltdown 3D/2D, A National Geographic Giant Screen Film	Bipolar	education
408	Social-science migrating field station: monitoring the Human-Rangifer link by following herd migration	Arctic	land
410	Inuit Voices: Observations of Environmental Change	Arctic	education
411	Norwegian and Russian Arctic Resources: Prospects for Social and Economic Development	Arctic	people
417	INTERPOLAR Transnational Art Science Consortium	Bipolar	education
423	Pan-Arctic Lake Ice Cover Under Contemporary and Future Climate Conditions	Arctic	land
430	Pan-Arctic Tracking of Belugas	Arctic	ocean
431	ARCTEC: A Cumulative Effects Toolbox for Northern Ecological and Social Systems	Arctic	people
432	The Phoenix Mars Polar Lander and Antarctic Analog Studies	Bipolar	land
433	Pressures and Impacts on the Health and Well-being of Indigenous People of the Arctic: Invitational International Symposium and Symposium Publication	Arctic	education
435	Culturally and Scientifically Significant Materials Recovered from Melting Ice and Cryosols: Recovery, Research, Stabilization and Community Education	Arctic	people
436	Moved by the State: Perspectives on Relocation and Resettlement in the Circumpolar North	Arctic	people
438	International Polar Year Arctic Nations Exhibition and Activities including Symposia, Seminars, Workshops, Residencies, Documentation and Event Coordination	Arctic	education
439	Temporal and spatial distribution of mercury and methylmercury source types, transfer and impact in the North American arctic and sub-arctic food web using seabird eggs and feathers.	Arctic	ocean
440	IPY Books	Bipolar	education
441	Bringing the Poles to Life	Bipolar	education
443	The Use of Radionuclides and Other Contaminants as Tracers of Climate Change Effects in the North.	Bipolar	atmos
446	Circumpolar Indigenous Youth Conservation Project	Arctic	education
448	People and wilderness resources in arctic. Is local subsistence harvest and exclusive wilderness tourism a road to sustainable well-being or a source of conflict	Arctic	people
451	Antarctic Touring Exhibition	Antarctic	education
452	Internationally coordinated studies on Antarctic environmental status, biodiversity and ecosystems	Antarctic	land
453	IPY POLAR GATEWAYS: IPY Education and Outreach Centres in Polar Communities	Bipolar	education
454	Enhancing the Environmental Legacy of the IPY in Antarctica	Bipolar	education
455	IGLO (International action on GLObal warming).	Bipolar	education
456	Practical Applications for Sustainable Development in Arctic Communities	Arctic	people
457	Ice Stories: Educational Resources for the International Polar Year	Bipolar	education
459	IceCube South Pole Neutrino Observatory	Antarctic	space
460	Cape Farewell's youth, science and cultural expeditions to the High Arctic in September 2007 will continue our work in Climate Change education and address the causes and physical effect Climate Change is having on the High Arctic.	Arctic	education
461	Landsat Image Mosaic of Antarctica (LIMA)	Antarctic	space
462	Arctic Social Indicators	Arctic	people

APPENDIX 3

Joint Committee Meetings, 2005–2010

First Meeting of the IPY Joint Committee (JC-1)

March 7-9, 2005, ICSU, Paris, France

PARTICIPANTS

JC Invited Members

Ian Allison (Co-Chair)
Michel Béland (Co-Chair)
Yoshiyuki Fujii
Jerónimo López-Martínez
Grete Hovelsrud-Broda
Chris Rapley
Robin Bell
Vladimir Kotlyakov
Tillmann Mohr
Kjell Danell
Igor Krupnik
Edith Fanta
Qin Dahe

Ex officio Members

Keith Alverson (IOC)
Eduard Sarukhanian (WMO)
Leah Goldfarb (ICSU)
Colin Summerhayes (SCAR)
Odd Rogne (IASC)

Apologies

Eberhard Fahrbach (JC Member)

Other Attendees

Hong Yan (Deputy Secretary-General, WMO)
Thomas Rosswall (Executive Director, ICSU)
Cynan Ellis-Evans (Interim Director, IPO)
Tim Moffatt (JC Minutes)

AGENDA

1. Welcome and Introductions
   - 1.1 ICSU (Prof. Thomas Rosswall)
   - 1.2 WMO (Prof. Yan Hong)
   - 1.3 IPY Co-Chairs (Ian Allison and Michel Béland)
   - 1.4 Introduction of JC members and their backgrounds
   - 1.5 Terms of Reference for JC
   - 1.6 Purpose and Objectives of the Meeting
2. Review IPY planning to date inc. "Framework" Document/ 6 Themes
   - 2.1 Progress and activities since PG-4 meeting
   - 2.2 Identifying tasks left over from the Planning Group 4 meeting
3. Activities of the IPO
   - 3.1 Selection of IPO Director
   - 3.2 IPY Websites
   - 3.3 IPY logo and badging
   - 3.4 WMO "project office" activities
4. Expressions of Intent
   - 4.1 Analysis of EoI's across entire database/ developing clusters
   - 4.2 JC assessments of EoIs
     - 4.2.1 Breakdown for individual categories based on JC skill set
     - 4.2.2 Clumping and Cross-referencing between the categories
5. Programme structure at project level
   - 5.1 Structure and role of Project Steering Committees (refer to Science Plan)
   - 5.2 Developing links and collaboration between EoIs
   - 5.3 Identifying cross cutting issues
   - 5.4 Identifying gaps
6. Development of Full Proposals
   - 6.1 Format, procedure and timetable for full IPY Proposals
   - 6.2 Process for assessment and identification of final IPY projects
   - 6.3 Interactions with funding and logistic agencies
   - 6.4 Interactions with National Committees

Second Meeting of the IPY Joint Committee (JC-2)

November 15 - 17, 2005, Geneva, Switzerland

PARTICIPANTS

JC Invited Members

Ian Allison (Co-Chair)
Michel Béland (Co-Chair)
Jerónimo López-Martínez
Robin Bell
Kjell Danell
Eberhard Fahrbach
Tillmann Mohr
Vladimir Kotlyakov
Igor Krupnik
Qin Dahe
Chris Rapley
Grete Hovelsrud-Broda

Ex officio Members

Leah Goldfarb (ICSU)
Odd Rogne (IASC)
Eduard Sarukhanian (WMO)
Colin Summerhayes (SCAR)

Observers

Vitaly I. Churkin (Arctic Council)
Johannes Huber (Antarctic Treaty)

International Programme Office
David Carlson (Director)
Cynan Ellis Evans
Nicola Munro (Minutes)

Invitees

Mark Parsons, Taco de Bruin – Co-Chairs, Data Policy and Management Subcommittee

Apologies

Keith Alverson (Ex officio Member)
Edith Fanta (JC Member)
Yoshiyuki Fujii (JC Member)

AGENDA

1. Opening of the session (welcome, addresses, presentation of participants, approval of agenda)

2. Role of JC members and the role of Observers

3. Updates on IPY related activities
   3.1 Report from ICSU General Assembly
   3.2 Report on WMO Intercommission Task Group
   3.3 Report on IPO activities

4. Reports on recent IPY activities from international agencies and programmes
   4.1 IPY Discussion Forum (Copenhagen, 13 November 2005)
   4.2 EPB-ESF meeting (9 November 2005)
   4.3-9 IPY-related reports: AC; ATCM; WCRP (including CliC); ICARP; SCAR; IASC; IASSA
   4.10 International years (IHY, eGY, Planet Earth)

5. IPY preparation
   5.1 Project proposals process and look forward
   5.2 Next JC activities: IPY science programme and key events for the next 18 months
   5.3 Role of the subcommittees
   (a) Subcommittee on Observations
   (b) Subcommittee on Data Policy
   (c) Subcommittee on Education, Outreach and Communications

6. Linking with logistical organisations (FARO, COMNAP, etc)
   6.1 Proposed Eurasian sub-office for IPY
   6.2 Support for CRYOSAT

7. Linking with funding agencies and general IPY fund raising, including funding of IPY Subcommittees
   7.1 Trust Fund for IPY

8. Brief statements from JC members and observers and National Committees.
   8.1 AC and ATCM representatives
   8.2 JC Members

9. IPO Future activities (websites, Subcommittees organisational support, volunteers)

Third Meeting of the IPY Joint Committee (JC-3)

April 20 - 22, 2006, Cambridge, U.K.

PARTICIPANTS

JC Invited Members

Ian Allison (Co-Chair)
Michel Béland (Co-Chair)
Jerónimo López-Martínez
Robin Bell
Kjell Danell
Eberhard Fahrbach
Tillmann Mohr
Vladimir Kotlyakov
Igor Krupnik
Qin Dahe
Chris Rapley
Edith Fanta

Ex officio Members

Laurie Geller (ICSU)
Eduard Sarukhanian (WMO)
Colin Summerhayes (SCAR)
Keith Alverson (IOC)
Volker Rachold (IASC)

Observers

Johannes Huber (Antarctic Treaty)

International Programme Office

David Carlson (Director)
Cynan Ellis-Evans
Odd Rogne
Nicola Munro (Minutes)

Invitees

Taco de Bruin – Data Policy Subcommittee
Margarete Pauls – EOC Subcommittee
(via conference call)

Apologies

Grete Hovelsrud (JC Member)
Yoshiyuki Fujii (JC Member)

AGENDA

1-3. Opening: agenda, JC-2 minutes and Action items

4. Updates on IPY-related activities
   (a) IPO
   (b) Subcommittees
      - Data Management
      - Education and Outreach
      - Observations
      - Youth
   (c) Other (EPB)

5. IPY Proposals
   (a) Processing of January 2006 proposals
   (b) Revised chart
   (c) Managing IPY information

6. Reports from logistical organisations (FARO, COMNAP, etc)

7. Funding
   (a) National funding
   (b) IPO and subcommittees
   (c) Project Coordinator funding
   (d) Commercial partnerships

8. Integration processes
   (a) Within clusters; Among/across clusters
   (b) Accelerating the IPY impact

9. Brief statements
   (a) AC and ATCM representatives
   (b) JC Members

10. IPO future activities
   (a) Launch activities/planning
   (b) Existing and special science events

11. Action item review

12. OCF at SCAR Hobart

13. Next JC meeting

14. Assessment of the session

Fourth Meeting of the IPY Joint Committee (JC-4)

September 26-28, 2006, Longyearbyen, Svalbard

PARTICIPANTS

JC Invited members

Ian Allison (Co-Chair)
Michel Béland (Co-Chair)
Jerónimo López-Martínez
Kjell Danell
Eberhard Fahrbach
Grete Hovelsrud
Vladimir Kotlyakov
Igor Krupnik
Chris Rapley
Edith Fanta

Ex officio Members

Gisbert Glaser (ICSU)
Eduard Sarukhanian (WMO)
Colin Summerhayes (SCAR)
Keith Alverson (IOC)
Volker Rachold (IASC)

Observers

Johannes Huber (Antarctic Treaty)

International Programme Office

David Carlson (Director)
Cynan Ellis-Evans
Odd Rogne
Rhian Salmon
Nicola Munro (Minutes)

Apologies

Qin Dahe (JC Member)
Tillmann Mohr (JC Member)
Yoshiyuki Fujii (JC Member)

AGENDA

1-3. Opening: agenda, JC-3 minutes and Action items

4. Updates on IPY-related activities
   (a) Hobart Consultative Forum
   (b) ESA IPY Solicitation
   (c) Polar Sessions at ESSP
   (d) IPO
      (i) Project update
   (e) National reports
   (f) Upcoming IPY secretariats meeting

5. Funding
   (a) National funding
   (b) Project funding
   (c) IPO and subcommittee funding
   (d) Project coordinator funding
   (e) Other

6. Reports from Subcommittees
   (a) Data Management
   (b) Observations
   (c) Youth
   (d) Education and Outreach
      (i) Media summaries
      (ii) Website

7. Joint Committee Outreach
   (a) Science Plan
   (b) Outreach Articles
   (c) Other activities
      (i) Event Planning

8. IPY Issues
   (a) Ethics and Environmental Guidelines
   (b) JC Term of Reference

9. Brief statements
   (a) AC and ATCM representatives
   (b) JC Members

10. Interactions with Norwegian IPY National Committee

11. Action item review

12. Next JC meeting

13. Assessment of the session

Fifth Meeting of the IPY Joint Committee (JC-5)

28th February to 2nd March, 2007, Paris, France

PARTICIPANTS

JC Invited members

Ian Allison (Co-Chair)
Michel Béland (Co-Chair)
Jerónimo López-Martínez
Kjell Danell
Eberhard Fahrbach
Grete Hovelsrud
Vladimir Kotlyakov
Igor Krupnik
Tillmann Mohr
Chris Rapley
Robin Bell
Qin Dahe

Ex officio Members

Carthage Smith (ICSU)
Eduard Sarukhanian (WMO)
Colin Summerhayes (SCAR)
Tom Gross (alternate IOC)
Volker Rachold (IASC)

Observers

Johannes Huber (Antarctic Treaty)

Apologies

Edith Fanta (JC Member)
Yoshiyuki Fujii (JC Member)
Keith Alverson (IOC)
Karsten Klepsvik (Arctic Council, Observer)

International Programme Office

David Carlson (Director)
Cynan Ellis-Evans
Odd Rogne
Nicola Munro (Minutes)

Invited Participants

Mark Parsons (Data Management Subcommittee)
Taco de Bruin (Data Management Subcommittee)
Sandra Zicus (EOC Subcommittee)
Chen Zhenlin (CMA)

AGENDA

1-4. Opening (agenda, JC-4 minutes, Action Items; Chair's remarks)

5. Status of IPY Project Funding

6. Status of National Funding (JC role with respect to national IPY funding process)

7. Post-IPY events and conferences

8. Forging stronger links among IPY projects

9. Launch Ceremony

10. Subcommittees reports
    10.1 Education and Outreach Subcommittee
    10.2 Subcommittee on Observations and Space Task Group (STG)
    10.3 Youth Steering Committee (YSC)

11. JC activities to maintain IPY momentum

12. Data Management and Policy

13. IPY Legacy (JC role)
    13.1 Proposed legacy planning activities etc

14. Reports: SCAR, IASC, Arctic Council, Antarctic Treaty Secretariats

15. National Committee reports (Austria, Canada, Portugal, Spain, U.K.)

16. Update on IPO activities (funding, work plan)

17. Assessment of meeting

Sixth Meeting of the IPY Joint Committee (JC-6)

25th-26th October 2007, Québec City, Canada

PARTICIPANTS

JC Invited Members

Ian Allison (Co-Chair)
Michel Béland (Co-Chair)
Kjell Danell
Eberhard Fahrbach
Igor Krupnik
Tillmann Mohr
Robin Bell
Takashi Yamanouchi

Ex officio Members

Paul Cutler (ICSU)
Eduard Sarukhanian (WMO)
Colin Summerhayes (SCAR)
Keith Alverson (IOC)
Volker Rachold (IASC)

Observers

Johannes Huber (Antarctic Treaty)
Helena Ödmark (Arctic Council)

International Programme Office

David Carlson (Director)
Cynan Ellis-Evans
Odd Rogne
Rhian Salmon
Nicola Munro (Minutes)

Invited Participants

Mark Parsons (Data Management Subcommittee)
Sandra Zicus (EOC Subcommittee)
Margarete Pauls (EOC Subcommittee)

Apologies

Edith Fanta (JC Member)
Chris Rapley (JC Member)
Vladimir Kotlyakov (JC Member)
Jerónimo López-Martínez (JC Member)
Grete Hovelsrud (JC Member)
Qin Dahe (JC Member)
Taco de Bruin (Data Management Subcommittee)

AGENDA

1-4. Opening (meeting agenda; JC-5 minutes, JC-5 Action Items; Chair's Remarks)

- 5.1 Observers' Reports (ATCM, Arctic Council)
- 5.2 IASC
- 5.3 Other (IOC, ICSU, WMO),
- 5.4 IPO
- 5.5 Data Subcommittee
- 5.6 EOC Subcommittee

6. Session with Canadian IPY National Committee

7. IPY Status and Assessment
   - 7.1 Funding
   - 7.2 National Committees
   - 7.3 Project Coordinators
   - 7.4 IPY Assessment Report
   - 7.5 Extension/Termination options
   - 7.6 Publications

8. National Committees Reports (India, Japan New Zealand, Poland, Spain, Ukraine, U.K., Sweden, U.S.A, Portugal)
   - 8.1 APECS Report

9. IPY Legacies
   - 9.1 Observations; WMO Global Cryosphere Watch
   - 9.2 Data Integrations and Assessments
   - 9.3 Science infrastructure and cooperation
   - 9.4 SCAR-IASC Cooperation
   - 9.5 Cryosphere Coordinating group

10. Meetings, Event Planning
    - 10.1 SCAR-IASC Open Science Conference, 2008
    - 10.2 ATCM 32
    - 10.3 IPY Early Science Conference, Oslo 2010
    - 10.4 Other major science events
    - 10.5 Letter from Canada, IPY 2012 conference
    - 10.6 IPY conference in Salekhard (proposal)
    - 10.7 Extension of Term of JC

11. Other Business

Seventh Meeting of the IPY Joint Committee (JC-7)

4th – 5th July, 2008, St Petersburg, Russia

PARTICIPANTS

JC Invited Members

Ian Allison (Co-Chair)
Michel Béland (Co-Chair)
Robin Bell
Kjell Danell
Grete Hovelsrud
Vladimir Kotlyakov
Jerónimo López Martínez
Tillmann Mohr
Chris Rapley
Takashi Yamanouchi

Ex officio Members

Paul Cutler (ICSU)
Eduard Sarukhanian (WMO)
Colin Summerhayes (SCAR)
Keith Alverson (IOC)

Observers

Johannes Huber (Antarctic Treaty)
Helena Ödmark (Arctic Council)

International Programme Office (IPO)

David Carlson (Director) (DC)
Odd Rogne (OR)
Rhian Salmon (RS)
Nicola Munro (Minutes) (NM)

Invited Participants

Taco de Bruin (Data Management Subcommittee)
Sandra Zicus (EOC Subcommittee)
Margarete Pauls (EOC Subcommittee)
Kriss Rokkan Iversen (APECS)
Sergey Priamikov (Eurasian Arctic Sub-Office)
Olav Orheim (Research Council of Norway)

