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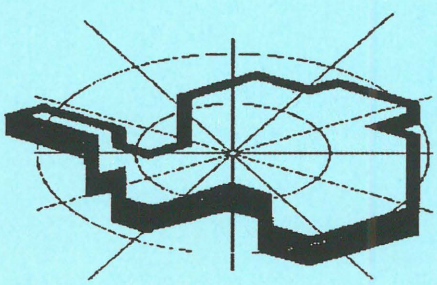
BELGIAN SCIENTIFIC RESEARCH PROGRAMME ON THE ANTARCTIC

1994 PROGRESS REPORT



Brussels - March 1995

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1 INTRODUCTION

The Belgian Scientific Research Programme on the Antarctic was initiated in 1985 by the Council of Ministers with a view to giving tangible form to Belgium's commitment towards the strengthening of the scientific knowledge of the area covered by the Antarctic Treaty. The programme is funded, managed and co-ordinated by the Federal Office for Scientific, Technical and Cultural Affairs (formerly the Science Policy Office). The money allocated to the two first phases of the programme, i.e. 1985-88 and 1988-92, was 92 and 96 million BEF respectively. The budget of the current phase, namely 1992-95, amounts to 126 million BEF. Research-work is implemented by means of 3-years projects undertaken by university-based scientists. All research costs (personnel, equipment, travel, working and overheads) are financed by OSTC.

Such research effort aims at contributing to the development of the knowledge required for a science-based conservation and management of the Antarctic environment and to the assessment of the mechanisms through which the Antarctic and the global climate interact. Emphasis is given on a multi-disciplinary approach of the dynamics of the global functioning of Antarctic main natural systems and of their evolution and interactions. The programme comprises seven research lines under three priority areas. They are:

- 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 following section gives an overview of the mid-term results of the research projects financed under Phase III of the Programme.

2 RESEARCH WORK

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

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

The distribution and uptake of N-nutrients have been analyzed in marginal ice zones in the Southern Ocean (SO). The observed nitrogen signature often departs from the "classical" SO nutrient profiles of high NO_3^- and low $NH4^+$ surface values. In the Weddell Sea, marginal ice zones often show enhanced NO_3^- depletions (up to 800 mmolN/m^2). $NH4^+$ stocks in the upper layer can be up to 7% of the inorganic nitrogen pool. The corresponding nitrogen uptake regime suggests elevated NO_3^- assimilation during the early phase of the productive season but significantly reduced NO_3^- assimilation at a later stage. Absolute as well as specific NO_3^- uptake rates decreased by an order of magnitude when $NH4^+$ stocks exceeded 1.7% of the N-nutrients. Variability in nitrogen utilisation reflected physiological changes in the phytoplankton assemblage. Phytoplankton showed a reduction in its capacity to take up NO_3^- and following an initial diatom bloom, non-siliceous phytoplankton became predominant in a regenerated production regime in response to increased $NH4^+$ stocks.

$Ba_{(p)}$-barite profiles in the mesopelagic zone of the water column have been compared with profiles of $O_{2(aq)}$. A 1D advection-diffusion consumption model was elaborated to estimate O_2 consumption in the water column starting from the information contained in vertical profiles of S, T and $O_{2(aq)}$. Contrarily to models applied widely since the late 60's, it allows for variability of the up(down)welling velocity and of the mixing coefficient as a function of depth. This provides valuable information of profiles of O_2 consumption and allows to compare regions. The model was tested using data from the INDIGO 3 expedition.

The model approach has been applied to $Ba_{(p)}$ and $O_{2(aq)}$ data sets obtained during ANT X/6 (Atlantic sector). In order to estimate rates of O_2 consumption, a value had to be assigned to the constant of eddy diffusivity (mixing coefficient). For the ACC we used the value of the Fine Resolution Antarctic model. Results indicate that the Ba signal is transient over the plankton growth season and that mesopelagic $Ba_{(p)}$ stocks are significantly correlates with water column consumption rates of O_2, thus opening the way for setting up a transfer function between the Ba-barite and export production. For the ACC region south of the PFZ the model calculations suggest that 10% of the C_{org} produced is oxidised in the upper 1000 m.

