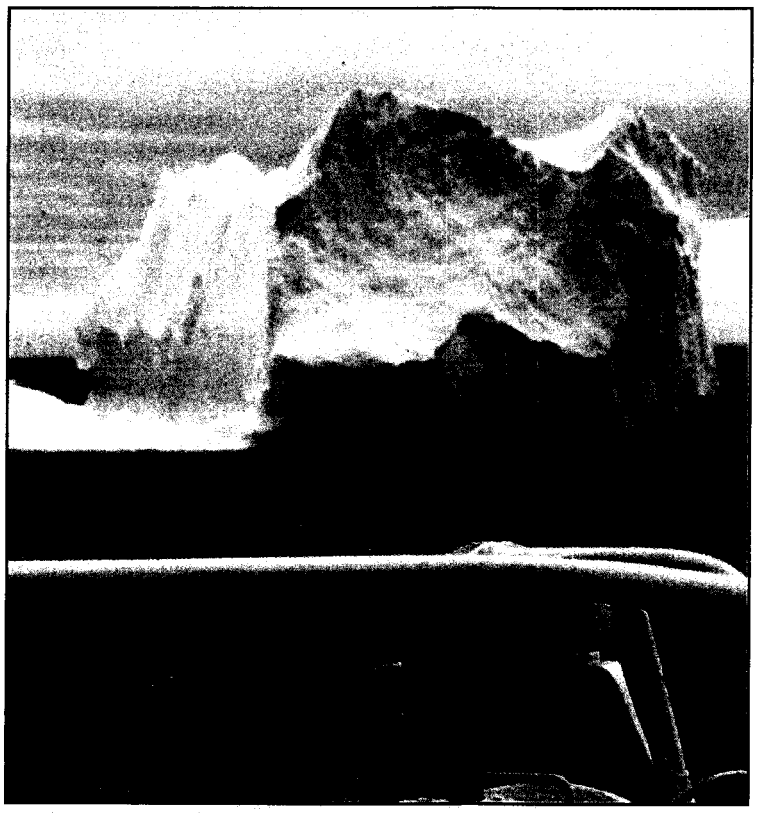
# SCIENTIFIC RESEARCH PROGRAMME ON THE ANTARCTIC

## *PHASE III*

## **SYNOPSIS**



**BELGIAN SCIENCE POLICY OFFICE**

# BELGIAN SCIENTIFIC RESEARCH PROGRAMME ON THE ANTARCTIC

## *PHASE III*

# SYNOPSIS


PRIME MINISTER'S SERVICES
**BELGIAN SCIENCE POLICY OFFICE**

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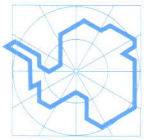
FEBRUARY 1994



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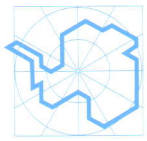


# INTRODUCTION

The Washington Treaty on the Antarctic establishes an international regime aimed at ensuring the peaceful use of this region. Its principles are demilitarization, the prohibition of nuclear tests or storage of radioactive waste and the promotion of scientific research within a framework of international cooperation. Scientific research has a central place in this objective. Apart from its integrating role, it also provides the terms of reference for the policy of rational management of the Antarctic pursued by the Antarctic Treaty System with a view to protection of the environment.

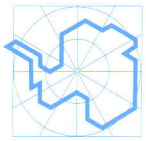
Through the scientific activities that it had already to its credit at that time, Belgium was able to contribute to the conclusion of the Antarctic Treaty in 1959. It was thus automatically granted the status providing it with decision-making powers.

As a founder member of the Treaty, Belgium aims at contributing towards the active and continuous development of scientific knowledge of the area covered by this Treaty.

Consequently, a first phase of the Scientific Research Programme on the Antarctic was launched by Cabinet decision of July 29th 1985 with a view to giving tangible form to Belgium's desire to play an active part in this research field. With a total budget of 91.6 million BF allocated to it, this first phase allowed the implementation, over a period stretching from October 1985 to January 1989, of ten research projects in four fields (Plankton Ecology, Marine Geochemistry, Marine Geophysics, Glaciology & Climatology).

In the light of the results of this first phase and the growing renewal of international interest in matters concerning the Antarctic, the Cabinet decided to implement a second phase of the Programme on August 2nd 1988. This second phase was designed along similar lines to the first, so as to ensure continuity of the research and optimal utilization of the results obtained, on the one hand, and to strengthen the international cooperation network developed during the first phase, on the other. A total budget of 96 million BF was allocated to this second phase. The research commenced at the beginning of October 1988 and was completed in May 1992.

At its meeting on June 25th 1992, the Cabinet decided to launch a third phase of the Programme essentially aimed at maintaining a level of scientific activity allowing Belgium to continue to shoulder its responsibilities as a founder member of the Antarctic Treaty.



# MOTIVATIONS - OBJECTIVES - IMPLEMENTATION

The research effort deployed by Belgium between 1985 and 1992 was in keeping with its desire to contribute, with a limited budget but in a tangible manner, towards the international development of this field of research :

- it produced a coherent body of knowledge corresponding to recent scientific issues concerning the Antarctic;
- it stimulated an integrated multidisciplinary approach;
- it developed an advanced scientific potential which has been consolidated within the international scientific community;
- it favoured the insertion of teams of Belgian researchers in international cooperation networks;
- it applied methods and concepts that have contributed towards advances in studies of more direct interest to the country and towards stepping up the operational capacity of certain teams.

Whilst retaining its traditional function as a counterpart to the exercise of decision-making powers, scientific research has taken on a new dimension within the Antarctic Treaty System over the last few years :

- it is now being called upon more than ever to reinforce the consensus within the Antarctic Treaty System;
- it is becoming an essential instrument in implementing a credible policy for the global protection of the Antarctic;
- it is helping to open up the Treaty to major societal problems of the moment, such as the evolution of the global climate.

A scientific potential has developed in Belgium which is the result of joint efforts by the State and by Belgian researchers. This investment is opening up development prospects with a multiplier effect. In fact, it is placing Belgium in a position to contribute towards a pertinent response to the scientific problems addressed by the Antarctic Treaty System.

