Expeditionsprogramm Nr. 79

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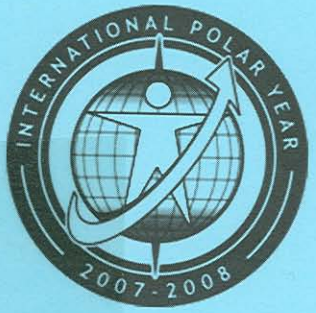

MI IFTUNG ALFRED-WEGENER-INSTITUT
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MANN VON HELMHOLTZ-GEMEINSCHAFT DEUTSCHER
FORSCHUNGSZENTREN E.V. (HGF)

BREMERHAVEN, OKTOBER 2007

EXPEDITION PROGRAMME No. 79

RV POLARSTERN

ANT-XXIV/1
26 October - 26 November 2007
Bremerhaven - Cape Town

ANT-XXIV/2
28 November 2007 - 4 February 2008
Cape Town - Cape Town
Weddell Sea

ANT-XXIV/3
6 February - 16 April 2008
Cape Town - Punta Arenas
Weddell Sea, Drake Passage

ANT-XXIV/4
18 April - 20 May 2008
Punta Arenas - Bremerhaven

Coordinator
Eberhard Fahrbach

Chief Scientists

ANT-XXIV/1:	Sigrid Schiel
ANT-XXIV/2:	Ulrich Bathmann
ANT-XXIV/3:	Eberhard Fahrbach
ANT-XXIV/4:	Andreas Macke

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ANT-XXIV/1

26 October - 26 November 2007

Bremerhaven - Cape Town

Chief scientist
Sigrid Schiel

CONTENTS

1. ÜBERBLICK UND FAHRTVERLAUF

Sigrid Schiel (AWI)

Am 26. Oktober 2007 tritt FS *Polarstern* ihre 24. Antarktisreise an. Während des ersten Fahrtabschnittes (ANT-XXIV/1) werden verschiedene wissenschaftliche Programme durchgeführt und das Tiefsee-Sediment-Echolot Parasound wird getestet.

Der Haupttest des Parasound findet auf früheren Tiefsee-Teststationen in der Biskaya statt. Anschließend wird die Testmannschaft in Las Palmas/Gran Canaria ausgeschifft.

Der Schwerpunkt des wissenschaftlichen Programmes liegt auf den Untersuchungen zur Biodiversität des Zooplanktons, eingebunden in das internationale Projekt "Census of Marine Zooplankton" (CMarZ), einem Feldprojekt des "Census of Marine Life" (CoML). CoML ist ein globales Netzwerk von Wissenschaftlern aus über 70 Ländern, das im Rahmen eines zehnjährigen Projekts die Diversität, die Verteilung und das Vorkommen mariner Lebewesen in der Vergangenheit, Gegenwart und Zukunft untersucht. CMarZ hat sich zum Ziel gesetzt, präzise und vollständige Informationen zur Artendiversität, Biomasse, biogeographischen Verteilung, genetischen Diversität und Gemeinschaftsstrukturen weltweit zu produzieren und zu ergänzen. Derzeit sind etwa 6800 Arten von 15 Stämmen beschrieben, mindestens genauso viele neue Arten werden erwartet.

Die zooplanktologischen Arbeiten während ANT-XXIV/1 finden vorwiegend südlich des Äquators statt und konzentrieren sich auf das Zooplankton aus größeren Tiefen (>200 m), dem Meso- und Bathypelagial. Ziel ist, genauere Kenntnisse über die Artenzusammensetzung und -reichtum in einem bisher nur sehr wenig erforschtem Gebiet zu erhalten und neue Arten aufzufinden. Die Zooplanktonproben werden mit morphologischen und molekularen Ansätzen teilweise sofort an Bord und später in den verschiedenen Labors bearbeitet. Dementsprechend setzt sich die internationale CMarZ Gruppe aus Taxonomen, Molekulargenetikern sowie Studenten zusammen.