Suspended matter sampled monthly within the KERFIX programme over two years and within the ANTARES 2 expedition (Indian sector) are being analyzed. First results show that the site is significantly under impact of bottom resuspension and/or terrigenous input. The biological signal, however, is not wiped out too much by the detritic signal and seasonal fluctuations can be clearly detected.

Suspended organic matter (SPOM) samples (Marine Science Voyage 6, Prydz Bay and ANT X/6, Atlantic sector) were studied for possible relationships between $\delta^{13}C$ composition of SPOM and plankton community composition, primary production, biomass, cell growth rate, specific NO_3^- uptake, sea surface T and $CO_{2(aq)}$ ambient concentration. Shelf areas with well stratified, shallow surface waters sustain a very high plankton biomass. Some of the highest $\delta^{13}C$ values for SPOM were observed despite very low T. Biomass impact on DIC content of shallow upper mixed layer, which functions as a semi-closed system with reduced input of CO_2 from the deeper layers due to the extreme density gradient, and plankton species appeared to be possible control parameters of $\delta^{13}C$.

Truly oligotrophic regions $\delta^{13}C$ of SPOM show an inversely correlation with ambient $CO_{2(aq)}$ content which is generally high and largely depending on temperature of the water. For the Polar Front Zone (PFZ), primary production and photosynthetic activity appeared to have a major impact on setting the $\delta^{13}C$ value of SPOM. Furthermore, a hypothesis is developed in which the variability of $\delta^{13}C$ in SPOM of the PFZ is controlled also by the cell's nitrogen demand for amino acid synthesis and the resulting variable activity of the Rubisco and phosphoenolpyruvate carboxylase (PEPcase) pathways.

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

ROLE OF THE MEIOBENTHOS IN ANTARCTIC ECOSYSTEMS:

Studies on the marine biota from the Antarctic, particularly on macrofauna, suggest some general ecological concepts such as high diversity, gigantism, slow metabolism and endemism. The Antarctic marine environment is characterised by constant low temperatures and a seasonal variation of light input and primary production, thus influencing all levels of the Southern Ocean food web *[Clarke, 1988]*. The impact of this seasonality on the community structure of the meiofauna, however, has not investigated to date.

In this perspective, the role of meiofauna in two different habitats in the Antarctic marine ecosystem (e.g. deep sea and shallow subtidal) was questioned.

For the deep-sea study a total of 18 stations were sampled. They were located in the Weddell Sea, in the region off Kapp Norvegia (71-72°S, 12-13°W) and

Halley Bay (74-75°S, 25-30°W), at a depth varying from 211 to 2,080 m. Total meiofauna abundance ranged from 790 to 5,120 individuals per 10 cm^2, total biomass from 0.09 to 0.97 mg dwt per 10 cm^2. Although 28 taxa were found, the meiofauna consisted mainly of nematodes (up to 97 %), followed by harpacticoid copepods, polychaetes and kinorhynchs. Length-frequency distributions of the nematodes were generally skewed to the left with most animals belonging to the 0.4-0.6 mm size-class. The widely accepted deeper-longer relation, known from vertical distribution studies of marine nematodes in the sediment, could be extended to most communities of the Antarctic waters off Kapp Norvegia. An attempt was made to estimate meiofauna production. Using two Production/Biomass ratios known from nematode production in temperate regions (e.g. P/B = 4 and 69), the annual production in the Weddell Sea varied between 0.47 and 12.96 $gC/m^2/y$. The validity of this method was discussed. The structure of the meiofauna community was positively correlated with grain size, organic matter and microbiota in the sediment. Total density and biomass showed different distributions along the sediment depth gradient. From multivariate analysis it was concluded the two regions in the Weddell Sea do not markedly differ. Depth and sediment grain size were the most important structuring factors.

The shallow subtidal study was carried out at Signy (60°42'S, 45°36'W). In this respect, meiobenthos was sampled fortnightly over a period of 18 months. The impact of the seasonal variation of different nutritive sources (e.g. chlorophyll, bacteria, organic matter) on the meiobenthic communities was followed. Total density ranged between 2,000 and 20,000 individuals per 10 cm^2 and showed a high seasonal variation. Biomass showed a similar, though less pronounced trend. The genus composition of the nematodes showed no seasonal influence yet, but further taxonomic investigation is necessary. A first attempt was made to follow respiration rates of the meiofauna in the sediments of Signy Island.