Apologies

Qin Dahe (JC Member)
Eberhard Fahrbach (JC Member)
Igor Krupnik (JC Member)
Volker Rachold (Ex officio, IASC)
Cynan Ellis-Evans (IPO)
Mark Parsons (Data Management Subcommittee)

AGENDA

1.1 Welcome and Introductions
1.2 Review JC6 Agenda
1.3 Accept Minutes from JC 6
1.4 Review JC-6 Action Items
1.5 Chair Opening Remarks

2. Reports
   - 2.1 Data – coordinator, progress, outlook for archives, report from subcommittee
   - 2.2 EOC – written report from Subcommittee
   - 2.3 APECS – written report from APECS
   - 2.4 SCOBS/STG – written report from Subcommittee
   - 2.5 SCAR/IASC report on bipolar working group
   - 2.6 Report from IPO Eurasian Sub-offce (EASO)
   - 2.7 National Reports
   - 2.8 Reports from AC and ATS
   - 2.9 Report from HAIS
   - 2.10 Reports from ICSU, WMO, IOC, IASC

3. Events around 1 March 2009
   - 3.1 Plans for February 2009
   - 3.2 "State of Polar Research" JC Statement

4. IPY Legacy – Legacy plans, large and small

5. Events
   - 5.1 IPY Oslo Science Conference, June 2010
   - 5.2 IPY Canada Science Conference, 2012

6. JC and IPO
   - 6.1 JC beyond 2009
   - 6.2 IPO beyond 2009

7. IPY Consultative Forum, July, 2008

8. Next Meeting
9. AOB

Eighth Meeting of the IPY Joint Committee (JC-8)

23rd – 24th February, 2009, WMO Headquarters, Geneva, Switzerland

PARTICIPANTS

JC Invited members

Ian Allison (Co-Chair)
Michel Béland (Co-Chair)
Robin Bell
Kjell Danell
Eberhard Fahrbach
Grete Hovelsrud
Vladimir Kotlyakov
Igor Krupnik
Jerónimo López Martínez
Tillmann Mohr
Chris Rapley
Takashi Yamanouchi

Ex officio Members

Paul Cutler (ICSU)
Eduard Sarukhanian (WMO)
Keith Alverson (IOC)
Volker Rachold (IASC)
Colin Summerhayes (SCAR)

Observers

Helena Ödmark (Arctic Council)

International Programme Office (IPO)

David Carlson (Director)
Odd Rogne
Nicola Munro (Minutes)

Invited Participants

Taco de Bruin (Data Management Subcommittee)
Mark Parsons (Data Management Subcommittee)
Sandra Zicus (EOC Subcommittee)
Daniela Haase (APECS)
Olav Orheim (Research Council of Norway)
Patrick Borbey (Indian and Northern Affairs, Canada)
David Hik (Canadian IPY Secretariat)

Apologies

Qin Dahe (JC Member)
Cynan Ellis-Evans (IPO)
Johannes Huber (Antarctic Treaty)

AGENDA

1. Opening; review agenda; Chair's remarks
   - 1.1 JC-7 Minutes, Action Items
   - 1.2. 'The State of Polar Research' document

2. IPY Assessments and Integration efforts
   - 2.1 SWIPA, SCAR ACCE
   - 2.2 JC "Synthesis" document on IPY
   - 2.3 Arctic Council Legacy Activities
   - 2.4 SCAR/IASC Bipolar Working Group
   - 2.5 JC role in coordinating existing activities
     - 2.5.1 Changes necessary to the JC ToR
   - 2.6 IPY History project – status report
   - 2.7 JC expression of thanks to IPY partners
   - 2.8 Maximising the 2010 and 2012 IPY conferences
   - 2.9 Plans and action items

3. Observational systems, facilities and infrastructure
   - 3.1-3 WMO roadmap; SAON; PAntOS

4. Data Management
   - 4.1 Letters sent to national committees
   - 4.2 Plans from Data Management Committee

5. APECS Report; other next generation activities

   - 6.1 Oslo IPY Conference 2010
   - 6.2 Canada IPY Conference 2012
   - 6.3 Other key conferences

7. EOC report (including forthcoming activities)
   - 7.1 Long-term partnerships

8. Other Reports
   - 8.1 HAIS
   - 8.2 AC
   - 8.3 ATCM
   - 8.4 WMO and ICSU
   - 8.5 ISAC, SCAR, UNESCO

9. Status and tasks of IPO; archival processes

10. International Polar Decade

Ninth Meeting of the IPY Joint Committee (JC-9)

7th June 2010, Oslo, Norway

PARTICIPANTS

JC Invited Members

Michel Béland (Co-Chair)
Jerónimo López-Martínez (Co-Chair)
Ian Allison
Robin Bell
Eberhard Fahrbach
Grete K. Hoveslrud
Vladimir Kotlyakov
Igor Krupnik
Tillmann Mohr
Colin Summerhayes
Takashi Yamanouchi

Ex officio Members

Paul Cutler (ICSU)
Eduard Sarukhanian (WMO)
Keith Alverson (IOC)
Chuck Kennicott (SCAR)
Volker Rachold (IASC)

Observers

Helena Ödmark (Arctic Council)
Manfred Reinke (Antarctic Treaty)

International Programme Office

David Carlson (Director)
Melissa Deets (Minutes)
Odd Rogne

Apologies

Kjell Danell
Qin Dahe
Chris Rapley

Subcommittee Members

Mark Drinkwater (Subcommittee on observations)
Taco de Bruin (Data management subcommittee)
Sandra Zicus (EOC Subcommittee)

Invited Participants

Kathleen Fischer (Canada IPY Federal Program Office
Olav Orheim (Research Council of Norway)
David Hik (Canadian IPY Secretariat)
Barry Goodison (WMO)
Jenny Baeseman (APECS)
Deliang Chen (ICSU)

AGENDA

1. Opening of the session (approval of agenda; chair's opening remarks, etc.)

2. JC 'Summary Report' on IPY 2007–2008
   - 2.1. Status of the Report, 6 June 2010
   - 2.2. Actions needed
   - 2.3. Planning for Report completion and publication

3. IPY 2010 Oslo Science Conference

4. IPY 2012 Canada Science Conference

5. International Polar Decade

6. Preliminary science achievements of IPY
   - 6.1. 'Status' Theme
   - 6.2. 'Change' Theme
   - 6.3. 'Global Connections' Theme
   - 6.4. 'Frontiers' Theme
   - 6.5. 'Vantage Point' Theme
   - 6.6. 'Human Dimensions' Theme

7. Unfinished business: How to complete IPY?
   - 7.1. Publication database and IPY bibliography
   - 7.2. Archiving IPY materials and records
   - 7.3. Opening JC minutes for public use (online)

8. Summaries from subcommittees and partners
   - 8.1. Subcommittee on observations
   - 8.2. Subcommittee on data management
   - 8.3. EOC subcommittee
   - 8.4-7 Final statements: IASC, SCAR, AC, ATCM

9. Concluding remarks
   - 9.1 JC Co-Chairs and IPO
   - 9.2 ICSU (Deliang Chang)
   - 9.3 WMO (Ed Sarukhanian)

APPENDIX 4

IPY Proposal Evaluation Form Used by the JC, 2005–2006

Altogether 422 'full proposals' were received by the IPO by three subsequent submission deadlines: 30 June 2005, 30 September 2005, and 31 January 2006, with 337 being scientific or data management proposals, and 85 being for education and outreach activities. The number of proposals received in each round was 109, 92 and 209 respectively, and 12 later submissions were also accepted. Each was independently reviewed by three to four JC members and assessed against 15 IPY criteria, six being 'primary' criteria and nine other listed as 'additional' criteria. (After the second round, education and outreach submissions were reviewed by the EOC committee rather than the JC). Proposals that were assessed by the JC members as meeting the requested criteria became 'endorsed IPY projects' and were added to the emerging IPY 2007–2008 project chart (Appendix 5). All submitted 'full proposals' were made openly accessible on the IPO website (http://classic.ipy.org/development/eoi/proposals.php).

	Criteria	Deficient	Acceptable	Excellent
P	**1. Significant Contribution**			
P	**2. Addresses IPY theme with Contribution**			
P	**3. Targets IPY geographic area**			
P	**4. Targets IPY timeframe**			
P	**5. Evidence of International Collaboration**			
P	**6. Clear Plans for project management**			
A	1. Provides essential infrastructure or other support			
A	2. Non-polar nations involvement			
A	3. Evidence of Legacy			
A	4. Builds on existing initiatives, where appropriate			
A	5. Evidence of links to other clusters			
A	6. Evidence of Interdisciplinarity			
A	7. Clear plans for data management			
A	8. Will this activity develop the next generation			
A	9. Is there a plan for Education, Outreach?			
	Category			
	Comments on Proposal			

Subcommittees

Subcommittee for Education and Outreach

Margarete Pauls, *Alfred Wegener Institute, Germany (Co-Chair)*
Sandra Zicus, *International Antarctic Institute, Australia (Co-Chair)*
Khadijah Abdul Rahman Sinclair, *Yayasan Anak Warsan Alam (YAWA), Malaysia*
Miriam Almeida, *Teacher, Brazil*
Linda Capper, *British Antarctic Survey, U.K.*
Jean de Pomereu, *International Polar Foundation, France*
Geoff Green, *Students on Ice, Canada*
Rachel Hazell, *Hazell Designs Books, U.K.*
Louise Huffman, *ANDRILL, U.S.A.*
Tove Kolset, *CICERO, Norway*
Lars Kullerud, *University of the Arctic, Norway*
Zhang Le, *China Meteorological Administration, China*
Linda Mackey, *Polar Artists Group, Canada*
Rene Malherbe, *Consultant, The Netherlands*
Mark McCaffrey, *U.S.A.*
Liz Murphy, *Squizmix, Australia*
Birgit Kleist Pedersen, *University of Greenland, Greenland*
Jennifer Pink, *Science North, Canada*
Melianie Raymond, *APECS Education, Outreach Communication representative, Denmark*
Elena Sparrow, *International Arctic Research Center, U.S.A.*
Rodion Sulyandziga, *Center for Support of Indigenous Peoples of the North, Russia*
Pattie Virtue, *University of Tasmania, Australia*

Ex officio Members:
Representatives from the International Programme Office, IPY Youth Steering Committee, International Council for Science, World Meteorological Organisation

Subcommittee for Data Policy and Management

Mark Parsons, *National Snow and Ice Data Center, U.S.A. (Co-Chair)*
Taco de Bruin, *Royal Netherlands Institute for Sea Research, The Netherlands (Co-Chair)*
Scott Tomlinson, *Canadian IPY Federal Programme Office, Canada*
Nathan Bindoff, *Antarctic Climate and Ecosystems CRC, Australia*
Joan Eamer, *GRID-Arendal, Australia*
Kim Finney, *Australian Antarctic Division Australia*
Hannes Grobe, *WDC-MARE World Data Center for Marine Environmental Services, AWI, Germany*
Ray Harris, *Department of Geography, University College London, U.K.*
Ellsworth LeDrew, *Department of Geography, University of Waterloo, U.S.A.*
Xin Li, *WDC for Glaciology and Geocryology, Chinese Academy of Sciences, China*
Hakan Olsson, *Swedish University of Agricultural Sciences, Umea, Sweden*
Vladimir Papitahivili, *Department of Atmospheric, Oceanic and Space Sciences, University of Michigan, U.S.A.*
Birger Poppel, *University of Greenland, Greenland*
Alexander Sterin, *Russian Research Institute for Hydrometeorological Information-World Data Centre B, Russia*

Subcommittee for Observations

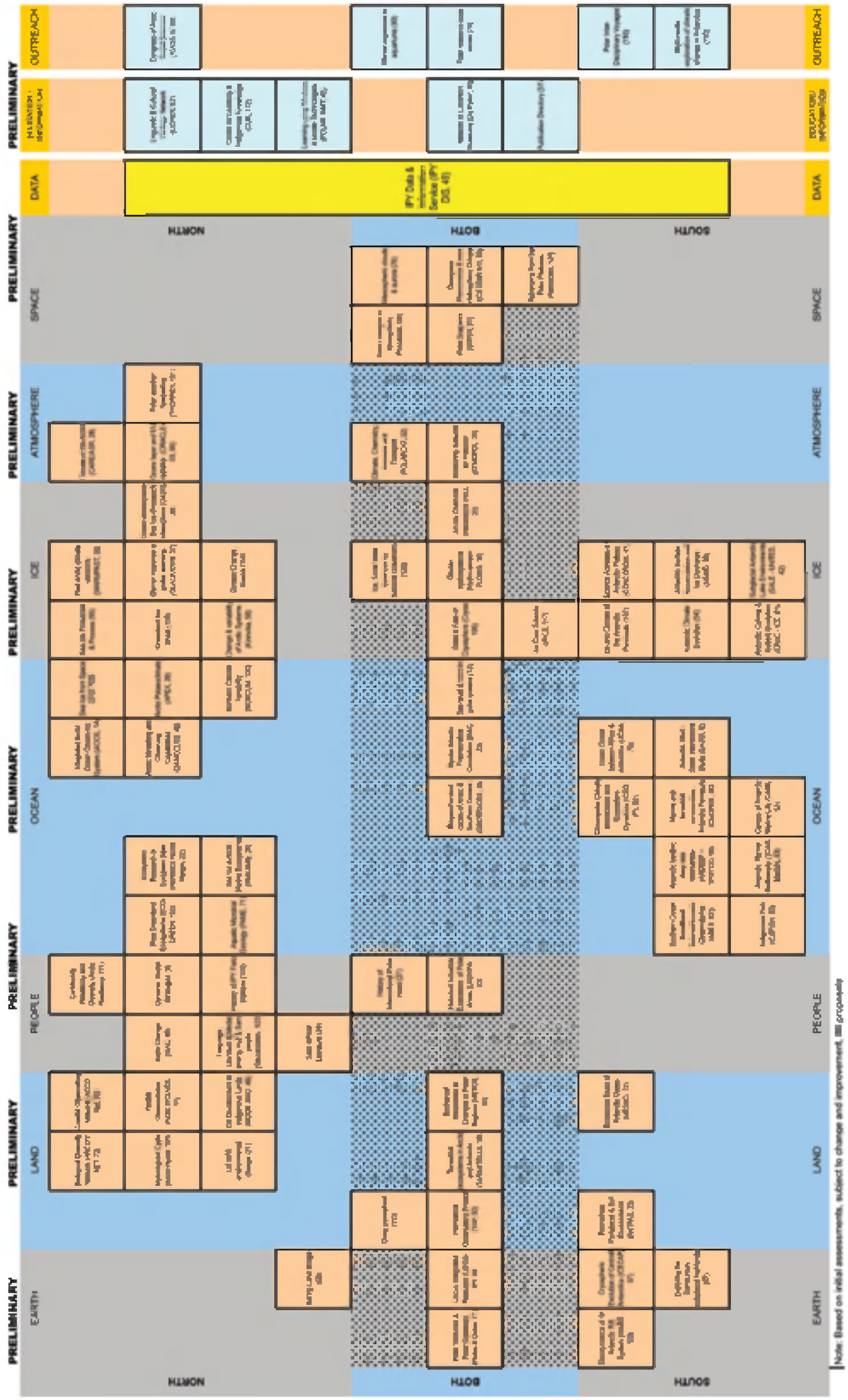
Wenijan Zhang, *China Meteorological Administration, Chair*
Jan Bottenheim, *Science and Technology Branch, Environment Canada, Canada*
Peter Dexter, *Australian Government Bureau of Meteorology, Australia*
Mark Drinkwater, *European Space Agency, The Netherlands*
Ken Jezek, *Ohio State University, U.S.A.*
Lene Kielsen Holm, *Representative of Indigenous Peoples community, Greenland*
Antoni Meloni, *Instituto Nazionale d eofisica e Vulcanolgia, Italy*
Arni Snorrason, *Icelandic Meteorological Office, Iceland*
Craig Tweedie, *University of El Paso, Texas, U.S.A.*
Tatiana Vlassova, *Institute of Geography, Russia*
David Williams, *British National Space Centre, U.K.*

