FS "POLARSTERN"

Expeditionsprogramm Nr. 25

ANTARKTIS X/6-8
1992

Frühling am Eisrand
Fahrtleiter: Prof. V. Smetacek

Sommer Weddell Wirbel Studie
Fahrtleiter: Dr. E. Fahrbach

Rückfahrt
Fahrtleiter: Prof. G. Krause

Alfred-Wegener-Institut
für Polar- und Meeresforschung
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1. ZUSAMMENFASSUNG

Die Fahrtabschnitte ANT X/6 bis 8 beschließen den Einsatz des FS 'POLARSTERN' in der Feldkampagne 1992/93 in antarktischen Gewässern. Die zentralen Fragestellungen der Fahrtabschnitte im südpolaren Ozean (ANT/X 6, 7) dienen einer Abschätzung der Stoff- und Energieflüsse im Südpolarmeer im globalen Rahmen. Beide Abschnitte sind wesentliche Bestandteile der laufenden internationalen Projekte Southern Ocean Joint Global Ocean Flux Study (SO-JGOFS des IGBP) und World Ocean Circulation Experiment (WOCE des WCRP). ANT X/6 beschäftigt sich speziell mit der Aufklärung und Abschätzung biogeochemischer Prozesse unter besonderer Berücksichtigung des Kohlenstoffkreislaufs; ANT X/7 setzt laufende Untersuchungen über die Zirkulation des Weddellwirbels und die Bildung antarktischen Bodenwassers fort. ANT X/8 ist im wesentlichen die Rückfahrt des FS "POLARSTERN" nach Bremerhaven; dieser Süd-Nord Transekt wird zur Untersuchung verschiedenster chemischer und physikalischer Gradienten im Atlantik genutzt, vor allem vom CO_2 Partialdruck und von optischen Eigenschaften des Meerwassers.

Der Abschnitt ANT X/6 ("Frühling am Eisrand") beginnt am 29.9.92 in Punta Arenas und endet am 29.11.92 in Kapstadt. Die Rolle des Südpolarmeeres bei der Aufnahme atmosphärischen CO_2 ist z.Zt. noch nicht verstanden, vermutlich nimmt es global eine Schlüsselstellung ein. Es ist hinreichend dokumentiert, daß der jährliche Rückzug des Meereises schnelles Phytoplanktonwachstum in der Schmelzwasserzone auslöst. Informationen über die Planktondynamik im breiten Bereich offenen Wassers zwischen antarktischer Konvergenz und der Eisrandzone im zeitigen Frühjahr gerade vor oder während der Eisschmelze sind bisher sehr gering. Die spärlichen Informationen deuten darauf hin, daß dieses riesige Gebiet im Spätwinter/frühen Frühjahr durch relativ hohe Phytoplanktonbestände charakterisiert ist. Ziel der Untersuchungen ist es, die verantwortlichen Prozesse zu ermitteln und zu beschreiben, um die Bilanzierung der Kohlenstoffflüsse dieses Meeresgebietes im globalen Kontext und die Aufklärung derjenigen Prozesse, die für Kohlenstoffaufnahme, -zirkulation und -sedimentation verantwortlich sind, zu ermöglichen.

Die Prozesse, die während ANT X/6 untersucht werden, umfassen die Aufnahme von CO_2 durch die Photosynthese des Phytoplanktons im oberen Ozean und die verschiedenen Prozesse, die Abbau und Modifikation organischer Substanz bestimmen. Der vertikale Partikelfluß in die Tiefsee und in die Sedimente wird untersucht. Die verschiedenen Arbeitsgruppen an Bord werden gemeinsam und detailliert Biomassen, Artenverteilung und Wachstumsraten der wichtigsten Komponenten im Ökosystem - Bakterien, Phyto-, Protozoo- und Zooplankton - und ihr physikalisch-chemisches Umfeld untersuchen. Regelmäßig werden CTD-Rosette, Zooplanktonnetze (vertikal und horizontal) und der Multicorer (für Tiefseesedimente) eingesetzt. Großwasserschöpfer und in situ-Pumpen (Instrumente, die für mehrere Stunden am Windendraht in definierten Wassertiefen hängen müssen) werden weniger häufig zum Einsatz kommen. Ebenso sollen der Eislage entsprechend Eiskerne gezogen werden und Oberflächeneisproben von Bord aus mit einem Spezialkorb gesammelt werden. Wann immer möglich, sollen vom Schlauchboot aus vom Schiff unbeeinflußte Wasserproben genommen werden. Zusätzlich werden frei treibende Instrumententräger ausgebracht, die über mehrere Tage Messungen in verschiedenen Wassertiefen durchführen; eine Verankerung wird versorgt.

Der folgende Fahrtabschnitt ANT X/7 beginnt am 3.12.92 in Kapstadt und endet am 22.1.93 in Ushuaia. Die Untersuchungen werden im Rahmen der Weddell Wirbel Studie durchgeführt, die Teil des World Ocean Circulation Experiments (WOCE) ist.

Neben den dafür notwendigen CTD Profilen werden 20 Verankerungen geborgen und 7 neue ausgebracht werden. Gemeinsam mit den 6 bereits verankerten Sonarsystemen, die von unten die Eisdicke registrieren, werden Daten für eine Bilanz des Wasser-, Salz- und Wärmetransports im Weddellwirbel ermittelt. Der Einfluß dieses Wirbels auf das Weltklima kann so abgeschätzt werden. Zusätzlich wird ein Atmosphären-Ozean Experiment durchgeführt, das den Wärmefluß durch diese Grenzfläche im eisbedeckten Ozean vermessen will. Die biologischen Arbeiten an Bord konzentrieren sich auf ökologische Untersuchungen von Phyto- und Zooplanktern. Der Problematik der UV-B Strahlungswirkung auf marine Organismen gilt besonderes Augenmerk. Untersuchungen über Kreisläufe anorganischer und organischer Verbindungen im Ozean und über den Austausch von CO_2 mit der Atmosphäre sind Bestandteile der bio-geochemischen Arbeiten im Rahmen von JGOFS.

Am 24.1.93 wird das FS 'POLARSTERN' Ushuaia in Richtung Deutschland verlassen, wo es am 21. Februar erwartet wird. Während dieses Fahrtabschnittes werden ein Ozon-Meßprogramm und Untersuchungen über die Aufnahme von Kohlendioxyd im Meer weitergeführt. Auch andere wichtige Parameter wie gelöster Sauerstoff, Chlorophyll-a, Nährstoffkonzentrationen und meteorologische Größen sollen erfaßt werden. Andere Programme erfassen die optischen Eigenschaften des Oberflächenwassers; erste Testmessungen erfolgen mit zwei Schiffs-LIDAR-Geräten. Diese Systeme messen Tiefenprofile der Raman- und Mie-Streuung sowie Chlorophyll und Gelbstoff in der euphotischen Zone. Diese Größen sind bedeutsam für großskalige biologische und chemische Forschungsvorhaben in EUROMAR- und JGOFS-Programmen. "POLARSTERN" wird am 21. Februar 1992 in Bremerhaven zurückerwartet.

2. SUMMARY

The three legs ANT/X 6, 7 and 8 bring the yearlong campaign of RV "POLARSTERN" in Antarctic waters to a close. The central themes of the cruises operating in the Southern Ocean (ANT/X 6, 7) are directed towards assessment of the global role of the Southern Ocean in matter and energy budgets respectively. Both represent significant contributions to the ongoing international programs Joint Global Ocean Flux Study (JGOFS of IGBP) and World Ocean Circulation Experiment (WOCE of WCRP). Whereas ANT X/6 is concerned with elucidation and quantification of biogeochemical processes, in particular the carbon cycle, ANT X/7 is a continuation of previous studies addressing the circulation of the Weddell Gyre and the magnitude of deep water formation. ANT X/8 on the other hand is essentially the return cruise of RV "POLARSTERN" to Bremerhaven and, subsequently, northern waters; this south - north transect will be used to study latitudinal gradients in various properties, in particular CO_2 partial pressure and ocean optics.

ANT X/6 "Spring at the ice edge" commences on 29th Sept. at Punta Arenas and ends on 29th Nov. 1992 in Cape Town. The role of the Southern Ocean in uptake of atmospheric CO_2 is poorly understood but there are indications that this region is of global significance. It is well known that the seasonal retreat of the ice cover induces rapid phytoplankton growth in the melt water zone. However, information on the situation prevailing in the broad band of open water between the Convergence and the ice edge in early spring prior to and just following ice melt is very meagre. The scant information available indicates that this vast area is most productive in late winter/early spring. The aim of this cruise is to assess the role of this area in the

global carbon budget and to elucidate the processes involved in carbon uptake, recycling and sequestration.

The processes that will be investigated during this cruise extend from CO_2 uptake by photosynthesis of phytoplankton in surface layers and the various processes mediating recycling and modification of this organic matter, to vertical flux and sequestration of carbon in the ocean interior and the deep sea floor. The various groups on board will cooperate in the detailed study of biomass, species composition and growth rates of the major ecosystem components - phytoplankton, bacteria, protozoa and zooplankton - and their physical and chemical environment. The investigations involve both field measurements and controlled experiments on board ship. The instruments routinely deployed will be the CTD rosette, zooplankton nets (vertical and horizontal) and the multicorer for sediment sampling. Large volume water samplers and in situ particle collectors (instruments attached to the ship´s wire but kept at depth for several hours) will be used less frequently. Sea ice samples - whether of small floes or cores from larger, more stable floes - will also be collected. The Zodiac will be used whenever possible for collection of non-contaminated water samples far from the ship. In addition, freefloating instrument arrays will be deployed occasionally for periods of several days and one moored array will be serviced.

ANT X/7 "Summer Weddell Gyre Study 1992/93" is part of a series of cruises along the same transect across the Weddell Gyre from Kapp Norvegia to the tip of the Antarctic Peninsula. The cruise begins on 3rd December 1992 in Cape Town and ends at Ushaia on 22nd January 1993. Assessment of the magnitude and seasonal and annual variation in circulation patterns of the Weddell Gyre forms the focus of this study. The chemistry (including CO_2) and biology of the water masses will be studied by different groups. A series of CTD rosette stations will be occupied along this transect; vertical net hauls for zooplankton will be taken. Twenty moorings with current meters will be recovered and 7 redeployed. Six upward-looking sonars that register ice thickness will also be serviced. The field measurements and data from the moorings will provide further information on the role of this region in the global budget of water, heat and salt, in particular deep circulation induced by formation of bottom water. In addition, experiments are planned that will address heat flux through the sea ice cover and the influence of UV/B radiation on phytoplankton. This cruise will hence contribute significantly to our knowledge of the hydrography, biogeochemistry and ecology of the Weddell Gyre.

RV "POLARSTERN" will depart Ushaia on 24th Jan. 1993 and is scheduled to arrive in Bremerhaven on 21st Feb. 1993. During this cruise - ANT/X8 - a number of measurements will be carried out from the moving ship, in particular ozone and CO_2 concentrations in the atmosphere and in sea water respectively. Other parameters such as oxygen, nutrient and chlorophyll concentrations will also be monitored in surface water collected underway. The optical properties of surface water will be measured with 2 LIDAR instruments mounted on the ship that record profiles of Raman and Mie scattering as well chlorophyll and Gelbstoff. These parameters are of importance for the understanding of global patterns in optical properties of the surface ocean.

3.1. ANT X/6 "FRÜHLING AM EISRAND" PUNTA ARENAS - CAPE TOWN - 29.09.92 - 29.11.92

ZUSAMMENFASSUNG

Am 29. September 1992 wird der Fahrtabschnitt ANT X/6 in Punta Arenas beginnen. Alle wissenschaftlichen Einzelvorhaben auf diesem Fahrtabschnitt sind dem internationalen Programm: Joint Global Ocean Flux Study (JGOFS) gewidmet, in dem die Art und die Menge des Transportes von Kohlenstoff und anderen wichtigen biogenen Elementen aus der Atmosphäre über die Ozeandeckschicht in die Tiefen der Ozeane gemessen wird. Aus der Vielzahl der physikalischen und biologischen Prozesse, die an diesem Transport beteiligt sind, werden die wichtigsten intensiv auf drei jeweils 10-tägigen Dauerstationen messend erfaßt. Unsere Meßstrategie wird von der vorgefundenen Struktur des jeweiligen pelagischen Systems und von den Ergebnissen der parallel laufenden mathematischen Modelle bestimmt, die die regelnden Steuergrößen im System erkennen helfen sollen.

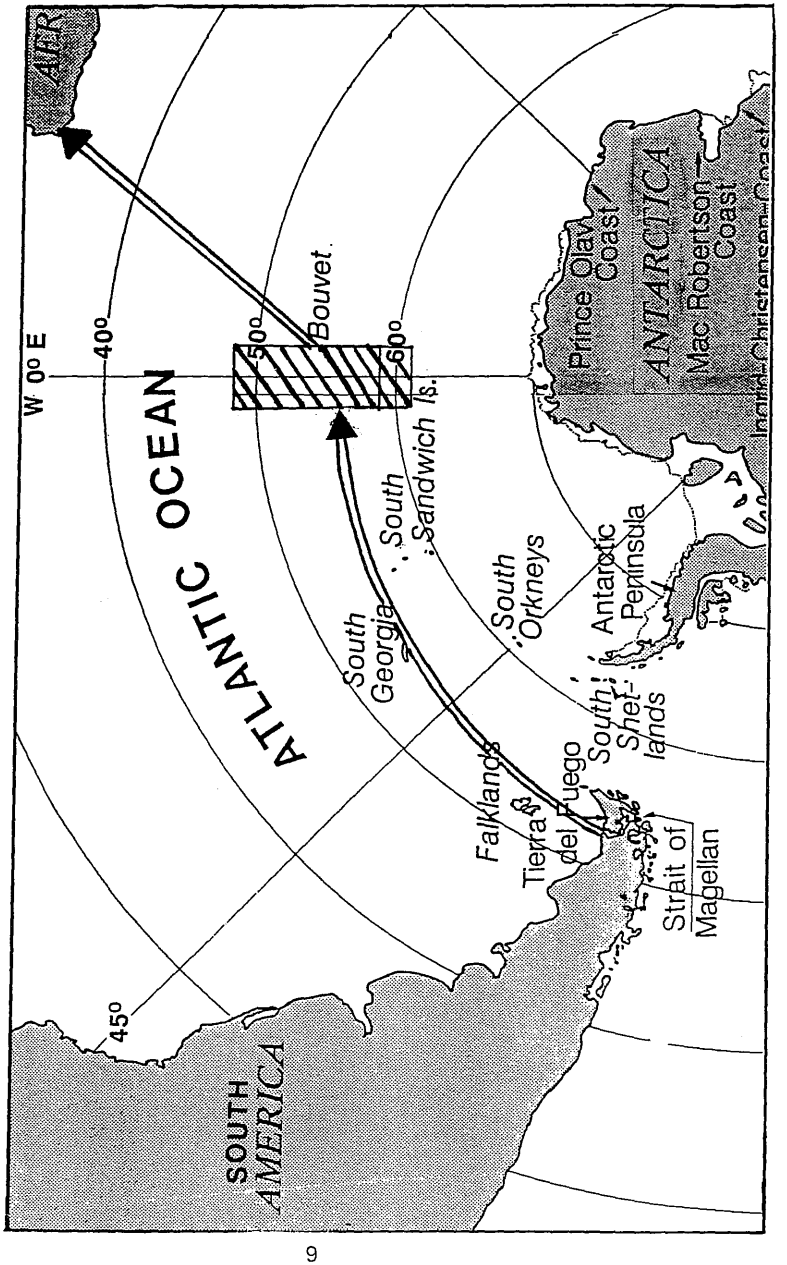
Das wissenschaftliche Programm wird nach dem Verlassen der Hoheitsgewässer mit Oberflächenregistrierungen von Temperatur, Salzgehalt, dem Karbonatsystem (u.a. CO_2), Chlorophyllgehalt des Meerwassers und dem wetterrelevanten Algenprodukt DMSP beginnen. Eine Probestation zum Test der Einsatzfähigkeit aller wissenschaftlichen Geräte wird möglichst schon am vierten Tag der Expedition, auf der Fahrtroute durchgeführt werden.