Folgende weitere wissenschaftliche Programme werden während der Fahrt ausgeführt:

- Die AWI - Universität Bremen – Helmholtz - Nachwuchsgruppe „Bio-Optics" wird optische und biologische Untersuchungen im Oberflächenwasser als Vergleichsmessungen für Satellitenbeobachtungen durchführen.

- Die Arbeitsgruppe der Universität Lancaster und der GKSS wird organische Schadstoffe sowohl im Wasser als auch in der Luft untersuchen, um Informationen zur Verteilung und zum Verbleib dieser Substanzen zu erhalten.

- Die IFM-GEOMAR Arbeitsgruppe wird im Rahmen des "Meridional Ocean Radiation Experiment" (MORE) durch eine Kombination aus Mikrowellenradiometer, Ceilometer, Vollhimmelskamera sowie Pyrano- und Pyrgeometer den Zustand der bewölkten Atmosphäre und ihren Einfluss auf die Nettostrahlungsbilanz an der Meeresoberfläche ermitteln. Die gemessenen Temperatur- und Luftfeuchtigkeitsprofile dienen auch zur Validation der Produkte des Radiometer IASI an Bord des neuen europäischen Wettersatelliten MetOp.

- Das atmosphärenchemische Programm des Heidelberger Instituts für Umweltphysik

untersucht mit Hilfe des "Differential Optical Absorption Spectroscopy" (DOAS) die Spurengasverteilung in der Atmosphäre.

Der Fahrtabschnitt endet am 26. November 2007 in Kapstadt.

ITINERARY AND SUMMARY

On 26 October 2007, RV *Polarstern* will start her 24th Antarctic expedition from Bremerhaven. During the first leg of the cruise (ANT-XXIV/1) the new upgraded Deep Sea Sediment Echo Sounder Parasound will be tested and different scientific programmes will be performed.

The Sea Trial and test of the Parasound will be carried out at former test locations in the Bay of Biscay. Thereafter the testing team will disembark in Las Palmas/Gran Canaria.

The main focus of the scientific programme during this expedition is based on the diversity of zooplankton contributing to the international "Census of Marine Zooplankton" project (CMarZ), an oceanic realm field project of the "Census of Marine Life" (CoML). CoML is a global network of researchers in more than 70 nations engaged in a ten-year initiative to assess and explain the diversity, distribution and abundance of marine life in the oceans – past, present and future. CMarZ is working towards a taxonomically comprehensive assessment of biodiversity of animal plankton throughout the world oceans. The overriding project goal is to produce accurate and complete information on zooplankton species diversity, biomass, biogeographic distribution, genetic diversity, and community structure. Zooplankton currently includes ~7,000 described species in fifteen phyla; the expectation is that at least that many new species will be discovered.

The zooplankton research will concentrate on the tropical/subtropical waters of the eastern Atlantic Ocean south of the equator in order to collect and identify the zooplankton distributed throughout the entire water column, with a focus on the under-sampled meso- and bathypelagic zones. The overall goal is to increase knowledge of the species composition and richness of dominant zooplankton taxa and pelagic fish in a hitherto understudied region and to discover new species. The zooplankton samples will be analysed on board and later on in the different laboratories including integrated morphological/molecular approaches to species identification and recognition. Thus, the international CMarZ team includes taxonomic experts and molecular specialists as well as students.

The following additional scientific programmes will be carried out during the complete cruise:

- The Bio-Optical Team of the AWI - Uni Bremen Helmholtz University Young Investigators Groups will carry out optical and biological measurements in the surface water as ground truthing for satellite observations.

- The group of the University of Lancaster and the GKSS will collect air and water samples for the analysis of persistent organic pollutants (POPs) along the cruise journey to clarify their distribution and fate in seawater and atmosphere.