These considerations led the Cabinet, at its meeting on June 25th 1992, to approve the implementation of a third phase of the Programme (1992-95) with a total budget of 126 million BF, for which the main objectives were formulated as follows :

- to demonstrate Belgium's willingness to participate in the international research effort on the Antarctic in accordance with the issues set out by the Antarctic Treaty System;

- to contribute towards the development of scientific terms of reference for the protection of the Antarctic and the rational management of its marine living resources and for the assessment of interactions between the Antarctic and the climate;

- to exploit the scientific achievements and potential developed so far.

A call for research proposals was issued on July 31st 1991 among all Belgian institutions likely to be in a position to present projects. The scientific assessment of these proposals was carried out by foreign experts in accordance with the "peer review" method.

Management, coordination and development of the Programme are in the hands of the Science Policy Office, at both administrative and scientific level. Scientific liaison with the Antarctic Treaty System is also the responsibility of the SPO.

An "Antarctic Support Committee", with advisory status, is empowered to formulate opinions on the progress made during the third phase of the Programme and to put forward any suggestions on the measures that it considers should be taken to attain the objectives of the Programme. Its composition is as follows: Foreign Affairs, Agriculture, Public Health and the Environment, Science Policy, French Community, Flemish Executive, Brussels-Capital Region and Walloon Region. The Committee is chaired by the Secretary-General of the SPO.

Prior consultations were held with the Communities and Regions to determine the different stages in the implementation of the third phase.

# FIELDS OF RESEARCH

The Antarctic is the only region in the world to have survived with virtually its original integrity. It is, however, an established fact that the Antarctic and its associated ecosystems are vulnerable to the adverse effects that can be produced by human activities. The Antarctic Treaty System is unambiguous about the need for the protection of the Antarctic and the rational management of its living resources, on scientific bases.

In the Southern Ocean, primary production develops in abundance only within strict limits of time and space. It is largely dependent on hydrodynamic, meteorological and biochemical interactions specific to the global dynamics of the area of seasonal extension and retreat of the sea ice. The active primary production of the complex trophic networks often results in a reduction in the food available for the higher organisms. Many of these organisms have adopted a food strategy favouring growth and longevity to the detriment of reproduction. The latter is often synchronized in accordance with the ephemeral nature of these food supplies. Consequently, everything points to a reduced capacity on the part of the ecosystem to absorb disturbances without any damage, especially if they coincide with critical stages in biological development. Although limited (600 $m^3$ of light hydrocarbons), the oil slick caused in 1989 by the grounding of the "Bahía Paraíso" is a good illustration of this. The first impact studies demonstrated the annihilation of reproduction of "skua" type birds that year, the direct cause of which was not hydrocarbons, however. The large-scale mortality among their chicks was due to an abnormally high level of predation resulting from reduced vigilance on the part of parents disturbed by the oil slick. In this connection, the repercussions of an oil slick can be considerable in the Antarctic and it is essential at this stage to try to develop models capable of simulating the dispersion of oil spills in polar conditions. Understanding the mechanisms and the fate of primary production is therefore a prerequisite for any attempt to introduce effective measures to protect the ecosystems of the Southern Ocean. Mathematical modelling linking up the biological and physical phenomena allows one to highlight the key factors in the dynamics of marine ecosystems and to simulate their evolution.

Furthermore, the Southern Ocean is likely to contribute, to an unknown but probably significant extent, to the burial of atmospheric $CO_2$, a process capable of negative feedback on the greenhouse effect. The photosynthesized organic matter is quickly remineralized in the surface waters by bacteria and zooplankton, thus replenishing the reservoir of nutrients used by the phytoplankton. This "regenerated production" does not, therefore, determine the capacity of oceans to fix the atmospheric $CO_2$. Only "new production" is involved, formed from nutrients imported into the surface waters by advection.

The Antarctic plays a decisive role in regulating the global climate. It acts as an enormous heat pump supplied by atmospheric and oceanic circulation. The sea ice plays a role in this process by modifying the albedo and reducing the amounts of momentum, heat and water vapour transferred. The dynamic response of the Antarctic ice cap to climatic variations must be defined in detail, taking more realistic account of phenomena such as interactions with the bedrock and overall balances (improving their parameterization or modelling their dynamics). The dynamics of drainage glaciers can provide these models with greater accuracy. It is also necessary to try to identify the causal relations between climatic, eustatic and cryospheric changes, and new predictive scenarios should be established on the basis of simulations.

The melting and freezing occurring at the base of the ice shelves control their stability and thus play a role in sea level variations. Isotopic, chemical and crystallographical analyses of this ice make it possible to reconstitute the oceanographic conditions of ice shelf formation. This ice can also provide valuable palaeoclimatic information in a relatively unexplored period of time. But these palaeoclimatic signals cannot yet be exploited given our inability to interpret them isotopically.

To assess any possible anthropic climatic change we need to know the evolution of the (referential) past climate. Studying the variations in sedimentation regimes through geological unconformities or alternations of stratigraphic facies makes it possible to reconstitute the conditions of the past global environment. Indications can be obtained, for example, on the alternations of glacial regimes or on the extension of the continental ice. Peri-Antarctic sedimentary basins are rich in such palaeo-signals, to which access with the necessary resolution and on the requisite scale can be gained only by geophysical methods.

In accordance with its objectives, the third phase of the programme has been given a technical content oriented towards the scientific problems set out above. The nine projects selected are based on coordinated multidisciplinary research targeting precise themes. They cover seven research themes in three fields (the same project can concern several themes) :

**Ecodynamics of the Southern Ocean and interactions with the climate :**

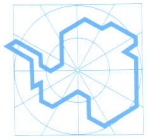
- Biogeochemical fluxes and cycles in the main trophic compartments.
- Development of tools to model the global dynamics of the ecosystems of the Southern Ocean.
- Assessment of the role of "new production" in the burial of atmospheric $CO_2$ by the Southern Ocean (negative feedback on the greenhouse effect).

**Evolution and protection of marine ecosystems :**

- Application of ecosystem models to simulation of the response to climatic disturbances connected with human activities.
- Study of the dispersion of hydrocarbon spills.

**Role of the Antarctic in global changes :**

- Ocean-Cryosphere-Atmosphere interactions.
- Sedimentary palaeoenvironment.