Die Fahrtroute wird uns unter Einbeziehung eines undulierenden Kursverlaufs jeweils über die Polarfront von Punta Arenas in unser Arbeitsgebiet zwischen 50 und 62°S um 0°E (Abb. 1) führen. Mit einem horizontal-vertikal Profil mit der CTD werden wir im Gebiet die hydrographische Struktur der Ozeandeckschicht soweit auflösen, daß ein Treiber innerhalb eines größeren Wirbels ausgebracht werden kann. Diese Treibevorrichtung besteht aus Oberflächenmarkierungen (Argos-Boje, Spiere mit Radarreflektor, Kette von Auftriebskugeln, in situ-Inkubationsflaschen) und mehreren wissenschaftlichen Meßgeräten (Sinkstoffalle, Strommesser, Multisampler), die bis zu 200 Wassertiefe angehängt sind. In der Nähe dieses Treibers werden täglich umfangreiche Messungen im Wasser und vom Tiefseeboden erfolgen. Die eingesetzten Geräte umfassen u.a. CTD, Multinetz, Bongonetz, RMT, in situ-Wasserpumpen, Schnorchel im Brunnenschacht und Multicorer. Ein weniger umfangreiches Programm wird zwischen den Messungen direkt am Treiber in bis zu 20 sm Abstand um die Treibevorrichtung durchgeführt werden, um das physikalisch-chemisch-biologische Umfeld um die Meßstation beschreiben zu können.

Drei solcher Treibestudien sind während unserer Expedition geplant. Eine muß an der Position einer Langzeitverankerung von Sinkstoffallen und Strommessern (GPS: 57°37,5'S, 04°02,3'E) durchgeführt werden, die während ANT X/3 ausgebracht wurde, von uns eingeholt und auf ANT X/7 erneut ausgesetzt wird. Zwischen diesen Untersuchungen der Prozesse auf kleinen Raum- und Zeitskalen an der Treibeposition sind mehrere Nord-Süd Transekte im Arbeitsgebiet bis in Bereiche von über 90% Eisbedeckung geplant. Auf diesen Transekten, auf denen neben den Oberflächenregistrierungen mehrere Wassersäulen-, Eis- und Sedimentprobenahmestationen durchgeführt werden sollen, soll die mesoskalige Verteilung physikalischer, chemischer und biologischer Größen und Prozesse erfasst werden. Während der Rückfahrt nach Kapstadt, wo wir am 29. November einlaufen wollen, werden wie auf der Hinfahrt Oberflächenwasserproben genommen.

Abb. 1: Die schematische Darstellung der Fahrtroute von "POLARSTERN" sowie des Arbeitsgebietes während ANT X/6.

Fig. 1: Schematic representation of the cruise track of "POLARSTERN" and the work area during ANT X/6.



3.1.1 Introduction

The cruise leg from Punta Arenas to Cape Town (ANT X/6) will start on September 29, 1992 and is dedicated to field work for the Southern Ocean Joint Global Ocean Flux Study (SO-JGOFS). Previous studies of the carbon cycle carried out from RV "POLARSTERN" have centered on biological processes occurring at the receding ice edge or on large-scale distributional patterns of biological properties in relation to seasonality of the physico-chemical environment in the Weddell Sea. One areally very important region - the permanently ice free waters of the Circumpolar Current - has been only marginally studied in the past. The few available data sets indicate the presence of surprisingly high phytoplankton biomass in this region during early spring, prior to or during commencement of seasonal retreat of the ice cover. Several mutually inclusive scenarios involving physical, chemical and biological factors can be invoked to explain why algal biomass in this region appears to be much higher during early spring as compared to the remainder of the growth season:
a) Low-salinity northern water overlies high-salinity Weddell Sea water prior to ice melt but with the same effect on phytoplankton biomass accumulation, i.e. stabilisation of a shallow mixed layer.
b) Algal growth rates are stimulated early in the year by the presence of adequate supplies of certain essential elements such as trace metals or even CO_2. As these nutrients are depleted more rapidly than the conventional limiting nutrients such as phosphate and nitrate, growth rate during the remainder of the year can well indeed be nutrient limited.
c) Low grazing pressure exerted by zooplankton whose populations have not yet attained their summer proportions.

The cruise is divided into two components: (a) meso-scale transects ranging from within the ice covered Weddell Sea to beyond the Antarctic Convergence with particular attention paid to the various fronts (b) process oriented studies within selected water masses identified by means of a drifting instrument array. The main aim of the meso-scale transects is to assess biomass and species distribution of the various components of the pelagic systems of the different water masses in relation to their respective physico-chemical environment; during the drift stations the role of the various factors influencing production, grazing, breakdown and sinking rates of organic substance in a given water body for a period of several days will be studied. In addition to the field measurements, a variety of experiments will be carried out on board to assess the role of specific factors on various processes of importance to the carbon cycle. The results of these investigations will provide the data necessary to realistically model ocean uptake of carbon.

The scientific program commences shortly after leaving the coastal area around South America with surface registrations of temperature, salinity, chlorophyll, DMSP and CO_2. A station will be occupied as soon as possible for checking instruments and gear, probably on the third day at sea.

After reaching our main area of investigation (between 50 and 62°S, around 0° E depending on the actual position of the sea ice; Fig. 1), a survey with CTD profiles will enable us to locate a reasonably homogeneous water mass such as a large eddy. The latter will be marked by a drifting array of surface flotations, sediment traps, multisampler and current meters deployed to several hundred meters depth. At and around the array, daily measurements of physical, chemical and biological parameters in the water column and on the deep-sea floor will be carried out continually for

at least 10 days. Such a drifting survey is planned at the beginning, in the middle and at the end of the cruise. The last drifting study has to be carried out in the vicinity of a long-term moored sediment trap/current meter array (GPS: 57°37,5'S, 04°02,3'E) which was deployed on ANT X/3 and will be redeployed during ANT X/7.

Between our short scale (in space and time) investigations on drifting position, several transects from north to south into areas of closed ice cover are planned to determine the mesoscale variability of the physical-chemical environment, of the biota and of biogeochemical processes. Adequate sampling on, in and under the sea ice is planned wherever possible.

On the transect to Africa at the end of the cruise, surface registration will be done as on the previous transects. We will reach Cape Town on November 29, 1992.

3.1.2 Weather observations
(DWD)

The ship`s meteorological station is staffed with a meteorologist and a meteorological radio operator by the Deutscher Wetterdienst. Their duties comprise:
- providing meteorological information to ship`s captain and chief scientist and, if required, to other research vessels, airplanes or helicopters and other vessels;
- continuous observations of meteorological parameters and data provision to other cruise participants;
- carrying out six to eight surface WMO-observations and transmission by the WMO Global Telecommunication System (GTS);
- launching of radiosondes for the determination of vertical profiles of temperature, humidity and wind up to a height of about 20 km with the radiosonde;
- receiving and analyzing meteorological satellite photographs.
- record of continuous measurements of ozone near surface and of global radiation.

Besides official tasks the scientific enterprises are supported as far as personnel capacities allow. The data collected in the ship`s meteorological station are available for all cruise participants.

3.1.3. Sea ice condition
(IBN)

Distribution and characteristics of sea ice are of extreme importance to Southern Ocean JGOFS because sea ice cover strongly affects physical, chemical and biological parameters of the system studied. Observations on sea ice conditions during the cruise will be combined with the program on top predators (marine birds and mammals). Two methods of ice observations will be used.

Firstly, ice conditions will be recorded according to the ice protocol currently prepared for the SO-JGOFS implementation plan. Details of the protocol are not yet known but records involve a variety of parameters on ice cover, floe size, thickness, floe development, ridging, and algal discoloration. These observations go into great detail but will have a relatively low frequency.

Less detailed, but frequent observations on ice conditions are part of the standard ten-minute counts of top predators that are made continuously when the ship is moving between stations.

The two methods are complementary, and together they should provide an adequate picture of ice conditions in the area in general as well as around station positions.

3.1.4 Ecophysiology of ice algae: Dimethylsulfoniumpropionate content during ice melt.

(FBB)

During formation of sea-ice, brine pockets and channels develop which contain numerous microalgae. These algae accumulate organic compounds with low molecular weight as osmolytes such as the amino acid prolin and the tertiary sulfonium compound dimethylsulfoniumpropionate (DMSP). DMSP is the precursor of dimethylsulfide (DMS) which accounts for a large portion of the atmospheric sulfur content.

With the onset of ice melt large amounts of algae will be released into the water column which, in turn, is expected to result in an increase of the concentrations of DMSP in the water.

In continuation of a long-term research project the DMSP and the chlorophyll content as well as the species composition of phytoplankton samples obtained from surface waters will be measured. The correlation between DMSP, plankton population and the abundance of high DMSP producers such as *Phaeocystis* is of special interest because the DMSP content of the phytoplankton varies according to its species composition.

These parameters will also be measured in depth profiles and in ice cores. Special emphasis will be given to the typical ice algae assemblages in the infiltration layer, the brine and the inner ice.

These data will contribute to further assess the DMSP production of microalgae in the Southern Ocean.

3.1.5 Physical structure and evolution of the water column and hydrography in the SO-JGOFS area of the Atlantic sector of the Southern Ocean near the O^0-Meridian (CTD-, O_2-, nutrient- and optical- measurements)

(NIOZ)

CTD-measurements, rosette sampler, oxygen sensor, fluorometer
In the JGOFS protocols CTD-measurements are prescribed with a high accuracy (equivalent to the WOCE standard) and for that reason a new Seabird CTD-system with state-of-the art sensors will be applied. This system is surrounded by a new type of water sampler, which combines the advantages of Niskin bottles and Go-Flo's and lacks some disadvantages. In addition to the standard CTD-sensors the system is equipped with a light meter, an oxygen sensor and a fluorometer for on-line measurements of PAR, dissolved oxygen and chlorophyll *a*. Most of the sensors are calibrated with in-situ samples: reversing thermometers and pressure meters, salinity samples, oxygen-titration and chlorophyll *a* measurements.

Optical measurements
The following optical measurements are planned, but at this moment it is not sure if all instruments will be available during the cruise:
- PAR as a function of depth
- Attenuation coefficient at 520 nm.
- UV-irradiance meter (attenuation coefficient, in 4 bands).
- Secchi-disc.

The optical measurements in the visible wavelengths are used for the determination of photosynthetically active radiation (PAR) at different levels in the water column. This parameter, where necessary corrected for sea-ice concentration, is of essential importance for the modelling of phytoplankton growth in the surface layer.

The determination of the attenuation coefficient for solar radiation is also an essential parameter in the modelling of the physical structure of the water column and the calculation of the thickness of the wind-mixed layer and temperature of the surface layer. In the SO-JGOFS area the attenuation is determined largely by the concentration of phytoplankton in the water column. The relation between both is used in both physical and ecological modelling, and must be established for this region. The in-situ optical measurements will be calibrated with on-deck determinations of PAR and global radiation. The penetration of UV in the water column is of much interest since the "Frühling am Eisrand" cruise coincides with the period of ozone-depletion over the South Pole area.

Chemical measurements: oxygen, nutrients
Oxygen measurements will be done by Winkler titration. These measurements are also used for calibration of the oxygen sensor on the CTD-system. From the water bottles the concentration of the "standard" macronutrients will be determined according to the JGOFS protocols (nitrate, nitrite, ammonia, phosphate and silicate). These nutrients will be used as forcing variables to model the ecological system of the marginal ice zone. These will also be used as hydrographical parameters, for example as chemical tracers for describing water masses.

Structure and evolution of the water column and hydrography
An essential part of the international JGOFS project is the study of fluxes of matter, in particular of carbon or CO_2, through the water column. The magnitude of these fluxes is largely determined by the structure and evolution of the water column, atmospheric forcing, the sea-ice cover, the global radiation, etc. The behavior of the water column will be studied by direct measurements of the structure during the cruise under different atmospheric circumstances, as well as by modelling the spatial and temporal behavior of the water column with a wind-mixed layer model. The model was developed during the EPOS Project (1988/89) and the data from the SO-JGOFS cruise will be used for providing initial conditions to run the model and for validation of the model under new circumstances. The physical model can be coupled to an ecological model which predicts phytoplankton growth, one of the main chains in the carbon cycle in the upper layer of the ocean, for which it provides the physical forcing parameters.

Repeated CTD-sections perpendicular to the ice-edge, preferably related to a marked water mass, will give the necessary temperature, salinity and density data. The meteorological observations will be done by the ship's meteorologists. The ob-

servation frequency and procedures will be, as far as possible, in accordance with the JGOFS protocols for meteorological measurements. Ice observations will be done in cooperation with the bird/mammal watch from the bridge according to the newly developed JGOFS mammal protocols for sea-ice observations (see abstract about SEA ICE CONDITIONS).