- In the framework of the "Meridional Ocean Radiation Experiment" (MORE), the IFM-GEOMAR group will determine the state of the atmosphere and its effect on the net radiation budget at the sea surface using a combination of a microwave radiometer, ceilometer and full sky imager as well as pyrano- and pyrgeometer. Retrieved temperature and humidity profiles will serve to validate products of the IASI radiometer on board the new European weather satellite MetOp.

- The Heidelberg Institute of Environmental Physics will carry out "Differential Optical Absorption Spectroscopy" (DOAS) measurements to determine the distribution and amount of different atmospheric trace gases in the atmosphere.

ANT-XXIV/1 will finish on 26 November 2007 in Cape Town.

2. CENSUS OF MARINE ZOOPLANKTON AND RELATED TOPICS

2.1 BIODIVERSITY OF ZOOPLANKTON

D. Allison, N. Copley, P. Wiebe, (WHOI); R, Escribano (UdeC); J. Grieve (NIWA); A. Pierrot-Bults (ZMA); S. Schiel (AWI); M. Kuriyama, Y. Nishibe (ORI); M. Angel (NOCS); C. Clarke-Hopcroft (IMS) K. Blachowiak-Samolyk (IOPAS);

Objectives

Our current understanding of global patterns of pelagic biodiversity results from decades of work by biological oceanographers, marine ecologists, and taxonomists. But despite more than a century of sampling the oceans, comprehensive understanding of zooplankton biodiversity has eluded biological oceanographers because of the fragility, rarity, small size, and/or systematic complexity of many taxa. For many zooplankton groups, there are longstanding and unresolved questions of species identification, systematic relationships, genetic diversity and structure, and biogeography. Molecular systematic analysis has revealed cryptic species within oceanic and coastal species, and has called into question previous interpretations of biogeographic patterns and evolutionary relationships.

There are distinctive latitudinal gradients in marine zooplankton species richness. An equatorial maximum in species richness is typical for marine benthos. In contrast, zooplankton species richness is highest in climatically-stable subtropical open ocean gyres and shows local minima along the equator. However, recent studies of species numbers of calanoid copepods in the upper 300 m along a transit from Bremerhaven to Cape Town with RV *Polarstern* in 2002 also demonstrated an equatorial maximum. Such exceptional diversity patterns indicate that more detailed studies are needed to elucidate the underlying mechanisms driving zooplankton diversity.

Less-studied areas - where the ratio of unknown to known species is greatest ("biodiversity hotspots") - include:

- Southern hemisphere: Oceans of the southern hemisphere are poorly studied relative to the northern hemisphere in both coastal and oceanic regions (except parts of the Antarctic).
- Open ocean waters: Oceanic waters are generally under-sampled relative to coastal regions.
- Deep sea: This widely unexplored part of the ocean is inhabited by a multitude of undiscovered species, emphasizing the need for its continued intensive study.

The main task of the CMarZ research during ANT-XXIV/1 will therefore be the investigation of zooplankton throughout the entire water column of oceanic stations south of the equator (Fig. 1), with a particular focus on the poorly-known meso- and bathypelagic realms, and then to determine DNA sequences (i.e., DNA barcodes) for identified zooplankton specimens at sea. Thus, the research will concentrate on the joint analysis of the samples; and the scientific team will include CMarZ researchers, taxonomic experts, molecular specialists and students.

After the cruise, follow-up molecular analysis, expert taxonomic evaluation and description, species counts and biodiversity analyses will be closing up the examination of the samples.

Work at sea

Zooplankton will be sampled by different types of plankton nets. Since species occur in very low abundances at greater depth, a large Multiple Opening/Closing Net and Environmental Sensing System (MOCNESS, Wiebe et al. 1985) with a 10-m^2 opening (MOC-10), will be deployed below 1,000 m to filter large volumes of water to compensate for the low numbers of individuals. A smaller MOCNESS, with a 1-m^2 opening (MOC-1) and the "maxi"-MultiNet (opening 0.5 m^2) will be used for sampling the upper 1,000 m.