Space Task Group

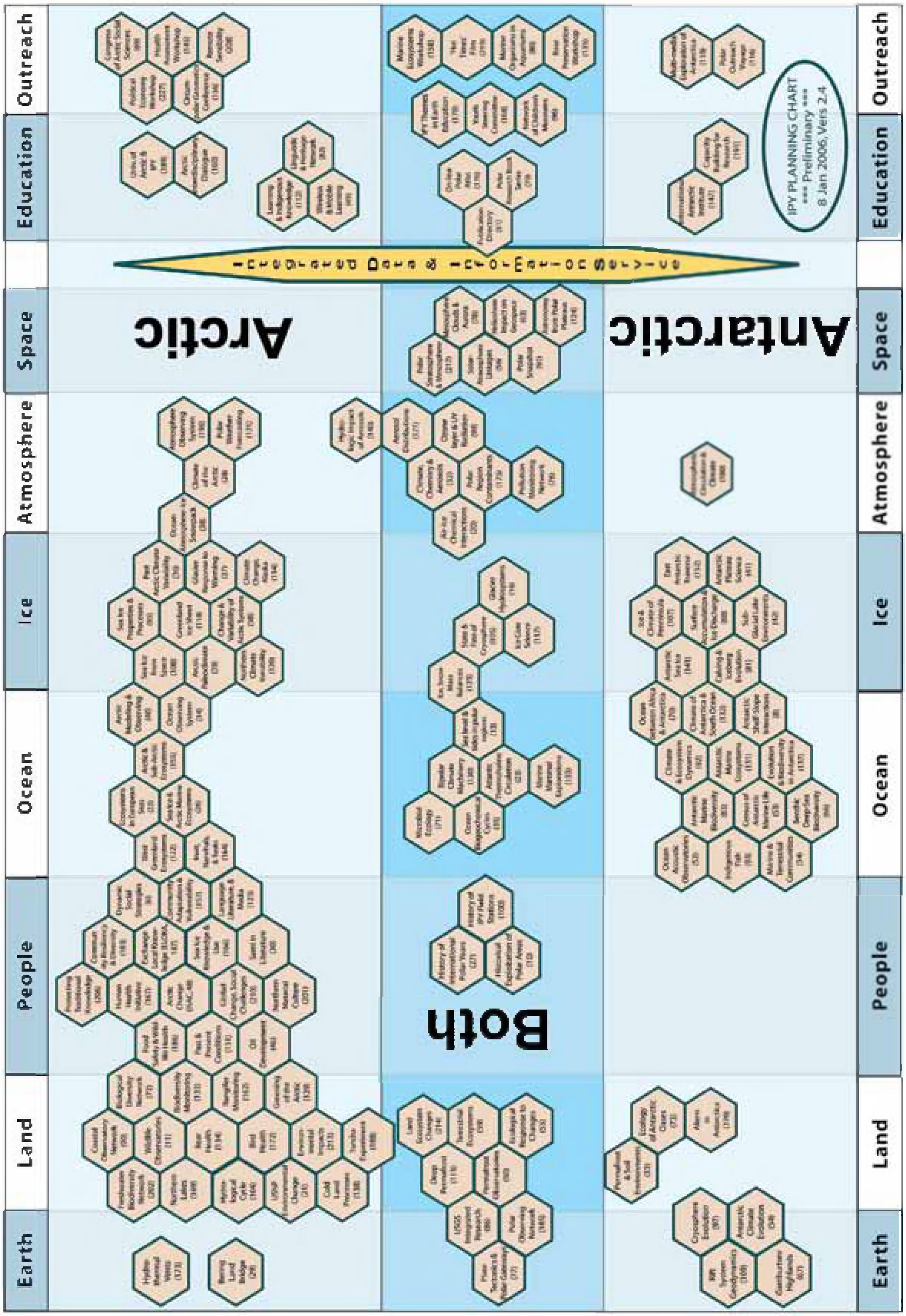
Mark Drinkwater, *European Space Agency, The Netherlands (Co-Chair)*
David Williams, *British National Space Centre, U.K. (Co-Chair)*
Vasilii Asmus, *Russian Federal Service for Hydrometeorology and Environmental Monitoring, Russia*
Pablo Clemente-Colon, *National Oceanic and Atmospheric Administration, U.S.A.*
Yves Crevier, *Canadian Space Agency, Canada*
Craig Dobson, *National Aeronautics and Space Administration, U.S.A.*
Battaza Fabrizio, *Agenzia Spaziale Italiana, Italy*
Oystein Godoy, *Norwegian Meteorological Institute, Norway*
Manfred Gottwald, *German Aerospace Centre, Germany*
Kenneth Holmlund, *European Organisation for the Exploitation of Meteorological Satellites*
Chu Ishida, *Japan Aerospace Exploration Agency, Japan*
Jeffry Key, *National Oceanic and Atmospheric Administration, U.S.A.*
Henri Laur, *European Space Agency, The Netherlands*
Seelya Martin, *National Aeronautics and Space Administration, U.S.A.*
Alberto Setzer, *Instituto Nacional de Pesquisas Espaciais, Brazil*
Masanobu Shimada, *Japan Aerospace Exploratin Agency, Japan*
Eric Thouvenot, *Centre National d'Etudes Spatiales, France*
Licheng Zhao, *China Meteorological Administration, China*

IPY Project Charts, 2005–2010

The set of evolving IPY project charts (known as IPY 'honeycomb' planning chart) illustrate the growing numbers and various features of the international projects planned during IPY 2007–2008 and endorsed by the IPY Joint Committee. Each honeycomb chart shows how the approved IPY projects are distributed between the Arctic and the Antarctic, with some being bipolar, and how the projects are clustered into eight fields dealing with the solid Earth, the Land, the People living in the polar regions, the Oceans, Ice, the Atmosphere, Outer space, Education and Outreach and Data Management. The number in each cell refers to the proposal ID number in the IPY Full Proposal database. The IPY honeycomb charts were created by David Carlson (courtesy IPO).

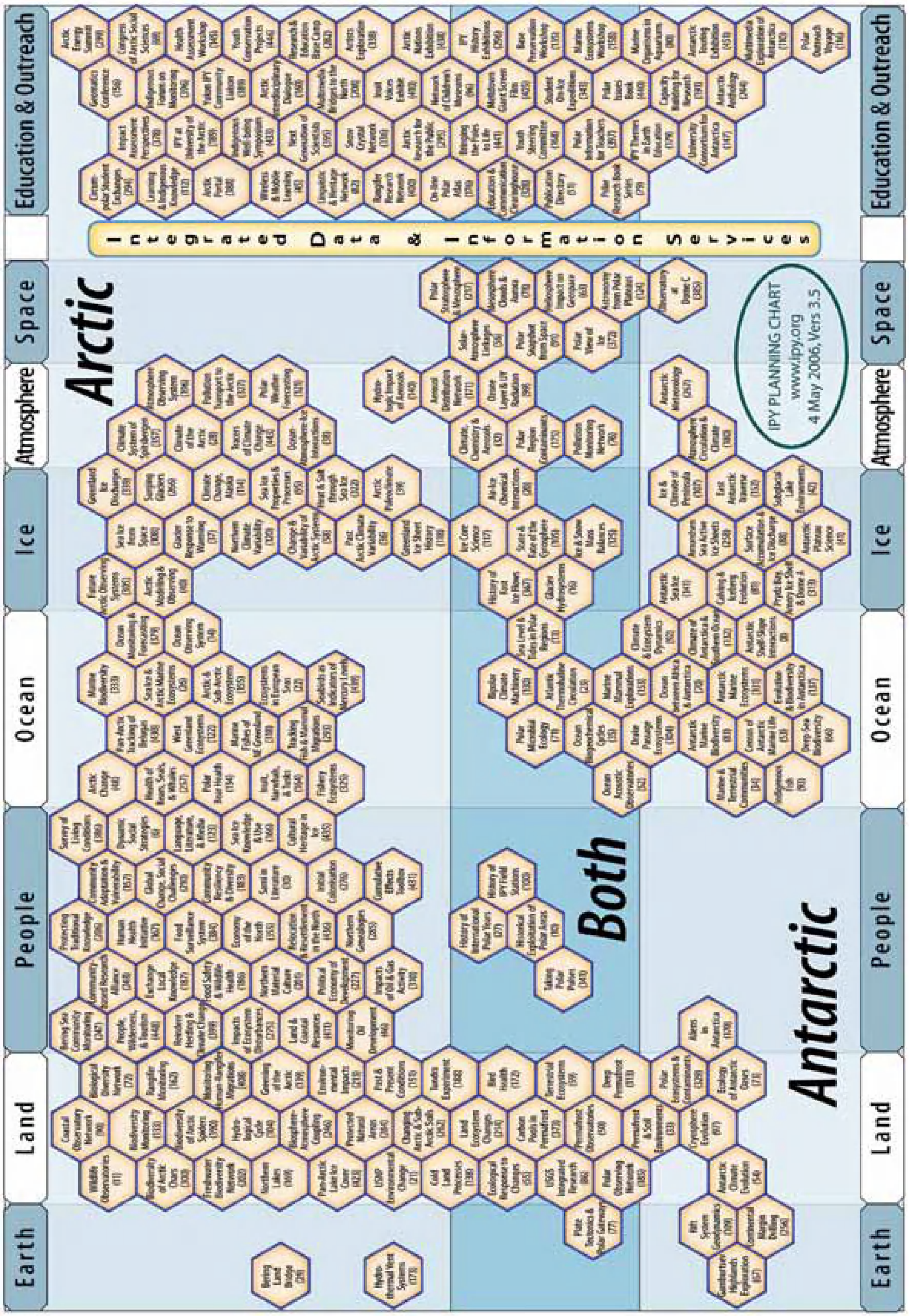


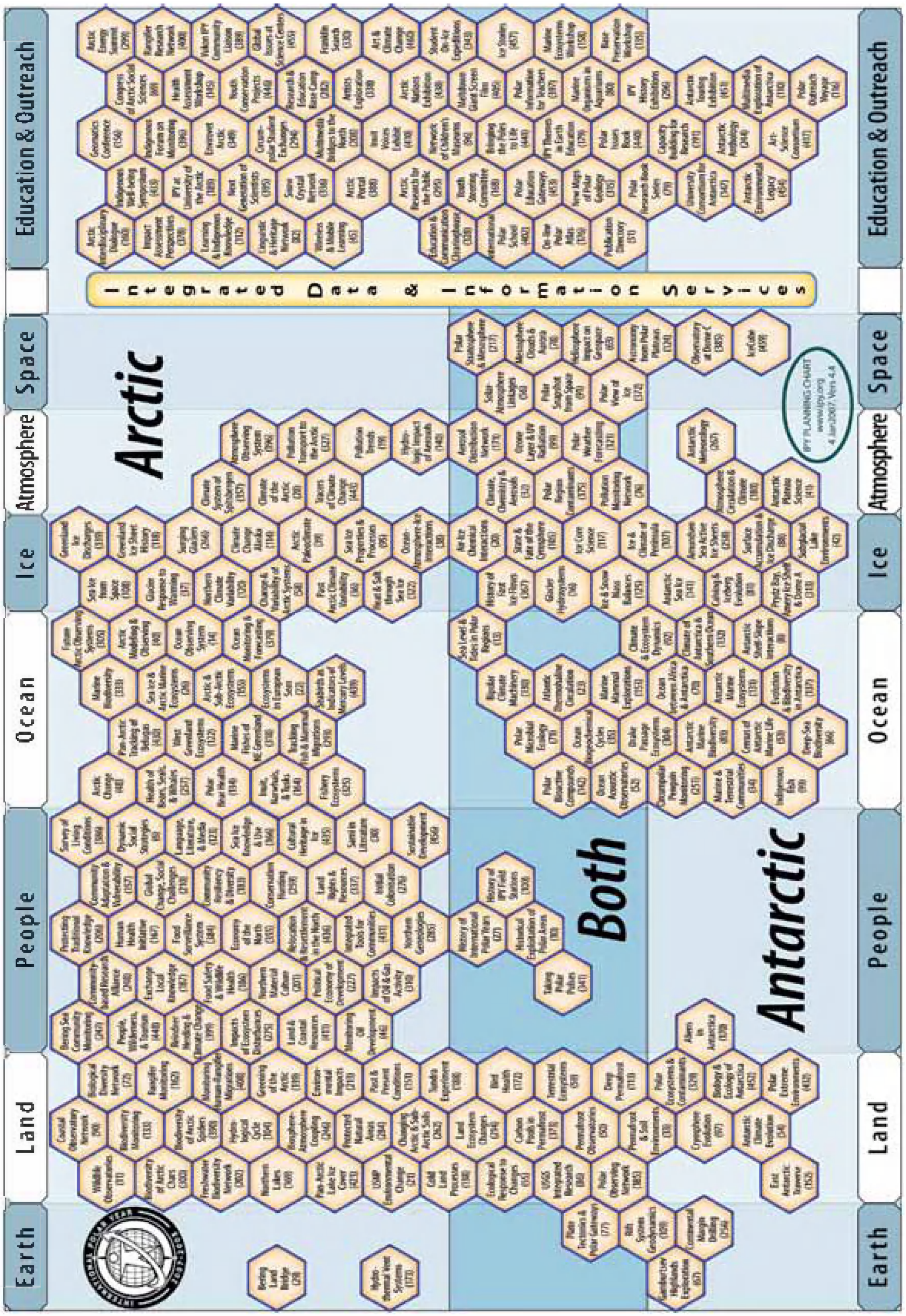
Appendix 6 Fig.1. IPY project chart, version 1, August 2005, lists 85 projects that were endorsed by the IPY Joint Committee following the first round of IPY 'full proposal' submission in June 2005.



Appendix 6 Fig.2. Version 2.4, January 2006 contains about 140 projects endorsed after the second round of full proposal submission in September 2005. An earlier version of this chart was approved by the Joint Committee at the JC-2 meeting in November 2005.

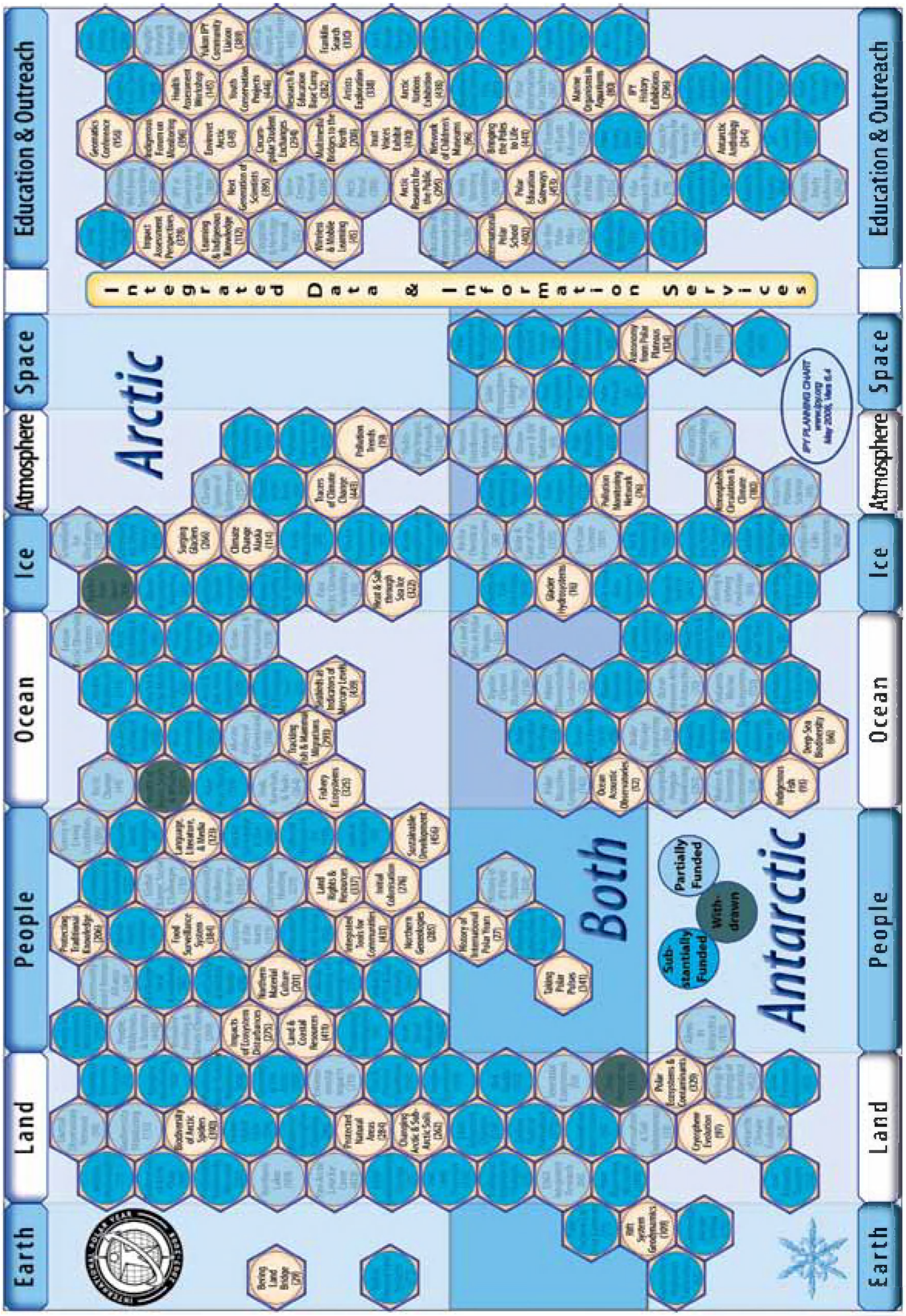
Appendix 6 Fig.3. Version 3.4, April-May 2006 prepared at the end of the 'full proposal' review process and approved at the JC-3 meeting in April 2006.

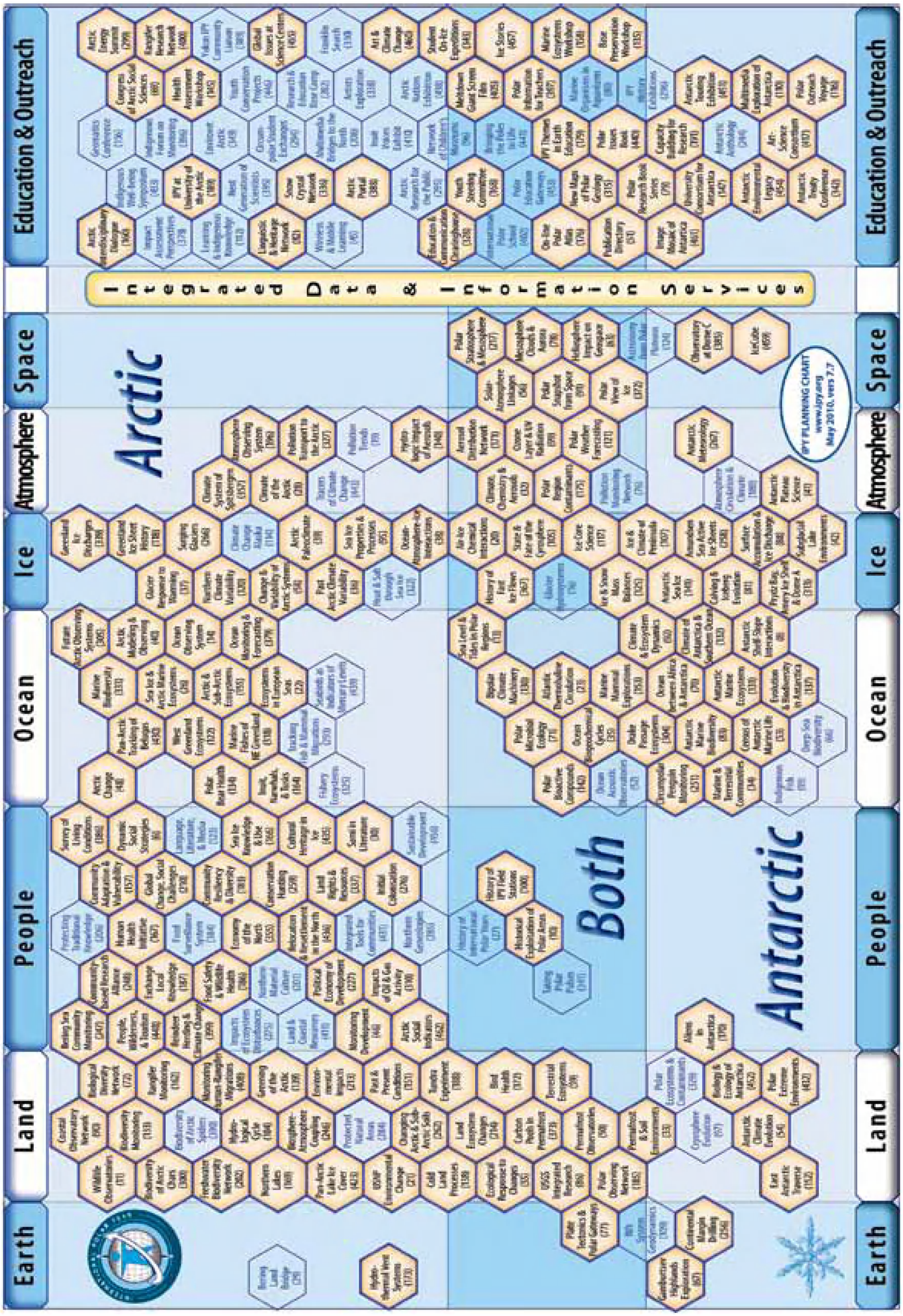




Appendix 6 Fig.4. Version 4.4, January 2007 presents 228 endorsed IPY proposals: 166 in science and 52 in education and outreach. It was published in The *Scope of Science for IPY 2007–2008* (Allison et al., 2007) prior to the official launch of IPY in March 2007.

