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# BELGIAN SCIENTIFIC RESEARCH PROGRAMME ON THE ANTARCTIC

## *1993 PROGRESS REPORT*

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# 1 INTRODUCTION

In its meeting of 25 June 1992, the Council of Ministers approved the implementation of the *third phase of the Scientific Research Programme on the Antarctic* to develop further the co-ordinated research effort initiated by Belgium since 1985. A budget of 126,000,000 BEF is being allotted to this three-year phase. The Science Policy Office (Prime Minister's Services) is responsible for the overall operation and management of the Programme. It is assigned the task of carrying out the co-ordination of the research projects and the following up all scientific matters in the framework of the Antarctic Treaty System.

The technical content of Phase III was designed in such a way as to centre the whole of the research effort on some those of the scientific topics most relevant to the protection of the Antarctic environment and to the unravelling of the role of Antarctica in the Earth's climate. The research work encompasses the following topics:

- ECODYNAMICS OF THE SOUTHERN OCEAN AND INTERACTIONS WITH THE CLIMATE:
  - Biogeochemical fluxes and cycles in the main trophic compartments
  - Modelling the global dynamics of ecosystems
  - Assessment of the role of "new production" in the burial of atmospheric $CO_2$ by the Southern Ocean
- EVOLUTION AND PROTECTION OF MARINE ECOSYSTEMS:
  - Application of predictive ecological models to simulate ecosystem responses to man-made climatic disturbances
  - Study of hydrocarbons spills dispersion
- ROLE OF THE ANTARCTIC IN GLOBAL CHANGES:
  - Ocean-Cryosphere-Atmosphere interactions.
  - Sedimentary palaeoenvironment.

The contents and goals of each of the projects financed and managed by the SPO under Phase III of the Programme are given in the following section. It is worth noticing that given the multi-disciplinary approach of the Programme, several projects cover more than one of the above topics.

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# 2 RESEARCH PROJECTS - GOALS AND CONTENTS

## 2.1 PROJECT A3/03/001 - Dr F. DEHAIRS, VUB

### SPATIAL AND SEASONAL VARIABILITY OF BIOGENIC ELEMENTAL TRANSPORT IN THE SOUTHERN OCEAN:

The project aims at the study of three intensely related fluxes of biogenic matter in the Southern Ocean ecosystem.

The study of nutrient regime type will include: (i) the use of $^{15}N$ incorporation experiments (labelled nitrate and ammonium); (ii) the evaluation of nitrate depletions, relative to the winter concentration, from water column profiles of different geographical locations sampled at different periods in the season; and (iii) the variability of natural $^{15}N$ abundances ($\delta^{15}N$) in particulate matter. The study of the translocation of $^{15}N$ to higher trophic levels (copepods, krill) will provide information on the secondary production process and on the release of dissolved organic substrates as a result of the zooplankton feeding behaviour.

The recycling processes in the upper layer of the water column will be studied by $^{15}N$ isotope dilution experiments. Ammonium remineralization and nitrification feed the return flux of inorganic nitrogen. The quantification of both processes will provide information on bacterial and protozoan excretion processes.

Characterization of the export flux will be based on the study of the elemental composition of total suspended matter in the water column, sediment trap material and underlying sediments. The study of suspended matter elemental composition will be parallelled, whenever possible, with the study of plankton community composition and cell carbon estimates by Dr Lancelot's team (ULB). Besides particulate carbon and nitrogen, full characterization obtained by ICPMS investigation and especially tracers (Ba, Ca, Sr, Si and $\delta^{15}N$), will describe origin and fate of the material and on the evolution of the settling matter.

## 2.2 PROJECT A3/02/001 - Dr M. VINCX, UG

### ROLE OF THE MEIOBENTHOS IN ANTARCTIC ECOSYSTEMS:

Two main topics will be addressed to assess the role of the meiobenthos in the process of remineralization: (i) the biomass budget (POC/DOC) at the seawater/sediment interface in benthic ecosystems, and (ii) the energy fluxes characterizing meiobenthic communities. Regarding flux evaluations, emphasis will be put on the activity of nematods that account for up to 90-95% of meiobentos densities. Central to this research are the following topics:

- the influence of the primary production in the water column on benthic activity (in the bioturbation zone);
- the standing-stock of organic C in the bottom layer beneath the bioturbation zone;
- the magnitude of the recycling of organic matter into the water column owing to benthic activity.

The role of meiobenthos will be determinded on the basis of:

- estimates of secondary production (calculated on the basis of detailed temporal series of biomass data) and metabolic activity (measurements of respiration and perhaps also production of direct heat);
- relations between the meiobenthos and its abiotic environment (e.g. what role is played by meiobenthos in the biogeochemistry of the bottom sediments (in remineralization processes) and what is the influence of organic C (POC and DOC), coming from the water column or regenerated on the sea bed, on the distribution and activity of sea floor fauna);
- determination of the POC/DOC biomass budget at the water column/ sediment interface and determination of the importance of meiofauna in this budget;
- food experiments (nematodes-bacteria grazing and importance of diatoms as a food for meiofauna in the littoral regions).