Although the deep-sea fauna has been studied very intensively, only little is known about meiofauna on the continental shelves and slopes. In this context the meiobenthic exploration of the deep sea surrounding Antarctica has been described for the first time. Densities and biomasses of Antarctic deep-sea meiofauna were shown to be comparable with values from the NE Atlantic.

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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:

A 1-D model of the water column with a k-1 turbulent closure has been applied to the study of interactions between sea-ice and ocean and their influence on planktonic communities. The sea-ice model is the one proposed by *Semtner (1976)*, but with a parameterization of leads. Special attention was paid to: (1) the sharing of energy between lateral and basal melting; (2) melting induces persistent shallow mixing layer thus favouring primary production; (3) the absence of ice nearly forbids blooming; (4) the modification of biological parameters (maximum production rate or I_k) can have important consequences on biomasses; and, (5) the lesser sensitiveness of results to initial conditions of zooplankton than of phytoplankton.

Planktonic data (HPLC pigments, zooplankton, krill) and samples obtained during ITALIANTARTIDE cruises were used to parametrize and calibrate a model of the secondary planktonic levels in the Ross Sea. A preliminary coupling between 1-D physical and a ecological model has been achieved which includes explicitly the effect of vertical turbulence on biological processes. Data on phytopigments and degradation products were used as tracers along the food chain. Pigments distribution was investigated in connection with: (i) distribution, structure and composition of meso-zooplankton communities; (ii) vertical repartition of trophic levels; and, (iii) krill patchiness.

Hydrodynamical data confirmed the importance of physical processes within the circumpolar marginal ice zone in regulating the Ross Sea pelagic food chain. In the Ross Sea, the ice free surface propagates from S to N. The wind and superficial circulation are responsible for the accumulation of algae containing ices in coastal area. The control of phytoplankton by herbivores in the mixed layer is characteristic of the Ross Sea: krill (Euphausia superba) outside the shelf, pelagic pteropods (Limacina helicina) in coastal ice edge or mesozooplanktonic copepods (Calanus propinquus) in the shelf ice-free zone. In the shelf area, omnivorous organisms below the pycnocline are heavily feeding on fecal pellets: amphipods in coastal zone and copepods (Metridia gerlachei) offshore. The diversity of pattern of planktonic vertical profiles seems due to constraints such as macroscale water masses distribution associated to frontal systems, ice coverage and vertical structuration of the water column, rather than to ecosystem diversity. The ice edge melting occurs sooner in the central and southern Ross Sea. Also, areas shallower than 500 m seems to be inaccessible to krill which strongly influences the utilisation of primary production. Finally, the W Ross Sea is richer in phytoplankton than the E one, probably because of the different ice algae content of the ice pack.

Nutrients, phytoplankton size-fractionated Chl.a, photosynthetic pigments (by HPLC) and primary production were studied during the 1991 austral summer in the Strait of Magellan in relation to meteorological and hydrodynamical constraints and runoff/land forcing. Chl.a, nutrients and primary production showed uneven but similar distributions, allowing the characterization of different sectors each showing distinct hydrographic typologies: an oligotrophic, wind-mixed coastal area, adjacent to the Pacific opening; a high runoff fjord and a divergence zone in the Andean sectors; a stratified inland sea in the basin-like part of the channel in the Patagonian sectors. Global features of the channel were the confinement of the microphytoplankton fraction to the external areas and the uniform structure of phytoplankton communities < 5 μm within the internal ones. Phytoplankton biomass (active Chl.a) was 10-51 mg/m^2 and primary production 275-1,170 mgC/m^2/d. Nitrates were never exhausted. The assemblage of plant pigments indicated that the high levels of phytoplankton pigments and production were attributable to Chlorophytes, Prasinophytes, Prymnesiophytes and/or Gyrodinium and Gymnodinium-like dinoflagellates that were submitted to superfluous feeding activity. When diatoms, Cryptomonads and Prymnesiophytes were dominant, efficient zooplankton grazing occurred and characterized a balanced food chain.