Appendix 6 Fig.5. Version 6.4, May 2008 features reported level of funding for the endorsed IPY projects: 'substantially funded' (dark blue), 'partially funded' (light blue), 'no funding' or 'funding status unknown' (original cell color), withdrawn (black color).





Appendix 6 Fig.6. Version 7.7, May 2010 distinguishes 'active' and 'non-active' IPY projects (shown as light blue cells) that did not receive funding or failed to report to IPO about their progress. Several of those listed as 'non-active' projects nonetheless advanced as national IPY initiatives or by using matching funds.

APPENDIX 7

List of the National IPY Committees

Argentina

IPY National Committee for Argentina

Chair: Sergio Marenssi

Address: Instituto Antarctico Argentino, Cerrito 1248, Buenos Aires, C1010AAZ, Argentina

Australia

IPY National Committee for Australia

Chair: Amanda Lynch

Address: National Committee for Antarctic Research, Australian Academy of Science, GPO Box 783, Canberra, ACT 2601, Australia

Austria

IPY National Committee for Austria

POC: Wolfgang Schöner

Address: Central Institute of Meteorology and Geodynamics, Hohe Warte 38, Vienna 1190, Austria

Belgium

IPY National Committee for Belgium

Chair: Hugo Decleir

Address: The Royal Academies for Science and Arts for Belgium, Hertogsstraat 1 Rue Ducale, Brussels, B-1000, Belgium

Brazil

IPY National Committee for Brazil

Chair: A.C. Rocha-Campos

Address: Instituto de Geosciéncias, Universidade de São Paulo, Rua do Lago 562, CEP 05508-900, Brazil

Bulgaria

IPY National Committee for Bulgaria

Chair: Christo Pimpirev

Address: Bulgarian Antarctic Institute, 15 Tzar Osvoboditel blvd, Sofia, 1504, Bulgaria

Canada

IPY National Committee for Canada

Chair: Ian Church

Address: Canadian IPY Secretariat, Department of Biological Sciences, University of Alberta, Edmonton, Alberta, T6G 2E9, Canada

Chile

IPY National Committee for Chile

Chair: Jose Retamales

Address: Instituto Antártico Chileno (INACH), Plaza Munoz Gamero 1055, Punta Arenas, Chile

China

IPY National Committee for China

Chair: Yang Huigen

Address: Polar Research Institute of China, 451 Jinqiao Road, Shanghai Pudong, 200129, China

Czech Republic

IPY National Committee for Czech Republic

Chair: Pavel Prosek

Address: Department of Geography, Faculty of Science, Masaryk University, Kotlarska 2, Brno, CZ-611 37, Czech Republic

Denmark

IPY National Committee for Denmark

Chair: Dorthe Dahl-Jensen

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Chair: Pentti Mälkki

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Chair and Member: Juan de Dios Trioche

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APPENDIX 8

Ethical Principles for the Conduct of IPY Research

At the JC-5 meeting (March 2007), the ICSU-WMO Joint Committee for International Polar Year 2007–2008 has established the following ethical guidelines for IPY researchers. These were posted on the main IPY website on 22 May 2007 (www.ipy.org/links-a-resources/item/796-ethical-principles-for-the-conduct-of-ipy-2007–2008-research)

All researchers working in Polar regions have an ethical responsibility to avoid harming the environment and to respect and avoid disruption to the lifestyles and livelihoods of Polar peoples. These responsibilities are entrained in a variety of international, national and regional laws, guidelines and codes-of-conduct, and researchers have a duty to be familiar with these before commencing their projects.

Every endorsed IPY 2007–2008 project will operate under and comply with the guidelines and policies determined by a combination of the location and subject of their work, the source of their research funds and their professional training and affiliation. This includes obtaining all necessary permits for their research and strictly complying with the conditions of these.

Those projects taking place in the Antarctic will be subject to the requirements of the Antarctic Treaty system, including those of the Convention on Antarctic Seals, the Convention on the Conservation of Antarctic Marine Living Resources, the Protocol on Environmental Protection to the Antarctic Treaty and the relevant measures of the Antarctic Treaty Consultative Meeting (ATCM) and the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR).

Projects in the Arctic will abide with the national laws and regulations on access, permits, environmental regulations and other obligations. The IPY Joint Committee urges researchers not only to satisfy the legal requirements which are obligatory in many polar nations, but to comply with the relevant ethical principles for the conduct of research in Polar regions in every aspect of IPY-endorsed activities. Examples of the type of guidelines that should be followed include:

- The Ethical Principles adopted by the International Arctic Social Sciences Association (IASSA), *Guiding Principles for the Conduct of Research* (1998; www.iassa.org/about-iassa/research-principles).
- The U.S. National Science Foundation Office of Polar Projects (NSF-OPP) "Principles for the Conduct of Research in the Arctic." A more detailed discussion of these principles is presented in *People and the Arctic. A Prospectus for Research on the Human Dimensions of the Arctic System* (1997; www.arcus.org/harc/HARC_Prospectus.pdf).
- The Canadian *Ethical Principles for the Conduct of Research in the North* (1997; http://ycdl4.yukoncolleg.yk.ca/~agraham/ethics/ethics/htm). See also An Overview of Conflicting Concerns and Ideas about Northern Research by Amanda Graham (1997).
- The Alaska Native Knowledge Network (ANKN) guidelines, *Alaska Federation of Natives Guidelines for Research* (1993; www.ankn.uaf.edu/IKS/afnguide.html).

All IPY 2007–2008 biomedical research on human subjects should be conducted in accord with the Declaration of Helsinki on Ethical Principles for Medical Research Involving Human Subjects (1964, amended in 1975, 1983, 1989, etc., 2008; www.wma.net/en/30publications/10policies/b3/index.html).

APPENDIX 9

IPY Timeline 1997–2010

Compiled by Amanda Graham
Edited by Igor Krupnik and Nicola Munro

*The 'Chronological List of IPY 2007–2008 Events' (IPY Timeline) was originally developed by Amanda Graham, coordinator and instructor of the University of the Arctic at the Yukon College in Whitehorse, Canada for her online class on the International Polar Years. The course continued until December 2009 under the title 'International Polar Year IV: Context and promises (*Northern Studies 216 – *see http://ycdl4.yukoncolleg.yk.ca/frontier/files/ipy/yukoncollegeipycoursenost216.pdf). By April 2007, the IPY Timeline, which was a part of the IPY course materials, featured over 150 events from 1999 till spring 2007. The list was arranged as an excel spreadsheet and included both international and national activities, conferences, publications, and online and published sources for each item. It was by far the largest and the most detailed chronology of activities associated with IPY 2007–2008 then available to the IPY students and general public.*

In November 2007, Igor Krupnik added scores of other IPY-related dates and documents, primarily from the time of the early planning for IPY 2007–2008. Other online sources were searched, including the original IPY website (http://classic.ipy.org/news/index.php, http://classic.ipy.org/about/events) and the U.S. national IPY website (www.ipy.gov); both featured several important events associated with the early IPY planning and implementation. Amanda Graham continued to update her 'IPY Timeline,' so that by November 2009 it included more than 950 entries. At this time it was agreed to publish the Timeline as an Appendix to the forthcoming JC Summary IPY 2007–2008.

The present list contains more than 300 events, a fraction of the 2009 completed timeline, mostly those associated with the activities of the IPY Joint Committee and its Subcommittees, other international groups active in IPY, major international meetings and publications. For this version we surveyed the news entries featured in the electronic issues of the IPY Monthly Report *produced by the IPO from May 2007 to May 2010 and in the IPY 'news archives' posted on the main IPY website between December 2006 and September 2010 (www.ipy.org/news-a-announcements). We also deleted references to most online and published sources, as many are featured in the chapters of this Report. Ian Allison, Jerónimo López-Martínez, Volker Rachold, Eduard Sarukhanian and Colin Summerhayes made valuable additions to the list. The timeline ends on 30 September 2010, the day the IPY International Programme Office was closed.*

Igor Krupnik

1. Origination Phase, 1997–August 2003

1997

Chris Rapley, Executive Director of the International Geosphere-Biosphere Programme (IGBP) in Stockholm sends a letter to the ICSU Secretariat arguing for a major celebration event to be organized for the 50th anniversary of IGY in 2007

Late 1990s (?)

Several letters by Leonard Johnson, former Director of the Arctic program, U.S. Office of Naval Research, to the IASC Secretariat in Oslo, Norway inquiring about the prospects for a new International Polar Year in 2007

1999

July 28. 22nd General Assembly of the International Union of Geodesy and Geophysics (IUGG) in Birmingham, U.K. (18–30 July); International Association of Geomagnetism and Aeronomy (IAGA) adopts resolution suggested by the Scientific Committee On Solar-Terrestrial Physics (SCOSTEP) on commemorating the 50th anniversary of IGY 1957–1958 in 2007

????. SCOSTEP Bureau (Scientific Committee on Solar-Terrestrial Physics) adopts a proposal for 'IGY+50' event by Dan Baker, University of Colorado

2000

July 10. ICSU Secretariat receives the first 'IGY+50' proposal from SCOSTEP based upon Dan Baker's plan for 'IGY+50'endorsed by the SCOSTEP Bureau in 1999; the proposal, 'The IGY plus 50 years: New Perspectives for the Next Millennium' argues for a worldwide program of research into the geophysics, geochemistry, biology, and the dynamics of the solar-terrestrial and solar-planetary systems in 2003–2008

July 17. SCAR XXVI biannual meeting in Tokyo, Japan (17–21 July); the delegates are briefed about the recommendation of the XII COMNAP (Council of Managers of National Antarctic Programmes) meeting a week prior 'to prepare for recognition of the 50th anniversary of the International Geophysical Year in 2007–08'

December 15. European Polar Board Executive Committee discusses the forthcoming celebration of the 50th anniversary of IGY 1957–1958 in 2007 as a "long term issue" (15–16 December, Paris)

2001

February. First proposal for an 'International Heliophysical Year' (Joseph Davila, Arthur Poland, and Richard Harrison) to commemorate the 50th anniversary of IGY in 2007

April 22. Arctic Science Summit Week (ASSW) in Iqaluit, Canada (22–29 April); the possibility of a new IPY is discussed briefly by the European Polar Board (EPB), Forum of Arctic Research Operators (FARO), and IASC Executive Council; no actions taken

June 24. International Symposium "Perspectives of Modern Polar Research" Bad Durkeim, Germany (24–26 June) to celebrate 175th anniversary of the birth of Georg von Neumayer; strong consensus from the participant discussion that an international program should be launched to commemorate the 125th anniversary of the first IPY in 2007

July 31. IUGG (International Union of Geodesy and Geophysics) Bureau Meeting on 'IGY+50' to discuss plans for the 50th anniversary of International Geophysical Year (IGY) in 2007

August 19. IAGA Executive Committee meeting in Hanoi, Vietnam (19–25 August) to discuss the 'celebration of the 50th anniversary of the International Geophysical Year in 2007'; the idea of an "Electronic Geophysical Year" is also suggested

August 22. Joint SCAR/COMNAP meeting discusses possible activities that may be promoted to celebrate the 50th anniversary of the International Geophysical Year in 2007–2008

October 25. International workshop with EU-Russia-Canada-U.S. participation, "A Common Approach to Collaborative Technological Research for Arctic Development" organized by the EU Joint Research Centre in Brussels, Belgium (25–27 October 2001); Russian polar explorer Arthur Chilingarov proposes launching 'Third International Polar Year' among several prospective collaborative projects

December. Leonard Johnson publishes a short article in *Eos*, 82(51) on the Neumayer Symposium, with a proposal for the 'Fourth International Polar Year'

December 20. Arthur Chilingarov reiterates his appeal for a series of collaborative initiatives in the polar regions, including the 'Third International Polar Year,' in a letter to the Directorate-General for Research of the European Commission in Brussels

2002

February. Consultations between ICSU and IUGG about planning of a follow-up to the International Geophysical Year (IGY+50)

April. "International Polar Year 2007: A Discussion Paper" by Leonard Johnson published by the *AOSB Newsletter,* spring 2002 issue

April 9. Leonard Johnson promotes IPY at the 84th meeting of the U.S. Polar Research Board (PRB) in Washington, DC, U.S.A. in a talk titled *Origins and Content of Proposal to Conduct International Polar Year*

April 21. Arctic Science Summit Week (ASSW) in Groningen, The Netherlands (21–26 April); several participating bodies discuss the possibility of IPY in 2007

April 21. At the Arctic Ocean Science Board annual meeting (AOSB XXI, 21–23 April) during the ASSW in Groningen, Leonard Johnson presents a proposal for 'International Polar Year 2007'; the Board encourages 'further development of the IPY 2007 concept'

April. Russian scientists visit the European Commission Joint Research Centre office in Brussels for discussion on the Russian proposal for a 'Third International Polar Year'

July 22. 27th Meeting of SCAR Delegates in Shanghai, China (22–26 July); the Delegates support the motion for a new IPY program "to celebrate the 50th anniversary of the IGY"

August. "The International Heliophysical Year (IHY)," news item in COSPAR *Information Bulletin,* 154, August 2002, pp. 2–3

October 17. IHY planning session at the World Space Congress in Houston, TX, U.S.A.

October 21. World Climate Research Programme' (WCRP), joint Scientific Steering Group for the Arctic Climate System Study (ACSYS) and Climate and Cryosphere (CliC) Project meeting in Beijing, China (21-25 October 2002); the concept of an International Polar Year (IPY) to mark the 50th anniversary of IGY in 2007–2008 is introduced as "being discussed in many fora"; the group agreed that the cryosphere and climate should be important elements of the future IPY

November 25. U.S. Polar Research Board special planning session, "How Might the Polar Science Community Commemorate the Upcoming Anniversary of the International Polar Year?" Washington, DC, U.S.A.

2003

January 22. Russian Polar Foundation hosts an international meeting in Moscow, Russia with the representatives of the EC Joint Research Centre and EPB on scientific collaboration for a 'Third International Polar Year 2007/8'

February 6. Chris Rapley and Robin Bell submit two-page proposal to the ICSU Executive Board with the aim to "establish an ICSU Planning Group for an International Polar Year 2007/8" on behalf of the European Polar Board, SCAR, and U.S. Polar Research Board

February 8. ICSU Executive Board at its 86th Meeting (8–9 February) approves the proposal and work-plan for the 'ICSU Planning Group for International Polar Year 2007/08; the Group is charged to provide a draft plan for an IPY 2007/8 for the ICSU Executive Board meeting in February 2004, and then develop a final plan for presentation to the ICSU 28th General Assembly in 2005

March 3. European Polar Board sends a letter to all EPB National Delegates to inform them of the ICSU decision and request their input to IPY planning

March 28. AOSB meeting in Kiruna, Sweden endorses IPY 2007–2008 and nominates AOSB 'drafting group' to develop a white paper with specific suggestions for the IPY planners by May 15, 2003

March 31. Arctic Science Summit Week (ASSW) in Kiruna, Sweden (31 March–4 April) offers several venues for discussions regarding proposed IPY 2007–2008; Chris Rapley and Chris Elfring (U.S. Polar Research Board) give plenary talk on the emerging vision for IPY on behalf of the EPB and U.S. PRB

April 9. Arctic Council Senior Arctic Officials (SAO) meeting in Reykjavik, Iceland (9–10 April) is briefed on the proposal for IPY 2007–2008

April 22. Russian Academy of Sciences approves "Concept of Conducting the 3rd International Polar Year"

May 5. 14th World Meteorological Congress (5–24 May, Geneva) endorses Russian proposal for the 'Third International Polar Year' and charges WMO Executive Council to establish an ad hoc working body to develop a plan of action in preparation for the Third International Polar Year and to coordinate its implementation

June 9. ATCM XXVI, Madrid, Spain (9–20 June) adopts Resolution 3 on "Support of the ATCM for the International Polar Year 2007/8"

June 17. Proposal for IPY activities submitted to AOSB by the AOSB IPY 'drafting group'

June 26. Joint Russia-EU Workshop on Polar Research at the Centre Albert Borschette, Brussels (26–27 June), discusses plans for collaborative activities during IPY 2007–2008

July. The *AOSB Newsletter (News from the AOSB)* features special 'IPY Issue' with a front-page article "Planning for the International Polar Year 2007–08" and an extended paper by the AOSB 'drafting group' (Bob Dickson, Leif Anderson, Sergey Priamikov, and Tom Pyle)

July 10. Proposal from the International Association of Geomagnetism and Aeronomy (IAGA) task group for the "IGY+50 program" (later to become the 'electronic Geophysical Year, e-GY) approved by the IAGA Executive Committee meeting in Sapporo, Japan