## 2.3 PROJECT A3/12/001 - Dr J.-H. HECQ, ULg

**CONTROL OF THE ANTARCTIC PELAGIC ECOSYSTEM BY HIGHER TROPHIC LEVELS IN RELATION WITH ENVIRONMENTAL CHANGES:**

The main objective of the project is to understand the mechanisms that control the functioning of the Antarctic planktonic ecosystem and to develop modelling tools for predicting the evolution of the global dynamics of the major ecosystems of the Southern Ocean. The more specific objective is to understand and to model how the secondary planktonic trophic levels interact with the lower and higher trophic levels. The model will be used to test the effects of different forcing phenomenons on the marine ecosystem. The main processes considered in analysing and modelling the marine Antarctic ecosystems are:

- ▲ the control of plankton activity and vertical distribution in relationship with sea ice melting and retreat (water column physical structure);
- ▲ the control of the exportation of the primary production by zooplankton grazing;
- ▲ the switch of the organic material of phytoplanktonic origin according to the composition of zooplankton communities.

The above processes will be studied on the grounds of the determination of:

- standing stocks;
- spatial and temporal variations of the biomass;
- the trophic position and role of the zooplanktonic components in the food web and their turnover rate;
- the importance of the sea ice dynamics in the structural organization of the zooplanktonic populations;
- the grazing, ammonium excretion, production of fecal pellets, sedimentation fluxes, nutrient recycling;
- vertical migrations of zooplankton;
- predation pressure on zooplankton by higher trophic levels.

A 1D ecological model will be developed on the grounds of the study of these fluxes and processes and will be used to test the effects of "possible stresses" acting on macroscale secondary pelagic levels in various marine ecosystems of the Southern Ocean.

## 2.4 PROJECT A3/11/001 - Dr Ch. LANCELOT, ULB

**DYNAMICS OF THE PLANKTONIC MICROBIAL FOOD-WEB OF THE SOUTHERN OCEAN IN RESPONSE TO ENVIRONMENTAL CHANGES:**

This project aims at developing a predictive mathematical model of C, N and Si cycling through the microbial network of the upper waters of the Antarctic Ocean (that part of the Southern Ocean limited by the polar front) along the course of a seasonal cycle. The model consists in a 1D hydrodynamical model calculating the thickness of the wind mixed layer from classical meteorological data and the dynamics of sea ice retreat and formation coupled with a biological model of the lower trophic levels composed of different modules.

This model will be used to predict more realistically the dynamics of the Antarctic planktonic microbial food-web in response to man-made perturbations; at a global scale, such as those resulting from expectable long-term climatic changes; at more regional scale, such as those resulting from expectable increase of krill catches in some sub-areas.

The specific objectives of the project are the followings:

- to establish a coupled physical-biological box model describing the dynamics of the planktonic microbial food web in the various habitats of the Antarctic Ocean;
- to validate the model by applying it to various geographical sites where time series of physical and biological data are available;
- to exploit this model for predicting its response to expectable long-term climatic global change and the resulting feedback it can induce;
- to use the model at regional scale in the perspective of rational management of marine living resources.

## 2.5 PROJECT A3/58/001 - Dr G. PICHOT, MUMM

**OIL SPILL MODELLING FOR THE ANTARCTIC SEAS (OSMAS):**

The overall goal of the project is to develop and demonstrate a deterministic computer model capable of predicting the behaviour and fate of a large oil spill in the Antarctic coastal zone in the presence of ice cover over a seasonal cycle. The evolution of the oil spill at the sea surface, in the water column and in the ice will be simulated, and the impacted targets will be displayed graphically to show the extent and magnitude of the oil impact. The model will be demonstrated for the area of the Weddell Sea and several simulations will be run using different times and places of oil release.

The model that will be developed differs from the classical, short-term oil tracking systems. There is a needed for a longer-term assessment tool that predicts the impact of a large oil spill in the Antarctic under varying circumstances. The intention is to simulate the evolution of the spill at the sea surface, in the water column and in the ice, over a seasonal cycle. After a run, the trajectories of the oil fractions and the impacted targets should become visible and enable one to assess the extent of the pollution. The processes affecting oil released in a cold sea, the processes affecting Antarctic ice, and the oil/ice interactions will require a thorough literature survey as well as a theoretical approach. Three models developed at MUMM will thus be reevaluated:

- a fully deterministic oil-spill model (MU-SLICK);
- a composite deterministic/probabilistic model (PARCEL); and
- the SEAICE model developed under Phase II of the Programme.

The appropriate components will be selected, the necessary adaptations will be made and the models will be coupled in a single system. The possibility of interconnecting these predictive models with an atmospheric model being developed separately by Prof. A. Berger's team (UCL) will be investigated. The new oil sub-model is likely to be a 3D particle-fate oil model using the results of an ocean-circulation model for current advection, calculating wind drift from atmospheric predictions, and simulating all the important weathering processes. The ice model will have a thermodynamic component (freezing/melting) and a dynamic component (ice movement). In addition, a statistical approach will be followed to assign a position to the ice in each mesh of the grid.