The combined CTD-data and macro nutrient data will be used to perform water mass analysis of the sea area under consideration. In particular silicate (silicic acid) is an important natural tracer in Antarctic waters. This water mass analysis is essential to distinguish the different hydrographical zones separated by fronts and to determine the extent of regions of horizontal homogeneity where 1D-models for wind-mixed layer studies can be applied.

3.1.6 Carbon dioxide research in Antarctic waters (NIOZ)

The melted sea-ice of the Southern Ocean forms a layer over the relatively more haline seawater. The ensuing stratification results in a layered structure which favours algal growth. Wax and wane of the plankton blooms have a strong effect on the CO_2-flux into and out of the ocean. It will be interesting to perform detailed measurements of the CO_2-system combined with measurements of biological activity in this area to increase our understanding about the interaction between biology and physico-chemical factors which control algal blooms.

Measurements of CO_2 will be performed, both in seawater and in the atmosphere. In seawater, total inorganic carbon (TCO_2) will be measured by coulometry. On the transects to and from the Antarctic waters this will be done continuously, whereas in the ice-dominated areas discrete samples will be taken. With this method CO_2 is extracted from the seawater, after which it reacts quantitatively with ethanol-amine. The product of this reaction is back-titrated with OH- ions which are electro-generated. The amount of coulombs used is directly proportional to the amount of CO_2 molecules extracted.

The exchange of CO_2 between the ocean and the atmosphere is governed by the difference between the partial pressures of CO_2 (pCO_2) in these reservoirs. pCO_2 in seawater and air are measured by gas-chromatography. The pCO_2 of seawater is determined from air equilibrated with a seawater sample in a specially designed equilibrator. The gas-chromatograph measures the CO_2 content alternately between the seawater sample and the air against reference gases.

A third basic property of the CO_2-system is alkalinity, which will be determined by a potentiometric titration with hydrochloric acid. Additionally, this titration gives a value for TCO_2, albeit with less accuracy. Although two parameters suffice for determining the speciation of the CO_2-system completely, an overdetermination will ensure a comprehensive and reliable dataset.

3.1.7 Distribution and biological aspects of some trace elements in the Southern Ocean (JGOFS - POLARSTERN). (NIOZ, AWI)

To study more intensively the biogeochemical reactions between trace elements and phytoplankton in the upper layer of the ocean, observations on the distribution of Cu, Zn, Fe, Ni, Pb, Mn, Cd and Co will be made in:

1) the top 200 meters. A high resolution sampling program will be made using a rubber boat and a newly developed winch, in order to prevent contamination. In addition, nutrients will be determined in these samples.
2) ice and snow. Icebergs and snow are assumed to contain substantial amounts of trace elements, which can, upon melting, enrich the environment.
3) water just below the ice. The distribution of trace elements in regions where algae bloom under the ice will be studied.
In addition, the total water column will be sampled in order to get more information on surface and deep water exchange of trace elements.

The biological part of the research will be aimed at testing the following hypothesis: in parts of the oceans around Antarctica, NH_4+ concentrations are low, Fe concentrations are extremely low, while NO_3- and PO_4^{3-} amounts are not depleted. It seems that the standing stock of phytoplankton is limited by Fe, grazing and sinking from the euphotic zone. In this situation, Fe addition will lead to new production and a change in species composition, but not necessarily to an enhanced biomass.

In order to test this hypothesis the following biological aspects will be taken into account:
1) phytoplankton distribution patterns, species composition, pigments and Fe quota in phytoplankton cells at stations where experiments (described under 2) will be performed.
2) Fe addition experiments, comparable to those executed during EPOS 1988, will be performed. Ultra-clean culture techniques will be used, in areas with extremely low Fe concentrations and more sensitive parameters, with ^{55}Fe and ^{15}N uptake as most important analyses. In addition, basic data, such as cell counts, species composition, pigments, nutrients, POC/PON, etc. will be collected.

The role of grazing by heterotrophs in connection with Fe addition will be studied using a dilution method. Grazing by copepods will be investigated in collaboration with Kuipers/Gonzalez.

3.1.8 Microplankton
(AWI)

Species composition of the protistan microplankton assemblages in the ice-edge area will be investigated and experiments will be performed onboard.

a) Phytoplankton
Phytoplankton species composition determines amongst other factors the developmental speed of blooms as well as the establishment of the heterotrophic microbial network and the sedimentation patterns. A reason for regionally diverse phytoplankton colonization patterns in the ice-edge area are the start-populations in the various water bodies at the beginning of favourable growth conditions. Seeding-cells for an ice-edge bloom in this region can originate from the always ice-free water masses of the Circumpolar Current, from the seasonally ice-covered water masses of the Weddell Gyre, or from the sea-ice itself. It is not yet known, how variable are the inputs from these sources. The diverse assemblages of species will, on the other hand, serve as tracers for the different water bodies. Monitoring the species composition of the ice-edge populations in combination with other methods can give information about alterations of the phytoplankton population by - possibly selective - grazing by protozoan and metazoan plankton. Investigations of diatoms in the deeper water column will give information about the flux and the alteration of

frustules by sinking and grazing. Both factors determine biogenic silica deposition on the sediment.

Work at sea
Samples will be taken from the upper and the deep water column with Niskin-bottles and nets; the water layer immediately below sea-ice will be sampled with a special pumping device and cores will be drilled for samples from the sea-ice. The samples will be split. One part will be used for observations on the living cells and for online monitoring; the other will be fixed for counting and taxonomic purposes in the home labs.
Grazing experiments with zooplankton and diatoms will be conducted onboard in order to investigate the alteration of cells by zooplankton gut passage under controlled conditions; these results will be compared with the field observations (see also chapter 10. "Diatom Populations").

b) Protozooplankton
It seems clear to us now that protozoan influence in marine biological processes can be important because of their high growth efficiency, grazing impact and short generation times ranging from hours to days, comparable to those found for phytoplankton. One interesting aspect of protozoan biology is the production of faecal material. Field sampling has shown the presence of different types of faecal material which have probably been produced by heterotrophic protozoans. The observed depth distribution of these pellets suggest that they can sediment out of the water column, contributing to geochemical fluxes of biogenic material. Another point arising from current research is the increasing complexity of marine pelagic food webs in the protozooplanktonic compartment, adding new parameters to our view of nutrient cycling. Still very little is known about feeding ecology and behavior as well as faecal material production for protozooplanktonic organisms, especially herbivores. As an example, work published by Nöthig & Gowing, (1991) suggests that radiolarians, foraminifera and dinoflagellates can feed on diatoms and could play an important role in controlling primary production as well as in the transportation of intact diatom frustule and particulate carbon to depth. In order to understand the influence of these organisms in biogeochemical cycles we think it important to get more information on trophic relationships in the pelagic system as well as on the processes of faecal material production and structure (aggregates, membrane surrounded pellets).
The purpose of this project is to study the influence of herbivorous heterotrophic dinoflagellates and larger protozoans (radiolaria and foraminifera) feeding on diatoms in the study area by determining their concentration and distribution as well as faecal products in the water column. Observations on feeding behavior and faecal material production of protozoans feeding on diatoms will also be conducted.

Field samples
Samples of the water column for counting will be taken with water bottles and multinet (64 µm mesh size).
- Multinet samples will be used for the assessment of larger protozooplankton (radiolarians and foraminiferans).
- Water bottle samples (10 l) concentrated by reverse filtration will be used for counting of smaller and more delicate species. They will be fixed with formalin and Lugol's iodine
- Sediment trap samples will be taken for counting of particulate sinking material.

Experiments
Concentrated samples from the water bottles taken in the photic layers will be incubated and fed with different types of cultured diatoms as well as natural nanoplanktonic communities in order to get an enrichment in herbivorous naked protozoan assemblages. They will also be observed with light microscopy for feeding behavior and faecal pellet production. Samples obtained by this method will also be prepared for TEM and SEM analysis for studies on faecal material structure and for taxonomic purposes.

3.1.9 Development of a mathematical model (ULB)

Phytoplankton
The phytoplankton programme includes the coordination of the routine measurement of daily net primary production (JGOFS core parameter 13) as well as specific experiments for the determination of the physiological parameters characterizing large diatom-dominated phytoplankton communities. The former experiments will be used for model validation whilst the latter will be integrated in a model of diatom growth description. The phytoplankton submodel consists of two phytoplankton compartments: large phytoplankton species (dominated by large diatoms) and nano-sized phytoplankton. This distinction is essential for the ecological model, the two groups feeding different trophic levels of the Antarctic food web. Physiological parameters of nano-sized phytoplankton were determined during the EPOS expedition. Emphasis will therefore be given to the determination of physiological parameters typical of large phytoplankton and their controlling variables. Short-term ^{14}C incubations at various light intensities (photosynthetic parameters) as well as long-term kinetics of ^{14}C assimilation into four distinct cellular constituents (growth and respiration parameters) will be conducted on unfiltered and prefiltered (20 µm) field samples.

Microbial loop
Protozoa grazing was described by a temperature dependent first order kinetics due to the lack of a better understanding of its control factors. Owing to the key ecological role played by protozoa in the Weddell Sea sector of the Southern Ocean (Hawers et al., 1985, Bjørnsen and Kuparinen, 1991, Becquevort et al., submitted) it is of prime importance for the model to include them explicitly as state variable and to accurately assess the quantitative value of their grazing activity on both phytoplankton and bacteria as well as their control factors.

Conceptually, the sub-model of protozoa activity is based on size selectivity, distinguishing two protozoa groups differing from each other by their grazing mode: the filter-feeding protozoa (choanoflagellates, ciliates) on the one hand the raptorial protozoa (dinoflagellates) on the other hand. Kinetics characterizing the feeding activity of both the protozoan compartments will be established from field experiments including biomass and grazing activity measurements. Abundance and carbon biomass of nano- and microphytoplankton, bacterioplankton, nano- and microprotozooplankton will be determined by epifluorescence microscopy on DAPI stained preparations (on board) and by inverted light microscopy (at home).

Protozoan ingestion of phytoplankton and bacteria specifically will be measured by the method developed by Sherr et al. (1991) based on the use of fluorescence-labelled prey (FLA (fluorescent-labelled algae), Rublee & Gallegos, 1989; FLB (fluorescent-labelled bacteria), Sherr et al., 1987). Protozoa feeding rate control by

temperature, prey concentration, size and quality will be studied through several microcosm experiments conducted in collaboration with P. Bjørnsen (Denmark).

Sea ice communities
Seeding of the water column by sea ice communities released at the time of ice melting constitutes the initial conditions of the ecological model. Previous observations suggest that seeding might be a key factor controlling early development of phytoplankton blooms. Seeding importance depends on the mixed layer depth in which sea ice microorganisms and organic substances are diluted as well as on lysis of microorganisms caused by osmotic shock. Mortality and development of sea ice communities released in the water column will be approached through shipboard microcosm experiments simulating seeding under controlled conditions. Dissolved organic carbon, algal, bacterial and protozoan biomasses and related activities will be measured daily before and after the ice melting process during several days.

3.1.10 Diatom populations
(AWI)

Diatom populations will be monitored at cruise stations and preparations of live material will be used to detect major changes between different horizontal localities and selected depths in the water column. Samples will also be treated in three other ways.

A. Live samples will be used to seed culture medium and monitored with an inverted microscope.
B. Samples will be fixed in formalin for detailed taxonomic study in Germany and
C. samples will be fixed for electron microscopy and thin section studies. Color photography will be correlated with microscopy of prepared cells in order to present a link between what the phytoplanktologist sees on board ship and the opinion of the specialist taxonomist.

These methods will be used to investigate a number of questions.
1. How many taxa are in the water column but are not normally recorded? Rare and benthic species will be picked up in culture studies.
2. What is the biological state of the chief elements of the population in terms of cell division rate, chain length, sexuality ?
3. what are the characteristics of the organic component of the cell wall in the thriving population?
4. How is the organic material affected after population decline and how is the cell wall broken up in different diatoms with its passage down the water column and/ or with its passage through the guts of zooplankters. To this end faecal pel–lets will also be sectioned for electron microscopy. Material from sediment traps will also be examined with all of these methods.

3.1.11 Heterotrophic Nanoplankton production
(MBL)

3.1.11.1 The quantitative importance of the microbial loop

This part of the contribution will focus on growth rates and biomass of bacterioplankton and heterotrophic nanoflagellates. These parameters will be de-

termined along repeated transects to assess spatial and temporal variation in conjunction and coordination with the general sampling program.

Bacterioplankton net production will be determined by two independent methods: incorporation of ^{3}H-thymidine (into DNA) and incorporation of ^{3}H-leucine or ^{14}C-leucine (into protein). These measurements will be calibrated with direct measurements of bacterial cell and biomass production in mixed batch cultures as done earlier for the Weddell Sea (Bjørnsen & Kuparinen, 1991a). These calibration experiments will also evaluate bacterial growth yield by comparison with CO_2 production or O_2 consumption. Bacterioplankton abundance and biomass will be determined by epifluorescence microscopy on acridine orange stained preparations, using automated digital image analysis.

Abundance and biomass of heterotrophic (and autotrophic) nanoflagellates will be determined by epifluorescence microscopy on proflavin hemisulphate stained preparations on board, and by inverted epifluorescence microscopy on unstained samples at the home laboratory. The latter technique also provides the possibility of quantifying grazing by nanoflagellates (heterotrophic and mixotrophic) on picoplankton by incubating water samples with tracer quantities of fluorochrome labelled food particles.

3.1.11.2 Functional response and food size selectivity by heterotrophic dinoflagellates and ciliates

Preliminary results from microcosm experiments in the Weddell-Scotia Confluence (Bjørnsen & Kuparinen, 1991b) indicated a significant potential for herbivory by small heterotrophic dinoflagellates. Ciliates showed higher growth rates than dinoflagellates at high food concentration, while the latter were competitive at low food concentrations (high potential clearance). This working hypothesis will be tested in dedicated microcosm experiments, where phytoplankton composition and quantity is manipulated by size fractionation and nutrient enrichment. Growth and grazing by dinoflagellates and ciliates will be followed. Culture experiments, in which dinoflagellate and ciliate assemblages from the microcosms are transferred to well defined concentrations of cultured algae of different size classes will assess functional responses and size selectivity by the two groups of micrograzers. The potential for herbivory by the two groups will be evaluated by extrapolating results from microcosm and culture experiments to field data.