# LIST OF PROJECTS

| PROJECT | PROMOTER | TITEL | FIELDS | | |
|---|---|---|---|---|---|
| | | | MARINE ECODYNAMICS AND CLIMATIC INTERACTIONS | EVOLUTION AND PROTECTION OF MARINE ECOSYSTEMS | ROLE OF THE ANTARCTIC IN GLOBAL CHANGES |
| A3/03/001 | F. DEHAIRS (VUB) | Spatial and seasonal variability of the transport of biogenic compounds in the Southern Ocean | ••• | | |
| A3/02/001 | A. COOMANS, M. VINCX (UG) | Role of the meiobenthos in Antarctic ecosystems | ••• | | |
| A3/12/001 | J.-H. HECQ (ULg) | Control of the Antarctic pelagic ecosystem by higher trophic levels in relation to variations in environmental conditions | •• | • | |
| A3/11/001 | Ch. LANCELOT (ULB) | Ecological modelling of the planktonic microbial food web | •• | • | |
| A3/58/001 | G. PICHOT (MUMM) | Oil spill modelling for the Antarctic seas (OSMAS) | | ••• | |
| A3/11/002 | R. SOUCHEZ (ULB) | Isotopic and chemical composition of Antarctic shelf ice: implications for global changes | | | ••• |
| A3/10/001 | A. BERGER (UCL) | Formation of the Terra Nova Bay polynya and climatic implications | | | ••• |
| A3/03/002 | H. DECLEIR (VUB) | Dynamics of the Antarctic ice cap and climatic changes | | | ••• |
| A3/02/002 | M. DE BATIST (UG) | Belgian contribution to the "Antarctic Offshore Acoustic Stratigraphy Project" (BELANTOSTRAT) | | | ••• |

# PROJECT Nr A3/03/001

## PROMOTER

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## TITLE

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

## THEME

*It is becoming increasingly clear that the Antarctic plays a decisive role in the problem of "global change" through substantial interactions between atmosphere, ice, ocean and biota. The biological transformation of carbon dioxide into particulate biogenic matter is an important process in this respect.*

*Within this context, the present study is aimed at determining the origin, evolution and fate of particulate biogenic matter in the Southern Ocean. Special attention will be given to the nitrogen system in the upper layers of the water column and to the relationship with the flux of production towards the deep layers.*

## OBJECTIVES

The problems examined in this study primarily concern two topics :

- the factors determining the regime of nitrogen assimilation by the phytoplankton in the upper layers of the water column;

- the link between this regime and the production exportation flux.

Seasonal variations in nitrogen assimilation are determined according to the profile of nutrients in the water masses and the rates of assimilation of the different nitrogen compounds. The nitrogen assimilation regime is expressed in terms of variations in the "fratio" (measurement of the relative contribution to nitrate assimilation in primary production) and the RPI. At the same time, plankton composition and trophic transfers are

# PROJECT Nr A3/02/001

## PROMOTER

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## TITLE

## ROLE OF THE MEIOBENTHOS IN ANTARCTIC ECOSYSTEMS

## THEME

*Determination of the role of the meiobenthos in Antarctic ecosystems 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 the 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 balance at the water column-sediment interface and determination of the importance of meiofauna in this balance;*

- *food experiments (nematodes-bacteria grazing and importance of diatoms as a food for meiofauna in the littoral regions).*

## OBJECTIVES

Study of the biomass balance (POC/DOC) at the sediment-water interface in Antarctic sea floor ecosystems and study of energy fluxes through meiobenthic communities (numerically, the meiobenthos is the main group of metazoons in the sea floor ecosystem which occupies several trophic levels and has a very intensive bioturbation activity), with a view to assessing the role of the meiobenthos in, inter alia, remineralization processes.
The following problems will be examined within the framework of this research :

- What is the influence of primary production in the water column on benthic activity (in the bioturbation zone)?

- What quantity of organic C is stored in the bottom layer below the bioturbation zone?

- What quantity of organic material is reintroduced into the water column as a result of benthic activity?

Within the framework of this research, the accent will be placed above all, in so far as flux aspects are concerned, on the activities of nematodes, which represent 90-95% of meiobenthos densities. The total biomass of the benthos will be calculated partly from specific measurements (meiobenthos) and partly in conjunction with data from other research teams (macrobenthos: BAS; microbenthos : NIOZ). It has been clearly demonstrated in temperate regions that there is a direct and positive relationship between the quantity of organic matter in the water column and the sea bed biomass. The role played by the benthos in remineralization processes is deduced in particular from the fact that it has been demonstrated that meiobenthic organisms (and nematodes especially) can have a strong positive influence on the production of bacteria in the sediments, thus having a direct influence on the biogeochemistry of the sea floor. Determining the order of magnitude of the interactions mentioned is one of the primary objectives of this research.

## TASKS

**1** Determination of meiobenthos production from size/biomass spectra (Weddell Sea; EPOS Leg 3). For nematodes, accurate direct determinations will be achieved through known regression comparisons between the biomass of the populations, the temperature, the relative composition of species and the proportion of adult females in the population. For the other meiobenthic groups, approximate calculations on the basis of the P/B ratios will allow production estimates to be made.

**2** Determination of the seasonal nature of secondary production of meiobenthos by determining the densities and the biomass of the total meiofauna and the composition of the species of nematodes from samples taken every fifteen days during the summer/autumn period on the Signy Island.

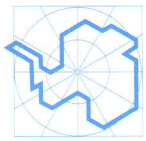
**3** Flux of organic matter through the benthic systems (e.g. grazing experiments around the BAS base on the Signy Island).

**4** Determination of the in situ respiration of the meiobenthos (Signy Island) using the "bell jar" method.

**5** Determination of the individual respiration of dominant meiobenthic species (using the thermal activity monitor on BAS material that can be examined in culture rooms in Ghent). Laboratory measurements of the individual respiration of specific but dominant meiobenthos groups in conjunction with in situ density data will allow an accurate estimate of respiration of the meiobenthos in the environment.

**6** Quantitative and qualitative determination of the amount of organic matter (POC + DOC) and nutrients in the sediments, in relation to the distribution of the meiobenthos in these sediments, and determination of the contribution of the meiobenthos to the remineralization processes (Signy Island) (correlations to be determined in vertical profiles between biotic and abiotic variables).