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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:

Biomass of auto- and heterotrophic microorganisms (nano- and net-sized phytoplankton; bacteria and 3 key taxons of nanoprotozooplankton) and their feeding activities (phytoplankton photosynthesis and growth; protozoan feeding on bacteria and autotrophic flagellates) were regularly measured during the early spring (29 Sept - 29 Nov '92) SO-JGOFS ANT X/6 polar expedition on board of the R/V Polarstern in the Atlantic sector of the Southern Ocean. In particular the technique of fluorescently labelled bacteria (FLA) and autotrophic flagellates (FLB) for measuring bactivorous and herbivorous nanoprotozoan grazing was successfully applied for the first time in the Southern Ocean.

Transects were repeatedly worked along the 6°W meridian, from the ice-covered Weddell Sea, across the Southern Antarctic Circumpolar Current (ACC) and into the Polar Frontal Zone. During that cruise, meteorological conditions were severe and no bloom of any significance was recorded in the vicinity of the ice-edge.

Maximum phytoplanktonic biomasses were recorded in the Polar Frontal zone. The analysis of the microbial network, as based on microscopic observations, revealed the occurrence of two different trophic webs with respect to the water masses: a diatom-mesozooplankton-dominant food-web in the Polar Front area; an active microbial food-web, composed of autotrophic flagellates, bacteria, and nanoprotozoa at the receding ice-edge. Budget calculations based on comparison of daily auto- and heterotrophic activities indicate, however, that the control of nanophytoplankton and bacteria development by nanoprotozooplankton was of little significance in early spring.

Theoretical considerations on the physical processes governing vertical stability of marginal ice zone surface layers on the one hand and mathematical simulations with the one-dimensional coupled physical-biological SWAMCO model of *Lancelot et al. (1993)*, forced by either the moderate or the extremely windy weather conditions experienced during the Polarstern marginal ice zone expeditions EPOS and ANT X/6 on the other hand, evidence, in accordance with observations, the tight coupling between atmospheric forcing - most notable in the frequency, duration and strength of storm events - and ice-edge phytoplankton bloom occurrence. In particular it is demonstrated that the windy meteorological conditions prevailing during the ANT X/6 expedition prevented blooms from developing. This implies that primary production associated to the circumpolar marginal ice zone of the Southern Ocean should be predicted to the same extent as weather can be predicted in these extreme latitudes provided the ice-covered area is known and biological controls evidenced in the studied sector hold for the whole circumpolar marginal ice zone.

References

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

OIL SPILL MODELLING FOR THE ANTARCTIC SEAS (OSMAS):

The danger of oil pollution in the Antarctic has been growing proportionally to human presence and activities, and to shipping in the area. The nature of the coastline, the presence of the ice pack and the sensitivity of the biological community explain the very high vulnerability of the Antarctic ecosystem to oil pollution. It seems thus necessary to develop adequate models able to predict the evolution of an oil slick in such an environment in order to assist in counter-pollution operations and in impact assessment studies.

This research work aims at developing a methodology for predicting the drift and spreading of oil spills in cold and ice-infested waters. We place emphasis on the physical behaviour, rather than the chemical fate of oil and try to adapt and link three models previously developed at MUMM (a circulation model, a sea ice model and an oil spill model in open seas) and empirical methods used to determine the spread of oil in ice-infested waters. The models mentioned above are shortly described. More emphasis is placed on the behaviour of oil on cold water and the physical interaction between oil and ice. The main influences of ice on oil behaviour are identified on basis of the (limited) available data.

This work is an important step before simulating the evolution of a spill at the sea surface, in the water column and in the ice, over a seasonal cycle, which is the goal of the present research.

A continuous formula proposed by Maykut to compute the ice albedo has been implemented in the SEAICE model.

The wind drift factor and the deflection angle used to compute the ice pack drift have been adopted according to the results of recent studies carried out in the Weddell Sea. These modifications have improved the agreement between the computed seasonal cycle of ice extent and the observations.

Tests have been carried out to incorporate the density effects in the 3D hydrodynamic model available at the beginning of this project. Problems, linked to the computation of the pressure gradient in sigma coordinates, have been encountered. Different techniques, recently proposed in the literature, have been investigated but none of them completely eliminate the error.

The spreading equation of the MUSLICK model *[Scory, 1991]* has been corrected to be applicable to cold water conditions. The equation is now able to reproduce the considerably reduced area of an oil slick on cold water. The strong influence of oil viscosity has been pointed out. The evolution equation has then been used to study the interaction between oil and ice. The previous study on the same topic *[El-Tahan et al., 1988]* used Fay's theory which considers that an oil slick evolutes according to three phases characterized by an equilibrium between forces acting on the oil slick (inertia/gravity, gravity/viscous and viscous/surface). Our spreading equation gathers all these forces and includes Fay's theory: the contribution of each force in the equation varies with time.