## 2.6 PROJECT A3/11/002 - Prof. R. SOUCHEZ, ULB

### ISOTOPIC AND CHEMICAL COMPOSITION OF ANTARCTIC SHELF ICE: IMPLICATIONS ON GLOBAL CHANGES:

The project aims at studying three properties of marine ice accreted at the bottom of ice shelves, which provide information on the conditions prevailing at the ice shelf-ocean interface and on the dynamic response of ice shelves to changes in boundary conditions related to man-made climatic changes.

Analysis of the stable isotope composition of marine ice accreted at the bottom of ice shelves, both in $\delta D$ and $\delta^{18}O$, will be used for reconstructing the origin of the waters that have subsequently frozen. Owing to the impoverishment in heavy isotopes with respect to sea water, which occurs during the atmospheric step of the water cycle, the isotopical content of melt water from continental glaciers or ice sheets exhibits highly negative $\delta$-values. By contrast, melt water from sea ice shows positive $\delta$-values since sea ice is slightly enriched in heavy isotopes relative to sea water. Further enrichment can occur if melt water from marine ice freezes and melts again. Indeed, isotope fractionation involving an enrichment of the ice phase in heavy isotopes is followed by melting that occurs without any isotopical change.

The analysis of major chemical compounds of marine ice accreted at the bottom of ice shelves will enable to reconstruct the chemical characteristics of the

original water. Major anions and cations are not rejected during ice growth at the same rate and the effect is dependent on the type of marine ice formed. Surface or subsurface sea water can be diluted either by water of continental origin or by melt water from marine ice, each case leading to different isotopical and chemical characteristics.

Crystallographical study of the marine ice in thin section will allow to distinguish between congelation ice and frazil ice. Congelation ice (columnar crystals with cell structure and brine layers) is formed by the progression of a freezing front in sea water. Frazil ice (small crystals) is generated within the sea water itself and is the consequence of a double-diffusion mechanism, heat diffusivity being one order of magnitude higher than salt diffusion. Under favourable conditions - as it uses to happen at the contact between two water layers both being at their freezing point but having different salinities or in ascending supercooled water - frazil ice will accrete at the bottom of an ice shelf. Some factors influencing isotopical or chemical fractionation during ice growth remain poorly known. Therefore, controlled experiments will be developed to supplement the data obtained in the field.

## 2.7 PROJECT A3/10/001 - Prof. A. BERGER, UCL

### FORMATION OF THE TERRA NOVA BAY POLYNIA AND CLIMATIC IMPLICATIONS:

The project aims at coupling a 3D AMCM able to simulate Antarctic katabatic winds to a polynia model, to simulate the opening of the Terra Nova Bay polynia. The phenomenon of the polynia formation will be assessed for its climatic implications.

In a first experiment, the large-scale atmospheric boundary conditions of the coupled polynia-AMCM will be taken from the observations of present climate. The physical processes playing a significant role in atmosphere-polynia interactions will be quantified. In a second experiment, the large-scale atmospheric forcing will be adapted from the results of AGCM experiments made for present climate. This second experiment will be compared with the first and the main differences will be discussed. In a sensitivity test of the atmosphere-polynia interactions to a climate change, the large atmospheric forcing will be adapted from the results of the AGCM experiments made with a $CO_2$ doubling. Again a comparison will be made between the third and the second experiment. For all the experiments, the mechanical and thermodynamical fluxes computed, as well as the polynia extent could be used as input data of the coupled ocean-sea-ice model of the MUMM. This could allow the MUMM model to simulate the oceanic circulation and in particular the deep-water formation near the Antarctic coast. In particular, the impact of the thermodynamical forcing of the atmosphere circulation on the oceanic circulation will be compared to that of the mechanical forcing alone.

The 3D AMCM will also be improved by nesting the fine meso-ß resolution grid that is used up to now (that is needed for the simulation of katabatic winds on steep slopes), in a coarser meso-$\alpha$ resolution grid that is sufficient to simulate the drainage flow on the Antarctic Plateau. Consequently, for the representation of

the same horizontal domain, the number of grid points will be decreased so that the computational costs of the model are reduced. This will also allow to represent a larger domain, to improve the katabatic wind simulation, and to couple the 3D version of the ASTR-AMCM to a 3D ocean-sea-ice model like the MUMM's ocean-sea-ice model. Before doing the nesting of the meso-ß resolution grid in the meso-$\alpha$ resolution grid, sensitivity tests of the inversion winds simulation to the grid resolution will be performed to determine the optimum grid size for the representation of these winds, and to determine which part of the Antarctic slope must be represented with a fine resolution grid.