**7** Interpretation of data in accordance with the determination of the biomass balance between the three "habitats", namely (i) water column, (ii) sediment-water interface and (iii) interstitial water, as appropriate. The role played by the meiobenthos in maintaining these biomass balances will be interpreted by comparing regions with different meiofaunal biomasses.



# PROJECT Nr A3/12/001

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## TITLE

# CONTROL OF THE ANTARCTIC PELAGIC ECOSYSTEM BY HIGHER TROPHIC LEVELS IN RELATION TO VARIATIONS IN ENVIRONMENTAL CONDITIONS

## THEME

*Modelling of the control of the pelagic ecosystem by the higher trophic levels in the marginal ice zone and application of the model to simulation of the effects of potential anthropic disturbances.*

## OBJECTIVES

- Determination of the interaction mechanisms between, on the one hand, the dynamics of the secondary planktonic trophic levels and, on the other hand, the dynamics of the lower and higher planktonic trophic levels, in accordance with the main environmental variables.

- Modelling of the functioning of the pelagic ecosystem based on these interaction mechanisms.

- Application of the model to simulation of the evolution of the pelagic ecosystem as a reaction to external constraints of climatic or anthropic origin.

A series of phenomena characteristic of the dynamics of the Southern Ocean's marine ecosystem are taken into consideration in pursuance of these objectives :

- The stabilization of the surface layers of the water column, which appears seasonally through the combined action of hydrodynamic and meteorological factors, stimulates primary production in the marginal area of the circumpolar ice by providing phytoplankton with optimum development conditions. Apart from its hydrographic

stabilization action, the seasonal melting of the sea ice also releases algae populations from which the development of phytoplankton begins in the water column (seeding process).

The primary production generated in this way, which is vertically structured, is gradually consumed by the higher trophic levels and thus contributes towards the determination of their spatial distribution. The process appears to be continuous and depends on how the sea ice retreats.

- Given their abundance in the Ross Sea in spring, herbivorous copepods and krill put strong grazing pressure on the diatoms and control their biomass. The quantities of ammonia excreted by these organisms stimulates the productivity of smaller phytoplanktonic forms which develop in summer.

- Depending on its specific composition, the zooplankton directs the organic matter of phytoplanktonic origin both towards different trophic compartments and towards different masses of water. Furthermore, depending on its specific migratory behaviour, the zooplankton recycles the organic matter in the euphotic area or in the deeper layers.

The measurements made during oceanographic campaigns are aimed at parameterizing, calibrating and validating the numerical model simulating phytoplankton/zooplankton interactions along the water column. The strategy of these campaigns will be oriented towards long-term stations characteristic of a given temporal state.

## TASKS

**1** CONTROL OF THE VERTICAL DISTRIBUTION OF PLANKTON AND ITS ACTIVITY DUE TO THE PHYSICAL STRUCTURE OF THE WATER COLUMN, AS A FUNCTION OF THE SEASONAL MELTING AND RETREAT OF THE ICE (ANALYSIS AND MODELLING) :

1.1 Acquisition of temporal series on incident light, wind and temperature of the surface sea water.

1.2 Determination of the cloud cover and the extension of the ice (satellite imagery).

1.3 Determination of the vertical structure of the water column from temperature and salinity data (calculation of densities) and nutrients (nitrates, nitrites, ammonia and silica).

1.4 Determination of the structure of the ecosystem from measurements of :

- standing stocks;
- spatial and temporal variations in the biomass;
- the trophic position of the planktonic components;
- the organization in the food web and the turnover of planktonic components.

1.5 Assessment of the role of sea ice in the structure of zooplanktonic communities.

1.6 Parameterization of the physical constraints and processes considered under 1.1 to 1.5 above.

1.7 Discretization of the model to partial derivatives over the first 200 metres of the water column (taking account of the sudden turbulence gradients, the strong phytoplanktonic biomasses and the accumulation of zooplankton under the mixed layer).

**2** CONTROL OF THE EXPORTATION OF PRIMARY PRODUCTION THROUGH ZOOPLANKTONIC GRAZING (ANALYSIS AND MODELLING) :

2.1 Determination of zooplanktonic grazing by measuring the ingestion and turnover time of specific phytoplanktonic pigments in the main micro-, meso- and macro-zooplanktonic groups.

2.2 Determination of the levels of ammonium excretion by these main zooplanktonic groups (colorimetry by autoanalyzer) and testing of the influence of these concentrations on phytoplanktonic production.

**3** REDISTRIBUTION OF ORGANIC MATTER OF PHYTOPLANKTONIC ORIGIN ACCORDING TO THE ZOOPLANKTONIC COMPOSITION (ANALYSIS AND MODELLING) :

3.1 Stratification and vertical migrations of the main micro-, meso- and macro-zooplanktonic groups.

3.2 Specific content and vertical distribution of fecal pellets; sedimentation rate.

3.3 Predation pressure from higher trophic levels.

**4** SIMULATION OF THE RESPONSE OF SECONDARY TROPHIC LEVELS IN THE VARIOUS AREAS OF THE SOUTHERN OCEAN TO POSSIBLE CLIMATIC OR ANTHROPIC FORCING :

4.1 Horizontal integration of the 1D model with a view to taking account of the heterogeneity conditions of the Ross Sea (semi-enclosed sea, gradual melting and retreat of ice, frontal systems, anticyclonic circulation) and the large-scale spatial distribution of the higher trophic levels.

4.2 Readjustment of biological equations in accordance with the data from campaigns.

4.3 Coupling with large-scale biological processes (migration, higher trophic levels, etc.).

4.4 Testing the influence of typical scenarios (increases in temperature, climatic changes, predation by man, etc.).

# PROJECT Nr A3/11/001

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## TITLE

## ECOLOGICAL MODELLING OF THE PLANKTONIC MICROBIAL FOOD WEB

## THEME

*Study on the dynamics of the planktonic microbial food web of the Southern Ocean in response to changing environmental conditions.*

## OBJECTIVES

To develop a predictive mathematical model of the functioning of the microbial ecosystem in the Southern Ocean in response to anticipated global climatic changes or local anthropic disturbances.