3.1.12. Structure, dynamics and significance of the microbial food web in the Antarctic Pelagial

(IfM)

Research aims

During the cruise combined work of water column sampling and microcosm studies shall give new insight as to the abundance and biomass of organisms involved in the microbial food web, the rates within the microbial food web and the significance of the microbial food web for the dynamic processes in the Antarctic epipelagic system. Of specific interest are processes and regulating mechanisms occurring during the formation of ice-edge blooms. The main aims are:

- the elaboration of vertical profiles of bacteria, heterotrophic nanoflagellates, ciliates and phytoplankton, the latter in size fractions of picoplankton (<2 µm), nanoplankton (2-5 µm and 5-20 µm), and microplankton (>20 µm) as well as size-fractionated primary production, bacterial production and bacterial activity during

two two-weeks drift studies to follow changes within a marked water body in relation to environmental conditions (light, nutrients, hydrography);
- the quantification of algal exudation as a source of utilizable DOC, of the uptake of DOC by bacteria and the potential uptake of DOC by photo- and heterotrophic flagellates and ciliates;
- the elucidation of factors and mechanisms controlling the abundance and activity of 'microbial loop' organisms;
- the evaluation of different possible environmental factors having impact on the formation of ice-edge blooms and their impact on the microbial food web;
- the quantification of metabolically active bacteria as a proportion of the total population;
- the recording of horizontal/regional profiles of abundance of photo- and heterotrophic pico- and nanoplankton from the ice-edge across the subtropical convergence.

The results of this project shall lead to a conceptual description of the microbial food web of the Southern Ocean. They will be implemented into the JGOFS concept and, thereby, contribute to the understanding and modelling of the dynamic epipelagic processes in Antarctic waters.

Work at sea

During the two two-weeks drift studies, daily sampling of the upper 100 m water column is planned. While cruising from Chile to the study site and from the study site to Cape Town, horizontal profiles of microorganism abundance will be recorded by taking samples from the "Schnorchel" at intervals of about 4 hrs. and in relation to oceanographic frontal zones.

Water column sampling

From hydrocast samples of 10 depths of the upper 100 m, the following parameters will be determined:
- measurement of nutrients NO_3, NO_2, NH_4, urea, PO_4, and silicate;
- primary production by $H^{14}CO_3$-incorporation (12 hrs in situ incubation) in size fractions "total", <20 µm, 5-20 µm, 2-5 µm (post filtration);
- dark CO_2-fixation (in situ incubation);
- exudation as ^{14}C-DOC accumulation in the <0.2 µm filtrate and experimental correction for exudate uptake by heterotrophs during the incubation time;
- bacterial production by thymidine and leucine incorporation;
- bacterial activity by glucose uptake;
- abundance of photo- and heterotrophic pico- and nanoplankton (bacteria, phototrophic picoplankton, photo- and heterotrophic nanoplankton, dinoflagellates, ciliates) by epifluorescence microscopy and flow cytometry, ciliates by the Quantitative Protargol Staining;
- mean cellular pigment concentration (chlorophyll, phycoerythrin) of pico- and nanophytoplankton by flow cytometry;
- microautoradiography (MAR) of bacterial uptake of thymidine, leucine, and glucose to quantify metabolic active bacteria;
- MAR of thymidine, leucine, and glucose to test for heterotrophic uptake by organisms other than bacteria;
- uptake of fluorescence-labelled DOC (Dextran, amino acids) by photo-(mixotrophy) and heterotrophic flagellates using flow cytometry;
- extracellular enzymatic activity (EEA) of peptidases using the fluorigenic model substrate leucine-methylcoumarinylamide;
- collecting and freezing of samples for analysis of dissolved free and combined amino acids (DFAA and DCAA) in the lab.

Horizontal transects
From samples taken with the "Schnorchel", the following parameters will be determined:
- abundance of photo-and heterotrophic pico-and nanoplankton by epifluorescence microscopy and flow cytometry;
- relative metabolic activity of phototrophic pico-and nanoplankton by the incorporation and enzymatic processing of FITC-Diacetate by flow cytometry.

Microcosm experiments
The experiments will be run in 20 l Polycarbonate (Nalgene) tanks under in situ simulated conditions on the deck (temperate by running seawater) with daily sampling (ca. 350 ml) for 14-20 days. Several experimental setups with different manipulations are planned for specific questions:

Experiments No. 1 and 2: Top-down versus bottom-up controls
a) untreated water as control;
b) pre-filtration <20 µm (to exclude microzooplankton);
c) pre-filtration <5µm (to exclude nanozooplankton);
d) to f) same as a) to c) but addition of substrates and ammonium (the latter especially in setup c) to compensate for excluded nutrient regeneration in the tank).
Experiment No.1 will be run with "open water"-water (exhibiting low productivity) and No.2 with water from the ice-edge (more productive water), thus representing two different epipelagic systems.

Experiment No. 3: Impact of ice-melting on the composition and development of the microbial food web (transition to ice-edge bloom conditions)

The impact of the melting ice at the ice-edge at the beginning of an ice-edge bloom may be of different kinds. Firstly, the less saline melt-water induces a hydrographic stratification of the euphotic zone which may lead to higher primary productivity (Sverdrup-model of critical depth). Secondly, the retreat of the ice-cover provides more light to the water column. Thirdly, the (potentially well-developed) sea-ice microbial community (SIMCO) is released into the water; the role of these organisms as a seed population inducing ice-edge blooms is still under discussion. Fourth, potentially high concentrations of ammonium and DOC, as reported from sea-ice, and trace metals are released together with SIMCO into the water, whose effect on the microbial food web is certainly unclear.

a) untreated "winter-water" from near-ice depths; this setup will be kept under 1 hr light 1 hr dark conditions during daylight to simulate the vertical down-mixing in the unstratified water column;
b) untreated "winter-water" from near-ice depths exposed to normal daylight to simulate the hydrographic stratification;
c) "winter-water" from near-ice depths, exposed to normal daylight, addition of 0.2 µm filtrate of melted sea-ice to simulate the possible input of dissolved matter from sea-ice into the water;
d) "winter-water" from near-ice depths, exposed to normal daylight, addition of unfiltered gently melted (1°C) sea-ice to simulate the additional input of sea-ice organisms into the water; the amount of sea-ice added will be chosen corresponding to the surface area of the microcosms;
e) "winter-water" from greater depths, setup like c);

f) "winter-water" from greater depths, setup like d).

From each of these microcosms the following parameters will be determined daily:
- nutrient concentrations (NO_3, NO_4, NH_4, urea, PO_4, silicate) and freezing of samples for DFAA/DCAA analysis.
- abundance of photo-and heterotrophic pico- and nanoplankton by epifluorescence microscopy and flow cytometry;
- abundance of photo- and heterotrophic microplankton by the Utermöhl-technique, ciliates by the Quantitative Protargol Staining;
- size-fractionated primary production (^{14}C-technique);
- CO_2 dark fixation;
- exudation as ^{14}C-DOC accumulation in experiment No. 3;
- bacterial production by thymidine and leucine incorporation, bacterial activity by glucose uptake;
- MAR of thymidine, leucine and glucose (every other day);
- extracellular peptidase activity (EAA);
- size-fractionated chlorophyll and POC/PON on selected days.

Experiment No. 4: Salinity-optima of primary production and bacterial production
When sea-ice organisms are released into the water upon ice-melting, they are confronted with a drastic decrease in salinity. The degree to which sea-ice organisms can contribute to the formation of ice-edge blooms will also depend on how these organisms can cope with the changes in their environmental conditions. Sea-ice algae show their optimum for primary production at salinities much higher than occurring in the water but as found in sea-ice brines (e.g. 45-50‰; R. Gradinger, AWI, unpubl. data). Since there are no detailed investigations on salinity optima of sea-ice organisms so far results of this experiment may give valuable hints as to the interpretation of experiment No. 3.

Sea-ice will be gently melted (1°C) and the salinity in the sample will be measured. By diluting or adding salt, 8 different salinities ranging between 20 and 100‰ will be adjusted in subsamples. From each of the 8 subsamples primary production ($H^{14}CO_3$ incorporation) and bacterial production (thymidine uptake) will be measured and normalized by cell counts for comparison. To get information on the time-scale of re-adaptation to the changed salinity, the same measurements will be conducted on 5 consecutive days. These measurements will be compared to corresponding ones from the water column.

3.1.13 Dissolved organic matter (DOC, DON)
(SFB)

In former studies a seasonal and regional (Bransfield Strait, north-eastern Weddell Sea, Vahsel Bay, Gould Bay) comparison showed the occurrence of different phytoplankton organisms (centric diatoms, phototrophic nanoflagellates, pennate diatoms) depended on mixed-layer depth. During summer small forms dominated. The biomass ratio of phytoplankton and micro-zooplankton changed from 4:1 (spring) to 1:1 (summer) (Nöthig et al. 1991). In seawater with natural plankton communities (excluding meso and macro-zooplankton) enclosed in tanks only 55 to 78% of the nitrogen taken up was found in the accumulated biomass (v. Bodungen 1986). The missing nitrogen should be in the form of dissolved organic nitrogen (DON) (v. Bodungen 1989). The relationship between dissolved organic matter (DOM) and the phytoplankton species composition or micro-zooplankton activity has not yet been studied in such experiments.

Our planned investigations focus on dissolved organic matter in the study area. Water samples will be filtered, acidified, purged of inorganic carbon and combusted at 800C in contact with a platinum catalyst (Sugimura and Suzuki 1988). The measured combustion gases carbon dioxide and nitrogen oxide represent dissolved organic carbon (DOC) and total dissolved nitrogen, with the content of inorganic nitrogen species subtracted, dissolved organic nitrogen (DON).

This will contribute to the assessment of the DOM inventory of the seas, one of the primary goals in DOM-studies during the next years (Seattle workshop). Polar seas are of prime importance in the global assessment of carbon fluxes since deep water originates there, removing carbon from the surface.

To obtain information about important processes of DOM formation regional and temporal variations of DOM contents will be studied in relation to other parameters. It is expected that different developmental stages of the plankton community (new production vs. regenerated production, autotrophic vs. heterotrophic systems) will yield different quantities and qualities of DOM, considering e.g. the processes of exudation by phytoplankton and sloppy feeding by zooplankton as important sources of DOM.

The development of DOC/DON will be monitored in seawater enclosed in large tanks in relation to the development of the plankton community. This approach avoids the problem of small-scale spatial variation in the sea which renders the study of time series impossible with the expected small changes in DOM.

The measurement of the decline of DOM in filtered seawater incubated in dark bottles (degradation by the natural bacterial community) will give information on the biological availability of DOM from various sources. Whether its C/N-ratio and the presence of inorganic nitrogen species play a role in its degradability will be tested . Similar measurements to be made in various parts of the North Atlantic (including polar seas) during the Meteor cruises 1992 will enable us to compare different parts of the ocean. One important aspect concerns the high concentrations of inorganic nitrogen species in the Southern Ocean and their bearing on the dynamics of DOM.

Measurements of new production in situ and in the tank experiments with the ^{15}N-NO_3 tracer technique (Dugdale and Goering 1967) and of total primary production (^{14}C-method) will be used to characterize the state of the plankton community. Both total rates and rates of different size classes will be measured. Incubations will be close to the drifting sediment traps; thus a direct comparison of new and export production is possible.

At several selected stations the feeding activity of micro-zooplankton (MZP, <200 µm) will be studied employing the serial dilution technique of Landry and Hasset (1982). Measurements of pigments and of DOM in the dilutions will yield information on the influence of MZP on the phytoplankton community and on DOM dynamics.

To quickly characterize phytoplankton communities both in the open water and in various experimental incubations pigments will be measured by HPLC on shipboard. Feeding meso- and macro-zooplankton with natural phytoplankton assemblages and with cultures while monitoring the DOM content can provide information on the importance of sloppy feeding on DOM. Faecal pellets from these experi-

ments will be collected and their release of DOM studied. Possible selective feeding of dominant herbivore zooplankton species can be recognized by pigment analyses of their faecal pellets. Analyses of faecal pellets collected in situ and from freshly caught zooplankton will be used to obtain information on marker pigments for sedimented material from the drifting moorings.

The JGOFS core parameters measured by our group are: DOC/DON, new production, micro-zooplankton abundance and biomass, and HPLC measurements of pigments in the water column at various stations.

3.1.14 Microzooplankton abundance, biomass and grazing studies (SFB)

1.) Determination of the microzooplankton abundance and biomass in the different investigation areas of the expedition (JGOFS level 1 parameter). This part of the program is planned in order to compare the investigation areas which all show characteristic hydrographical regimes (off shore region, frontal region and on shore region with massive influence of melt water). Meteorological or seasonal factors cause additional variabilities. The program will focus on the main parameters which have influence on the microzooplankton development (hydrographical parameters, food supply or grazing pressure of species of higher trophic levels, top-down vs. bottom-up control).

2.) Besides the determination of these parameters on the microzooplankton development, another main subject will be the approximation of the quantitative (Chl*a*) and also the qualitative (HPLC, size fractionation) part of the primary production or phytoplankton standing stock which is utilized by microzooplankton grazing.

The microzooplankton itself plays a minor role in the direct export of POM out of the productive zone (e.g. formation of sinkable particles), but nevertheless occupies a key position in the particle flux. The microzooplankton as consumers of very small, unexportable particles also transfers a major part of the primary production or phytoplankton standing stock to a food-size spectrum which can be ingested by grazers of higher trophic levels. The degree of coupling between the microbial food web and larger grazers serves as a mediator for the formation of particles with high potential for export (Antia, 1991 e.g. zooplankton corpses or, more importantly, fecal pellets of these groups).

In co-operation with other members of the working group and based on the serial dilution technique (Landry & Hasset, 1982) the following program will be carried out:
- Most of the recent grazing studies were conducted by incubation of water samples out of the subsurface Chl-maximum (coincident with a microzooplankton maximum). The application of the maximum grazing rates out of the microzooplankton biomass maximum leads to an overestimated rate for the entire productive zone (methodical artefacts support this trend, e.g., exclusion of grazers on microzooplankton). This study will extend the procedure to incubation of samples out of varying water depth.
- A combination of the serial dilution technique with HPLC analyses and flow cytometer measurements will provide qualitative/quantitative results of the food spectrum which is utilized by the microzooplankton.
- A combination of the serial dilution technique and respiration measurements of the incubated samples will first give a functional correlation of both parameters and

in addition to the biomass/standing stock, analysis will lead to an approximation of the generation times of in situ populations.
- The influence of the microzooplankton on the DOC pool will be analyzed in enclosure experiments. Besides its indirect role in the export of POM, the microzooplankton could play an important role for the DOC pool.