Finally, the parameters of the transport equation of the oil slick have been adapted to take into account the presence of ice.

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

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

The question of the stability of Antarctic ice shelves in the context of climate changes has been tackled in the literature mostly by developing models of oceanic circulation underneath ice shelves and of the relevant ice shelf-ocean interactions or by measuring various geophysical parameters on these ice masses. Another way of approaching the problem is to study the isotopic and chemical properties of the marine ice accreted at the base of some ice shelves in order to infer, in connection with a crystallographic study, the mechanisms responsible for its formation.

The Terra Nova Bay area offers an unique opportunity for sampling marine ice accreted at the bottom of small ice shelves. Because of tectonic disturbances and/or heavy ablation by katabatic winds, this marine ice outcrops in the downstream or in the lateral parts of some ice shelves and floating ice tongues. Two sites were studied in that area:

Campbell Glacier Tongue (north of Terra Nova Bay): Two types of marine ice formed near a grounding line have been distinguished on the basis of isotopic composition and textural properties of the ice and characteristics of the included debris. In both cases, the ice samples are aligned in a δD-$\delta^{18}O$ diagram on a mixing line. This does not necessarily imply a mixture of continental water and sea water in varying proportions.
In the first type, the isotopic characteristics are explained by the filling of basal fissures appearing close to the grounding line with marine ice. The change of state is probably due to the pressure dependence of the freezing point.
In the second type, the isotopic characteristics are explained by a variable contribution of continental meltwater versus sea water within a water-filled sediment at the glacier-ocean-rock contact. The freezing results in this case from the difference in freezing points between two waters of different salinities.

Late-Wisconsin ice-cored moraines in the coastal region exhibit features suggesting that this ice partially formed near a fossil grounding line in accordance with the processes studied.

Hells Gate Ice Shelf (south of Terra Nova Bay): Comparison of the textural, isotopic and chemical characteristics of frazil ice at the base of HGIS provides new insights in the dynamics of marine ice accretion under small ice shelves. Medium to coarse grained orbicular frazil accretes upstream in a relatively calm environment and eventually piles up as thick units in inverted channels or domes where the subglacial topography is favourable. As these frazil ice bodies or congelation ice, formed via heat conduction through the ice shelf, enter the zone of influence of warm oceanic waters, they are subjected to melting. This produces isotopically heavy waters that progressively dilute the interstitial sea water of the loose frazil, initiating chemical differentiation that is preserved in the frazil matrix. These diluted waters will converge in the highest parts of the inverted depressions, where they are further protected from mixing by mechanical convection.

Farther downstream, where the ice shelf is thinning under the effect on katabatic winds, the remaining ice will recrystallize resulting in the final crystal sizes and fabrics of medium and coarse grained solid frazil. In places where no channel or dome exists, or where those are already filled with frazil, the effect of interfacial streaming will increase where water currents exist. Individual frazil crystals will align more or less parallel to the ice/ocean interface showing strong c-axes fabrics with a single maximum. In places, non-laminar flow will create vortices that will be frozen-in later on. In this type of frazil the chemical sorting is "single-step" and total salinity is higher, though less than in typical congelation or frazil in fast ice. It is not clear yet whether the individual frazil ice crystals are generated by a double-diffusion process in a small scale diluted layer at the ice-sea water interface or as the result of supercooling in the rising watercolumn.

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

FORMATION OF THE TERRA NOVA BAY POLYNIA AND CLIMATIC IMPLICATIONS:

The 3-D Atmospheric Mesoscale Circulation Model (MAR) has been improved by including a more detailed this scheme for the representation of atmospheric turbulence. Sensitivity tests to this scheme have been performed and show that the katabatic wind speed is improved by 5 to 10%. This is not enough comparing with the observations and suggests that other processes not represented in the simulations have also to be tested [synoptic scale forcing, blowing snow process, see *Gallée and Schayes, 1994*]. Nevertheless the relative small sensitivity to the representation of turbulence indicates that these schemes are sufficiently realistic for simulating katabatic winds.