The purpose of the model is to describe the cycles of carbon, nitrogen and silicon through the microbial food web of the surface waters of the Antarctic Ocean (that part of the Southern Ocean limited by the polar front) throughout the seasonal cycle. It is designed from the coupling of a 1D hydrodynamic model - which calculates the depth of the mixed layer of the water column from meteorological data - with a biological model of the dynamics of the first trophic levels - which incorporates different models representing the behaviour of phytoplankton, heterotrophic bacteria and herbivorous macro-invertebrates.

In particular, construction of this model requires a more detailed knowledge of the physiology of "netplanktonic" diatoms (> 20 µm) and nanoplanktonic algae (< 20 µm), on the one hand, and factors controlling the grazing of protozoans on phytoplankton and bacterioplankton, on the other.

## TASKS

**1** STUDY OF PROCESSES:

1.1 Experimental field studies :

1.1.1 Photosynthesis and growth of "netplanktonic" diatoms and nanoplanktonic algae. The physiological parameters characterizing the photosynthesis and growth of phytoplanktonic communities dominated by "netplanktonic" diatoms will be determined by a method combining $^{14}C$ marking technique and biochemistry.

1.1.2 Assimilation of inorganic nitrogen by "netplanktonic" diatoms and nanoplanktonic algae and preferences for ammonia or nitrates. The question of the selective assimilation of nitrates and ammonia associated with the growth of the different populations of phytoplankton will be studied in collaboration with the team led by Dr F. Dehairs (VUB).

1.1.3 Ingestion by protozoans of nanoplanktonic algae and bacteria. The method developed by Sherr et al. (1987, 1991), based on the use of prey marked with a fluorochrome (FLB or FLA) will be adopted to the study on microbial ingestion in the food web. Techniques of epifluorescence microscopy and flux cytofluorimetry will be used in this connection.

1.1.4 Regeneration of nitrogen by microheterotrophs. Determination of the relative parts played by bacteria and protozoans in the regeneration of ammonia, in collaboration with the team led by Dr F. Dehairs (VUB).

1.2 Collection of published data :

1.2.1 Fate of the microbial communities in the ice at the time when the ice melts. A comparison of the existing data on the microbial communities living in the sea ice and the adjacent water at the time when the ice melts, combined with data on the wintering krill populations, will provide indications as to the fate of ice algae (inoculum of the water column, ingestion by krill, sedimentation).

1.2.2 Geographical and seasonal distribution of krill swarms. The existing data on the size of krill swarms and the frequency with which they pass through and on their impact on planktonic communities will be synthestized.

1.2.3 Sedimentation of organic particles. The major parameters controlling the exportation fluxes of organic matter towards the deep layer will be taken into account in the model, in collaboration with the team led by Dr F. Dehairs (VUB).

## 2 DEVELOPMENT OF THE MODEL AND VALIDATION :

2.1 Elaboration of biological models :

The model will produce a general description of the planktonic system in each subregion of the Southern Ocean. It will describe the circulation of C, N ($NO_3$ and $NH_4$) and Si through the microbial network. The chemical and biological state variables include nutrients ($NO_3$, $NH_4$, $SiO_2$), dissolved and particulate organic matter, two groups of phytoplankton, bacteria and nanoplanktonic and microplanktonic protozoans. The incident light, the vertical stability of the water column and the temperature are obtained from the physical model. Additional forcing will be introduced by taking account of the grazing pressure exerted by krill.

2.2 Definition of the subregions considered in the Southern Ocean :

The different "boxes" considered in the model will be demarcated on the basis of an examination of :

- the circulation of the water masses;
- the advance and retreat of the ice;
- the krill distribution;
- the sedimentation areas.

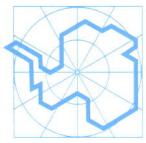
2.3 Validation of the coupling of the physical and biological models :

The model will be validated on its ability to reproduce the essential features of seasonal variations in the chemical and biological variables in a few boxes for which temporal series of observations during preceding or future campaigns are available.

## 3 EXPLOITATION OF THE MODEL :

3.1 Assessment of annual primary production in the Southern Ocean :
The gross (fixation of autotrophic $CO_2$) and net (new and regenerated) annual primary production will be calculated, together with their inter-annual variations.

3.2 Exploration of scenarios linked with global change :
Several scenarios linked with possible climatic changes and modifications in human pressure on krill will be explored on the basis of the results generated by the model.



# PROJECT Nr A3/58/001

## PROMOTER

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## TITLE

## OIL SPILL MODELLING FOR THE ANTARCTIC SEAS (OSMAS)

## THEME

*The risk of oil pollution in the Antarctic has grown considerably due to human presence and activities and to shipping in this region. The nature of the coastline, the presence of the ice pack and the sensitivity of the biomass explain the high vulnerability of the Antarctic ecosystem to oil pollution. Although adequate models exist to simulate the behaviour of oil spilled at sea, no reliable model is available to predict the interaction of oil with sea ice in Antarctic conditions. Observations made in the Arctic by Canadian and Scandinavian authors suggest a complex behaviour of oil spills in the presence of sea ice. The MUMM proposes to construct a model capable of describing the behaviour of an oil spill and the evolution of the sea ice when the two interact.*

## OBJECTIVES

The aim of the project is to develop a deterministic model capable of predicting the behaviour of an oil spill in the Antarctic coastal area in the presence of ice over a seasonal cycle. The evolution of the spill on the surface, in the water column and in the ice will be simulated and represented graphically so as to assess the impact of the spill. The following objectives have been defined in order to achieve this goal:

- study of the processes affecting hydrocarbons in a cold sea;
- study of sea/ice interactions;
- study of the processes affecting the ice following a possible oil spill in the Southern Ocean;
- development of models describing these different phenomena;
- examination of the possibilities of collaboration with the atmospheric model developed separately by the UCL;
- application to the Weddell Sea area over a seasonal cycle.

Means and methodology :

Three models developed at the MUMM will serve as the basis for the study :

- a deterministic oil dispersion model (MU-SLICK);
- a composite deterministic/probabilistic oil dispersion model (PARCEL);
- a sea ice evolution model developed during Phase II of the Belgian Research Programme on the Antarctic (SEAICE).