## 2.8 PROJECT A3/03/002 - Prof. H. DECLEIR, VUB

### DYNAMICS OF THE ANTARCTIC ICE CAP AND CLIMATE CHANGES:

The main goal of the project is to develop a 3D model able to simulate the dynamics of the ice cap in response to climate and oceanic forcing. A new modelling experiment will be carried out with inclusion of a refined grid in specific drainage basins and in areas where significant gradients occur. The present ice topography and a complete glacial-interglacial cycle will be simulated. The main purpose of the experiment is to establish the link between the more locally or regionally generated characteristics of the ice sheet and those that are more fundamentally related to the general behaviour of the ice cap in relation to climatic forcing.

More specifically, the research goals are to understand better:

- the local imbalance (rising/lowering of the ice surface) as observed in certain areas of drainage basins;
- the high velocities and deviating surface topography in and around certain ice streams in East Antarctica and their significance in discharging the ice cap as compared to sheet flow in other areas;
- the convergence and divergence around nunataks and marginal areas and their relationship to the occurrence of supra-glacial moraines and/or meteorite fields;
- the relationship between simulated glacier variations in the mountain areas and the observed sedimentation and erosion phenomena. Special attention will be given to the timing of these phenomenons within the glacial cycle and to investigate the possibility of a local origin (local ice divide) of the glaciations. This is important for the correlation of the stratigraphic units with other mountain areas. To model the glacier behaviour (both past and present) within mountain areas a flow-line model is needed for which the 3D model will provide the necessary boundary conditions.

Special attention will be devoted to the deglaciation of marginal mountain areas. During the deglaciation process of some of the outlet glaciers can - once cut off from the main ice supply from the plateau due to lowering of the ice surface - invert their flow pattern because of the high ablation with the mountain area.

## 2.9 PROJECT A3/02/002 - Dr M. DE BATIST, UG

**BELGIAN CONTRIBUTION TO ANTOSTRAT PROJECT (BELANTOSTRAT):**

This research is a contribution to the international ANTOSTRAT project, which was initiated in 1989 by the SCAR Group of Specialists on the Evolution of Cenozoic Palaeoenvironments of the Southern High Latitudes. ANTOSTRAT aims at the integration of the existing offshore geophysical and geological data bases to enhance their usefulness in coordinating future research studies and to eventually come to a unified Antarctic Offshore Seismostratigraphy.

It consists of a marine geophysical study (high-resolution multi-channel seismic reflection) of the palaeoenvironment along the Antarctic continental margins, with particular attention to analysing the potential climatic influence on its stratigraphic genesis and its evolution. Its specific topics and goals are:

- Spatial analysis of the sequence-stratigraphic genesis of the Antarctic continental margins, taking account of all the geological and tectonic processes which can control this genesis.
- Identification and inventory of the various "signals" (discordances, erosion surfaces and discontinuities, deposits/migrations, etc.) contained in the stratigraphy of these continental margins, likely to be linked up to palaeoclimatic phenomena (extension of the ice cap, variations in sea level).
- Determination of the volumes and structures of dispersion of the sedimentary bodies of the continental margins, in order to quantify sedimentary fluxes over their geological history. The basic data for this study have been taken from the networks of high-resolution multi-channel seismic reflection profiles already available to the RCMG (Weddell Sea, Antarctic Peninsula) or still to be acquired. Preferably, these should be acquired close to deep drilling sites (cf. ODP) or from the oceanic crust dated with sufficient accuracy through magnetic anomalies, so as to be able to deduce an approximate age "window" through stratigraphic correlation.
- Development of a qualitative model of the structural and stratigraphic evolution of these continental margins in relation to long-term climatic changes ($>$ 1 Ma).

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# 3 RESEARCH WORK

## 3.1 SPATIAL AND SEASONAL VARIABILITY OF BIOGENIC ELEMENTAL TRANSPORT IN THE SOUTHERN OCEAN (Dr F. Dehairs):

The research has been mainly devoted to the treatment and interpretation of the data collected during the 1992-93 austral spring and summer in the northern Weddell Sea and in the Weddell Gyre (ANT X/6 and ANT X/7 expeditions). Complementary chemical analyses were carried out on natural samples and on incubation-experiment samples of seawater and suspended particulate matter.

Vertical distributions of nitrogen-nutrients, POC, particulate nitrogen, $\delta^{13}C$, $\delta^{15}N$, biogenic elements (Ba, Ca, Sr and Si) and particulate Al have been completed for all sampling stations and interpreted in relationship with hydrographical parameters, oxygen, chlorophyll_a, silica and phosphates.

The incorporation of $^{15}N$ in particulate matter ($^{15}N$-labelled nitrate or ammonium incubation experiments) has been measured by emission spectrometry. Rates of nitrogen uptake by phytoplankton obtained from these values enabled to calculate RPI and f-ratio values. Total ammonium remineralization by micro-heterotrophic activity has been determined by $^{15}N$-dilution experiments. The evaluation of the rate of nitrogen incorporation by grazing ($^{15}N$ incorporation experiments) is under current finalization.

The seasonal assimilation of nitrates has been calculated from nitrate concentration values observed respectively in the temperature minimum zone and in the upper layer of the water column.