July 15. Paper proposing an International Heliophysical Year in 2007 (Davila et al., 2003) published in *Advances in Space Research*, 34(11): 2453-2458

July 21. International Permafrost Association (IPA) Council meeting in Zurich, Switzerland (21–25 July) endorses IPA participation in the IPY 2007–2008 planning process

2. Early Planning, August 2003–December 2004

2003

July 31, 2003. 1st meeting of the ICSU Planning Group (PG) for IPY 2007–2008 (PG-1) at ICSU Secretariat in Paris (31 July–2 August)

July 31. Thomas Rosswall, Executive Director of ICSU and Michel Jarraud, WMO Secretary-General, meet at the first Earth Observing Summit in Washington, DC (31 July –1 August 2003); the two parties agreed to share information about their respective work on the 'third' (WMO) and 'fourth' (ICSU) polar year

September 3. ICSU releases full list of members of the ICSU PG and issues first call for submission of 'ideas' for prospective IPY activities

September 3. Open letter from the ICSU International Polar Year 2007/8 Planning Group informing the polar science community of the beginning of the planning process for IPY 2007–2008 and sharing the Planning Group approach and work plan

September 7. Memo from Thomas Rosswall to ICSU constituent bodies in support of the planning for IPY 2007–2008 and ICSU PG activities

September 9. IPY Planning timeline compiled by ICSU PG

September 17. Thomas Rosswall meets with Michel Jarraud and Directors of leading WMO Departments at the WMO Secretariat in Geneva and briefs them on the activities of ICSU PG for IPY; at the meeting Eduard Sarukhanian presents a document, *Third International Polar Year (2007–2008)* regarding the WMO position on IPY and proposing "to hold the International Polar Year in 2007/08 as a WMO and ICSU joint initiative"

September 19. "International Polar Year 2007–2008" letter in *Science* by P.A. Berkman, 301(5640)

September. Special issue of the journal *Water & Atmosphere* (Vol.11, no. 3, September 2003) on science research in Antarctica informs of the plans for an "International Polar Year" in 2007/08 to mark the fiftieth anniversary of IGY of 1957–58"

October 3. European Science Foundation creates an 'About IPY 2007–2008' webpage

October 14. UNESCO General Assembly refers to identifying the "desirability of joint action in relation to the International Polar Year (2007–2008)"

October 23. Senior Arctic Officials Meeting of the Arctic Council, Svartsengi, Iceland (23–24 October) reviews information on IPY 2007–2008 and expresses its support to IPY planning

November 3. 3rd Shelf-Basin Interaction Pan-Arctic Meeting, Cadiz, Spain (3–7 November) proposes an "ARCTIC SNAPSHOT" of key parameters at the shelf break for IPY 2007–2008

November. IASC Executive Committee discusses preparation for IPY

December 15. American Geophysical Union (AGU) Fall Meeting in San Francisco (8–12 December) features two sessions on IPY, a massive poster session, and an IPY 'town-hall' meeting

December 17. 2nd Meeting of the ICSU Planning Group for IPY 2007–2008 (PG-2), in Paris (17–19 December)

2004

January 15. Revised draft plan for the Electronic Geophysical Year (eGY) disseminated online

January 19. International Council of Science (ICSU) invites offers via National IPY Committees or IPY National Points of Contact to host a future International Programme Office (IPO) for IPY 2007–2008

January 22. International Meeting on Cooperation for IPY 2007–2008 at the Arctic and Antarctic Research Institute (AARI), St Petersburg, Russia (22–23 January), with some 40 participants, including representatives of WMO, the ICSU Planning Group, European and U.S. Polar Boards, Arctic Council, IASC, the EC, and Directors of Polar Centers of Chile, Finland, Japan, and Sweden; the meeting adopts Joint Statement on "Cooperation for the International Polar Year 2007–2008"

January 28. ICSU PG for IPY produces an update for ICSU on the IPY planning process and issues its second call for additional input from the national IPY committees, ICSU Scientific Unions, and broad science community for research 'ideas' for the IPY science program

February 9. ICSU PG submits its report to the 88th Meeting of the ICSU Executive Board (11–12 February)

February 11. ICSU Executive Board approves the interim report of the PG and votes to establish International Polar Year 2007–2008, subsequent to confirmation by the 28th General Assembly of ICSU in 2005; the Board proposes that ICSU and WMO should jointly sponsor IPY and appoint a Committee to plan and coordinate IPY activities

February 13. ICSU PG sends a community update letter notifying that 14 nations have established National IPY Committees or National Points of Contact and at least 6 more are in the process of doing so

March 5. Short statement on IPY by the U.S. National IPY Committee published in *Science* ("The International Polar Year" by M. R. Albert et al., *Science* 303(5663): 1437)

March 15. Deadline for "Input from National IPY committees, ICSU National and Union Members, other scientific bodies and the broader science community" for submission to ICSU PG for a summary discussion at the Arctic Science Summit Week 2004

March 9. Chris Rapley gives a presentation on the ICSU PG activities at the WMO Secretariat in Geneva; discussion on the joint ICSU-WMO efforts for IPY preparation

March 31. 1st IPY 'Discussion Forum' (open community meeting), Reid Hall, Paris

April 1. 3rd Meeting of the ICSU PG (PG-3), Reid Hall, Paris (1–3 April)

April 20. The initial *Outline Science Plan for IPY 2007–2008* released by ICSU PG

April 21. IASC Arctic Science Summit Week (ASSW), in Reykjavik, Iceland (21–25 April); draft Outline Science Plan for IPY presented for comments to participants

April 25. IASC expresses its reservations about the 'weak handling of the human element' in the initial *Outline Science Plan* during ASSW in Reykjavik

April 26. Arctic Ocean Sciences Board (AOSB) Twenty-third Meeting (AOSB XXIII, 26–28 April), in Reykjavik, endorses initial *Outline Science Plan for IPY 2007–2008* and advances in the preparation of the AOSB integrated feasibility study for IPY

April 29. Draft Outline Science Plan for IPY 2007–2008 presented for comments to participants of the European Geosciences Union (EGU) Assembly, Nice, France

April. Provisional IPY central website www.ipy.org established; eventually migrated to http://classic.ipy.org

May 4. Arctic Council' Senior Arctic Officials meeting in Selfoss, Iceland (4–5 May); IPY Outline Science Plan endorsed by the parties though criticized for inadequate attention to the cultural and social issues in the Arctic

May 18. IPY Session at 2004 Joint Assembly of the American Geophysical Union, Canadian Geophysical Union, Society of Exploration Geophysicists, and the Environmental and Engineering Geophysical Society in Montreal, Canada (17–21 May)

May 23. 5th International Congress of Arctic Social Sciences (ICASS V), Fairbanks, U.S.A. (19–23 May); General Assembly of the International Arctic Social Sciences Association (IASSA) adopts resolutions supporting IPY 2007–2008 and arguing for more active role of social scientists and polar residents in its planning; special IASSA-IPY task group formed to assist in developing socio-cultural components for the IPY program

May 23. ATCM XXVII, Cape Town, South Africa (23 May–4 June); Item 10. Relevance of Developments in the Arctic and in the Antarctic and the International Polar Year 2007/2008

June 1. ICSU Officers meeting approves the merger of ICSU and WMO planning processes for IPY 2007–2008 (1–2 June, Paris)

June 11. Paper "Building on the IGY anniversary" by J.A. Joselyn published in *Science* 304(5677): 1599

June 14. 56th session of WMO Executive Council endorses joint co-sponsorship of IPY with ICSU and the establishment of the 'Joint Organizing Committee' (later renamed to *Joint Committee*) for IPY 2007–2008

June 23. U.S. workshop "Bridging the Poles: Linking Education with Research" in Washington DC, U.S.A. (23–24 June), first documented effort to advance education and outreach component of IPY 2007–2008

June 26. 37th session of Executive Council of Intergovernmental Oceanographic Commission (IOC) of UNESCO adopts Resolution EC-XXXVII.3, to express interest in joining the ICSU–WMO Joint Organizing Committee for IPY 2007–2008 and to develop a plan for IOC participation in IPY

July 25. SCAR 28th Meeting and 1st SCAR Open Science Conference "Antarctica and the Southern Ocean in the Global System," Bremen, Germany (25–31 July); draft *Outline Science Plan* for IPY is presented for comments to participants

July 30. Meeting of SCAR Ad Hoc Advisory Committee on IPY, in conjunction with the SCAR 28th Meeting, Bremen

August 3. Scientific Committee on Oceanic Research (SCOR) research programme iAnZone workshop at the University of East Anglia, Norwich, U.K. to discuss the next iAnZone project, which will be an IPY contribution

August 16. Letter of invitation by ICSU and WMO (20 August) addressed to ICSU National Members, Scientific Unions, Interdisciplinary Bodies, WMO Executive Council members and IPY National Committees asking for nominations to the membership on the Joint Committee for IPY 2007–2008

August 19. SALE (Subglacial Antarctic Lake Environments) science plan document for IPY 2007–2008 released

August 29. Workshop on Frontiers and Opportunities in Antarctic Geosciences, Siena, Italy (29–31 August), with several papers outlining research plans for IPY 2007–2008

September 1. The revised document "A Framework for IPY 2007–2008" completed by the ICSU PG; new theme to feature socio-cultural and human research in IPY ('human dimension') added

September 5. Sixth Conference of Parliamentarians of the Arctic Region, Nuuk, Kalaallit Nunaat, Greenland, (3–6 September 2004) endorses IPY and encourages participating nations to take an active part in the planning of IPY, support the creation and funding of National Committees and the coordination by ICSU, and promote the full inclusion of the social, cultural and economic dimension of the Arctic, including the traditional knowledge of northern indigenous societies

September 10. Second Asian Forum on Polar Sciences (AFoPS II), in Seogwipo, Korea; members approve of joint contribution to IPY

September 13. Second IPY Open Discussion Forum, Reid Hall, Paris (13–14 September)

September 15. Fourth and final meeting of ICSU PG (PG-4) endorses the IPY *Framework* document, Paris (15–17 September)

September 23. SCOR Meeting on Coordination of International Marine Project, Mestre, Italy (23–24 September) reviews several IPY-related issues, including project coordination in the area of Southern Ocean research and participation in IPY

September 28. Prepublication version of the IPY *Framework* document (Rapley et al., 2004) made public to facilitate timely access to the PG report

October. ICSU PG completes its Terms of Reference

October 3. SCAR Recommendations on IPY approved at XXVIII SCAR Delegates meeting in Bremerhaven, Germany (3–9 October)

October 6. IPY is brought up in a session of the International Group of Funding Agencies for Global Change (IGFA) Annual Meeting in Reykjavik in a keynote presentation by Robert Corell (6–8 October)

October 7. U.S. National IPY Committee's report, *A Vision for International Polar Year 2007–2008* (Albert et al., 2004) published

November 1. *Framework for the International Polar Year, 2007–2008* document produced by the ICSU PG published

November 1. IPY International Programme Office established in Cambridge, U.K. with Dr. Cynan Ellis-Evans as the interim director

November 5. ICSU and WMO announce a new call for "Expressions of Intent" (EoI) for future IPY 2007–2008 activities (a letter is distributed 19 November in Arabic, English, French, Spanish, and Russian)

November 17. Announcement of position of Director, IPY International Programme Office issued by ICSU and WMO

November 18. Official release of the membership of the ICSU-WMO Joint Committee for IPY

November 20. 89th Meeting of the Executive Board of ICSU, Trieste, Italy (20–22 November) approves the IPY *Framework* document, expresses appreciation to the Planning Group members, and approves the Terms of Reference for the ICSU-WMO Joint Committee for IPY 2007–2008 and its membership

November 20. WMO Secretary-General approves Terms of Reference and membership of the ICSU-WMO JC for IPY 2007–2008 Co-Chaired by Ian Allison and Michel Béland

November 24. Arctic Council Meeting of Foreign Ministers in Reykjavik, Iceland adopts a Declaration that recognizes IPY 2007–2008 as a unique opportunity to stimulate cooperation and coordination on Arctic research and increase visibility of the Arctic region; underlines the role of the Arctic Council as a high level intergovernmental forum in providing political support for IPY; and decides that the Arctic Council will develop proposals to the IPY Joint Committee

December 14. Three IPY special sessions at AGU Fall Meeting, San Francisco, U.S.A. (13–17 December)

December 31. Japan announces that its Antarctic Syowa Station will be open to scientists from other Asian nations for research on global warming during IPY 2007–2008

3. Program Development and Implementation, 2005–March 2007

2005

January 12. AMAP (Arctic Monitoring and Assessment Programme of the Arctic Council) Secretariat in its letter of support to IPY argues for close cooperation between the AMAP and IPY efforts in the Arctic

January 14. Deadline for first call by ICSU and WMO for expressions of intent for the IPY 2007–2008 science activities

February 21. A total of 856 Expressions of Intent for IPY 2007–2008 activities are loaded into the searchable IPY database; EoIs are reviewed by the members of the ICSU-WMO Joint Committee for IPY

February 22. 3rd International Symposium on the Arctic Research, Tokyo, Japan (22–24 February)

March 4–5. Interviews for the position of the International Programme Office Director, Cambridge, U.K.

March 7. 1st Meeting of the ICSU-WMO Joint Committee for IPY (JC-1) at the ICSU Headquarters in Paris (7–9 March)

March 10. IPY Open Consultative Forum at the Headquarters of UNESCO, under the aegis of the Intergovernmental Oceanographic Commission in Paris, France, in conjunction with JC-1

March 15. JC Announcement of Call for IPY 'Full Proposals,' first submission deadline by June 30, 2005

March 30. International Workshop on the *Arctic Climate Impact Assessment Report* and on the Climate Changes in the Arctic and on planning for IPY 2007–2008 in the Arctic at the Arctic and Antarctic Research Institute (AARI), St. Petersburg, Russia (30 March–1 April)

March 30. EoI assessment letters signed by the JC Co-Chairs Ian Allison and Michel Béland dispatched to all EoI applicants encouraging them to proceed with the coordinated 'full proposals' for IPY 2007–2008 activities (30 March–1 April)

April 4. 1st Meeting of the WMO Inter-Commission Task Group on IPY reviews status of IPY preparation by National Meteorological Services and WMO technical commissions and prepares recommendations to Executive Council (4-6 April)

April 6. IPY presentation at the Arctic Council SAO meeting, Yakutsk, Russia

April 11. WCRP CliC (Climate and Cryosphere Programme) Science Conference in Beijing, China discusses plans for IPY 2007–2008 (11–15 April)

April 17. Arctic Science Summit Week in Kunming, China, with several meetings discussing plans for IPY 2007–2008 collaboration (17–24 April)

April 19. 3rd Meeting of the Asian Forum for Polar Sciences (AFoPS III) in Kunming, China in conjunction with the Arctic Science Summit Week (ASSW) and Pacific Action Group Meeting

April 27. Town Hall meeting for IPY 2007–2008 planned teaching initiatives at the European Geosciences Union (EGU) General Assembly, Vienna, Austria (24–29 April)

April 28. Research seminar and international workshop, "Nordic research cooperation within the social sciences and humanities connected to the International Polar Year, IPY 2007–2008" in Ilulissat, Greenland (28 April–2 May)

May 5. IPO releases Proposal Template and Guidance Notes for June 30 submission of the 'full proposals' for the IPY activities

May 9. David Carlson appointed to the position of Director of the IPY 2007–2008 International Programme Office (IPO) in Cambridge, U.K.

May 12. Joint Paper, *Coordination of International Research Programmes in the Arctic and Polar Region* prepared by the Secretariats of IPY, ICARP II, and ACIA released online

May 17. 12th International Symposium on Polar Sciences, Seoul, Korea (17–19 May)

May 23. "Study of Environmental Arctic Change: Plans for Implementation During the International Polar Year and

Beyond," implementation workshop in Landsowne VA, U.S.A. (23–25 May). First plans for an Arctic Observing Network (AON) to be developed during IPY

May 25. Special session, "The International Polar Year Takes Shape" and the IPY Town Hall meeting at the American Geophysical Union (AGU) Spring Meeting, New Orleans, U.S.A. (23–27 May)

May. ICSU and WMO invite the Arctic Council and the Antarctic Treaty Consultative Meeting to appoint one observer each to the JC for IPY

June 6. ATCM XXVIII meeting in Stockholm, Sweden reviews plans for IPY 2007–2008 (6–17 June)

June 9. CliC (Climate and Cryosphere, Programme Data Management and Information Panel Meeting, Boulder, CO, U.S.A. discusses IPY (9–11 June)

June 27. Modes of Southern Hemisphere climate variability workshop and panel meeting, Cambridge, U.K. with the theme 'Modes of Variability and the IPY' (27–30 June)

June 26. 57th session of WMO Executive Council notes the progress made by WMO and ICSU in the IPY planning and preparation, and encourages WMO Members to support IPY activities

June 30. First 'Full Proposals' for IPY 2007–2008 activities submission deadline; 109 proposals submitted to IPO

July 20. International Workshop, "Poles Together: Coordinating IPY Outreach and Education" in Boulder, CO, U.S.A. (20–22 July)

July-August. Joint Committee members and IPO staff process the first installment of IPY 'Full Proposals'; 85 initiatives endorsed for implementation

August 29. SCOR Executive Committee Meeting in Cairns, Australia, discusses international collaboration during IPY (29 August–1 September)

August 30. Initial version of the IPY Planning Chart featuring first 85 "Full Proposals" endorsed by the Joint Committee released online

September 6. Joint meetings of representatives of IPY 2007–2008, Electronic Geophysical Year (eGY), International Heliophysical Year (IHY), and International Year of Planet Earth (IYPE) signed a formal agreement ('Celimontana Declaration') on collaboration in data and information management, and education and public outreach activities under their respective initiatives (6–7 September, Rome, Italy)

September 18. International Polar Meeting organized by the German Society of Polar Research in Jena, Germany, discusses plans for IPY 2007–2008 (18-24 September)

September 30. Second submission deadline for 'Full Proposals' for IPY 2007–2008 research and public activities; 92 submitted

October 19. Outline for IPY implementation under the JC stewardship is presented by Ian Allison to the delegates at the 28th ICSU General Assembly in Suzhou, China (17-21 October); the Assembly officially endorses IPY and stresses its commitment to IPY goals and activities

November 13. 2nd IPY Open Consultative Forum in conjunction with the International Conference on Arctic Research Planning (ICARP), Copenhagen, Denmark (10–12 November)

November 15. 2nd Meeting of the ICSU-WMO Joint Committee for IPY (JC-2) at WMO Headquarters in Geneva (15–17 November)

November 21. WMO Coordination Meeting on Antarctic Meteorology and related IPY Activities, St. Petersburg, Russia bringing experts from Argentina, Australia, Chile, Italy, Russian Federation and U.K. (21-25 November)

November 28. The International Hydrographic Organization (IHO/IHB) calls for increased hydrographic surveying around the Antarctic Peninsula during IPY

December 4. International workshop, 'Antarctic Sea Ice in IPY' in Dunedin, New Zealand to review plans for cruises, station work, modeling, and remote sensing that are being planned for Antarctic sea ice during IPY and to organize efforts for international collaboration, data archiving, and communication with other IPY efforts, both Arctic and Antarctic

2006

January 1. U.S. National Oceanic and Atmospheric Administration (NOAA) publishes 200-page 'International Polar Year 2007–2008' bibliography that includes references to historical sources related to IPY-1, IPY-2, and IGY

January 10. 1st Meetingof the IPY Education, Outreach and Communication (EOC) Subcommittee in Paris

January 31. Third submission deadline for IPY 'full proposals'; 209 proposals are received

February 14. AMAP–IPY Coordination meeting, Oslo, Norway

February 22. New IPY Education and Outreach website launched http://cires.colorado.edu/education/k12/ipyoe/index.html

March 2. IPY Data Management Subcommittee meeting and Data Management Workshop at the British Antarctic Survey in Cambridge, U.K. (2-4 March)

March 6. Two IPY Education and Outreach joint sessions with the International Permafrost Association at the annual meeting of the American Association of Geographers in Chicago (6-10 March 2006)

March 14. BBC "Countdown to IPY" event

March 16. European IPY Education meeting in Brussels (16–17 March)

March 22. Arctic Science Summit Week with several meetings related to IPY 2007–2008 planning, Potsdam, Germany (22-29 March)

March 24. 4th Meeting of the Asian Forum for Polar Sciences (AFoPS IV) discusses IPY activities, during the Arctic Science Summit Week in Potsdam, Germany

March 27. 1st Meeting of the IPY Subcommittee on Observations in Potsdam, Germany (27-28 March)

March 29. Permanent Committee of Legislators of the Arctic Region meeting in Ottawa to discuss preparations for IPY 2007–2008 and other issues related to the development of the North.