MultiNet sampling of mesozooplankton

As standard device for the quantative collection of mainly small sized zooplankton a multiple opening and closing net (MultiNet, mouth opening: 0.5 m^2) equipped with 9 nets of 150 µm will be used. The net will be towed vertically, sampling standard layers between 1,000 m and the surface, with subsuccesive nets opening at 1,000, 800, 600, 400, 300, 200, 150, 100 and 50 m.

MOCNESS sampling of zooplankton and micronekton

Larger and fast-swimming zooplankton and micronekton will be sampled quantitatively throughout the water column using two types of MOCNESS. The MOC-10 will carry five nets, and will be deployed with the first net (with 3 mm mesh) open down to the deepest depth desired (about 4,000 m). At depth, the first net will be closed and subsequent nets (all 335 µm mesh size) will be opened at desired depths as the MOC-10 is hauled obliquely towards the surface. Thus, the first net will sample from the surface to the bottom and the other nets will sample in about 1,000 m intervals from the bottom up to a depth of 1,000 m. Above 1,000 m, vertically-stratified sampling will be done using a MOC-1 equipped with 9 nets. each with 335 µm mesh.

Two types of stations will be carried out (Fig. 1):
Short station: 1 MultiNet to 1,000 m
Long station: all three nets (MOC-10 to 4,000 m, MOC-1 to 1,000 m, MultiNet to 1,000 m)

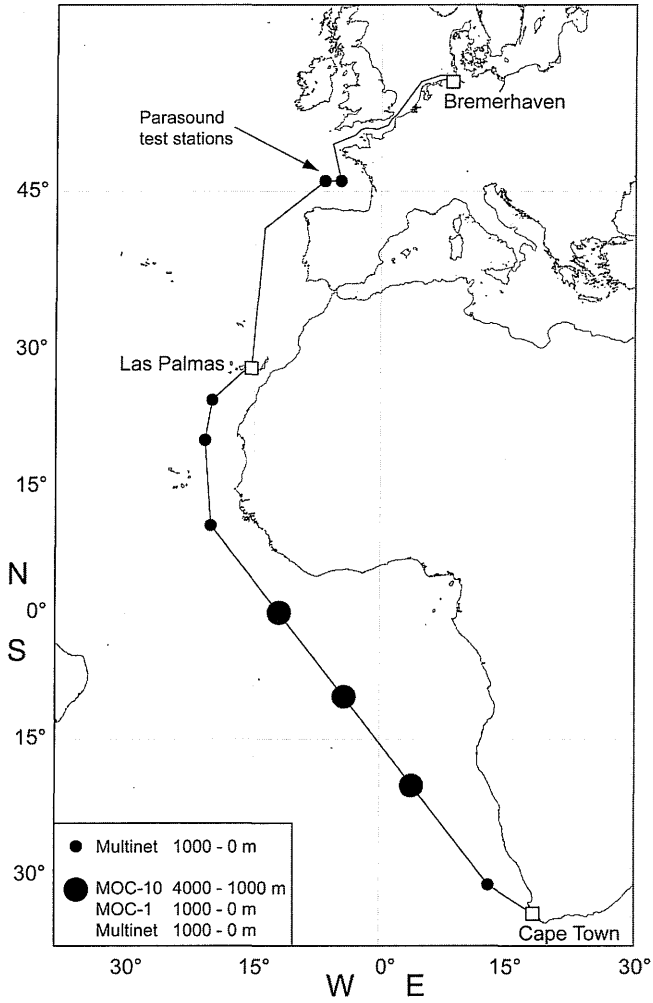

Abb. 1: Fahrtroute und geplante Stationen ANT-XXIV/1
Fig. 1: Cruise track on ANT-XXIV/1 and planned station grid

Ship-board laboratory processing

Immediately after sampling, large individuals (e.g. gelatinous forms, fish, macrozooplankton and nekton) will be removed, recorded and subjected to a variety of procedures including

further identification, dissection, photographic imaging and preservation (in alcohol, formalin or frozen).