A preliminary treatment of the whole set of data has allowed to characterize and compare the seasonal biogeochemical fluxes in the Polar Front, the ACC and the MIZ zones of the Southern Ocean. Remineralization has been shown to affect mainly the inorganic nitrogen stock in the MIZ where high concentrations of ammonium were observed. The observed accumulation of meso-pelagic Ba-barite clearly differentiate the Polar Front and ACC zones, with highest values in the Polar Front. This suggests a higher export flux in the Polar Front versus the ACC.

## 3.2 ROLE OF THE MEIOBENTHOS IN ANTARCTIC ECOSYSTEMS (Dr M. Vincx):

The production of nematods from the Weddell Sea (Halley Bay and Cape Norvegia), which account for 90-95% of the total meiobenthic population density, has been estimated from size/biomass spectra analyses and making use of P/B ratio annual values assumed to vary between 3 and 25. Horizontal and vertical distribution patterns of the nematods production have been analyzed by statistical methods and compared site to site.

The study of the seasonal variations of the secondary production of meiobenthos is ongoing. The faunistic composition of nematods collected around Signy Island is being determined by means of light-microscope analyses and the total meiofauna (all taxa) biomass measured. Preliminary results clearly show secundary production to reach maximum values in April-June with rather constant values during the rest of the year.

A technique for measuring the in situ respiration of meiobenthos is being developed (bel-jar method). Several tests have been carried out on cultures of nematods and bacteria of natural sediment samples to assess for the performances of the method in various conditions.

## 3.3 CONTROL OF THE ANTARCTIC PELAGIC ECOSYSTEM BY HIGHER TROPHIC LEVELS IN RELATION WITH ENVIRONMENTAL CHANGES

(Dr J.-H. Hecq):

A 1D ecological model is being developed to describe the time-evolution of the phytoplanktonic communities and main zooplankton groups and their degradation products in function of the water column structure (dynamics of the mixed layer owing to wind stress). It has been built by coupling two 1D mathematical (sub-)models. The physical sub-model is a vertical model with a turbulent k-$\epsilon$ closure which provides depth of upper wind-mixed layer and pycnocline and turbulent diffusion coefficient profiles needed to force the biological sub-model. This latter describes the time-evolution of primary biomass — assumed to be produced by diatoms solely — in terms of C photosynthetic fixation, grazing by krill and physical dispersion (sedimentation + turbulent diffusion).

Hydrographical and meteorological data sets over the Ross Sea covering two successive austral summers (seawater temperature, sea ice cover, vertical structure of the water column, wind velocity, solar irradiance and cloud cover) have been used as time-series to calibrate the 1D ecological model. These time-series enabled to determine initial conditions and boundary-conditions of the model. Rates of ingestion of zooplankton and fluxes of ammonium excretion have been determined on the grounds of analyses of their stomachal contents in phytopigments and kinetical measurements.

Preliminary modelling experiments allowed to test the effect of initial krill abundance on the phytoplankton biomass time-evolution along the water column during the first stage of sea ice melting. The results indicate that irrespective of nutrients concentration complete depletion of phytoplankton occurs within a few days for krill abundances $\geq$ 1,000 $mgC.m^{-3}$.

The structural analysis of the planktonic ecosystem of the Ross Sea has confirmed that major variations in biomass, dominant species and vertical distribution are controlled by interactions between the seawater column physics, sea ice cover dynamics and aging of phytoplanktonic communities.

## 3.4 DYNAMICS OF THE PLANKTONIC MICROBIAL FOOD WEB OF THE SOUTHERN OCEAN IN RESPONSE TO ENVIRONMENTAL CHANGES

(Dr Ch. Lancelot):

Field experiments (JGOFS-ANT X/6 campaign) and complementary biochemical analyses (home-laboratory) were carried out to determine the ecodynamical parameters involved in the SWAMCO ecological model. At the current stage of the interpretation of the data collected during JGOFS-ANT X/6 some refinements to the SWAMCO model are being studied (i.e., incorporation of micro-nutrient iron and addition of a meso-zooplankton module).

Physiological parameters characterizing the photosynthesis and growth of total phytoplankton and nano- and net-planktonic communities (10 $\mu$m selective filtration) were measured by means of $^{14}C$ incubation experiments. The effect of temperature on these parameters has been experimentally evaluated. Phytoplankton assemblages have been assessed for their faunistic composition and their standing stocks (Chl_a and C-biomass).

A method based on the marking of preys with fluorochrome (FLB and FLA) was successfully applied to the determination of the selective ingestion of nano-planktonic algae and bacteria by protozoans. Rates of ingestion of spring protozooplanktonic communities calculated from these experimental data were shown to exhibit values characteristic of the MIZ and the Polar Front zones of the Atlantic sector of the Southern Ocean. Based on epifluorescence microscopy analyses of microbial communities protozoans and their preys (bacteria and flagellates) have been sorted by taxon and determined as to their abundance (number of cells and C-biomass). Preliminary tests were performed on the application of flux cytometry to the evaluation of the rate of ingestion of bacteria and algae by protozoans. Although promising, the method has not yet been proved to be fully reliable and adjustments are under current development. Cytometry has been, however, successfully used for counting bacteria.