The useful components of these models will be selected and adapted with a view to coupling within a single system. Contacts will be established to examine the possibilities of access to the atmospheric model of the UCL. A statistical law will be developed to determine the position of the ice in each mesh of the discrete application grid.

Products and results :

The project will synthesize current knowledge on the behaviour of hydrocarbons in a cold sea, the ice/oil interactions, the oceanic circulation in the Antarctic and the seasonal evolution of the ice in the Antarctic in a coherent whole allowing the behaviour of an oil spill in the Weddell Sea over a seasonal cycle to be studied.

The model developed in this way will be a three-dimensional oil model using the results of an ocean-circulation model, calculating wind pressure from atmospheric predictions and simulating the important weathering and ageing processes. The ice model will include a thermodynamic component (melting/freezing) and a dynamic component (ice movement). The complete model will be applied to the Weddell Sea and several simulations will be carried out modifying the time and place of the oil spill. The results will provide us with an initial idea of the impact of a major oil spill on the Antarctic environment.

The following information will be available at the end of a simulation :

- trajectory of the oil slick;
- trajectories of dispersed oil fractions;
- trajectories of oil fractions trapped by the ice;
- final position of the different fractions;
- inventory of the impacted targets.

The model created in this way is not intended to constitute a marketable product but will essentially remain a research tool. In the event of a real oil spill, the MUMM would be able to apply the model to obtain a quick assessment of the foreseeable environmental consequences.

## TASKS

**1** REVIEW OF THE LITERATURE

**2** EVALUATION OF EXISTING MODELLING TOOLS AND SELECTION OF USEFUL COMPONENTS FOR THE CONSTRUCTION OF A GLOBAL MODEL :

2.1 Hydrodynamic ocean-circulation models (three-dimensional, three speed vector components).
2.2. Sea ice models providing the seasonal evolution of the pack ice in the Weddell Sea.
2.3 Ice/circulation coupling providing the dynamics of sea ice and its influence on marine currents.

**3** CONCEPTUAL MODEL :

3.1 Oil dispersion submodel :

3.1.1 adaptation of the model to polar conditions: evaporation and degradation of the oil, modification of its physical properties (density, viscosity) due to low temperatures;

3.1.2 choice of a type of oil whose behaviour at low temperatures is well known;

3.1.3 possible modelling of thermal effects: disturbance of heat exchanges between the ocean and the atmosphere due to the presence of oil.

3.2 Sea ice submodel :

3.2.1 location of the ice: thickness and surface of the ice in each mesh and distribution within the mesh.

3.3 Oil/ice interactions :

3.3.1 behaviour of the oil in the presence of ice: location of the oil above, below or in the ice layer;

3.3.2 possible feedback : influence of oil on the freezing, melting and movement of the ice and on the surface wind pressure.

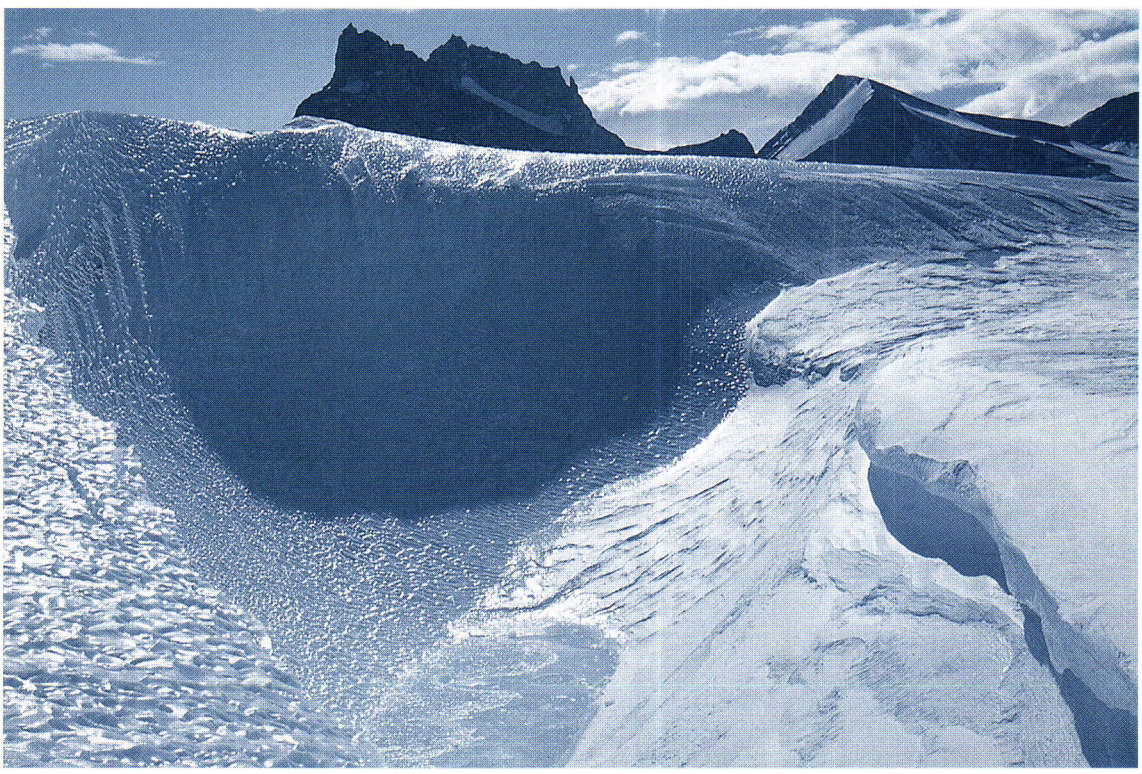
**4** DEVELOPMENT OF THE COMPUTER PROGRAM :

4.1 Digital resolution techniques.
4.2 Coupling of the submodels and integration.
4.3 Sensitivity analysis.

**5** DEVELOPMENT OF GRAPHIC SOFTWARE TO FACILITATE INTERPRETATION OF THE THREE-DIMENSIONAL RESULTS

**6** TEST CASES :

6.1 Hypothetical scenarios: tests on the quantities of oil released and the places and times of the year presenting major risks for the Antarctic environment.
6.2 Real cases of pollution (if available).