The atmospheric model has also been coupled to a wind-forced polynya model, generalized from that of *Ou [1988]*, by including drifts varying in space and time. The second horizontal dimension is also taken into account and the polynya model is discretized as MAR. Several assumptions generally done in the *Ou [1988]* model remain and are discussed here: (i) the sea-ice dynamics are not included, and the ice drift speed is that of the sea-ice edge; in the case of katabatic winds, which offshore extent is limited, this could lead to an overestimation of the ice drift speed and consequently of the polynya extent; another consequence of the non inclusion of sea-ice dynamics is that small leads are not allowed to form in the model; (ii) the accretion process is also poorly represented in the model; for the Terra Nova Bay area, a value of 22 cm has been chosen for the frazil collection thickness; however, this assumption does not seem to be critical, as it has been found in preliminary sensitivity experiments (not shown) to the value of the collection thickness; (iii) the oceanic current is not taken into account; this is a good approximation for the Terra Nova Bay area as far as the polynya extent is smaller that the length of the Drygalski Ice Tongue; a next generalization of the model should be to include the oceanic current in order to allow operational forecast for example; (iv) although the turbulent heat fluxes are well represented in the model, it is possible that secondary processes like evaporation from drops entrained in the atmosphere by the wind may be important; (v) the hydrological cycle is not switched on in the simulations presented in this paper; it is recognized that for air temperatures below -20°C, an ice fog forms as warm moist surface air mixes upward and cools; this could have an influence on the radiative transfer and consequently modify the polynya surface energy balance; further tests have to be performed with the model in order to examine this possibility.

Despite the above mentioned assumptions, the coupled atmosphere-polynya model allows to take into account in an interactive way the polynya impact on ocean-atmosphere-ice interactions in the antarctic coastal zone. Encouraging results are obtained: in particular the model seems to represent accurately the Terra Nova Bay polynya. The atmospheric model simulates realistic katabatic winds over the polynya, simulated winds are probably in closer agreement with the observations than over the ice sheet. It is the first time that a meso-τ scale atmospheric model is coupled to a wind-forced polynya model. The Terra Nova Bay polynya is well represented by this model and constitutes an important component in the ocean-atmosphere-ice interactions in Terra Nova. It was also found that the atmospheric circulation in Terra Nova Bay is significantly influenced by the presence of an open (warm) water area. A breeze effect results and increases the katabatic wind speed when it passes the coastline. On the contrary, the breeze effect which is also present at the downwind edge of the polynya acts in the opposite way there and the katabatic wind is stopped.

Because of the strong mesoscale heat fluxes generated by the Terra Nova Bay polynya, its climatic impact could be important. Despite this fact, the size of this polynya is not large enough to be represented into a GCM. For this reason its

effects could be parameterized and the parameterization may be developed using a coupled atmosphere-polynya model. Other possible applications of the coupled atmosphere-polynya model are numerous. It has been found that the model is not only able to simulate the Terra Nova Bay polynya but other observed polynyas like that existing along the north-western part of the Ross Ice Shelf. An application should be to evaluate with the model the formation of wind forced polynyas everywhere along the antarctic coast. Moreover, such model could be of considerable interest to operational meteorologists. Indeed, polynyas forecasting is important for the navigation. Polynyas are strongly dependant of the wind field and in turn influences local weather [e.g. *Anderson, 1993*].

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

DYNAMICS OF THE ANTARCTIC ICE CAP AND CLIMATE CHANGES:

New insights into the glacial and paleo-climatologic history of the East Antarctic Ice Sheet underscore the importance of an interdisciplinary approach towards a more profound understanding of the paleo environment which, from the ice sheet modellers side, require an effort in detailed regional modelling of the dynamics of the East Antarctic Ice Sheet. Therefore, research efforts were focused on (i) an improved numerical computation and a refined analysis of the dynamic ice flow, with respect to a more detailed modelling, and (ii) the simulation of the behaviour of drainage basins in East Dronning Maud and Enderby Land in accordance with the climatic signal in the past.

Two ice flow models were developed, each with a different computational scheme: (i) a three-dimensional ice flow model based on a finite element scheme and (ii) an ice sheet - ice shelf flow line model based on a finite difference scheme with irregular grid-size spacing. Both schemes are able to cope with the inhomogeneous data distribution on Antarctica and therefore allow a more detailed computation in areas of particular interest (outlet glaciers, ice streams, grounding zones of ice shelves).