Experiments on the selective assimilation of (labelled) nitrates and ammonium by nano- and net-planktonic communities and on ammonium regeneration by microheterotrophs were conducted in close collaboration with Dr F. Dehairs' team (VUB).

In addition, Dr Lancelot's team contributed to the acquisition of the following JGOFS core-parameters during ANT X/6:

- continuous recording of PAR (#5)
- bacterial biomass (#10)
- abundance and biomass of auto- and heterotrophic micro- and nano-plankton (# 2)
- daily primary production (#13)
- autotrophic flagellates biomass (#16)
- grazing activity of protozoans (#18)
- inventory of ice microbial communities (#23).

## 3.5 OIL SPILL MODELLING FOR THE ANTARCTIC SEAS (OSMAS) (Dr G. Pichot):

The research work has been centered on the improvement of computer coding of the sea ice and 3D circulation models that will be coupled to a model describing the long-term behaviour of hydrocarbons in cold waters.

The Newton-Raphson iterative method can be divergent if it is applied to a piecewise continuous function. This was the case of the balance of thermal fluxes at the ice surface, from which the sea ice surface temperature and the ice thickness can be drawn. To avoid this problem, a continuous ice albedo formula proposed by Maykut was introduced in the sea ice model.

The 3D hydrodynamic model has been used to reproduce the circulation induced in the Weddell Sea sector by monthly averaged winds. In these simulations, the Coriolis term has been computed in a semi-implicit way to avoid instabilities. Consequently, the convergence towards a steady state is rather slow due to the small damping of the inertial oscillations. Tests dealing with the computation of the baroclinic circulation are currently in progress.

## 3.6 ISOTOPIC AND CHEMICAL COMPOSITION OF ANTARCTIC SHELF ICE: IMPLICATIONS ON GLOBAL CHANGES (Prof. R. Souchez):

The research has been devoted to the analyses and data interpretation of ice samples collected in the Terra Nova Bay area at two sites where marine ice, initially accreted at the ice-ocean interface, now outcrops at the surface of a small ice shelf and of a floating ice tongue.

Vertical profiles of Na, K, Ca and Mg concentrations, measured by AAS, and stable isotopes abundances, measured by mass spectrometry (Centre d'Etudes Nucléaires de Saclay), have been determined in twenty-five ice cores 1-1.5 m in length drilled into the Hell's Gate Ice Shelf. The various types of ice present in the cores have been identified according to their textural and crystallographical characteristics.

Granular frazil ice is largely dominant (92.7% of the total length of marine ice). It consists of orbicular and banded ice which are easily distinguished on the grounds of optical axes orientation, particulate matter and cation concentration. The observed properties indicate that there is a progressive evolution of the individual frazil ice crystals initially accreted at the base of the ice shelf. Basal melting caused by descending plumes of water at a temperature above their local freezing point initiates partial melting of the frazil ice crystals. This dilutes the interstitial water and causes chemical fractionation effects. The orbicular and banded ice appear to result from different environmental conditions at the ice shelf-ocean interface. These findings provide a tentative explanation for the apparent contradiction between the very low salinity levels detected in marine ice at the base of ice shelves, and the comparatively minor salinity fluctuation in sea water profiles near ice shelves.

Similar analyses have been performed on a great number of marine ice samples from the base of the floating part of Campbell Glacier. The characteristics of the included debris were also investigated. The results were interpreted on the base of interactions between the floating ice tongue and the ocean. It has been shown that two types of marine ice can be formed near the grounding lines, either in crevasses, which commonly occur at these locations because of tidal bending, or within sediment layers at the glacier base when contact is made with sea water. In the first type, the isotopic characteristics are explained by the role of diffusion in crevasses after filling with marine ice and recrystallisation. In the second type, the isotopic characteristics are explained by a variable contribution of continental meltwater versus sea water within water-filled sediment layers close to grounding lines. Ice formed near grounding lines thus presents a specific isotopic signature.

## 3.7 **FORMATION OF THE TERRA NOVA BAY POLYNIA AND CLIMATIC IMPLICATIONS** (Prof. A. Berger):

During this year simulations of the atmospheric model have been performed by prescribing open water areas over the Ross Sea. Strong enhancement of turbulent sensible and latent heat fluxes was simulated. The simulated fluxes (radiative and turbulent) at the surface were used to compute the energy balance of a twodimensional polynia model. Results show the importance of even small open water areas in polar regions.

The mesoscale atmospheric model has been further improved by including more sophisticated parameterizations of turbulence. It has then been tested by carrying out katabatic winds simulations.

First order turbulence scheme which was used in the standard version of the model was compared to 1 ½ turbulence schemes. The turbulent kinetic energy balance was first included, depending on production and destruction by buoyancy and wind shear, transport and diffusion. Nevertheless, the turbulent kinetic energy dissipation was parameterized by computing a mixing length. In a second type of 1 ½ turbulence scheme, an additional equation for turbulent kinetic energy dissipation was introduced. This allows to take into account local turbulence characteristics, which is very important when considering the complex vertical structure of the katabatic layer. The last type of turbulence closure is called K-$\epsilon$ turbulence closure.