April 2. IPY Exhibit and sessions at EGU General Assembly, Vienna, Austria (2–7 April)

April 10. IPY Education and Outreach Discussion at COMNAP/INFONET meeting in Washington, DC, U.S.A. (10–11 April)

April 18. IPY planning chart (project 'honeycomb' chart) v. 3.1 released by IPO

April 20. 3rd Meeting of the ICSU-WMO Joint Committee for IPY (JC-3), Cambridge, U.K. (20-23 April)

April 21. JC letter to National IPY Committees urging to focus on funding for national research programs and data management resources and policies

April 24. International workshop, "Subglacial Antarctic Lake Environments (SALE) in the International Polar Year (IPY) 2007–2008: Advanced Science and Technology Planning" in Grenoble, France (24-26 April)

April 26. Arctic Council Senior Arctic Officials meeting in Syktyvkar, Russia endorses preparations for IPY 2007–2008 (26-27 April)

May 1. Report from the *Planning the Legacy of IPY 2007–2008: International Polar Year Data Management Workshop* (3-4 March 2006) published

May 9. 13th International Symposium on Polar Science, Seoul, Korea, with the theme "From Molecules to Ecosystem in Polar Science: Toward IPY 2007~2008"

May 14. International conference, "Antarctic Peninsula climate variability: observations, models, and plans for IPY research" at the University of Colorado, Boulder, Boulder, U.S.A. (14-16 May)

May 22. *International Polar Year 2007–2008 Data Policy* document (v. 1.0) posted by the IPO

May 26. International scientific, public and outreach event, *EcoPolar Ushuaia 2006* in Ushuaia, Argentina features several activities related to IPY in Antarctica (26–28 May)

June 10. Special session, "International Polar Year – global research and European public outreach: how can science centres contribute" in Mechelen, Belgium (8-10 June)

June 12. IPY 2007–2008 represented for the first time at the ATCM XXIX in Edinburgh, Scotland (12–23 June)

June 19. ATCM XXIX adopts the 'Edinburgh Declaration on IPY 2007–2008' pledging the ATCM members' support for IPY

June 21. 39th session of IOC (Intergovernmental Oceanographic Commission) Executive Council confirms its support to IPY 2007–2008

June 30. ESA (European Space Agency) announces it will provide current and historical data, dating back 15 years, from its ERS-1, ERS-2 and Envisat satellites to support IPY projects covering the Arctic and Antarctic regions

July 1. First electronic quarterly *IPY IPO Newsletter* published online by the IPO

July 8. 3rd IPY Open Consultative Forum in Hobart, Australia organized as part of the SCAR Open Science Conference

July 8. 2nd Meeting of ad hoc SCAR Advisory Committee on IPY 2007–2008, Hobart, Australia

July 12. Second SCAR Open Science Conference, "Antarctica in the Earth System", Hobart, Australia (12-14 July), with several sessions on IPY topics

August 2. Seventh Conference of Parliamentarians of the Arctic Region in Kiruna, Sweden reviews Arctic cooperation and preparation for IPY 2007–2008

August 16. IPY Education and Outreach Subcommittee's Executive Meeting, Maine, U.S.A. (16-18 August)

September 8. First news item posted on the official IPY website managed by IPO; the website will serve as the main information venue for IPY until September 2010

September 11. First IPY 'Youth Steering Committee Working Group' announcement posted online

September 15. IPO releases the final count of international activities developed for IPY 2007–2008 including 1145 Expressions of Intent and 222 Full Proposals endorsed by the IPY Joint Committee

September 18. International IPY Education, Outreach and Communication workshop at Tarfala Research Station, Norbotten, Sweden

September 25. International Centre for Reindeer Husbandry in Kautokeino, Norway proposes for IPY Joint Committee to arrange the Opening of the Indigenous Peoples' International Polar Year in Kautokeino in February 2007

September 26. 4th Meeting of the ICSU-WMO Joint Committee for IPY (JC-4) in Longyearbyen, Svalbard, Norway (26-28 September)

October 5. 1st meeting of the Heads of the Arctic IPY Secretariats (later renamed as 'Heads of Arctic and Antarctic IPY Secretariats, HAIS) in Washington, DC, U.S.A.

October 10. Eurasian Sub-Office for IPY 2007–2008 is established at the Arctic and Antarctic Research Institute of Roshydromet (AARI) in St. Petersburg, Russia

October 19. IPY Education, Outreach, and Communication (EOC) Subcommittee Meeting in Bremerhaven, Germany (19–21 October)

October 24. 5th Arctic Council Meeting of Foreign Ministers in Salekhard, Russia adopts a Declaration that acknowledges the need for strong national financial support for IPY and welcomes "the expansion of IPY to include *the human dimension*", which the AC considers to be an important new feature of IPY 2007–2008

October 26. Joint Meeting of IPY Subcommittee on Observations and IPY Data Management Subcommittee in Beijing (26-27 October)

November 6. Second issue of the *IPY IPO Newsletter* posted

November 28. 9th Meeting of the WMO Working Group on Antarctic Meteorology in St. Petersburg, Russia (26-30 November) adopts the overview document, "International Polar Year 2007–2008 (IPY): Status of Preparation and the Role of EC-WGAM in the Implementation of the IPY in the Antarctic"

December 1. Space Task Group (STG) of the Subcommittee on Observations of the ICSU-WMO Joint Committee for IPY formed

December 10. The IPY Early Career Polar Scientists Network launched

December 11. American Geophysical Union (AGU) 2006 Fall Meeting, San Francisco, CA features several sessions related to IPY 2007–2008 (11–15 December)

December 20. UNESCO, Intergovernmental Oceanographic Commission (IOC) launches its IPY web site at http://ioc.unesco.org/iocweb/index.php

2007

January 1. 228 Full Proposals out of 422 submitted endorsed by the IPY Joint Committee

January 4. IPY project 'honeycomb' chart, v. 4.4 released by the IPO featuring 228 proposals that constitute IPY science, data management, and education-outreach program

January 17. 1st Meeting of the Space Task Group of the IPY Subcommittee on Observations in Geneva (17-19 January)

January 24. AMAP meeting in Tromsø, Norway (24-25 January) to fulfill the 26 October 2006 request of the Arctic Council to create a coordinated Arctic observing network that later became the SAON (Sustained Arctic Observing Network) initiative, an integral contribution to IPY

February 1. 2nd meeting of Heads of the Arctic and Antarctic IPY Secretariats (HAIS), Copenhagen, DK (1-3 February)

February 7. International Polar Year (IPY) 2007–2008 Facebook group formed (www.facebook.com/group.php?gid=2237529364)

February 13. *The Scope of Science for the International Polar Year 2007–2008* (Allison et al., 2007) produced by the IPY Joint Committee released by WMO (WMO/TD-No.1364. Geneva: World Meteorological Organization)

February 14. Opening of the Indigenous Peoples' International Polar Year 2007–2008 (IPIPY) in Kautokeino, Norway

February 16. Scientists at the South Pole station in Antarctica collected first test observations using new South Pole telescope, as the kick-off to IPY 2007–2008. The enormous telescope stands 22.8 m tall, measures 10 m across, and weighs 280 tons

February 19. Kickoff ceremony for the International Heliophysical Year 2007 in Vienna, Austria

February 22. IPY joint philatelic special issue, metal spiral, cased book of IPY stamp issues (19,500 print run; published by POST Greenland), Arctic 2007, from Canada, Denmark, Finland, Greenland, Iceland, Norway, Sweden and the U.S.

February 21 – March 9. National IPY launch ceremonies in Australia, Argentina, Brazil, Bulgaria, Canada, China, Denmark/ Faroe Islands/Greenland, Iceland, Finland, France, Germany, India, Italy, Japan, The Netherlands, Norway, Poland, Portugal, Russia, South Africa, Spain, Sweden, U.K., Ukraine, U.S.A.

February 26. IPY international media launch

February 26. The European Science Foundation and the European Polar Board mark the launch of IPY in Europe with a day-long event in Strasbourg, France

February 27. IPY Data Management Subcommittee meeting in Paris, France

February 28. 5th Meeting of the IPY Joint Committee (JC-5) in Paris (28 February-2 March)

February 28. IPY Education and Outreach Subcommittee meeting Paris, France

4. Observation Period, 1 March 2007–1 March 2009

2007

March 1. Official launch of IPY 2007–2008 at an ICSU-WMO joint ceremony at the Palais de la Découverte in Paris

March 1. Breaking the Ice: Educational online launch event for IPY 2007–2008

March 1. Parliamentary Conference on the Northern Dimension of the European Parliament at its meeting in Brussels recognizes the significance of IPY 2007–2008 for "the development of Arctic science and for the possibility of creating a Charter for Arctic Governance"

March 5. "Polar Environment and Climate: The Challenges of European Research in the context of the International Polar Year," European Commission symposium in Brussels (5-6 March)

March 7. The launch of the online IPY Publications Database of bibliographic records for publications about or resulting from IPY 2007–2008 and three previous IPYs

March 13. IASC Arctic Science Summit Week (ASSW) in Hanover, NH, U.S.A., with a special plenary session celebrating the launch of IPY 2007–2008

March 15. HAIS 3rd meeting during the ASSW in Hanover, U.S.A.

March 16. European Polar Board, European Science Foundation releases brochure "Europe and International Polar Year 2007–2008"

March 23. World Meteorological Day 2007 celebrates the launch of IPY by focusing on Polar Meteorology and understanding of global impacts

March 30. 3rd and final quarterly electronic issue of the *IPY IPO Newsletter*

April 12. Arctic Council Senior Arctic Officials meeting in Tromsø, Norway discusses IPY

April 15. IPY sessions at the European Geosciences Union (EGU) General Assembly, Vienna, Austria (15-20 April)

April 23. ICSU Unions meeting in Rome is briefed on the developments in IPY 2007–2008

April 30. ACTM XXX: Antarctic Treaty Consultative Meeting in New Delhi, India (30 April - 11 May) reviews progress in IPY 2007–2008

April 30. Antarctic and Southern Oceans Coalition (ASOC) releases its 7-page report, "The Human Footprint of the IPY 2007–2008 in Antarctica," at the XXX ATCM

May 1. First issue of the monthly electronic *IPY Report* released by the IPO to all IPY project coordinators, national IPY committees, IPY subcommittees and other community groups. Eventually 37 monthly issues were posted on IPY website till May 2010

May 7. 15th World Meteorological Congress in Geneva, (7–25 May) reviews progress in IPY and welcomes Canadian proposal to establish Global Cryosphere Watch as IPY legacy

May 22. Ethical Principles for the conduct of IPY 2007–2008 research posted online by the IPY Joint Committee (*Appendix 8*)

June 5. The United Nations World Environment Day celebrated this year with a polar theme and a focus on polar issues and IPY 2007–2008

June 5. Preliminary discussions with Google Earth about an IPY layer at the 5th International Symposium on Digital Earth (ISDE5), University of California Berkeley (5-9 June)

June 11. IPY Education and Outreach Subcommittee meeting in Cambridge, U.K. (11–13 June)

July 1. IGY+50-Antarctic science pioneers meeting in Wellington, NZ brings together about 40 scientists who participated in IGY research in Antarctica in 1957–1959

July 7. Launch of the Electronic Geophysical Year (eGY) sponsored by the International Union of Geodesy and Geophysics (IUGG) at the IUGG General Assembly in Perugia, Italy

August 20. First International Circumpolar Conference on Geospatial Sciences and Applications, "IPY GeoNorth 2007," in Yellowknife, Northwest Territories, Canada (20-24 August)

August 26. 10th International Symposium on Antarctic Earth Sciences, *Antarctica: A Keystone in a Changing World* (ISAES X) at the University of California, Santa Barbara (26-31 August) includes sessions on the earth science contribution to IPY

September 10. OECD Global Science Program releases its assessment of the initiation and planning of IPY as a role model for International Years (Stirling 2007)

September 16. International conference "50th Anniversary of the International Geophysical Year and Electronic Geophysical Year" in Suzdal, Russia (16-19 September)

September 21. "International Polar Day–Sea Ice," first in the series of 'International Polar Days' focused on sea ice launched by the IPO

September 26. International Planning Workshop for IPY Youth and Early Career Scientists in Stockholm, Sweden (26-30 September). Following the meeting, the IPY International Youth Steering Committee (IYSC) and the Association of Polar Early Career Scientists (APECS) merged under a new structure keeping the name 'APECS'

September 28. The IPY operational data coordination web site launched by the IPY Data Policy and Management Subcommittee and the IPO

October 1. SCAR meeting on the planning of a Southern Ocean Observing System (SOOS), Bremen, Germany, (1-3 October)

October 18. Special issue of the *WMO Bulletin* (vol. 56, no. 4) focused on IPY 2007–2008, with an IPY overview and six articles covering polar weather, stratospheric ozone, polar atmospheric chemistry, polar oceans, cryosphere, and future space observations of polar regions

October 23. IPY Data Management Subcommittee meeting, Quebec, Canada (23-24 October)

October 24. IPY Education and outreach Subcommittee meeting, Quebec, Canada

October 25. 6th Meeting of the ICSU-WMO Joint Committee for IPY (JC-6) in Quebec City, Canada (25-26 October)

October 31. International Conference "Making Science Global: Reconsidering the Social and Intellectual Implications of the International Polar and Geophysical Years," Smithsonian Institution, Washington, DC, U.S.A. (31 October 31-2 November)

November 5. HAIS meeting, St. Petersburg, Russia (5-6 November)

November 12. First IPY Workshop on Sustained Arctic Observing Network (SAON), Stockholm, Sweden (12-14 November)

November 16. Official launch of the 'Polar Artists' Group in Kleinberg, Ontario, Canada

November 26. 2nd Meeting of the Space Task Group of the IPY Subcommittee on Observations in Darmstadt, Germany (26-27 November)

November 27. LIMA (Landsat Image Mosaic of Antarctica) project releases new satellite-based map of Antarctica, one of the earliest products of IPY produced by a team of researchers from NASA, the U.S. Geological Survey, the National Science Foundation, and the British Antarctic Survey

November 27. IPY exhibit at the Exhibition on Earth observations organized during the Ministerial Summit of the Group on Earth Observations (GEO) in Cape Town, South Africa (27–30 November)

December 10. Several IPY-focused sessions at the American Geophysical Union (AGU) Fall Meeting in San Francisco, U.S.A. (10–14 December) featuring 'Live from IPY' videoconferences

December 13. Second International Polar Day, "Ice Sheets" launched by IPO

2008

January 20. 2nd Annual 'Arctic Frontiers' Conference, Tromsø, Norway (20–25 January)

January 23. Polar Gateways: Understanding to Solar System Exploration for IPY-IHY Conference, Barrow, Alaska

January 25. 2nd Meeting of the WMO Inter-commission Task Group on IPY in Geneva (25-26 January)

February 15. A new fully robotic astronomical observatory is installed at Dome Argus, the highest point of the East Antarctic Ice Sheet, by an IPY team representing six international institutions and led by China

February 12. The International Year of Planet Earth (IYPE) launched at UNESCO headquarters in Paris

February 28. Standing Committee of Parliamentarians of the Arctic Region meeting, Rovaniemi, Finland (28–29 February)

March 2. First two IPY fatalities during a helicopter crash near the German Antarctic station Neumayer; a pilot and a Dutch scientist killed, three passengers injured (French, German, and Dutch nationals)

March 2. APECS Executive Committee meeting in Akureyri, Iceland (2–6 March) to finalize the organization's Terms of Reference and Rules of Procedure

March 10. IPY 2007–2008 Legacies - The supporting activities document produced by IPO published online (www.ipy.org/images/uploads/IPYlegacies.pdf)