After the removal of the large individuals, the samples will be splitted. One half (1/2) of the sample will be preserved in formalin for quantitative studies. The other half will be split again, with one-quarter (1/4) preserved immediately in alcohol. The other one-quarter (1/4) will be used for live picking. Species will be identified by the taxonomic experts on board. Several individuals of the identified species will be used for experimental and biochemical studies. At least three individuals per species will be submitted to the DNA Barcoding laboratory for DNA extraction and sequencing.

References

Wiebe PH, Morton AW, Bradley AM, Backus RH, Craddock JE, Cowles TJ, Barber VA, Flierl GR (1985) New developments in the MOCNESS, an apparatus for sampling zooplankton and micronekton. Mar Biol 87: 313-323

2.2 DNA BARCODING

P. Batta Lona, A. Bucklin, R. Jennings, L. Nigro (UConn); L. Blanco Bercial (UniOviBOS); C. Sweetman (HBOI); C. Folkers (DZMB)

Objectives

Onboard discussions with other cruise participants will allow development of specific applications of the DNA barcode data and preparation of planned publications. Among the possible applications are: identification of unknown species, discovery of new species, identification of prey species in gut contents of predators, identification of larval and adult life stages of a given species, and population genetic analysis to determine the taxonomic significance of geographic variation, including cryptic species.

The UConn-base Team DNA includes personnel who have carried out DNA barcoding at sea during earlier cruises (Bucklin et al. 2007). Based on prior experience, we expect to catalogue 1,500 – 2,000 specimens, carry out 1,000 DNA extractions and PCR reactions, and complete about 1,000 sequences for 600 specimens of 250 different species.

Work at Sea

DNA sequencing must be carried out in a separate laboratory, with closable doors off an interior hallway (not the open deck), located as close to the centre of moment of the vessel as possible to minimize motion. The lab should have sturdy benches for securing heavy gear. We will have one dehumidifier running to keep conditions suitable for the planned analyses. The lab should have a sink and drain with running fresh water.

Specimens for analysis: Samples for DNA analysis will be used live, flash-frozen, or preserved in pure 95 % ethanol. Specimens will be identified to species using a dissecting microscope. Care must be taken to minimize heat and light during microscopic examination of the specimens, to preserve DNA quality for analysis. For species smaller than ~25 mm, the entire specimen is consumed for DNA sequencing. Then, one or more additional intact individuals will be retained as specimen vouchers. For larger organisms, small portions of specimens can be excised and used for analysis. Intact specimen vouchers are still retained if possible.

DNA extraction: A Qiagen DNeasy Kit is used to extract DNA following standard protocols. Tissue is dissected under sterile conditions and digested with proteinase K until no solid pieces of tissue are visible. Purified genomic DNA is eluted in Buffer AE (supplied in the DNeasy Kit) with elution volumes of 100 - 200 mL.

PCR amplification: A 708 base-pair region of the mitochondrial cytochrome oxidase C subunit I (mtCOI) gene is amplified using consensus PCR primers from Folmer et al. (1994). The reaction is carried out in a thermal cycler or PCR machine (Applied Biosystems, Inc. ABI 9600). Three PCR machines will be available at sea. The resulting PCR product, millions of copies of the target sequence, is subjected to 55 volt current through 1 % agarose/TBE gel medium stained with ethidium bromide. After electrophoresis, the gel is visualized under UV light to diagnose the PCR results. The PCR products judged successful are prepared for DNA sequencing by purification using a Qiagen PCR Cleanup Kit, following manufacturer's protocols. The purified template DNA is then eluted in Buffer EB (10 mM Tris) in preparation for sequencing.