Tests performed with the model have shown that the K-$\epsilon$ scheme improves the katabatic layer structure. Entrainment in the upper part of the layer, which was overestimated with the first order turbulence scheme is correctly simulated. In particular, the resulting heating of the katabatic layer compares better with the observations.

The alternance of katabatic and anabatic winds in Adélie Land during summer has also been studied. In particular, such cases which have been observed during the IAGO (Interaction Atmosphère Océan Glace) campaign, are well simulated by the model.

In order to improve the domain representation, the model grid is currently nested into a larger grid domain. First tests are two-dimensional. Linear mountain waves experiments compare well with the analytical solution. Next step consist to perform three-dimensional experiments.

## 3.8 DYNAMICS OF THE ANTARCTIC ICE CAP AND CLIMATE CHANGES
(Prof. H. Decleir):

The adaptation of the 3D glacier model and the flow-line model to enable their application at local scale is ongoing. The main effort has been devoted to the refinement of the grid used in previous experiments (40 by 40 km). The numerical method retained for the modelling of ice streams from outlet-glaciers is a finite difference method in order to cope with the necessity to follow small-scale topographical contours. The computer programme is being optimized in terms of memory space and calculation time. Special attention has been paid to avoid mas balance numerical instabilities. Test experiments with anisotropic diffusion along flow-lines en Petrov-Galerkin functions provided good results even with ground-line mesh-sizes as small as 1 km.

The potential of satellite imagery in mapping the glacierized surface has been investigated in the central part of the Sφr Rondane Mountains (study partly made in the framework of the SPO impulse programme on satellite remote sensing). A map of ice and snow temperatures has been obtained from the thermal IR reflectances of Landsat TM, reflecting large-scale topography. The "middle" and "near" IR bands turned out to be most effective to enhance the variations on the snow surface itself. Six multispectral SPOT images have been used to produce a glacio-morphological map which allowed to evaluted the significance of ablation in that mountain area. The analysis of multitemporal images led to the development of a classification tool to quantify the extent of ablation and accumalation areas and to the identification of drift and permanent snow cover.

Field data on Shirase glacier and Sφr Rondane (ice thickness, subglacial relief, flow velocity, topography) are being collected — thanks to the help of the NIPR of Japan mainly — which, together with satellite imagerie observations, will serve to calibrate the models.

## 3.9 BELGIAN CONTRIBUTION TO ANTOSTRAT PROJECT (BELANTOSTRAT)
(Dr M. De Batist):

The seismostratigraphical and structural processing and interpretation of reflection seismic profiles recorded jointly with AWI's research teams in the Weddell Sea during the ANT X/2 expedition have been completed.

Further insight into the origin and evolution of the Crary Fan has been got through a detailed analysis of intermediate-resolution seismic profiles. The fan has been shown to be composed of three mega-scale channel-levee complexes deposited since Late-Oligocene times on the lower slope and continental rise of the southern Weddell Sea and extending over 400 km into the basin. Seismic

profiles recorded over the distal part of the Crary Fan revealed the existence of channel-fills characterized by high-amplitude and chaotic seismic facies. These facies are associated in the upper part of the fan with major erosive surfaces which define northeastern stacks of levee and erosion channels facing the continental slope. This suggests that such erosive structures might have been generated by turbiditic current flows along the continental slope rather than by any Weddell Sea gyre system. Large sea floor channel systems that were identified thanks to recent bathymetric data seem to confirm such possible bottom-current reworking and depositional process.

The top of the acoustic basement of the Explora Escarpment (southeastern Weddell Sea, about 15 miles north of ODP 693 site) has been mapped and interpreted. The analysis of the basement reflector is ongoing in order to determine whether the basement consists of oceanic crust, continental crust or volcanic flows spread onto the continental crust (dipping reflectors).

Depth maps are being established for major regional onlap surfaces or sequence boundaries identified in the area during a previous phase of the research work, namely WO4a, WO4b and WO5 (WO standing for Weddell Sea Onlap surfaces) in order to attempt to correlate seismic and stratigraphic observations. Fine scale seismostratigraphical data and clay mineralogy analyses (University College of North Wales) carried out in ODP Leg 113 sediments have been interpreted in order to trace possible sedimentary records of the climatic control of the evolution of the Weddell Sea sedimentary basin.

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# 4 FIELD ACTIVITIES

Field activities i.e., at sea sampling and measurements, are being achieved in the framework of scientific voyages to the Antarctic organized by other countries.

Through their involvement in such campaigns, the research teams of the Programme were also provided with the unique opporunity to develop or strenghten international co-operation links. As an outcome, most of the Programme's research projects are increasingly contributing to, and taking advantage of, the common implementation of internationally integrated studies.

**Recorded field activities (April 1992 - March 1993):**

Five scientists of the Programme participated in a scientific expedition in the Southern Ocean organized by Germany (Table I, page 17).