March 12. The third 'International Polar Day': Changing Earth: Past and Present, launched by the IPO

March 17. European Science Foundation hosts a meeting for the IPY Education, Outreach, and Communication subcommittee and working groups in Strasbourg, (17-20 March) with 21 participants representing 14 nations

March 26. Arctic Science Summit Week, Syktyvkar, Komi Republic, Russian Federation (26 March–2 April); IASC Pacific Arctic Group (PAG) discusses plans for the PAG 'IPY synthesis' document

April 9. Second IPY Workshop on Sustained Arctic Observing Network (SAON) in Edmonton, AB, Canada, (9-11 April)

April 12. International Polar Year Film Festival 2008, TELUS World of Science, launched in Edmonton, AB

April 13. Several international sessions focused on IPY research activities held at the European Geosciences Union (EGU) General Assembly, Vienna, Austria (13–18 April)

April 23. Senior Arctic Officials Meeting in Narvik, Norway reviews progress in IPY, particularly with regard to the IPY legacy in observing systems, data access, scientific cooperation, and building the next generation of polar researchers and leaders

May 4. New Generation Polar Research Symposium for early career scientists involved in IPY, Colorado Springs, CO, U.S.A. (4–11 May)

May 5. 3rd Meeting of the Space Task Group of the IPY Subcommittee on Observations, Frascati, Italy (5–6 May)

May 16 1st Meeting of the 2010 IPY Oslo Open Science Conference Steering Committee in Oslo, Norway

June 2. XXXI Antarctic Treaty Consultative Meeting in Kyiv, Ukraine (2–13 June), with a report from the IPO on the implementation of IPY

June 16. UNEP Tunza International Children's Conference in Stavanger, Norway (16–20 June); IPO hosts one of the live events for the 'Land and Life' International Polar Day

June 18. International Polar Day: Land and Life (permafrost, terrestrial biodiversity, hydrology, snow) organized by the IPO

June 26. IPY Presentation at the 60th session of the WMO Executive Council. Council proposes to consider the launch of an International Polar Decade and decides to establish the Panel of Experts on Polar Observations, Research and Services, Geneva (18-27 June)

July 1. Launch of the IPY Open Science Conference (Oslo, June 2010) website www.ipy-osc.no with the first conference circular posted on July 2

July 4. 7th Meeting of the ICSU-WMO Joint Committee for IPY (JC-7) in St. Petersburg, Russia, preceding the SCAR-IASC Open Science Conference (4–5 July)

July 6. IPY Education, Outreach and Communications Subcommittee meeting, St. Petersburg, Russia

July 7. 4th IPY Consultative Forum, in conjunction with the SCAR-IASC Open Science Conference, St. Petersburg, Russia

July 7. APECS career development workshop and open meeting prior to the opening of the SCAR-IASC IPY Open Science Conference, St. Petersburg, Russia

July 7. IPY Data Management Subcommittee meeting, St. Petersburg, Russia

July 8. Joint SCAR-IASC Open Science Conference, "Polar Research - Arctic and Antarctic Perspectives in the International Polar Year," St Petersburg, Russia (8–11 July)

July 9. 2nd Meeting of the IPY Oslo Open Science Conference Steering Committee in conjunction with the SCAR-IASC IPY Conference in St. Petersburg, Russia

July 14. "International Polar Year: Science, Technology, Engineering, and Mathematics - Polar Connections, teacher opportunity," conference at the University of Massachusetts Amherst (Amherst, U.S.A., 14–18 July) to promote the teaching of science concepts and processes related to polar regions

July 18. IPY 2007–2008 featured at Euroscience Open Forum 2008, Barcelona, Spain

August 22. 6th International Congress of Arctic Social Sciences, Nuuk, Greenland (22–26 August), with the theme 'Opportunities and Challenges for Social Sciences in the International Polar Year 2007–2008'

September 8. WMO/WCRP/IPY Workshop on Climate Information and Prediction Services in Polar Regions, St-Petersburg, Russia (8-11 September)

September 15. IPY Media Working Group Meeting, ICSU, Paris

September 20. International philatelic event related to IPY 2007–2008 at the Austria Center in Vienna, Austria; the event proposed by Michelle Bachelet, the president of Chile, calls attention to polar science and environmental impact of global warming

September 24. International Polar Day: 'People,' featuring social and human science research in IPY launched out of Canada national IPY office

October 8. International conference, "Human Dimensions in the Circumpolar Arctic," Umeå University, Umeå, Sweden, under the auspices of IPY (8–10 October)

October 14. Third IPY Workshop on Sustained Arctic Observing Network (SAON), Helsinki, Finland (14-17 October)

October 19. IPY Presentation at the ICSU General Assembly, Maputo, Mozambique (19–24 October)

October 5. Third IPY fatality (construction worker), due to a fire at the Russian Antarctic *Progress* station

October 20. A tractor falls into crevasse near the Russian Antarctic *Mirnyi* station; fourth fatality during IPY

November 4. First International Symposium on Arctic Research (ISAR-1): Drastic Change under the Global Warming, in Miraikan, Tokyo, Japan (4–6 November) organized by IASC and CliC Subcommittee of the Science Council of Japan in conjunction with IPY 2007–2008

November 7. 3rd Meeting of the IPY Oslo Open Science Conference Steering Committee in Oslo, Norway

November 9. Conference "The Arctic: observing the environmental changes and facing their challenges" reviews some preliminary scientific results of IPY and components of IPY legacy, Monte-Carlo, Monaco (9-10 November)

November 10. International conference "Fifty years after IGY – Modern Information Technologies and Earth and Solar Sciences," Tsukaba, Japan

December 3. IPY Legacy Workshop: Sustaining Project Contributions to WMO Global Cryosphere Watch and the Global Earth Observations System of Systems, WMO, Geneva, (3–5 December)

December 4. International Polar Day: 'Above the Poles' (astronomy, meteorology, atmospheric sciences) launched by the IPO

December 15. IPY Sessions and exhibit at the AGU Fall Meeting, San Francisco, U.S.A. (15–19 December)

2009

January 25. HAIS Meeting, Cambridge, U.K. (25–26 January)

February 3. 4th Meeting of the Space Task Group of the IPY Subcommittee on Observations, WMO, Geneva (3–4 February)

February 23. IPY Education and Outreach Subcommittee meeting, WMO, Geneva (23–24 February)

February 23. APECS Executive Council Meeting, WMO, Geneva (23–25 February)

February 23. 8th meeting of the ICSU-WMO Joint Committee for IPY (JC-8), WMO, Geneva (23–25 February)

February 24. Opening of the special IPY photographic exhibit "Our Polar Heritage" sponsored by the UN and Government of Canada, Palais des Nations, Geneva

February 25. Joint WMO-ICSU 'IPY ceremony' at the WMO Secretariat in Geneva in conjunction with the release of *The State of Polar Research* (Allison et al., 2009) prepared by the Joint Committee

February 26. The Nordic Ministers' Globalisation Forum in Eldborg, Iceland is briefed on the science advances of IPY 2007–2008

March 1- End of the official observation period of IPY 2007–2008

5. Post-Observation Phase, March 2009–June 2010

2009

March 18. First IPY 'International Polar Week' focusing on Oceans and Marine Life

March 23. Arctic Science Summit Week 2009, Bergen, Norway (23–28 March), with several presentations featuring first results of the IPY activities in the Arctic

March 28. 4th Meeting of the Oslo IPY Open Science Conference Steering Committee, Bergen, Norway, in conjunction with the Arctic Science Summit Week

April 6. XXXII ATCM in Baltimore, U.S.A. (6-17 April), with report on progress in IPY

April 6 – First-ever Joint Meeting of the Arctic Council and ATCM Parties to mark the 50th anniversary of the Antarctic Treaty and the successful execution of IPY 2007–2008, in Washington DC; the meeting adopts the joint ATCM-AC 'Washington Declaration on the International Polar Year and Polar Science'

April 6. Joint celebration of IPY 2007–2008 by the U.S. National Academy of Sciences and National Science Foundation in Washington, DC organized in conjunction with the XXXII ATCM in Baltimore, MD

April 24. Several IPY-focused sessions at the European Geosciences Union General Assembly, Vienna, Austria (19–24 April)

April 29. 6th AC Ministerial Meeting in Tromsø, Norway endorses 'the Washington ATCM-AC Ministerial Declaration' highlighting IPY 2007–2008

April 29. IPY Data Management Subcommittee meeting, British Antarctic Survey, Cambridge, U.K. (29–30 April)

June 15. 5th Meeting of the Oslo IPY Open Science Conference Steering Committee, Oslo, Norway

June 28. APECS Field School, Svalbard (28 June–3 July)

July 11. 14th International Congress on Circumpolar Health, *Securing the IPY Legacy: From Research to Action*, Yellowknife, Canada (11–16 July)

July 26. SCAR International Biology Symposium, 'Antarctic Biology in the 21st Century – Advances In and Beyond IPY,' Sapporo, Japan (26–31 July)

July 27. International Symposium on Glaciology in the International Polar Year in Northumbria University, Newcastle, U.K. (27-31 July); sessions on the legacy from IGY 1957–1958 and the possible legacy of current IPY activities

September 17. 6th Meeting of the Oslo IPY Open Science Conference Steering Committee, Oslo, Norway

September 29. Joint IPY Data Management Subcommittee and Canada Data Meeting, Ottawa, Canada (29 September 29–1 October)

October 1. Association of Polar Early Career Scientists Workshop, Whitehorse, Canada

October 5. IPY International Polar Week 'What happens at the Poles affects us all' at IPO (5–9 October)

October 16. HAIS Meeting, Oslo, Norway

October 20. 'Space and the Arctic' workshop reviews IPY space activities, Stockholm, Sweden (20-21 October)

October 25. IPY Education and Outreach Meeting, Edmonton, Canada (25–29 October)

November 30. 50th Celebration of the Antarctic Treaty, *Antarctic Treaty 'Summit* followed by international conference 'Science-Policy Interactions in International Governance, Washington DC (30 November–2 December); special session on the history of IPY/IGY organized by the SCAR Polar History action group (3 December)

November 30. 5th Meeting of the Space Task Group of the IPY Subcommittee on Observations, WMO, Geneva (30 November–2 December)

December 14. AGU Fall Meeting, San Francisco (4–18 December) with several sessions focused on IPY-driven research

2010

January 21. 7th Meeting of the IPY Oslo Science Conference Steering Committee, Oslo, Norway

February 15. Initial Meeting of the Montreal 2012 Conference Steering Committee, Ottawa, Canada

March 12. 8th Meeting of the IPY Oslo Science Conference Steering Committee, Oslo, Norway

March 16. "State of the Arctic" Conference in Miami, U.S.A., with several IPY-related sessions (16–19 March)

March 22. IPY Data Subcommittee meeting in Paris (22 – 24 March)

April 9. 1st Meeting of the Montreal 2012 Conference Steering Committee, Oslo, Norway (9–10 April)

April 15. Arctic Science Summit Week 2010, Nuuk, Greenland (15–19 April), with several sessions discussing first results of the IPY activities

May 7. Last issue of the *IPY Monthly Report* (no.37) released by the IPO

June 6. International Teachers Conference and APECS Workshop, Oslo, Norway (6–7 June); *Polar Science and Global Climate: An International Resource to Education and Outreach* teachers' sourcebook produced by the IPY EOC Subcommittee (Kaiser et al. 2010) released

June 7. 9th and final Meeting of the ICSU-WMO Joint Committee for IPY (JC-9), Oslo, Norway

June 8. IPY 2007–2008 Oslo Science Conference with over 2300 participants, Oslo, Norway (8–12 June)

June 9. Joint AC-ATCM workshop, 'The Legacy of the International Polar Year' during the IPY Open Science Conference, Oslo, Norway

June 9. 2nd Meeting of the Montreal 2012 Conference Steering Committee in conjunction with the IPY Oslo Conference

June 10. 6th Meeting of the Space Task Group (STG) of the IPY Subcommittee on Observations, Oslo, Norway recommends to reconstitute STG as a Polar Space Task Group

June 12. Official closing of IPY 2007–2008 at the Plenary session of the IPY Open Science Conference in Oslo; the outline of JC IPY summary report presented to the IPY community

June 14. 62nd session of the WMO Executive Council express its deep appreciation to WMO/ICSU Joint Committee for IPY, its Subcommittees, the IPY International Programme Office, and to thousands IPY participants for successful completion of IPY 2007–2008

June 30. ICSU-WMO Joint Committee for IPY 2007–2008 officially completes its tenure.
As agreed at JC-9, Co-editors of JC IPY Summary continue preparation of the Summary

July 27. Chair's Report from the AC-ATCM joint workshop on the legacy of the International Polar Year (June 10, 2010) published online

August 1. XXXI SCAR Meeting and 4th Open Science Conference, "Antarctica – witness to the past and guide to the future", Buenos Aires, Argentina (1–11 August), with several papers on progress in IPY projects

September 16. 3rd Meeting of the Montreal 2012 Conference Steering Committee, Montreal, Canada

September 30. The closure of the IPY International Programme Office; work on the JC IPY Summary continues

APPENDIX 10

Selection of IPY Logos

Compiled by David Hik

From the very beginning of IPY planning there were debates about how to label and 'brand' this event (Box 3, *Chapter 1.3*). In November, 2006 the Education, Outreach and Communications Subcommittee adopted the following IPY Branding Policy for consideration by the Joint Committee.

IPY Branding Policy

Developed by the IPY EOC Subcommittee, November 2006. A recommendation for the Joint Committee.

IPY, The International Polar Year 2007-2008, was established by the International Council for Science (ICSU) and World Meteorological Organisation (WMO).

We define the **IPY identity** as the IPY logo, hexagram chart, and other associated IPY graphics found in presentations, on the web, in printed material, etc.

We define **IPY participants** as:

- Members of endorsed IPY projects
- National IPY Committees
- Nationally endorsed IPY activities
- People involved in activities registered in the IPY Expressions of Intent database

IPY 2007–2008 official logo

1. We encourage the widest possible distribution and use of IPY information and materials.
2. We encourage the use of the IPY identity by all IPY participants for the promotion of IPY activities.
3. We request that commercial vendors interested in using the IPY identity, negotiate an agreement with either National IPY Committees, or the IPY International Programme Office.
   In cases of commercial enterprises, we will generally support the proposal if it is of benefit to IPY projects that have been internationally or nationally endorsed.
4. Within the array of IPY activities, there are no exclusive rights to the use of the IPY identity. As a consequence, there will not be one official IPY product (such as book, calendar, film, coin, stamp etc.).

Several national committees also discussed these issues of IPY branding, but since there apparently were no problems associated with the use of the IPY logo or brand, these concerns were not formally dealt with.

The evolution of the official IPY logo was described in *Chapter 1.3* (Box 3). While many countries adopted their own visual identities, Norway also developed a visual profile and image bank of IPY graphics for general use. On the following page a selection of IPY national and project logos are reproduced.

Examples of IPY National Logos

Bulgaria

Canada

South Africa

Ukraine

China

Poland

Russia

Portugal

Netherlands

Norway

Germany

Canada

Examples of IPY Project Logos

Antarctica's Gamburtsev Province

Arctic Human Health Initiative

North Pole Station 35

Census of Antarctic Marine Life

Circumpolar Flaw Lead System Study

PPS Arctic

Glaciodyn

PoleNet

Oasis

Geotraces

IceCube

SEDNA

Polarcat

IPY Rocks

IPY Alaska

Youth Steering Committee

Greening of the Arctic

SIMBA

APPENDIX 11

List of Acronyms

AAR	Arctic and Antarctic Regions
AARI	Arctic and Antarctic Research Institute
ABACUS	Arctic Biosphere-Atmosphere Coupling across multiple Scales, IPY project
ABBCS	Arctic Breeding Bird Condition Survey
ABPR	Arctic Bottom Pressure Recorders
AC	Arctic Council
ACC	Alaskan Coastal Current
ACC	Antarctic Circumpolar Current
ACCE	Antarctic Climate Change and the Environment
ACCO-NET	Arctic Circum-Polar Coastal Observatory Network
ACD	Arctic Coastal Dynamics Project
ACE	Antarctic Climate Evolution
ACIA	Arctic Climate Impact Assessment
ACRC	Arctic Peoples, Cultures, Resilience and Caribou
ACTP	Acoustic Ice Tethered Platform
ADCP	Acoustic Doppler Current Profiler
ADI	AON Design and Implementation
ADIS	ACSYS Data and Information Service
AFHCAN	Alaska Federal Health Care Access Network
AFoPS	Asian Forum for Polar Sciences
AGAP	Antarctica Gamburtsev Province
AGCS	Arctic in the Global Climate System
AHDR	Arctic Human Development Report
AHHI	Arctic Human Health Initiative
AHRN	Arctic Health Research Network
AIA	Aleut International Association
AMAP	Arctic Monitoring and Assessment Program
AMD	Antarctic Master Directory
AMES	Antarctic Marine Ecosystem Studies
AMSA	Arctic Marine Shipping Assessment
ANDEEP-SYSTCO	ANtarctic benthic DEEP-sea biodiversity colonization history and recent community patterns SYSTem Coupling
ANDRILL	Antarctic Geologic Drilling
ANTPAS	Antarctic and Sub-arctic Permafrost Periglacial and Soil Environments Project
ANTScape	Antarctic Paleotopographic Map
AOD	Aerosol Optical Depth
AON	Arctic Observing Network
AON-SIP	Arctic Observing Network Social Indicators Project
AOSB	Arctic Ocean Science Board
AOT	Aerosol Optical Thickness
AP	Arctic Portal
APECS	Association of Polar Early Career Scientists
ARCDIV	Arctic Climate Diversity
ArcOD	Arctic Ocean Diversity
ARCUS	Arctic Research Consortium of the United States
ArLISON	Arctic Lake Ice and Snow Observatory Network
ArcticWOLVES	Arctic Wildlife Observatories Linking Vulnerable EcoSystems
ASF	Alaska Satellite Facility
ASI	Agenzia Spaziale Italiana
ASI	Arctic Social Indicators, IPY porject
ASOC	Antarctic South Ocean Coalition
ASP	ArcticNet Student Association
ASPeCI	Antarctic Sea Ice Processes and Climate
ASR	Arctic System Reanalysis
ASSW	Arctic Science Summit Week
ASTI	Arctic Species Trend Index
ASTIS	Arctic Science and Technology Information System
ATCM	Antarctic Treaty Consultative Meeting
ATCP	Antarctic Treaty Consultative Party
AVHRR	Advanced Very High Resolution Radiometer
AVNIR	Advanced Visible and Near Infrared Radiometers
AWI	Alfred Wegener Institute
AWS	Automatic Weather Station
AZ	Antarctic Zone
BAS	British Antarctic Survey
BATC	Bipolar Atlantic Thermohaline Circulation
BCTEIASO	Biogeochemical Cycles of Trace Elements and Isotopes in the Arctic and Southern Oceans
BGOS	Beaufort Gyre Observing System
BIOMASS	Biological Investigation of Marine Antarctic Systems and Stocks
BiPAG	Bipolar Action Group
BNSC	British National Space Center
BON	Biodiversity Observation Network
BSIT	Bundesanstalt fur See Schiffahrt und Hydrographie (German Navigation and Hydrographic Service)
BSRN	Baseline Surface Radiation Network
BSSN	Bering Sea Sub-Network
BUFR	Binary Universal Format Representation
CADIS	Cooperative Arctic Data and Information Service
CAF	Clean Air Facility
CAFF	Conservation of Arctic Flora and Fauna
CAFT	Consortium of Arctic Flora and Fauna