DNA sequencing: A reaction cocktail is prepared with the purified template DNA (mtCOI PCR product), one of the PCR primers as sequencing primer, and the BigDye 3.1 Terminator sequencing chemistry (Applied Biosystems, Inc.). The reactions are one-quarter standard volume (1/4X) and are carried in an ABI 9600 thermal cycler, using the manufacturer's protocols. The sequences are then purified by ethanol/EDTA/sodium chloride precipitation, followed by centrifugation to pellet the sequenced DNA. The DNA is washed with 80 % ethanol and re-centrifuged, then dissolved in 10 mL high-quality deionized formamide (HiDi, ABI) in preparation for sequence determination. The sequence is read by a 4-capillary ABI 3130 DNA Sequencer, using a 50 cm capillary array and standard operating conditions. A one-hour electrophoresis time is sufficient to determine a 500 - 700 base-pair sequence. Sequencing is ideally done from each end of the DNA template, providing complete bi-directional coverage of the mtCOI gene fragment.

Data analysis: When available, the DNA sequences from either direction for a given specimen are aligned and checked against each other to identify any discrepancies, which are manually corrected or noted as unresolvable, as appropriate. Alternatively, DNA sequences from different individuals of the same species are aligned to manually check and edit the machine sequence data. The final DNA sequence for an individual is the sequence resulting from these checks, including the bi-directional comparisons when available. The DNA barcode for a given species is the DNA sequence for one individual, selected among the sequences for at least three individuals per species. Each DNA barcode must be supported by a bi-directional sequence read for at least one specimen.

Database management: Specimens are tracked from collection to DNA barcode using an ACCESS database. Specimens are assigned a number in sequence according to an agreed-upon format. Other metadata include: genus and species names; collection date, time, latitude, longitude, and depth; person identifying the specimen; PCR and sequencing reaction numbers; and sequence identifier. The database is maintained on a PC computer in the laboratory.

References

Bucklin A, Wiebe PH, Smolenack SB, Copley NJ, Beaudet JG, Bonner KG, Färber Lorda J, Pierson JJ (2007) DNA barcodes for species identification of euphausiids (Euphausiacea, Crustacea). J Plankton Res 29: 483-493

Folmer O, Black M, Hoen W, Lutz R, Vrijenhoek R (1994) DNA primers for amplification of mitochondrial cytochrome c oxidase subunit I from diverse metozoan invertebrates. Molec Mar Biol Biotech 3: 294-299

2.3 ZOOPLANKTON METAGENOMICS

R. Machida (ORI)

Objectives

Zooplankton metagenomic analysis will target all metazoans collected by plankton nets. After the collection, a portion of the sample will be preserved in RNALater (Ambion), which keeps the RNA intact. Then, those samples will be brought back to a laboratory, and messenger RNA will be extracted from the bulk zooplankton sample. From the extracted messenger RNA, cDNA library will be constructed (this library contains all transcribed protein coding gene sequences from all metazoan animals). Using this cDNA library, mitochondrial COI gene sequences will be amplified (this library contain mitochondrial COI gene sequences from almost all metazoans) and sequenced exhaustively.

Advantage of this analysis is that we can acquire almost all-metazoan mitochondrial COI gene sequence. However, we do not have the species information of those sequences because the starting template of the analysis was extracted from bulk zooplankton sample. Therefore, we will further compare the zooplankton metagenomic sequences and DNA barcoding sequence, and try to estimate the species information of those sequences. From the zooplankton metagenomic analysis, we will also obtain sequences those DNA barcoding have not finished. We are now constructing the database to open those sequences to public. Another advantage of zooplankton metagenomic analysis is that they are not contaminated by mitochondrial pseudogenes since all of those sequences have been determined from messenger RNA.

Work at sea

The sampling will be carried out with the MOC-1, MOC-10, and MultiNet in cooperation with the CMarZ group (see 2.1).