3.1.15 Microbial Turnover of Organic Matter in the Water Column and Sediment
(AWI)

A large proportion of the primary production, particularly the DOC fraction, is consumed by bacteria in the water column. Bacterial consumption of this organic matter can be estimated from bacterial biomass and growth, which are two of the JGOFS core parameters. Biomass will be determined by epifluorescence microscopy, growth by incorporation of radioactively labelled thymidine or leucine. Since the data are to be compatible with the JGOFS data pool, they are produced according to JGOFS standard protocols. These measurements are carried out parallel to determinations of phytoplankton biomass and primary production on daily hydrocast samples during the drift stations and on transects.

The amount of vertical export of organic matter from the euphotic zone is also reflected in the level of microbial biomass and activity in the sediment. Parallel to the investigations in the water column, which span regions of different productivity and sedimentation, the benthic bacterial biomass and their rate of degradation of organic matter will be determined. Activity of extracellular enzymes, bacterial growth and rate of remineralisation of ^{14}C-labelled algal cells will be measured in the top 10 cm of sediment. From these investigations the rate of organic carbon turnover in the sediments will be estimated.

3.1.15.1 Zooplankton biomass and egg-production
(NIOZ)

Phytoplankton biomass and production are terms that summarize two important aspects of an extremely complicated system of autotrophic competitors for light and nutrients, which are at the same time subjected to grazing by herbivores. When concentrating on an ecosystem where algal biomass is low and macronutrients are high - the Antarctic waters are the most striking example - grazing is very likely to be a key factor. Krill has been shown to control algal growth in the meltwater zones. Besides krill, which gained most attention, mesozooplankton and microzooplankton are serious candidates when it comes to controlling algal standing stocks and species composition by grazing. Not only krill, but also copepods have overwintering strategies which enable them to respond very efficiently to phytoplankton blooms in spring. Copepods reach higher biomass than krill. It is, therefore, important to study copepod biomass, species composition and grazing rate, however difficult it may be to measure the latter, in order to estimate the impact of this group. The same holds for microzooplankton, of which the dominating role as consumers of the smaller phytoplankton has become increasingly clear during the last decade.

Mesozooplankton (>200 µm) density, biomass, species composition will be determined for depth strata 500-200; 200-100; 100-50; 50-25, and 25-0 m with the 200 µm Multi-net. The samples are split (FOLSOM plankton splitter); one subsample stored in 4% buffered seawater formalin solution for later analysis of age distribution of dominating species. The other subsample is divided into size fractions 200-

100 and >1000 µm, each fraction being concentrated on pre-weighed GF/C filters for later determination of AFDW.

Material will be collected for determination of carbon weight for successive developmental stages of different species. Copepods from separate vertical net catches will be incubated for determination of egg-production during the following 24 hrs.

Additionally, vertical net-hauls will be made with a WP-2 type 50 µm plankton net with closing mechanism below, in and above the thermocline. Samples will be treated as multinet-samples; ADFW determination will include the size fraction 50-200 µm. Biomass measurements of microzooplankton will be made according to JGOFS protocol chapter 12 nr. 2 and 3, i.e. 1 liter from Rosette sampler bottles from different depth preserved for later settlement microscope; 20 liter samples for sieving over 30 µm plankton gauze and preserved for counting of tintinnids etc. Additional microzooplankton data will come from the 50 µm vertical net samples.

Since mesozooplankton grazing measurements will be done by the German participants (JGOFS PROTOCOL gut fluorescence), we have no special comments. A possible contribution may be the video system we intend to bring for storing on video tape a large amount of microscopic information; grazing rates of mesozooplankton could be estimated from changes in phytoplankton density and species composition during grazing experiments (dark).

A hypothesis on microzooplankton grazing as the main controlling factor in production of flagellate phytoplankton may be tested in a number of field incubations, where the effect of chemical inhibition of grazing could be studied by repeating chlorophyll measurement, HPLC pigment analysis, or microscopic counting, in untreated and treated enclosures. Inhibition method is tested at present at NIOZ.

3.1.15.2 Zooplankton grazing and defecation
(AWI)

3.1.15.2.1 The impact of copepods on the phytoplankton biomass and implications for sedimentation processes and rates

Zooplankton grazing will be measured according to JGOFS protocol by means of the gut fluorescence method. The main aim is the determination of the feeding pressure of the main zooplankton species on phytoplankton; feeding on protozooplankton will be determined as outlined under chapter 3.1.14. For capture of zooplankters, vertical tows will be done in the upper 150 m of the water column (or to the depth of the pycnocline) by means of a Multinet and/or a Bongo net. Living, undamaged animals will be transfered into filtered sea water as soon as possible and gut fluorescence will be measured every 10 minutes for at least 4 hours. The initial decrease in gut fluorescence gives a measure of the gut evacuation rates which translates to the *in situ* feeding rates if one knows the gut fluorescence of freshly captured animals.

In addition to the evaluation of the *in situ* feeding rates, fecal pellet production experiments will be measured. Abundant zooplankton species will be held under various food conditions in experimental containers. The pellets will be separated by means of a nylon screen on the bottom of the containers which allows only the pellets to pass. Total pellet production, carbon, nitrogen, silicate and chlorophyll content of individual pellets, and microscopical analysis of their content will be deter-

mined. The fate of fecal pellets *in situ* will be observed by means of vertical plankton hauls (20 µm mesh sized net) or by reverse filtration of large volumes of water from CTD casts out of different water depths. Classification of pellets is done according to their size and shape using the information collected on previous cruises. The main aim is an estimate on the role of zooplankton fecal pellets for the vertical particle flux in the different regimes of the pelagic habitats. Therefore additional information on total pellet flux and its variability over time to different depths is required and will be obtained from the time series collection of the sediment traps and from the multisampler deployed during our drifting stations (see. chapter 3.1.16). Total flux rates, and flux rates for the different chemical elements mentioned above will be calculated.

3.1.15.2.2 The impact of Krill on the phytoplankton biomass over time and implications for sedimentation processes and rates

Antarctic euphausiids play an important role not only in the structuring effect of the pelagic ecosystem but also on the transfer of particles within the Biological Pump either *via* retention of food or *via* export of organic matter packed in fecal strings or as moult products. The main targets for our investigations will be:
- to locate the krill and its densities (with the echosounder on board 'POLARSTERN')
- to identify the different species of *Euphausiids* (captured with an RMT-net)
- to investigate feeding and defecation of krill in experiments in glass-tanks

The experimental work may be separated into two parts.
a) The feeding behavior of krill will be investigated in relation to food supply in quality or quantity. Phytoplankton will be offered as food in the range from natural assemblages to enriched phytoplankton cultures. The uptake will be measured by two independent methods: determination of the decrease of the various food organisms in the water by means of microscopy and analysis of the food particles inside fecal strings.
b) The feeding pressure upon the phytoplankton will be determined as for copepods by gut fluorescence. For control, absolute fecal production will be measured.

3.1.16 Sedimentation
(AWI)

The export of organic matter *via* the Biological Pump is an important mechanism to remove CO_2 from the atmosphere and the surface layer of the ocean. The first approach, to determine the flux of carbon and various associated elements out of the surface mixed layer, is possible by means of moored or drifting sediment traps below the seasonal (on shorter time scales) or below the permanent (on annual scales) pycnocline.
The annual budget of vertical particle flux is measured by means of two moored sediment traps at 57°37,5'S, 04°02,3'E which were deployed first in March 1991. Preliminary information of material collected so far show distinct seasonal pattern in vertical flux, but detailed analysis of the material which will allow further interpretations of the variability of the export production is in progress at the time of writing this cruise plan. These studies are planned to be continued until at least 1997; the present cruise is important for the investigation of physical, chemical and biological boundary conditions important for the flux as well as for serving the mooring.

In addition, at the beginning, in the middle, and at the end of our cruise, two weeks-long drifting experiments are planned. Therefore, sediment traps will be deployed well below the seasonal pycnocline together with a current meter attached with a fluorescence probe, and a multisampler for collection of plankton material. This material will be investigated by microbiologists and geochemists (see chapter 3.1.15 and 3.1.17) to determine biological and geochemical processes interacting vertical flux.
The drifting array is marked at sea surface by surface flotations, radar reflectors and an ARGOS - buoy allowing the daily location of the array *via* satellite. Daily sampling of the water column parameters and sediment samples close to the drifter will provide detailed information on short time scales on the processes mediating vertical particle flux.

3.1.17 Geochemistry
(AWI)

3.1.17.1 New production/ export production

Isotopes of the particle-reactive elements Th, Pb, Po, Pa are produced in the water column by decay of their relatively soluble U and Ra parents. When particles settle through the water column, they take up these nuclides, thus providing us with a tool to study particle flux rates, production rates in the water column, and sedimentation of particles.

The isotope ^{234}Th (24 days half-life) is a suitable tracer for study of the development of a plankton bloom. At the end of the winter, as we found in 1987 in the Bransfield Strait, this isotope is in secular equilibrium with its parent, ^{238}U, the activity of which is accurately known from the salinity. Only 5% of the activity is bound to particles. With the onset of the plankton bloom, particles become more abundant in the surface water, and the percentage of ^{234}Th activity bound to particles increases. Sinking of particles out of the surface layer shows as a disequilibrium between total ^{234}Th and ^{238}U. This disequilibrium enables us to quantify the export rate of ^{234}Th from the surface water, and, if we know the $^{234}Th/C_{org}$ ratio in sinking particles, it also becomes possible to quantify indirectly the export production of organic carbon. This method complements flux rate measurements with sediment traps, and offers the advantage that it measures a time-integrated signal that is moreover independent of the sometimes questionable collecting efficiency of the trap.

Samples will be collected with 270-L Gerard bottles. The dissolved and particulate phase will be analyzed separately for ^{234}Th, ^{210}Pb and ^{210}Po. Additional samples will be collected with a multisampler that will be used in cooperation with the plankton group. It can be programmed to take 18 times one plankton sample and one sample for radionuclides. It will be deployed together with a sediment trap on a drifting buoy. We hope to be able to follow the development of a bloom and the associated export production with a very good time resolution.

There are indications of very active bottom transport of particles in the Antarctic Circumpolar Current. Particle transport in the bottom water and the erosional exchange between sediment and bottom water can also be studied with ^{234}Th: At mid-depths this isotope is always in secular equilibrium with its parent ^{238}U. Resuspension and adsorption cause a depletion of ^{234}Th relative to ^{238}U in the bottom water. The extent of this disequilibrium tells us the residence time of

particles in the bottom water. A check and more detailed information can be obtained from the measurement of additional nuclides with different half-lifes (^{210}Po: $t_{1/2}$ 138 days; ^{228}Th: $t_{1/2}$ 1.9 year).

3.1.17.2 Fluxes to the seafloor and early diagenesis

The decomposition of organic matter at the deep-sea floor occurs predominantly with oxygen as electron acceptor. In this process CO_2 is produced, and $CaCO_3$, whenever available, is dissolved. The supply rate of organic matter can be obtained from the diffusive flux of oxygen into the sediment. This flux can be calculated from high-resolution concentration profiles at the sediment-water interface. The dissolution rate of CaCO3 can in principle be derived from gradients of pH and alkalinity. On earlier expeditions we have measured these gradients on board in multicorer samples. From these measurements we know the gradients within the sediment, but the essential part of the gradients at the very interface can not be determined accurately in this way. The $CaCO_3$ equilibria are moreover pressure-dependent, which makes it impossible to measure undisturbed pH profiles on board. We plan to measure O_2 and, if possible, pH *in-situ* with a free-fall device. It is designed to lower a set of microelectrodes into the sediment, and to return it to the surface after a timed or acoustic release.

3.1.18 Pelagic production and dissolution of biogenic silica (IEM)

Every study of the cycles of biogenic elements in the Southern Ocean must pay attention to silicon, a key element of the Antarctic ecosystems (De Master, 1981; Ledford-Hoffman et al., 1986; Treguer & van Bennekom, in press), as well as any study of the global oceanic silica cycle must pay attention to processes occurring in the Southern Ocean (Spencer, 1983). Unlike the numerous data available about fluxes of net deposits of biogenic silica at the sea bottom (both in abysses and continental shelves of Antarctica, Ledford-Hoffman et al., 1986), only a few measurements are available for the fluxes of production and dissolution if biogenic silica in surface layers of the Southern Ocean (Review in Treguer & van Bennekom, in press). By using radioactive tracer (^{32}Si) as well as stable isotope (^{30}Si) during EPOS Leg 2, a French-Dutch-U.S. cooperative action has demonstrated the relative importance of the seasonal ice zone and of the open ocean zone of the northwest Weddell Sea (Nov. 1988 - Jan. 1989) with regard to the standing stock (Leynaert et al., in press), the production (Queguiner et al., in press; Treguer et al., subm.) and dissolution (van Bennekom et al., in press; Leynaert et al., in prep.) of biogenic silica. During austral spring 1990 this group recently took part in the cruise ANT IX of the "POLARSTERN" going on with production/dissolution studies in the Weddell Sea (Queguiner et al., cruise report).

The cruise of the "POLARSTERN" to be held during October-November 1992 offers a unique opportunity to study the fluxes of pelagic production and dissolution of biogenic silica in an area of the Atlantic sector, where the different subsystems are well separated.

Objectives
Rates of dissolution of biogenic silica:
using the ^{29}Si-method for surface and bottom waters. 2.5 l at each depth to be collected with GO-FLO teflon coated samplers, both in surface water (at 6

quantametric levels in the photic zone) and 6 extra levels distributed in the nepheloid layer.

Isotope addition will be carried out under clean conditions and size fractionation (o.4 to 10 μm) will be performed for the experiments in the photic layer. These experiments will be conducted in cooperation with other groups: "Kinetics of dissolution of biogenic silica on diatoms collected by nets".

Production of biogenic silica:
- option A: (conducted with the Dutch group). Use of ^{32}Si (if available) under clean conditions to measure the size fractionated (0.4 and 10 μm) production of biogenic silica in the photic zone (6 levels cf 1-).
- option B: (conducted with the French group). Use of ^{30}Si (if ^{32}Si is not available) under clean conditions to measure the size fractionated (0.4 and 10 μm) production of biogenic silica in the photic zone (6 levels cf 1-).