CALM	Circumpolar Arctic Layer Monitoring
CAML	Census of Antarctic Marine Life
CANDAC	Canadian Network for the Detection of Atmospheric Change
CANHR	Center for Alaska Native Health Research
CAPGIA	Constraints on Antarctic Peninsula Glacial Isostatic Adjustment
CAPP	Carbon Pools in Permafrost
CARE	Climate of the Arctic and its Role in Europe
CARMA	Circumpolar Arctic Rangifer Monitoring and Assessment Network
CASO	Climate of Antarctica and the Southern Ocean
CASP	Circum-Antarctic Stratigraphy and Paleobathymetry
CAT	Canadian Arctic Through Flow
CAVIAR	Community Adaptation and Vulnerability in Arctic Regions, IPY project
CBD	Convention on Biological Diversity
CBM	Community-Based Monitoring
CBMP	Circumpolar Biodiversity Monitoring Program
CCN	Cloud Condensation Nuclei
CDMP	Climate Data Modernization Program
CEAMARC	Collaborative East Antarctic Marine Census
CEOP	Coordinated Enhanced Observing Period
CEOS	Committee on Earth Observation Satellites
CFL	Circumpolar Flaw Lead
CGMW	Commission for the Geological Map of the World
CHINARE	Chinese National Arctic Research Expedition
CircHOB	Circumpolar Health Observatory
CIRES	Cooperative Institute for Research in Environmental Sciences
CLEOPATRA	Climate effects on planktonic food quality and trophic transfer in Arctic Marginal Ice Zones
CliC	Climate and Cryosphere Project, WCRP
ClicOPEN	Impact of CLImate induced glacial melting on marine and terrestrial COastal communities on a gradient along the Western Antarctic PENinsula
CLIPS	CCI Climate Information and Prediction Services
CLIVAR	CLimate VARiability and predictability project
CMA	China Meteorological Administration
CODATA	Committee on DATA
COMNAP	Council of Managers of National Antarctic Programmes
COSPAR	Committee on Outer Space Research
CRBP	Cold Regions Bibliography Project
CReSIS	Center for Remote Sensing of Ice Sheets
CSW	Chukchi Summer Water
CSA	Canadian Space Agency
CTD	Conductivity – Temperature – Depth
CWG	Cryosol Working Group
CYFN	Council of Yukon First Nations
DAHLI	Discovery and Access of Historic Literature of the IPYs
DBO	Distributed Biological Observatory
DCP	Data Collection Platform
DEM	Digital Elevation Models
DG	Director-General, European Commission
DIMES	Diapycnal and Isopycnal Mixing Experiment in the Southern ocean
DOI	Digital Object Identifier
DVM	Diel Vertical Migration
EBA	Evolution and Biodiversity in Antarctica: the Response of Life to Change, IPY project
EGU	European Geosciences Union
eGY	electronic Geophysical Year
ELOKA	Exchange for Local Observations and Knowledge of the Arctic
EC-PORS	Executive Council Panel of Experts on Polar Observations, Research and Services
ENVISNAR	Environmental Baselines, Processes, Changes and Impacts on People in the Nordic Arctic Regions, IPY project
EO&C	Education, Outreach & Communication
EoI	Expression of Interest
EPB	European Polar Board
ESA	European Space Agency
ESA-ESRIN	ESA Centre for Earth Observation
ESAS	East Siberian Arctic Shelves
ESF	European Science Foundation
ESSP	Earth System Science Partnership
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
EUROCORES	European Collaborative Research
EUROSPAN	European Special Population Network
FARO	Forum of Arctic Research Operators
FMI	Finnish Meteorological Institute
FTIR	Fourier Transform Infrared

FWC	Freshwater Content
GAMSEIS	Gamburtsev Antarctic Mountains Seismic Experiment
GARP	Global Atmosphere Research Program
GAW	Global Atmosphere Watch Programme
GBMF	Gordon and Betty Moore Foundation
GCMD	Global Change Master Directory
GCOS	Global Climate Observing System
GCW	Global Cryosphere Watch
GEO	Group on Earth Observations
GEOSS	Global Earth Observing System of Systems
GIA	Glacial Isostatic Adjustment
GIIPSY	Global Interagency IPY Polar Snapshot Year, IPY project
GLISN	Greenland Ice Sheet Monitoring Network
GLOBEC	Global Ocean Ecosystem Dynamics
GMES	Global Monitoring for Environment and Security
GOOS	Global Ocean Observing System
GRACE	Gravity Recovery and Climate Experiment
GSN	Global Snowflake Network
GTN-P	Global Terrestrial Network for Permafrost
GTOS	Global Terrestrial Observing System
GTS	Global Telecommunication System
HAIS	Heads of the Arctic and Antarctic IPY Secretariats
HHAG	Human Health Assessment Group
HRLDAS	High-Resolution Land Data Assimilation
HuBLE	Hudson Bay Lithosphere Experiment
IAATO	International Association of Antarctic Tour Operators
IACS	International Association of Cryospheric Sciences
IAGA	International Association of Geomagnetism and Aeronomy
IAI	International Arctic Institute
iAOOS	Integrated Arctic Ocean Observing System
IARC	International Arctic Research Center
IARPC	Interagency Arctic Research Policy Committee
IASC	International Arctic Science Committee
IASC-WAG	IASC Working Group on Arctic Glaciology
IASOA	International Arctic Systems for Observing the Atmosphere, IPY project
IASSA	International Arctic Social Sciences Association
IBP	International Biological Programme
ICARP II	2nd International Conference on Arctic Research Planning, 2005
ICASS	International Congress of Arctic Social Sciences
ICC	Inuit Circumpolar Council
ICECAP	International Climate and Environmental Change Assessment Project
ICED	Integrating Climate and Ecosystem Dynamics
ICESat	Ice Cloud and Land Elevation Satellite
ICESTAR	Interhemispheric Conjugacy Effects in Solar-Terrestrial and Aeronomy Research
ICR	International Centre for Reindeer Husbandry
ICS	International Circumpolar Surveillance
ICSU	International Council for Science
IFM-GEOMAR	Liebniz Institute for Marine Science
IGBP	International Geosphere-Biosphere Programme
IGC	International Geophysical Collaboration
IGFA	International Group of Funding Agencies for Global Change Research
IGLO	International Action on Global Warming
IGOS	Integrated Global Observing Strategy
IGY	International Geophysical Year 1957–1958
IHY	International Heliophysical Year
IKC	Inuit Knowledge Center
INCHR	International Network for Circumpolar Health Research
INPE	National Institute for Space Research (Brazil)
IOC	Intergovernmental Oceanographic Commission
IOI	International Ocean Institute
IPA	International Permafrost Association
IPCC	Intergovernmental Panel on Climate Change
IPD	International Polar Decade
IPEV	L'Institut Polaire Français Paul Émile Victor
IPIC	International Partnerships in Ice Core Sciences
IPS	Indigenous Peoples' Secretariat
IPW	Integrated Precipitable Water
IPYDIS	IPY Data and Information Service
IPY IPO	International Polar Year International Programme Office
IPYPD	IPY Publications Database
ISAC	International Study of Arctic Change

ISAR	International Symposium on Arctic Research
ISMASS	Ice Sheet MASS Balance and Sea Level
ISOS	International Southern Ocean Studies
ISOS	Integrated School of Ocean Sciences
ISSS	International Siberian Shelf Study
IAU	International Astronomical Union
I-TASC	Interpolar Transnational Art Science Constellation
ITEX	International Tundra Experiment
ITK	Inuit Tapirlit Kanatami
IUCH	International Union for Circumpolar Health
IUCP	International University Courses on Permafrost
IUGG	International Union of Geodesy and Geophysics
IUGS	International Union of Geological Science
IYPE	International Year of Planet Earth
JAMSTEC	Japan Agency for Marin Earth Science and Technology
JARE23	23rd Japanese Antarctic Research Expedition
JASE	Japanese-Swedish Antarctic Expedition
JAXA	Japan Aerospace Exploration Agency
JC	ICSU-WMO Joint Committee for IPY 2007–2008
JCADM	Joint SCAR-COMNAP Committee on Antarctic Data Management
JGOFS	Joint Global Ocean Flux Study
JOIS	Joint Ocean and Ice Studies
JWACS	Joint Western Arctic Climate Studies
K-12	Kindergarten to Grade 12, public schools, U.S.A. and Canada
KOPRI	Korea Polar Research Institute
KORDI	Korea Ocean Research and Development Institute
LAPNET	LAPland NETwork
LARISSA	LARsen Ice Shelf System Antarctica
LGM	Last Glacial Maximum
LIMA	Landsat Image Mosaic of Antarctica, IPY project
LOiCZ	Land-Oceans Interaction in the Coastal Zone
LOLITA-PSC	Lagrangian Observations with Lidar Investigations and Trajectories in Antarctica of PSC
LSM	Land Surface Model
LTK	Local and Traditional Knowledge
MarBIN	Marine Biodiversity Network

MARP	Malaysia Antarctic Research Program
MaxNDVI	Maximum Normalized Difference Vegetation Index
MEMG	Marine Expert Monitoring Group
MEOP	Marine Mammal Exploration of the Oceans Pole to Pole
MERGE	Microbiological and Ecological Responses to Global Environmental Changes in Polar Regions, IPY project
MERIS	Medium Resolution Imaging Spectroradiometer
MiniMAMM	Modified Antarctic Mapping Mission
MISR	Multi-Angle Imaging SpectroRadiometer
MIZ	Marginal Ice Zone
MMCR	Millimeter Cloud Radar
MMM	Mesoscale and Microscale Meteorology Division
MODIL-NAO	Monitoring of the Development of Traditional Indigenous Land Use Areas in the Nenets Autonomous Okrug, IPY project
MODIS	Moderate Resolution Imaging Spectroradiometer
MUOCAA	Monitoring Upper Ocean Circulation between Africa and Antarctica
NADC	National Antarctic Data Center
NAS	National Academy of Sciences, U.S.A.
NBS	Northern Bering Sea
NCAOR	National Center for Arctic and Ocean Research
NCAR	National Center for Atmospheric Research
NCEP	National Center for Environmental Prediction
NCP	Northern Contaminants Program
NEEM	North Eemian Ice Core Project
NERC	Natural Environment Research Council
NES	NISC Export Services
NF	Northern Forum
NGPR	New Generation of Polar Researchers
NICOP	Ninth International Conference on Permafrost
NIPR	National Institute of Polar Research, Japan
NISC	National Information Services Corporation
NMHS	National Meteorological and Hydrological Services
NOAA	National Oceanic and Atmospheric Administration
NSF	National Science Foundation
NSIDC	National Snow and Ice Data Center
NSTM	Near Surface Temperature Maximum
NVFL	North Vostok flow line
NWP	Numerical Weather Prediction

OCH	Oscillating Control Hypothesis
OGC	Open Geospatial Consortium
OPF	Ocean Polar Front
ORACLE-03	Ozone layer and UV RAdiation in a changing CLimate Evaluated during IPY
OSC	Oslo Science Conference
OSI-PMH	Open Archives Initiative Protocol for Metadata Harvesting
OSL	Otto-Schmidt Laboratory for Polar and Marine Research
OSSE	Observing System Simulation Experiment
PAME	Protection of the Arctic Marine Environment
PAME	Polar Aquatic Microbial Ecology
PANDA	Prydz Bay, Amery Ice Shelf and Dome A Observatories
PAntOS	Pan-Antarctic Observing System
PARCA	Program for Arctic Climate Assessment
PAWS	Polar Area Weather System
PCOF	Polar Climate Outlook Forum
PERMUS	Permafrost in Switzerland
PIC	Polar Information Commons
PILMS	Portable Lab for Mercury Speciation
PMG	Polar Meteorology Group
PMGRE	Polar Marine Geological Research Expedition
PNPI	Petersburg Nuclear Physics Institute
POLENET	POLar Earth Observing NETwork
POLEX-South	Polar Experiment - South
PPE	Permafrost and Periglacial Environment
PPS Arctic	Present day processes, Past changes, and Spatiotemporal variability, IPY Project
PRB	Polar Research Board, U.S. National Academy of Science
PRB	Polar Resource Book
PRISM	Panchromatic Remote-Sensing Instrument for Stereo Mapping
PSC	Polar Stratosphere Clouds
PSW	Polar Surface Watch
PYRN	Permafrost Young Researchers Network
RAE	Russian Antarctic Expedition
RAIPON	Russian Association of Indigenous Peoples of the North, Siberia and the Far East
RAL	Research Applications Laboratory
RAS	Russian Academy of Sciences
RES	Radio-Echo Sounding
ROV	Remotely Operated Vehicle
RUSALCA	Russian-American Long-Term Census of the Arctic
SALE	Subglacial Antarctic Lake Environments
SALE-UNITED	Unified International Team for Exploration and Discovery
SAON	Sustaining Arctic Observing Networks
SAON-IG	Sustaining Arctic Observing Networks Initiating Group
SAR	Synthetic aperture radar
SAR-WG	Second Assessment report (IPCC 1996) Working Group
SASSI	Synoptic Antarctic Shelf – Slope Interactions
SAZ	Sub-Antarctic Zone
SBE	Shelf-basin exchange
SCACE	Synoptic Circum-Antarctic Climate-processes and ecosystem
SCADM	Standing Committee on Antarctic Data Management
SCAGI	Standing Committee on Antarctic Geographic Information
SCAR	Scientific Committee on Antarctic Research
SCAR-MarBIN	SCAR Marine Biodiversity Information Network
SCOBS	Subcommittee on Observations
SCOSTEP	Scientific Committee on Solar-Terrestrial Physics
SDB	Short data burst
SEaAOS	Southern Elephant Seals as Oceanographic Samplers
SEARCH	Study of Environmental Arctic Change
SHARE	Social Sciences and Humanities Antarctic Research Exchange
SIKU	Sea Ice Knowledge and Use, IPY project
SIMBA	Sea Ice Mass Balance of Antarctica
SIO	Sea Ice Outlook
SIPEX	Sea Ice Physics and Ecosystem eXperiment
SIWO	Sea Ice for Walrus Outlook
SMDB	Science Meta-Data Base
SO-FINE	Southern Ocean FINE structure
SOM	Soil Organic Matter
SOOS	Southern Ocean Observing System
SPACE	Synoptic Pan-Arctic Climate and Environment Study
SPRI	Scott Polar Research Institute
SRP	Scientific Research Project
STG	IPY Space Task Group
SST	Sea Surface Temperature
STAGE	Studies on Antarctic Ocean Global Environment
SUC	Sami University College
SUIT	Surface and Under-Ice Trawl
SVALI	Stability and Variations of Arctic Land Ice
SWIPA	Snow Water Ice and Permafrost in the Arctic

TASTE IDEA	Trans-Antartic Scientific Traverses Expedition – Ice Divide of East Antarctica
TAWEPI	THORPEX Arctic Weather and Environmental Prediction Initiative
TEC	Total Electron Content
TEK	Traditional Ecological Knowledge
THORPEX	The Observing System Research and Predictability Experiment, WMO
TIGGE	THORPEX Interactive Grand Global Ensemble
TOPP	Tagging of Pacific Pelagics
TReCs	Polar THORPEX Regional Campaigns
TSP	Thermal State of Permafrost
UAF	University of Alaska Fairbanks, Fairbanks, U.S.A.
UCAR	University Corporation for Atmospheric Research
UM	University of Malaysia, Kuala Lumpur
UNCLOS	United Nations Convention on the Law of the Sea
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNIS	University Centre in Svalbard
URSI	International Scientific Radio Union/Union Radio-Scientifique Internationale
USARC	U.S. Arctic Research Commission
USM	University of Science Malaysia, Pulau Pinang
VFL	Vostok Flow Line
VIRPOL	VIRuses for POLar Marine Ecosystem functioning
VNIIOkeanologia	Institute for Geology and Mineral Resources of the World Ocean
WAP	Western Antarctic Peninsula
WCRP	World Climate Research Programme
WCS	World Conservation Strategy
WDC	World Data Centre
WEAIS	West Antarctic Ice Sheet
WHO	World Health Organization
WIS	WMO Information System
WMO	World Meteorological Organization
WOCE	World Ocean Circulation Experiment
WRF	Weather Research and Forecasting
WRH	World Reindeer Herders
WWRP	World Weather Research Programme
YSC	Youth Steering Committee

The International Polar Year (IPY) 2007–2008 co-sponsored by ICSU and WMO became the largest coordinated research program in the Earth's polar regions.

An estimated 50,000 researchers, local observers, educators, students, and support personnel from more than 60 nations were involved in the 228 international IPY projects (170 in science, 1 in data management, and 57 in education and outreach) and related national efforts in the Arctic and Antarctica over a two-year period, 1 March 2007 - 1 March 2009, with many activities continuing beyond that date.

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