# PROJECT Nr A3/11/002

## PROMOTER

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## TITLE

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

## THEME

*The purpose of this research is to analyze the chemical and isotopic properties of ice formed at the interface between a small Antarctic ice shelf and the ocean, in so far as these can contribute towards a better understanding of the role that climatic changes can play in the stability of this type of ice shelf. The latter is likely to react rapidly to climatic changes connected with human activities. In fact, its stability is closely dependent on changes in the temperature of the oceanic waters with which it comes into contact.*

*The climatic changes forecast for the 21st century could lead to an increase of around 0.5°C in the average temperature of these oceanic waters. The response of small Antarctic ice shelves to a climatic change and their influence on the world sea level depend on changes in their conditions at the margins. The thermodynamic processes occurring at their bases control the melting or accretion of sea ice there.*

*An analysis of the chemical and isotopic composition of the ice formed at the ice shelf/ocean interface is a way of gaining a better understanding of the conditions prevailing there. In effect, the properties of sea ice reflect the properties of the water which produced them and these in turn define the melting or freezing conditions.*

## OBJECTIVES

To determine the conditions prevailing at the ice shelf/ocean interface from a chemical and isotopic analysis of the sea ice formed at this interface, coupled with a crystallographic examination. Three types of situations will be examined in particular :

- Accretions of sea ice at the base of ice shelves, which rise to the surface following ablation. Such situations can be observed in the Victoria Land region, where the lower section of a number of small ice shelves is made up entirely of sea ice formed at their base following ablation linked with katabatic winds. Analyses of this ice will allow much more information to be obtained than that collected from affected ice during limited sampling.

- The basal ice created at the anchor line where the glacier gives way downstream to the floating ice shelf. Such ice can be seen at the surface in the Terra Nova Bay region.

- The sea ice produced in crevasses affecting the ice shelves, whose properties depend on the characteristics of the water under the ice shelves. The floating George VI ice shelf in Western Antarctica and the Nansen ice shelf in Victoria Land are favourable to this type of study.

## TASKS

**1** DEVELOPMENT OF THE ANALYSIS OF THE MAIN ANIONS IN SAMPLES OF SEA ICE BY MEANS OF IONIC CHROMATOGRAPHY

**2** ANALYSES OF ICE SAMPLES FROM THE HELL'S GATE ICE SHELF, LOWER SECTOR :
2.1 Analysis of stable isotopes.
2.2 Analysis of major cations.
2.3 Crystallographic analyses.
2.4 Analysis of major anions.

**3** ANALYSES OF ICE SAMPLES FROM THE CAMPBELL ICE SHELF :
3.1 Analysis of stable isotopes.
3.2 Analysis of major cations.
3.3 Crystallographic analyses.
3.4 Analysis of major anions.

**4** ANALYSES OF SEA ICE SAMPLES FROM THE RIFTS OF THE GEORGE VI ICE SHELF :
4.1 Analysis of stable isotopes.
4.2 Analysis of major cations.
4.3 Crystallographic analyses.
4.4 Analysis of major anions.

**5** ANALYSES OF ICE SAMPLES PREVIOUSLY COLLECTED IN VICTORIA LAND :
5.1 Analysis of stable isotopes.
5.2 Analysis of major cations.
5.3 Crystallographic analyses.
5.4 Analysis of major anions.

**6** LABORATORY EXPERIMENTS ON CHEMICAL FRACTIONATION BETWEEN SEA ICE AND SEA WATER

**7** INTERPRETATION OF THE RESULTS WITH A VIEW TO DEFINING THE THERMODYNAMIC CONDITIONS PREVAILING AT THE ICE SHELF/OCEAN INTERFACE :
7.1 Determination of the sectors subject to basal accretion and melting.
7.2 Implications in relation to the problem of global climatic changes.

# PROJECT Nr A3/10/001

## PROMOTER

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## TITLE

# FORMATION OF THE TERRA NOVA BAY POLYNYA AND CLIMATIC IMPLICATIONS

## THEME

*Modelling of interactive relations between the ice cap, the atmosphere and the ocean in the Terra Nova region, in association with the Antarctic climate. To this end, simulating the katabatic wind generated above the ice cap and simulation of the formation of the polynya (area of ice-free sea) forced by the wind in Terra Nova Bay.*

## OBJECTIVES

- To achieve a better understanding of the processes favouring energy exchanges between ocean and atmosphere in the Antarctic coastal area on a seasonal basis.
- To study and model the physical processes generated by these energy exchanges and, in particular, the formation of sea ice and the release of salt into the ocean under the effect of the katabatic wind.
- To quantify the impact of these processes on the formation of deep waters in the Southern Ocean and to determine their significance for the evolution of the climate.

## TASKS

**1** DEVELOPMENT OF THE POLYNYA MODEL :

1.1 Extension to two horizontal dimensions of the one-dimensional polynya model already developed.

1.2 Coupling of the polynya model to the 3D AMCM - UCL.

1.3 Simulation of the seasonal evolution of the Terra Nova Bay polynya for the present climate.

1.4 Simulation of the seasonal evolution of the Terra Nova Bay polynya for the present climate disturbed by an increase of factor two in the $CO_2$ concentration in the atmosphere.

1.5 Discussion and comparison of the results obtained under points 1.3 and 1.4, with a view to understanding the processes connected with the formation of the polynya and their evolution for an increase of factor two in the $CO_2$ concentration in the atmosphere.

**2** IMPROVEMENT OF THE SPATIAL RESOLUTION OF THE AMCM:

2.1 Nesting of a fine grid in a coarser grid of the model.

2.2 Sensitivity tests at mesh width on the simulation of the katabatic wind on the Antarctic Plateau.

2.3 Choice of dimensions for the coarse grid (case of the Plateau) and the fine grid (case of the slope and the coastal area).

2.4 Simulation of the katabatic wind in the Terra Nova region with the nested AMCM model coupled to the polynya model.

2.5 Discussion of the results under point 2.4 and comparison with the results obtained under 1.3, with a view to optimizing representation of the integration field whilst keeping a realistic computational cost for integration of the model.