For both options measurements of biogenic silica and particulate organic carbon concentrations will be made by the French group as well as measurements of carbon production (^{14}C method under similar conditions) to study the coupling between C and Si cycles (C and Si growth rates, C/Si standing stocks ratios, C/Si production ratios). Preliminary experiments will also be conducted to follow the incorporation of ^{14}C in aminoacids (measured by HPLC coupled together with a radioactivity detector) as a function of silica production (cooperation with Dr. V. Martin-Jezequel, CNRS-Roscoff, F).

3.1.19 Relationship between export and new/regenerated production

(VUB)

General framework
The relation between export production and the relative proportion of new to regenerated production and its spatio-temporal variability in different Southern Ocean ecosystems confines the framework of this research proposal. The nitrogen uptake regime is largely determined by nitrate uptake at the beginning of the growth season and a subsequent increase of the importance of regenerated production with increasing ammonium availability in the water. Drastic decreases in f-ratio were observed only in the MIZ and CCSZ ecosystems; the CPIZ and open sea systems, on the contrary, are characterized by very smooth and limited decreases in f-ratio. Export to the subsurface layers, as traced by particulate barium accumulation, is obviously more significant in the open ocean systems. Systems with enhanced biomass build up, as the MIZ and CCSZ, show rather poor export towards this subsurface layer. This is reflected by increased significance of ammonium uptake and poor accumulation of particulate barium in the subsurface layer.

Work at sea
Experimental approach designed to understand the relation between export production and the different fluxes in the lower levels of the trophic food chain. The N-15 methodology is used to determine nitrogen fluxes at the first levels of the food web. Isotope incorporation studies allow for estimates of the nitrate, ammonium and possibly nitrite assimilation. The remineralization of ammonium is studied by means of isotope dilution experiments.

Conservative estimates of new productivity in the water are obtained from nitrate depletion calculations. Another important parameter in the study of water mass variability is the ammonium availability.

Subsurface barium accumulation is assessed from vertical TSM profiles. The samples are obtained from large volume filtrations.

3.1.20 Seabirds, seals and whales
(IBN)

Studies of the pelagic distribution of Antarctic marine birds and mammals serve a variety of purposes. In the Antarctic, top predators represent an important component in carbon fluxes that needs to be quantified. Also, species composition and densities in the top predator community are a reflection of physical, chemical and biological characteristics of the environment and thus may be of use in "mapping" this environment. Finally, distributional studies (when combined with other oceanographical research) supply information on the ecology of different species and sizes of populations. Such information is needed in issues of nature conservation or management. For these reasons, quantitative observations of the distribution of top predators have been included as a part of the program on "POLARSTERN".

There is no specific JGOFS protocol for recording top predator observations but international standard methods will be used. Birds and seals will be counted by standard band-transect methods. Whales will be recorded following line-transect methodology. Results are expressed as top predator densities per unit surface area, which can be converted to e.g. top predator biomass or energy/food/carbon requirements. Data can be grouped according to special environmental conditions, marine zones, or geographical areas.

3.2 ANT X/7
CAPE TOWN - USHUAIA - 03.12.92 - 22.01.93

ZUSAMMENFASSUNG

Der Fahrtabschnitt ANT X/7 beginnt am 3. Dezember 1992 in Kapstadt. Das Hauptarbeitsgebiet liegt im Weddellmeer zwischen Kapp Norvegia und der Joinvilleinsel an der Nordspitze der Antarktischen Halbinsel (Abb. 2). Während der Durchquerung des Antarktischen Zirkumpolarstroms in Richtung der Neumayer-Station werden physikalische und chemische Messungen vom fahrenden Schiff aus durchgeführt. Im Gebiet der Antarktischen Polarfrontzone und des nördlichen Randes des Weddellwirbels werden zwei Verankerungen mit Sedimentfallen ausgetauscht, und eine dritte wird neu ausgelegt. An der Neumayer-Station wird das wissenschaftliche und technische Überwinterungspersonal mit dem notwendigen Ausrüstungs- und Versorgungsmaterial abgesetzt. Als Sommergäste bleiben neben logistischem Personal wissenschaftliche Arbeitsgruppen an der Station, die Eisbohrungen betreiben, eine automatische Meßstation aufbauen und ein meteorologisches Forschungsprogramm durchführen. Eine Baumannschaft wird die Arbeiten an der neuen Station abschließen und den Abbau der alten vornehmen.

Das wissenschaftliche Grundprogramm im zentralen Weddellmeer besteht in der Messung von Vertikalprofilen der Temperatur, des Salzgehalts und des Gehalts an Spurenstoffen im Meerwasser auf hydrographischen Stationen. Der Aufzeichnungen langfristiger Zeitreihen dienen Strömungsmesserverankerungen, von denen 20 aufgenommen und sieben neu ausgelegt werden. In drei Verankerungen sind Sedimentfallen eingebaut, die absinkende Partikel auffangen sollen. Eisecholote, die Zeitreihen der Eisdicke über der Verankerungsposition messen, werden in sechs Verankerungen eingesetzt. Mit diesen Messungen soll die Zirkulation und die Wassermassenverteilung im zyklonalen Strömungssystem des Weddellwirbels bestimmt werden. Daraus kann der ozeanische Massen- , Wärme- und Salztransport ins südliche Weddellmeer berechnet werden, der den Beitrag dieses Meeresgebietes zur Klimawirksamkeit des Ozeans begründet. Entscheidend dafür ist die Bildung des Bodenwassers, die einen tiefen Vertikalaustausch bewirkt und die Speicherfähigkeit des Ozeans für Wärme und gelöste Substanzen reguliert. Die Untersuchungen sind ein Teil der Weddell-Wirbel-Studie, die 1989 begann und zum World Ocean Circulation Experiment (WOCE) beiträgt. Ein weiterer Bestandteil des physikalischen Programmes ist die Ausbringung von drei Driftkörpern, die meterologische und ozeanographische Größen zur Beschreibung des Wärmeaustausches zwischen Ozean und Atmosphäre messen.

Die Kenntnis der physikalischen Bedingungen stellt die Grundlage der chemischen, biologischen und biogeochemischen Arbeiten. Die chemischen Untersuchungen befassen sich mit den im Meerwasser gelösten anorganischen und organischen Substanzen. Nährstoffe bilden die Voraussetzung für den biologischen Stoffkreislauf. Deshalb werden die Verteilung von Nitrat, Nitrit, Ammonium. Silikat und Phosphat in der Wassersäule bestimmt. Das Treibhausgas Kohlendioxid ist Gegenstand eines Projektes, mit dem festgestellt werden soll, ob dieses Gas im Weddellmeer überwiegend vom Ozean an die Atmosphäre abgegeben wird oder umgekehrt. Die Beurteilung des globalen Kohlendioxidproblems erfordert die Kenntnis des vollständigen Kohlenstoffkreislaufs. Hier stellt der im Ozean gelöste organische Kohlenstoff mit den Huminstoffen ein bedeutendes Reservoir dar. Diesbezügliche Daten sind im Südatlantik äußerst rar. Einen Bestandteil der organischen Kohlen-

stoffverbindungen bilden die Sterole, deren gelöster und partikulärer Anteil bestimmt werden soll.

Die biologischen Programme befassen sich mit der Ökologie des Phyto- und Zooplanktons. Dazu wird die Verteilung verschiedener Planktonarten erfaßt, sowie die Produktion und der Stoffumsatz gemessen. In diesem Zusammenhang erfolgen auch Untersuchungen der Anpassung unterschiedlicher Organismen an antarktische Bedingungen, die durch die Lebensweise und durch physiologische Eigenschaften erfolgen kann. Um die Verfügbarkeit von Nährstoffen im Stoffkreislauf zu bestimmen, ist nicht nur der Aufbau organischer Substanz, sondern auch der Abbau durch Bakterien von Bedeutung, der in einem mikrobiologischen Projekt behandelt wird. Die Abschätzung der Wirkung zunehmender UV-B Strahlung auf das Phytoplankton und die im Wasser lebenden Bakterien durch die Abnahme der Ozonschicht gibt diesen Programmen einen aktuellen Bezug.

Am Ende des Schnittes bei der Joinvilleinsel werden die Stationsarbeiten eingestellt und bei der Durchquerung der Drakestraße nur noch Messungen vom fahrenden Schiff aus durchgeführt. Am 22. Januar 1993 wird "Polarstern" in Ushuaia einlaufen.

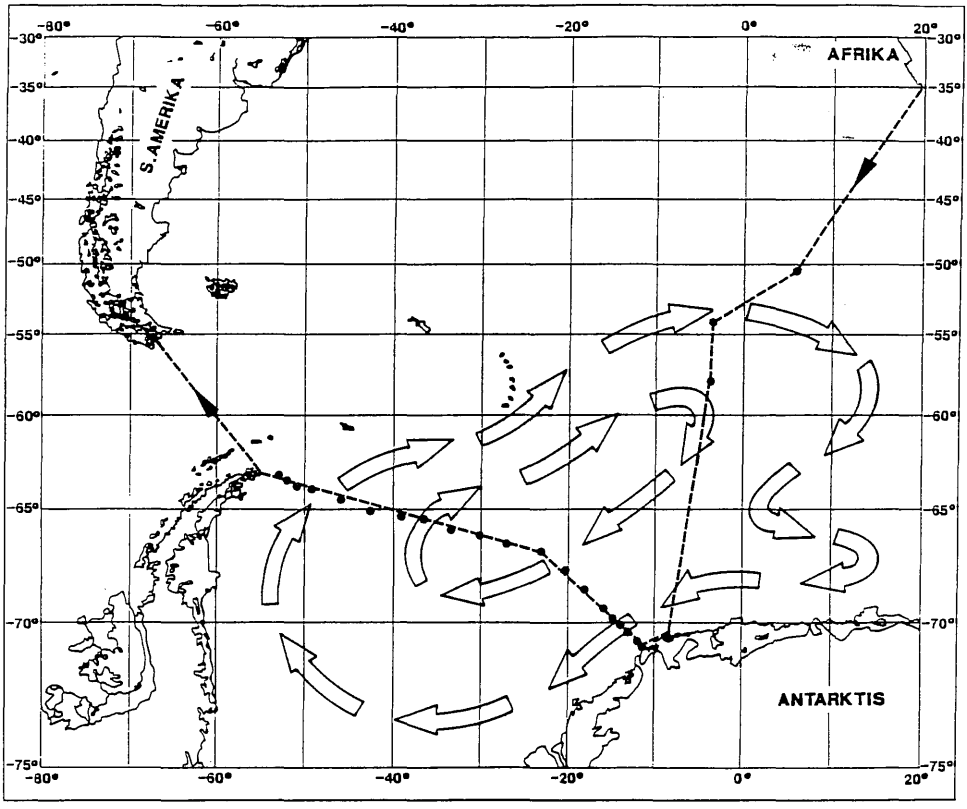
3.2.1 Introduction

The cruise starts on 3 December 1992 in Cape Town. The main operation area is located in the Weddell Sea between Joinville Island at the northern tip of the Antarctic Peninsula and Kapp Norvegia (Fig. 2). Physical and chemical measurements from the moving ship will be started during the transect across the Antarctic Circumpolar Current towards the Neumayer-Station. Two moorings with sediments traps will be recovered and three will be deployed in the area of the Antarctic Polar Frontal Zone and the northern Weddell Gyre boundary. At the Neumayer-Station technical and scientific overwintering personnel and a building crew will disembark. Additionnal groups which will build an automatic measuring station, carry out a drilling programme in the shelf ice, and conduct a meterological research project, will stay at the station. Supply goods and equipment for the next overwintering period will be deposited.

The basic scientific program in the Weddell Sea consists of the measurement of vertical profiles of temperature, salinity and natural trace substances at hydrographic stations. In addition, 20 moorings with current meters and sediment traps will be recovered and 7 will be redeployed. Six upward-looking sonars are presently installed to measure ice thickness and will be exchanged. The measurements aim to determine the circulation and the water mass distribution in the Weddell Gyre with the related transports of mass, heat and salt. This allows estimation of the contribution of the Weddell Sea to the world oceans' effect on climate. In this context the program focuses on the rate of bottom water formation in the Weddell Sea which controls to a large extent vertical exchange and consequently the ability of the ocean to store heat and dissolved substances. These investigations are part of the Weddell Gyre Study which began in 1989 and contributes to the World Ocean Circulation Experiment (WOCE). An air-sea interaction program, based on measurements from drifting buoys, aims on the heat exchange between ocean and atmosphere of the ice covered ocean.

Abb.2: Die schematische Darstellung des Weddellwirbels und der Fahrtroute von "POLARSTERN" während ANT X/7. Die Punkte stellen Verankerungen dar.

Fig. 2: Schematic representation of the Weddell Gyre circulation and the cruise track of "POLARSTERN" during ANT X/7. The dots show locations of moorings.



The knowledge of the physical conditions provides the basis for chemical, biological and biogeochemical investigations. The biogeochemical programs refer to cycles of different inorganic and organic compounds in sea water and the exchange of carbon dioxide between ocean and atmosphere. The biological work focuses on phyto- and zooplankton ecology. Distribution of microbial biomass and respiratory activity will be studied. Dissolved organic carbon and humic substances as well as dissolved and particulate sterols will be measured. Altogether these programs contribute to a better understanding of the global carbon cycle and are to be viewed in the context of the Joint Global Ocean Flux Study (JGOFS). Special emphasis is given to the investigation of the effect of increasing UV-B radiation on Antarctic marine organisms.

The hydrographic station work stops east of Joinville Island from where "POLARSTERN" will proceed to Drake Passage. The physical and chemical work from the moving ship will be continued across the Antarctic Circumpolar Current. On 22 January 1993 "POLARSTERN" will dock in Ushuaia.

3.2.2 Physical Oceanography

3.2.2.1 Circulation and water masses (AWI)

The main subject of the physical oceanography work is the circulation of the Weddell Gyre and the related distribution of water masses. The activities contribute to a multiyear program, the Weddell Gyre Study, which is part of the World Ocean Circulation Experiment (WOCE). A hydrographic survey along a transect from the northern tip of the Antarctic Peninsula to Kapp Norvegia (Fig. 2) is repeated four times, twice during summer and winter seasons, to measure seasonal as well as interannual variability. The program was initiated with a winter survey in 1989 and the deployment of current meter moorings. A summer cruise followed in 1990 and a second winter survey in 1992. After recovery of the moorings the data will be used for a direct estimate of the volume transport in the Weddell Gyre which is essential because of the importance of the barotrophic current which can only be detected by direct measurements. From the obtained mass, heat, and salt transports across the transect we can derive formation rates of Weddell Sea Bottom Water. The salt budget of the area is strongly influenced by the ice transport.