Furthermore, detailed ice flow modelling requires that the proper ice dynamics and physics are included in order to deal with the behaviour of the central ice sheet, outlet glaciers as well as ice streams. Therefore, in the flow line model, basal drag, basal sliding and longitudinal stresses were incorporated, the latter not only at the grounding line, but in the ice sheet as well. Also a full thermo-mechanical coupling in the ice sheet was established, taking into account the two-dimensional temperature calculation and heat conduction in the bedrock.

The Sør Rondane Mountain glacier Gjelbreen was used as a reference experiment in modelling the last glacial-interglacial cycle (by imposing the Vostok temperature signal), in order to calculate the present local imbalance of the ice sheet. The results were compared and discussed in accordance to recent geomorphologic and glacio-geologic findings in the Sør Rondane area and the Transantarctic Mountains. Experiments in other drainage areas (such as Shirase Drainage Basin) are on their way.

Finally, a method was developed to retrieve glacier surface velocities from sequential satellite images, using an automatic matching procedure. In the near future, this method will be applied on images of the central S¢r Rondane glaciers.

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

BELGIAN CONTRIBUTION TO ANTOSTRAT PROJECT (BELANTOSTRAT):

During the 1st term of the 3rd Phase of the Belgian Antarctic Research Programme, RCMG's research activities were strongly focused on the application of high-resolution reflection seismic stratigraphy to the study of Cenozoic medium- to long-term glacial/interglacial cycles along different continental margins of Antarctica. Three study areas were investigated in these terms so far:

* ODP Site 693 off Cape Norvegia in the northeastern Weddell Sea, using the seismic data acquired during the ANT V/4 (1986-1987) and ANT VIII/5 (1989-1990) surveys;

* Crary Fan, one of the world's biggest submarine fans occupying a large part of the eastern and southeastern Weddell Sea, using seismic data acquired during the ANT V/4 (1986-1987), ANT VIII/5 (1989-1990) and ANT X/2 (1992) surveys;

* Bransfield Basin along the Antarctic Peninsula, using the seismic data acquired during the GEBRA-93 (1993) survey.

ODP Site 693: Re-examination of the seismic records in the vicinity of ODP Site 693 have allowed a number of fine-scale unconformities to be identified in addition to those previously defined. They all occur within seemingly lithologically homogeneous Pliocene strata. The unconformities coincide with stratigraphic horizons characterized by spikes in smectite percentage in an overall illite-dominant lithology. Smectite spikes probably indicate a change in sediment source from the Antarctic continent where glacial activity produced illite in response to direct rock erosion, to the continental shelf where previously hydrolysed Cretaceous and Tertiary sediments were exposed. Eroded detritus could have been transported to the shelf edge by ice sheets. Melt water debouching from the ice-sheet grounding line may have initiated mass flow through Wegener Canyon on the mid-slope bench. The smectite horizons at ODP Site 693 would represent overbank deposition.

Crary Fan: Seismic profiles on the Weddell Sea basin floor reveal the existence of thick and extensive chaotic facies units, which are interpreted as debris flows. They fill the base of erosional channels within Crary Fan at five stratigraphic horizons, and are overlain by acoustically stratified fan lobes and channel/levees. The debris flows are probably sourced from sedimentary material collapsed from large, shelf-edge deltas on the upper slope. These large, upper-slope deltas were deposited by ice sheet during extended glacial periods, which is probably a pre-condition to large-scale slope collapse. Slope deltas were composed of glacial and glacial-marine detritus. Mobilization of glacial debris from the upper slope to the basin could be initiated after ice-sheet retreat during isostatic rebound of the continental shelf. Hereby, it is inferred that at least five long-term glacial expansions occurred in the Weddell Sea region since the Middle Miocene. Shorter duration glacial periods probably did not create a sufficiently unstable upper slope, hence, not all stratigraphic sub-divisions in Crary Fan are associated with major debris flows.