2.6 Development of a strategy to force the SEAICE ocean-ice model of the MUMM through the AMCM-polynya model.

# PROJECT Nr A3/03/002

## PROMOTER

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## TITLE

## DYNAMICS OF THE ANTARCTIC ICE CAP AND CLIMATIC CHANGES

## THEME

*A] Study on the behaviour of the Antarctic ice cap (specific drainage basins, ice divides) in terms of climatic changes, with the help of a refined local 3D model and a flow-line model.*

*B] Field observations of the dynamics of glaciers (ice thickness and flow velocities), for the calibration and validation of modelling experiments.*

## OBJECTIVES

- To determine the implication of the regional behaviour of the Antarctic ice cap in relation to:

  a) the general climatic history during the Cenozoic and the atmosphere-cryosphere-sea level relationship;
  b) the role of the local geomorphology (subglacial relief, gradient) in the reaction of the ice cap to climatic forcing;
  c) the stability of the Antarctic ice cap and its future behaviour.

- To simulate the local behaviour of glaciers in relation to glaciation and deglaciation during a glacial cycle.

## TASKS

**1** MODELLING OF THE ICE CAP:

1.1 Collection of data (ice thickness, topography, subglacial relief, flow velocities, ice surface characteristics) and creation of a databank.

1.2 Study and adaptation of the 3D glacier model and the flow-line model in terms of a refined local grid.

1.3 Experiments and feedback effect on modelling procedures.

1.4 Implementation of models and simulation of the behaviour of glaciers in accordance with the climatic signal in the past (glacial periods).

1.5 Interpretation of the regional behaviour of the ice cap in relation to the more general reactions of the ice cap as a whole to changes in the climate and the sea level:

1.5.1 To what extent can the simulations therefore determine whether the glaciological and glacio-geological phenomena observed indicating variations in the glacier are local or general?

1.5.2 What implications does this have on our climatic knowledge of the past which has been deduced from these very same observed phenomena.

1.5.3 What are the consequences for the future of the Antarctic ice cap?

**2** FIELD OBSERVATIONS:

2.1 Elaboration of a measurement programme in terms of logistical possibilities. Adaptation and improvement of equipment (radio-echo sounder).

2.2 Study of satellite images for field comparisons and recording of velocity through matching procedures.

2.3 Field observations of some glacier regions over two consecutive seasons:

2.3.1 transverse and longitudinal profiles (ice thickness and topography);

2.3.2 measurement of ice velocity by means of topographical photographs;

2.3.3 morphological characteristics of the ice and moraines;

2.3.4 ice sampling.

2.4 Processing and interpretation of observations:

2.4.1 utilization of these observations as basic data and temporal phenomena for certain glacier models;

2.4.2 detailed interpretation of the local behaviour of glaciers in terms of glaciation/deglaciation in glacial cycles in this region of glaciers;

2.4.3 generalization through comparisons with other Antarctic regions.

# PROJECT Nr A3/02/002

## PROMOTER

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## TITLE

BELANTOSTRAT

## THEME

*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.*

## OBJECTIVES

- 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, which can 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 for the stratigraphic and structural evolution of these continental margins, with particular attention to its influence on long-term climatic changes (> 1 My).

## TASKS

**1** PREPARATORY STUDIES:

1.1 Weddell Sea:

1.1.1 completing the seismic databank (AWI-RCMG profiles) with pertinent profiles from other research groups;

1.1.2 acquiring additional geological and sedimentological data.

1.2 New research fields (e.g. Prydz Bay and Gerlache Strait):

1.2.1 collecting geological and geophysical data (seismic, magnetic, etc.) and the literature;

1.2.2 consultation, planning and coordination with new partners.

**2** ACQUISITION OF NEW GEOPHYSICAL DATA:

2.1 Weddell Sea:
Acquisition of additional high-resolution seismic reflection profiles with a view to completing the existing series.

2.2 New research fields:
Acquisition of new high-resolution seismic reflection profiles.

**3** PROCESSING AND INTERPRETATION OF GEOPHYSICAL DATA:

3.1 Weddell Sea:

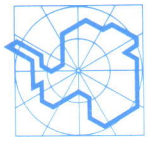
3.1.1 seismic processing (deconvolution, multiple filtering, etc.) with a view to optimizing the quality of digital seismic profiles;

3.1.2 integrated interpretation (discordances, detailed 3D stratigraphy, sedimentary volumes and dispersion models, etc.) of all available seismic profiles, with special attention to identifying and inventorizing palaeoclimatic signals.

3.2 New research fields:
Integrated interpretation (discordances, detailed 3D stratigraphy, sedimentary volumes and dispersion models, etc.) of the seismic profiles collected, with special attention to identifying and inventorizing palaeoclimatic signals.

**4** INTEGRATION OF GEOPHYSICAL AND GEOLOGICAL DATA AND MODELLING:

Integration of the geophysical data interpreted with all the geological data available in the ANTOSTRAT databank, with a view to characterizing the different palaeoclimatic signals and developing a model for qualitative evaluation of the Antarctic continental margins, taking account of the reconstruction of old sedimentation processes controlled by palaeo-oceanographic and palaeoclimatic factors.



## ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| AMCM | Atmospheric Mesoscale Circulation Model |
| ANTOSTRAT | Antarctic Offshore Acoustic Stratigraphy Project |
| AWI | Alfred Wegener Institut für Polar und Meeresforschung |
| BAS | British Antarctic Survey |
| BELANTOSTRAT | Belgian contribution to ANTOSTRAT |
| DOC | Dissolved Organic Carbon |
| EPOS | European Polarstern Study |
| FLA | Fluorescent Labelled Algae |
| FLB | Fluorescent Labelled Bacteria |
| MUMM | Management Unit of the North Sea and the Scheldt Estuary<br>Mathematical Models - Public Health and the Environment |
| NIOZ | Nederlands Instituut voor Onderzoek der Zee, Texel |
| ODP | Ocean Drilling Program |
| OSMAS | Oil Spill Modelling for the Antarctic Seas |
| POC | Particulate Organic Carbon |
| RCMG | Renard Centre of Marine Geology |
| RPI | Relative Preference (of phytoplankton for nutrients) Index |
| SPO | Science Policy Office (of Belgium) |
| UCL | Université Catholique de Louvain |
| UG | Universiteit Gent |
| ULB | Université Libre de Bruxelles |
| ULg | Université de Liège |
| VUB | Vrije Universiteit Brussel |