In order to obtain the necessary information, a hydrographic section will be carried out with CTD-profiles (Conductivity, Temperature, Depth) and discrete casts for temperature, salinity, oxygen, nutrients and trace substances. Twenty moorings will be recovered and seven will be laid. On six of them the ice thickness is measured by upward-looking sonars (ULS). The moorings will stay in position for two years.

On the way to and from the major working area XBTs will be launched and current profiles will be measured with an acoustic doppler sonar current meter (ADCP) to obtain information on the variability of the Antarctic Circumpolar Current. In the area of the Antarctic Polar Frontal Zone and the northern boundary of the Weddell Gyre two current meter moorings will be recovered and three will be deployed.

3.2.2.2 Air - ice -ocean interaction (INPE)

In order to study the horizontal and vertical heat fluxes within the upper 100 m of the ocean and the exchanges between the ocean, sea ice and the atmosphere, three

drifting buoys will be deployed on ice floes in the Weddell Sea. The initial distance of the buoys will be about 100 km. The buoys will carry sensors for wind speed and direction, atmospheric pressure and air temperature. A thermistor cable of 100m length below the buoy will measure the water temperature in eight levels and the water pressure at the end of the cable.

3.2.3 Chemistry

3.2.3.1 Nutrients (AWI, OSU, VUB)

The measurements of nutrients dissolved in the water column are closely connected with physical and biological investigations. Nutrients will be used as water mass tracers and for plankton ecology studies. From the water samples collected with a rosette sampler, nitrate, nitrite, ammonium, silicate and phosphate will be measured with an Technicon Autoanalyser II system. Together with the data of previous cruises of the Weddell Gyre Study the combined data set will be used to describe the seasonal cycle of the nutrient concentrations.

3.2.3.2 The carbon dioxide system in Antarctic waters (AWI,NIOZ)

The deep and bottom water formation in the Weddell Sea may be accompanied by export of CO_2 from the near surface layers. The exchange of properties between the surface mixed layer and the atmosphere is highly dependent from the ice cover. To investigate the role of the Weddell Sea as a sink or source of atmospheric CO_2, measurements will be performed in the ocean and the atmosphere. The combination of the data set with data collected previously during the Weddell Gyre Study will result in a better description of the seasonal cycle of the air-sea exchange.

In sea water total inorganic carbon will be measured by coulometry. In open water this will be done continuously, whereas discrete samples will be taken in the ice covered areas. For this purpose CO_2 is extracted from the sea water to react quantitatively with ethonalmine. The product of the reaction is backtitrated with OH^-ions, which are electrogenerated. The amount of electricity used is directly proportional to the amount of CO_2 molecules extracted.

The exchange of CO_2 between ocean and atmosphere is determined by the difference of the partial pressures (pCO_2) in both reservoirs. The pCO_2 in sea water and in the air is measured by non-dispersive IR analysis. For this purpose air is equilibrated with the sea water samples and the CO_2 content of the collected and equilibrated air samples is measured in comparison with reference gases

3.2.3.3 Organic carbon and humic substances in Antarctic waters (AMK)

Dissolved organic matter (DOM) in the ocean is the largest organic carbon reservoir in the global carbon cycle. Depending on which region, about 10 to 50 % of the oceanic dissolved organic carbon (DOC) is found as humic substances (HS), which is an operationally defined fraction. HS are a complex mixture of polyelectrolytes of moderate molecular weight (mean molecular weight less than 2000) which are made up of C, O, N and H. The few estimates that have been made of the composition of oceanic HS suggest a different composition from that of terrestrial HS. In the recent literature, some evidence that oceanic DOM contains building blocks typical of terrestrial material derived from vascular plants has been documented. The pro-

posed project aims to increase the scarce information on DOC and HS in the open ocean, in particular in the South Atlantic to assess the role of DOC in the global carbon cycle.

DOC will be measured by the high-temperature catalytic oxidation method, and HS by fluorescence detection. An attempt will be made to isolate HS in sufficient quantity to estimate the elemental composition and for preparing a standard for the fluorescence measurements. Primarily, the fluorescence will be measured in quinine sulphate units, and the preparation of an HS standard from the water studied will allow a direct comparison on the molecular scale between the concentration of carbon in the form of HS and the total concentration measured as DOC. We will also bring some samples back to perform molecular size fractionation by gel filtration chromatography with fluorescence detection.

3.2.3.4 Dissolved and particulate sterols in the Weddell Sea (AWI)

Investigations of dissolved and particulate phytosterols in the Weddell Sea aim to understand transport and turnover of dissolved organic compounds in the oceans and contribute to the understanding of the global carbon cycle. Sterols are selected due to their widespread occurrence. Their structural diversity allows to refer them to distinct organisms and to conclude on previous biological activity. Due to the normally stable stratification of the ocean, the main source of organic carbon in the deep sea is settling of particulate matter. Bottom water formation in the Weddell Sea could also lead to the vertical transport of organic carbon. To reveal the pathways of organic carbon, horizontal and vertical distributions of sterols will be measured in the. Additionally, the sterol input from ice algae, after seasonal sea ice melting, will be investigated by measurements of sterol in the sea ice.

Sterol concentrations will be measured at 10 stations, and 6 depths will be sampled at each station. It is planned to separate from 20 l of water taken with Niskin samplers the particulate and dissolved fraction of organic material, using glassfiber filters and glass bottles. The dissolved material will be extracted from the filtered water with n-hexane. Extracts and filters are stored in glass vials protected from the air. The samples will be transferred to Bremerhaven for the chemical analysis of sterols, which will be carried out with chromatographic and mass spectrometric methods.

3.2.4 Biology

3.2.4.1 Phytoplankton ecology (AWI, CBM, VUB)

Build-up of plankton biomass in the Weddell Sea commences with the onset of ice melting. Plankton blooms may occur if the upper water column is stabilized due to ice melting. Data collected from the shelf regions of the Weddell Sea and from the Weddell Confluence region confirm that such blooms are triggered by organisms released from the melting ice and from species which had previously overwintered in the water column below the ice. Melting and bloom formation may finally result in enhanced vertical particle flux. The planktonic food web structure probably influences the amount and composition of sinking material. Thus, material collected with sediment traps will allow the reconstruction of processes involved in particle modification. Satellite information on surface chlorophyll indicates that those processes occur in the Weddell Gyre advancing from north to southwest with the melting ice.

To estimate the phytoplankton biomass distribution during the austral summer samples from 10 light depths in the euphotic zone and below, down to 500 m will be taken at about 40 stations. These samples will be used to measure chlorophyll, particulate organic carbon, nitrogen, primary production and species distribution.

Different phyto- and zooplankton species will be isolated from plankton net hauls and cultivated for autecological experiments on board and later in Bremerhaven. Investigations on the nitrogen and carbon flux will be undertaken.

Experiments on the impact of dissolved organic substances released from "brown ice" on the development of phytoplankton in the marginal ice zone revealed a production enhancing effect during earlier cruises. Additional experiments will be carried out during this cruise.

It is well known that depletion of stratospheric ozone results in an enhanced Ultraviolet-B radiation in Antarctica during the austral summer. The effect of UV-B radiation on primary production and phytoplankton growth will be tested in autecological experiments to estimate the possible impact of further ozone reduction on Antarctic marine life.

3.2.4.2 Effect of UV-B radiation on Antarctic phytoplankton (BIF)

Impact of ambient solar UV-B radiation on growth, cell components and nitrogen metabolism of Antarctic phytoplankton and the effect of enhanced levels of UV-B irradiance under laboratory conditions will be investigated. Possible adaptation by UV protecting pigments or mycosporine-like amino acids will be studied. For this purpose the contents of pigments and proteins will be measured. Additionally pool sizes of free amino acids and pigments are analyzed with HPLC (High Performance Liquid Chromatography) and the nitrogen metabolism by ^{15}N uptake. Survival rates of different phytoplankton species will be deduced which allow to estimate the effect of the ozone depletion on the species composition. Informations on the impact of UV-B on the pattern of amino acids and proteins help to estimate the changes of the nutritional quality for primary consumers.

3.2.4.3 Zooplankton ecology (AWI)

The zooplankton program in the Weddell Sea aims to study the secondary production of herbivorous copepods under in-situ and laboratory conditions. It concentrates on deep stratified inventory and reproduction experiments of *Calanus propinquus, Metridia gerlachei, Microcalanus pygmaeus* und *Stephos longipes*. Vertical hauls with a multinet (100µm mesh width) from 1000 m to the surface will be made on stations selected in relation to the hydrographic conditions to examine horizontal and vertical distribution of the above species. The vertical distribution of developmental stages with regard to their ontogenetic migration is of special interest. Ice cores and an under ice pump will be used to examine the distribution of *S. longipes* within and beneath the ice on a transect from the shelf to the open ocean. Furthermore, examination of the gonad development of preserved adult females will give evidence of the maturity in different geographical regions and at various times. Length-frequency measurements will show wether the growth of the populations is directly related to the phytoplankton stock and primary production, respectively.

For all experiments copepods will be sampled with a bongo-net (100µm mesh width) on selected multinet stations within the upper 500 m of the water column. Ripe females will be incubated at 0°C in a laboratory container to determine egg production. Since these females do not grow further, the egg production will be used as a measure of net production and is thus directly related to the food supply. To examine the influence of food on egg production, females will be fed with nutritionally different algae at various concentrations. Activity measurements of digestive enzymes will be conducted with deep frozen material to ascertain if specimens are still in a state of overwintering and thereby in a condition of reduced activity. Lipid analysis will show the different types of overwintering strategies, the food habits and the mobilization of energy reserves.

3.2.4.4 Larval distribution and development of high Antarctic shrimps (AWI)

Decapod crustaceans are scarce in the high Antarctic and represented only by eight species of natant shrimps. Results of the distribution, growth and reproductive biology of the three common species *Chorismus antarcticus*, *Notocrangon antarcticus* and *Nematocarcinus lanceopes* are present for the adults. It is suggested that adaptations of their ontogenetic development, especially to the short period of primary production, which lasts only few weeks during the austral summer, may be the key for the successful colonization of shrimps in the high Antarctic environment. Up to now, information of the larval development is available only from tank observations. However, hardly anything is known about the duration of the pelagic development, about depth zonation, where the different stages occur and the development and feeding behavior under natural conditions.
The following specific questions will be addressed by samples from net hauls.
- Which are the water depths the larvae occur at each stage of their development?
- Are there special nursery areas in the water column (water masses) where the larvae grow up?
- Are there differences with respect to the above mentioned questions between *C. antarcticus*, *N. antarcticus* and *N. lanceopes*, occurring in contrast to the two former species mainly in deeper areas (> 800 m) of the Weddell Sea and further offshore?

Feeding experiments under natural conditions with larvae kept in tanks aboard "POLARSTERN" will provide information about the energy uptake from planktonic food and the ability to store this energy to survive periods of food-shortage during autumn and winter, especially after metamorphosis when the newly moulted shrimps start their bottom-living behavior.

3.2.4.5 Biogeochemistry of barium (AWI, VUB)

Total suspended matter contains barium as barite microcrystals originating from the disintegration of loosely packed bio-aggregates. The concentration is not necessarily correlated with local productivity and biomass but represents the integrated effect of former biological activities. For a better understanding of this relation, it is intended to establish the correlation between the distribution of particulate barium in the water column and biologically mediated uptake and breakdown processes. By measuring the barite accumulation in subsurface layers the export of organic material from the euphotic zone will be estimated. Therefore the question has to be answered if the nitrogen uptake regime -new or regenerated production- or the intensity of the bloom is reflected in the exported material.

With this aim, uptake and remineralisation will be measured by incubation with labelled NH_4 and NO_3. Barium concentration will be determined from filtered particulate matter from water samples and from material collected with sediment traps.

3.2.4.6 Lipid investigations (AWI)

The phytoplankton is the fundamental food for the major calanoid copepod species of the Weddell Sea. The herbivorous copepods incorporate the polyunsaturated fatty acids into the storage and membrane lipids. With the aid of the high unsaturated fatty acids as markers it is possible to obtain more informations about the physiological adaptation concerning the environment and food supply.

From net hauls at different stations the dietary stage of the copepod species, the turnover of the lipids in dependence on the stage of development and the incorporation of the phytoplankton fatty acids in the copepods will be determined by gas chromatography. The incorporation of fatty acids will be determined in additional experiments by use of radioactive labeled material.

Besides the *in-situ* experiments, phytoplankton and zooplankton samples will be collected for further experiments in Bremerhaven.

3.2.4.7 Distribution of microbial biomass and respiratory activity (NIOZ)

Photosynthesis and respiration are among others responsible for modifications in the chemical composition of water masses. In the relatively thin photic zone of the oceans, organic matter and oxygen is produced, while carbon dioxide is consumed. The opposite reaction, remineralisation or respiration with oxygen consumption and carbon dioxide production, occur in the whole water column and the sediment.

The aim of this study is to describe the distribution of microbial biomass and respiration activity. The latter contributes to the biological effect on oxygen and carbon dioxide changes. From observations of the oxygen deficit and respiration rates, ventilation rates of water masses can be calculated. Besides the underwater light regime of photosynthetically available radiation (PAR), UV-A an UV-B will be described.
The following observations will be carried out at about 30 stations:

- light measurements with PAR, UV-A and UV-B in the upper 50 m of the water column.
- microbial biomass measurements (ATP-method) at 10 depth levels between the sea surface and the bottom.
- respiration activity measurements (ETS-method) of the same water samples.
- calibration experiments to calibrate the ETS-method with the oxygen uptake measurements. The high precision Winkler titration will be used.
- experiments on the effect of UV-B irradiation on the energy metabolism of microorganisms.

3.2.4.8 Particle flux in the water column (AWI, FGB)

The particle flux from the photic zone to the deeper water layers will be monitored over several years at three positions in the Weddell Sea, on the western and eastern continental slope and in the center, and at three positions in the Antarctic

Circumpolar Current, in the Polar Frontal Zone and at the northern boundary of the Weddell Gyre. The objective is to quantify seasonal changes of the primary productivity in the photic zone, specifically the export production revealed by the material settling out. Another objective is to determine the settling velocity of particles. These investigations are linked to other sediment trap experiments of the Sonderforschungsbereich 261 in the South Atlantic.