2.4 PHYLOGENY OF PLANKTONIC CHAETOGNATHA

R. Machida, H. Miyamoto (ORI)
Not on board: S. Nishida (ORI)

Objectives

Currently, about 100 species of pelagic chaetognatha are known to occur in the world oceans. They are one of the most abundant carnivore zooplankton and play important roles in terms of matter and energy transfer in the ocean ecosystems. We are currently analyzing the complete mitochondrial DNA sequences from various chaetognatha species and will try to elucidate the phylogenetic relationship of them.

Work at sea

The sampling will be carried out with the MOC-1, MOC-10, and MultiNet in cooperation with the CMarZ group (see 2.1).

2.5 BIODIVERSITY AND ECOLOGY OF DEEP-SEA EUCHAETIDAE AND AETIDEIDAE (CALANOID COPEPODS)

H. Auel (University Bremen)

Objectives

Since 2005 the DFG funded project "Biodiversity and ecology of deep-sea copepods in polar seas – speciation processes and ecological niches in the homogeneous environment of the pelagic realm" has been focusing on the biodiversity and feeding ecology of dominant deep-sea copepods in Polar Regions.

The two copepod families Euchaetidae and Aetideidae are important components of zooplankton communities throughout the World Ocean, especially in deep oceanic waters. Most of these species inhabit meso- and bathypelagic depths, while some are epi- or benthopelagic. Euchaetidae contribute significantly to the zooplankton biomass in both Polar Regions, while Aetideidae are characteristic inhabitants of the deep-sea pelagial. The genus *Paraeuchaeta* is carnivorous and includes major predators on other mesozooplankton. Aetideid copepods are generally referred to as omnivorous. Species of both families can be responsible for one to two thirds of the total energy flow through the carnivorous trophic level, and may consume nearly half of the vertical carbon flux. Thus, these meso- and bathypelagic copepods substantially affect pelagic-benthic coupling processes and, hence, may have a significant impact on carbon and energy fluxes in marine ecosystems.

A characteristic, but still enigmatic feature of Euchaetidae and Aetideidae is the co-occurrence of several to many closely related species in pelagic deep-sea habitats. For instance, 14 species of the genus *Paraeuchaeta* coexist in the Southern Ocean off South Georgia and as well in the North Atlantic Rockall Trough. Since the pelagic deep-sea is an almost homogeneous environment without physical barriers, the sympatric co-occurrences of such closely related species raise the questions how the biodiversity of these deep-sea species evolved and what mechanisms effectively minimize inter-specific competition, which would otherwise lead to the extinction of less fit competitors. Most deep-sea ecosystems depend on primary production in the thin euphotic surface layer of the ocean and the sedimentation of organic matter to deeper strata. Therefore, resource limitation presumably represents an important factor in the evolution of meso- and bathypelagic species.

Our project focuses on differences in vertical distribution, life-cycle strategies, diet spectra and feeding behaviour of different co-occurring deep-sea copepods in order to characterise their distinct ecological niches in the deep-sea pelagic realm. Thus, the project contributes to an improved understanding of deep-sea biodiversity and evolutionary patterns in general and, in particular, of the reasons and mechanisms sustaining a relatively rich meso- and bathypelagic fauna with a comparatively high biodiversity despite the limited food supply and in the absence of physical barriers. With these objectives, our project covers central issues of international marine biodiversity initiatives, such as Census of Marine Zooplankton (CMarZ) and Census of Marine Life (CoML).

Concentrating on important families of deep-sea copepods and applying state-of-the-art molecular genetic and biochemical methods, the project will address the following questions:

1) How do closely related species (or even congeners) find individual niches in the almost homogeneous environment of the deep-sea pelagial?
2) Are there any differences in the vertical distribution of sympatric species?