Bransfield Basin: New high-resolution reflection seismic data acquired during the GEBRA-93 survey have shown the presence of glacial unconformities on the Trinity Peninsula margin of Bransfield Basin, indicating that at least six major glacial periods occurred since the Pliocene. Magnitude of slope progradation varies along the margin and appears to be related to local sources of sediment supply associated with separate glacial troughs: a thick stack of prograding units is preserved at the mouth of Orleans Trough, whereas most of the correlative section has been removed by repeated canyon incision at the GEBRA Channel, located at the mouth of the Antarctic Sound. Sediment eroded from the canyons is probably an important contributor to basin-floor sedimentation. Development of basin-floor strata appears to be temporally distinct from the development of slope foresets which downlap the basinal strata.

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3 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 opportunity to develop or strengthen 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 (austral summers 1993-94 and 1994-95):

Sixteen scientists of the Programme participated in expeditions to the Antarctic organized by France, Germany, Italy, Spain and United Kingdom (Table I, page 16).

Planned field activities (austral summer 1995-96):

Seven scientists of the Programme will participate in an expedition to the Southern Ocean organized by France, Germany, Italy and New Zealand (Table II, page 17).

*

TABLE I : **RECORDED FIELD ACTIVITIES (AUSTRAL SUMMERS 1993-94 AND 1994-95)**

LOCATION	PERIOD	DOMAIN (PROJECT Nr)	PARTICIPANT	EXPEDITION	HOST COUNTRY
Terra Nova Bay area	Oct. 93 - Jan. 94	Glaciology (A3/11/002)	Dr J.-L. Tison	Italiantartide IX	Italy
Bransfield Strait, South Shetland Islands	Nov. 93 - Dec. 93	Marine Geophysics (A3/02/002)	Mr Ph. Bart Dr M. De Batist 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 Dr L. Goeyens Mr M. Semeneh	ANTARES 2 M/V Marion Dufresne	France
		Marine Ecology (A3/11/001)	Dr Ch. Lancelot Ms P. Menon		
Amundsen Sea, Bellingshausen Sea	Jan. 94 - Mar. 94	Marine Geophysics (A3/02/002)	Eng. E. Maes Eng. K. Vanneste	ANT XI/3 R/V Polarstern	Germany
South Orkney Islands	Jan. 94 - Apr. 94	Marine Ecology (A3/02/001)	Ms M. Beghyn Ms S. Vanhove	Signy base	UK
Ross Sea	Oct. 94 - Jan. 95	Marine Ecology (A3/12/001)	Dr A. Goffart Dr J.-H. Hecq Ms C. Veeschkens	Italiantartide - ROSSMIZE	Italy

TABLE II : **PLANNED FIELD ACTIVITIES (AUSTRAL SUMMER 1995-1996)**

LOCATION	PERIOD	DOMAIN (PROJECT Nr)	PARTICIPANT	EXPEDITION	HOST COUNTRY
Indian sector of the Southern Ocean	Sep. 95 - Dec. 95	Marine Ecology (A3/11/001)	Dr Ch. Lancelot Ms J. Piraux	ANTARES 3	France
		Marine Biogeochemistry (A3/03/001)	Dr L. Goeyens		
Terra Nova Bay area	Oct. 95 - Feb. 96	Glaciology (A3/11/002)	Dr J.-L. Tison	Italiantartide XI	Italy
Dry Valleys South Victoria Land	Dec. 95 - Feb. 96	Glaciology (A3/11/002)	Prof. R. Lorrain	NZAP expedition 95-96	New Zealand
South-eastern Weddell Sea	Jan. 96 - Mar. 96	Marine Ecology (A3/02/001)	Ms M. Beghyn Ms S. Vanhove	CS-EAZIZ R/V Polarstern	Germany

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6 ABBREVIATIONS AND ACRONYMS

ACC	Antarctic Circumpolar Current
ANTOSTRAT	Antarctic Offshore Acoustic Stratigraphy Project
BELANTOSTRAT	Belgian contribution to ANTOSTRAT
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
HPLC	High Performance Liquid Chromatography
JGOFS	Joint Global Ocean Flux Study
MUMM	Management Unit North Sea and Scheldt Estuary Mathematical Model
ODP	Ocean Drilling Program
OSMAS	Oil Spill Modelling for the Antarctic Seas
OSTC	Federal Office for Scientific, Technical and Cultural Affairs
RCMG	Renard Centre of Marine Geology, Gent
ROSSMIZE	Ross Sea Marginal Ice Zone Ecology
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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