3.2.5 Ship`s meteorological station (DWD)

The personnel of the ship's meteorological station conducts full three hourly WMO-observations (World Meteorological Organization). Furthermore, every day at least one radio sonde will be released for upper-air measurement of temperature, humidity and wind. Also, the received meteorological satellite images will be analyzed. Short to medium range forecasts about the weather- and sea-ice situation will be issued for navigation and the day to day scientific management. In addition the helicopter crew is provided with information about the flight-weather conditions in the operating area.

3.3 ANT X/8
USHUAIA - BREMERHAVEN 24.01.92 - 21.02.92

ZUSAMMENFASSUNG

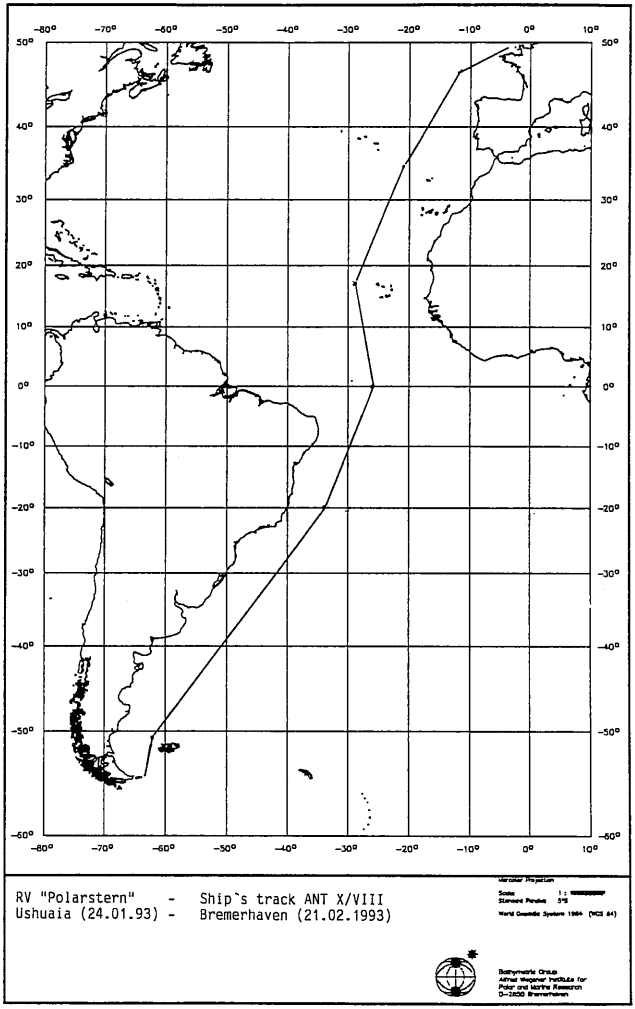
Auf ihren fast regelmäßigen Reisen über beide Hemisphären zwischen der Antarktis und dem Heimathafen, bietet sich "POLARSTERN" als bewegliches Observatorium und Forschungsplattform für großskalige Prozesse in Ozean und Atmosphäre an.

Während dieses Fahrtabschnittes werden ein Ozon-Meßprogramm und Untersuchungen über die Aufnahme von Kohlendioxyd im Oberflächenwasser weitergeführt. Zur Messung des Ozons stehen ballongetragene Ozonsonden und ein Ozonanalysator zur Verfügung. Wasserstoffperoxid wird mittels einer fluorimetrischen Methode gemessen. Neben Ozon ist Wasserstoffperoxid (H_2O_2) ein weiteres wichtiges atmosphärisches Photooxidationsmittel, dessen horizontales Verteilungsprofil parallel zum Ozon erfaßt werden soll. Die Verteilung und Konzentrationen dieser Verbindungen sind als Eingabedaten für troposphärische Modellsysteme von großem Interesse, da Photooxidantien Schlüsselmoleküle für das Oxidationspotential der Atmosphäre darstellen. Ein möglichst lückenloses Datenprofil von hohen nördlichen zu hohen südlichen Breiten ist eine Voraussetzung für die Berechnung globaler troposphärischer Veränderungen durch die Zivilisation.

Man schätzt, daß etwa 40 % des durch die Verbrennung fossiler Energieträger in die Atmosphäre eingetragenen CO_2 vom Ozean aufgenommen wird. Bei 40°S scheint dies in besonderem Maße der Fall zu sein. Messungen des Partialdruckes von CO_2 im Pazifik zeigten eine erhebliche Untersättigung in diesen Breitenzonen. Im Atlantik dagegen gibt es dazu bisher fast keine Beobachtungen. Es ist deshalb geplant, in einem Zeitraum von etwa 5 Jahren die An- und Abreisen der "POLARSTERN" wahrzunehmen, um die Verteilung des Partialdrucks von CO_2 im Oberflächenwasser und in der oberflächennahen Atmosphäre zu messen. Auch andere wichtige Parameter wie gelöster Sauerstoff, Chlorophyll-a, Nährstoffkonzentrationen und meteorologische Größen sollen dabei erfaßt werden. Zur Verbesserung der Genauigkeit der Flußberechnungen wird ferner die Haut-Temperatur der Ozeanoberfläche durch einen Infrarot-Sensor vor dem Bug gemessen.

Abb.3: Die schematische Darstellung der Fahrtroute von "POLARSTERN" während ANT X/8.

Fig. 3: Schematic representation of the cruise track of "POLARSTERN" during ANT X/8.



Andere Programme beschäftigen sich mit den optischen Eigenschaften des Oberflächenwassers und den ersten Testmessungen mit zwei Schiffs-LIDAR-Geräten. Diese Systeme messen Tiefenprofile der Raman- und Mie-Streuung sowie Chlorophyll und Gelbstoff in der euphotischen Zone. Diese Grössen sind bedeutsam für großskalige biologische und chemische Forschungsorhaben in EUROMAR- und JGOFS-Programmen.

3.3.1 Introduction

During the almost regular interhemispheric voyages between Antarctica and her homeport "POLARSTERN" offers herself as a moving observatory to monitor and to investigate processes in Ocean and Atmosphere on a global scale.

During the cruise leg an ozone sounding programme and research into the uptake of carbon dioxide in surface waters will be continued. Other investigations include the determination of optical properties of surface waters and the first tests and measurements with two ship-borne LIDAR systems. These instruments will record depth profiles of Raman and Mie scattering, chlorophyll and Gelbstoff in the euphotic zone.

3.3.2 Accumulation effects in frontal zones and optical properties of sea-water (AWI, SFB 261)

As on previous cruises continuous underway-measurements of temperature, salinity and optical properties of surface sea-water will be carried out using the hydrographic well of the ship. Optical parameters are Mie-backscattering and the fluorescence of chlorophyll and Gelbstoff. These measurements contribute to the following topics:

- statistical approach to the accumulation process of fine particles and chlorophyll in convergences of frontal zones. This is part of the field programme for our particle flux studies in the South Atlantic.
- improvement of our knowledge of optical properties of sea-water with respect to the use of LIDAR systems and satellite remote sensing
- investigations on the use of Gelbstoff as a tracer of water masses

3.3.3 LIDAR measurements of optical parameters of seawater (UOL, AWI, IEMR)

A hydrographic LIDAR has been developed jointly by the University of Oldenburg and the Alfred-Wegener-Institute, Germany. It will be operated in first test measurements during the cruise ANT X/8. Goal of this development is to make available a method which allows to derive depth profiles of hydrographic parameters in the upper water layers by a remote sensing technique.

The instrument utilizes a high-power Nd:YAG laser with subnanosecond pulse emission at several ultraviolet and visible wavelengths, and a telescope multispectral detector system for the measurement of fluorescence and Raman scattering from the water column. Signal returns from the water column are registered with a time resolution of 1 nanosecond. From these data, the sea-water turbidity and the concentration of fluorescent organic compounds (DOM, Gelbstoff, fluorescent pigments in algae) are derived as depth profiles with a resolution of about 20 cm.

These parameters are relevant for large-scale biological and chemical investigation, as, for example, the EUROMAR and JGOFS programmes. Penetration depth into the water column is expected to be more than 50 m in clear oceanic waters, depending on the turbidity.

The LIDAR is installed above a window in the hull of RV "POLARSTERN" in a depth of 10 m. It is continuously operated along the ships track to obtain a data set across the whole of the Atlantic. The remotely sensed depth profiles are verified with CTD and optical in situ measurements performed on stations, and by use of a laboratory fluorometers and photometer for the analysis of sea-water samples.

The upper 10 m of the water column will be investigated by a separate LIDAR system of the Institute of Ecology and Marine Science, Tallinn. This device uses a mirror to reflect the Laser beam directly on to the sea surface.

3.3.4 The partial pressure of carbon dioxide in the Atlantic Ocean (NIOZ)

The oceans presumably serve as a net sink for about 40 % of the fossil fuel CO_2 emitted by mankind. The objective of our research is to quantify more accurately the locality, seasonality and magnitude of this sink. From records of atmospheric CO_2 and 13C/12C isotopic ratio over the past decade a distinct CO_2 minimum (13C/12C maximum) is observed at about 40°S latitude (Rocloffzen, Mook and Keeling, 1991). This minimum suggests a major sink at this latitude, quite possibly in the ocean waters. Recent studies of the partial pressure of CO_2 in surface waters show a dramatic undersaturation of those waters at about 35-45°S in the Southwest Pacific Ocean (Pearman, pers. comm., 1991). Combining these observations with gas exchange coefficients as a function of wind stress (Liss & Merlivat, 1986; Watson, Upstill-Goddard & Liss, 1991) point at an enormous uptake of CO_2 at this latitude. However, virtually no observations exist of the partial pressure of CO_2 in Atlantic or Indian Ocean waters within the 30-60°S latitude range.

The first and final legs of RV "POLARSTERN" on its way to and from Antarctica offer ample opportunity for underway CO_2 measurements. We envisage a 5-years survey of the partial pressure of CO_2 in surface waters and in the overlying atmosphere across the Atlantic during those legs. The first cruise has been run in November 1991, in collaboration with Dr. Schneider of the Institut für Meeresforschung (Kiel). Parameters to be measured are total CO_2 (coulometry), fugacity (partial pressure) of CO_2 in air and seawater, salinity (conductivity) and temperature. Other important quantities are dissolved oxygen, Chlorophyll-a, nutrient concentrations and meteorological observations, notably wind speed, sea state, humidity, atmospheric pressure and air temperature. A gaschromatograph and an equilibrator for continuous CO_2 measurement have been built upon advice of Dr. Watson of Plymouth Marine Laboratory.

The skin temperature of the ocean surface (i.e. within the upper 10-50 micron thick layer of water) may differ 0.1 to 0.5°C from the bulk temperature, which would slightly affect the calculated value of the flux of CO_2 across the air/sea interface (Robertson and Watson, pers. comm., 1992). In our system the bulk temperature is measured at the seawater intake some 11 metres below the sea surface. An infrared sensor at the bow will detect the skin temperature of a patch of water some 5 metres in front of the ship. Thus, we intend to obtain a suite of algorithms for proper correction of the calculated CO_2 flux. This approach will be used for the first time

during ANT X/6. From the gradient in partial CO_2 pressure between air and sea the gas flux into or out of the sea can be calculated using the exchange coefficient for the wind stress (and sea state).

3.3.5 Ozone-Sounding and the distribution of H_2O_2 in the marine troposphere and the Atlantic Ocean (AWI)

The investigations of the atmospheric chemistry group will continue the measurements performed during the "POLARSTERN"-expedition ANT X/1. The crucial point of the program is the vertical and horizontal distribution of ozone (O_3), which will be recorded along the cruise track Ushuaia - Bremerhaven by means of ozone sounding. Apart from ozone, hydrogen peroxide (H_2O_2) is a further important atmospheric photooxidant. The concentration profile will be measured parallel to the ozone distribution. Photooxidants are key molecules for the oxidation potential of the atmosphere. Thus, measured distributions and mixing ratios are pivotal for atmospheric modell systems. In order to simulate the possible impact of anthropogenic emissions on tropospheric chemistry it is decisive to measure the distribution of these compounds on a global scale.

An additional topic of our research program deals with the sources and sinks of the highly soluble H_2O_2 in sea water. We intend to measure the H_2O_2 - concentrations in surface water and in different water depths. In combination with laboratory studies on the H_2O_2 formation by photooxidation processes, these measurements should elucidate the role of the different H_2O_2 sources and sinks in the ocean.

Vertical ozone profiles will be measured with balloon-born ozone sondes, horizontal distribution of ozone by means of a ship-based ozone-analyzer. Hydrogen peroxide will be measured by a fluorimetric method.

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Kapitän	Suhrmeyer	H. Jonas	H. Jonas
1. Offizier	Pönitzsch	K.D. Gerber	K.D. Gerber
Naut. Offizier	Bürger	M. Rodewald	M. Rodewald
Naut. Offizier	Schwarze	S. Schwarze	---
Arzt	NN	NN	NN
Ltd. Ingenieur	Knoop	K. Müller	K. Müller
1. Ingenieur	Delff	G. Erreth	G. Erreth
2. Ingenieur	Simon	R. Fengler	R. Fengler
2. Ingenieur	Folta	O. Ziemann	O. Ziemann
Elektriker	Erdmann	G. Schuster	G. Schuster
Elektroniker	Hoops	H. Elvers	H. Elvers
Elektroniker	Lembke	M. Arndt	M. Arndt
Elektroniker	Piskorzynski	Hel. Muhle	Hel. Muhle
Elektroniker	Roschinsky	J. Roschinsky	J. Roschinsky
Funkoffizier	Müller	H. Geiger	H. Geiger
Funkoffizier	Butz	K.H. Wanger	K.H. Wanger
Koch	Köwing	E. Kubicka	E. Kubicka
Kochsmaat	Roggartz	M. Dutsch	M. Dutsch
Kochsmaat	Kästner	H. Hüneke	H. Hüneke
1. Steward	Peschke	H. Vollmeyer	H. Vollmeyer
Stewardess/Nurse	Meier	M. Reitz	M. Reitz
Stewardess	Hopp	M. Hoppe	M. Hoppe
Stewardess	Mund	K. Helpap	K. Helpap
Stewardess	Neves	J. Hasler	J. Hasler
2. Steward	L. Yu	NN	--
2. Steward	Yang	NN	--
Wäscher	NN	Ch. Yang	Ch. Yang
Bootsmann	Hopp	H.D. Junge	H.D. Junge
Zimmermann	Kassubeck	K. Marowsky	K. Marowsky
Matrose	Winkler	L.Gil Iglesias	L.Gil Iglesias
Matrose	Suarez Paisal	J. Soage Curra	J. Soage Curra
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Matrose	NN	NN	
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