**Planned field activities (April 1993 - March 1994):**

Fourteen scientists of the Programme will participate in expeditions to the Antarctic organized by Chile, France, Germany, Italy, Spain and United Kingdom (Table II, page 17).

*

TABLE I : **RECORDED FIELD ACTIVITIES (APRIL 1992 - MARCH 1993)**

| LOCATION | PERIOD | DOMAIN (PROJECT Nr) | PARTICIPANT | EXPEDITION | HOST COUNTRY |
|---|---|---|---|---|---|
| Northern Weddell Sea | Sep 92 - Nov 92 | Marine Biogeochemistry (A3/03/001) | Dr F. Dehairs | JGOFS- ANT X/6 R/V Polarstern | Germany |
| Northern Weddell Sea | Sep 92 - Nov 92 | Marine Ecology (A3/11/001) | Dr Ch. Lancelot<br>Ms S. Becquevort<br>Mr Th. De Hainau | JGOFS- ANT X/6 R/V Polarstern | Germany |
| Weddell Gyre | Dec 92 - Jan 93 | Marine Biogeochemistry (A3/03/001) | Dr L. Goeyens | ANT X/7 R/V Polarstern | Germany |

TABLE II : **PLANNED FIELD ACTIVITIES (APRIL 1993 - MARCH 1994)**

| LOCATION | PERIOD | DOMAIN (PROJECT Nr) | PARTICIPANT | EXPEDITION | HOST COUNTRY |
|---|---|---|---|---|---|
| Terra Nova | Oct 93 - Jan 94 | Glaciology (A3/11/002) | Dr J.-L. Tison | Terra Nova base | Italy |
| Bransfield Strait, South Shetland Islands | Nov 93 - Dec 93 | Marine Geophysics (A3/02/002) | Mr Ph. Bart<br>Dr M. De Batist<br>Eng. E. Van Heuverswyn | GEBRA 93 R/V Hesperides | Spain |
| Indian sector of Southern Ocean | Jan 94 - Mar 94 | Marine Biogeochemistry (A3/03/001) | Dr F. Dehairs<br>Dr L. Goeyens<br>Mr M. Semeneh | ANTARES 2 M/V Marion Dufresne | France |
| Indian sector of Southern Ocean | Jan 94 - Mar 94 | Marine Ecology (A3/11/001) | Dr Ch. Lancelot<br>Ms P. Menon | ANTARES 2 M/V Marion Dufresne | France |
| Amundsen Sea, Bellingshausen Sea | Jan 94 - Mar 94 | Marine Geophysics (A3/02/002) | Eng. E. Maes<br>Eng. W. Versteeg | ANT XI/3 R/V Polarstern | Germany |
| South Orkney Islands | Jan 94 - Apr 94 | Marine Ecology (A3/02/001) | Ms M. Beghyn<br>Ms S. Vanhove | Signy base | UK |
| Magellan Strait | Feb 94 - Apr 94 | Marine Ecology (A3/12/001) | Dr J.-H. Hecq | MAGELLAN 94 | Chile, Italy |

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# 7 ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| AAS | Atomic Absorption Spectrometry |
| ACC | Antarctic Circumpolar Current |
| AGCM | Atmospheric General Circulation Model |
| AMCM | Atmospheric Mesoscale Circulation Model |
| ANTOSTRAT | Antarctic Offshore Acoustic Stratigraphy Project |
| ASTR | Institut d'Astronomie et de Géophysique G. Lemaître |
| AWI | Alfred Wegener Institut für Polar- und Meeresforschung |
| BELANTOSTRAT | Belgian contribution to ANTOSTRAT |
| DOC | Dissolved Organic Carbon |
| EPOS | European Polarstern Study |
| FLA | Fluorescent-labelled Algae |
| FLB | Fluorescent-labelled Bacteria |
| GEBRA | Evolución Geológica de la Cuenca de Bransfield y de la Dorsal Sur del Mar de Scotia |
| ICPMS | Inductively Coupled Plasma Mass Spectrometry |
| JGOFS | Joint Global Ocean Flux Study |
| MIZ | Marginal Ice Zone |
| MUMM | Management Unit North Sea and Scheldt Estuary Mathematical Models - Public Health and the Environment |
| NIPR | National Institute of Polar Research, Tokyo |
| ODP | Ocean Drilling Program |
| OGS | Osservatorio Geofisico Sperimentale, Trieste |
| OSMAS | Oil Spill Modelling for the Antarctic Seas |
| PAR | Photosynthetically Active Radiation |
| POC | Particulate Organic Carbon |
| RCMG | Renard Centre of Marine Geology, Gent |
| RPI | Relative Preference (of phytoplankton for nutrient) Index |
| SCAR | Scientific Committee on Antarctic Research |
| SPO | Science Policy Office (of Belgium) |
| SWAMCO | Seawater Microbial Community Model |
| UCL | Université Catholique de Louvain |
| UG | Universiteit Gent |
| ULB | Université Libre de Bruxelles |
| ULg | Université de Liège |
| VUB | Vrije Universiteit Brussel |

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