3) How do feeding behaviour and diet composition differ between co-occurring species in order to minimise or avoid inter-specific competition?
4) When, how and why did the radiation of aetideid and euchaetid copepods occur leading to the high biodiversity of these groups of deep-sea inhabitants?
5) What are the speciation mechanisms in the almost homogeneous environment of the deep-sea pelagial?
6) What are the reasons and mechanisms sustaining a relatively rich meso- and bathypelagic fauna with a comparatively high biodiversity in polar seas despite the limited food supply and in the absence of physical barriers?

Work at sea
The sampling and sorting will be carried out in cooperation with the CMarZ group (see chapter 2.1).

While the primary focus of our DFG-funded project lies on Polar Regions, the Atlantic meridional transect during ANT-XXIV/1 provides the ideal opportunity for sampling deep-sea copepods throughout the Atlantic Ocean, effectively linking the two major study areas in the Arctic Greenland Sea and in the Atlantic sector of the Southern Ocean. We are very keen on collecting individuals of those species present in both Polar Regions in order to establish whether their distribution pattern is really bi-polar or rather more cosmopolitan.

Additional species of the families Euchaetidae and Aetideidae will be sampled for molecular genetic analyses in order to complete the phylogenetic tree. In addition, material will be collected for stable isotope and fatty acid biomarker analyses to study trophic level and dietary composition of deep-sea copepods from different latitudes. These samples will be sorted immediately after the catch and stored at -80° C for biochemical analysis in the home lab. If sufficient individuals are available, their individual energy demands will be determined by respiration measurements under simulated *in situ* conditions on board. Based on individual energy requirements and abundance data, the total ingestion of deep-sea copepods will be estimated and their impact on energy and carbon fluxes in the marine ecosystem can be assessed.

In connection with another project focusing on the role of hypoxic conditions in structuring marine pelagic communities in the Angola-Benguela frontal zone off Southwest Africa, we intend to sample certain mesopelagic copepod species specifically adapted to life in the oxygen minimum layer for physiological analyses. Results from previous cruises indicate that these species may find a refuge from predation and competition in the intermediate oxygen minimum layer.

2.6 COMPARATIVE STUDIES OF DISTRIBUTION, GROWTH AND REPRODUCTIVE STATUS IN EUPHAUSIIDS

F. Buchholz (BAH-AWI)

Objectives
Euphausiids, commonly known as krill, have been considered in previous extensive ecological investigations of the West-African upwelling systems as important components of the zooplankton communities. In fact, krill species can dominate the plankton by up to 60 % in biomass and consist of at least 8 principal species. Accordingly, their importance in specific neritic and pelagic food webs is high. Euphausiids have also served as water mass

indicators. Consequently, horizontal distribution has been recorded, and partly vertical distribution patterns.

However, these previous investigations usually have stopped short at a certain distance from the African coast or shelf. Nevertheless, due to the complicated current situation in the area there is a regular offshore export into the open Atlantic. The distribution patterns of the krill species will be evaluated with respect to this export along the planned transect. At the same time these patterns serve to be compared to the shelf situation where relevant research is currently ongoing. Species distribution studies will be flanked by detailed analysis of growth and reproduction by moult and reproductive staging of fresh specimens on board and of some adaptive traits in biochemical composition. Trophic relationships will as well be considered on a comparative basis.

Work at sea
The major commitment will be the deployment and maximisation of the 1 m^2 MOCNESS for the whole plankton group (see 2.1).

2.7 CARNIVOROUS ZOOPLANKTON

S. Kruse (AWI)

Objectives
The investigations during this cruise will include the Atlantic amphipod and chaetognath species taken from down to 4,000 m water depth. Generally the focus of this studies lies in the carnivores of the Southern Ocean and their role in mesopelagic food webs (see expedition programme ANT-XXIV/2). Therefore the investigations during this cruise will give the opportunity to compare the Antarctic data of different seasons with data of the Atlantic, as an extension of the studied area to the north. This sampling along a north-south transect in the Atlantic will reveal spatial distribution, abundance and composition of species. Additional gut content analysis in the home laboratories will give information on the investigated species' food composition. All information contribute to the understanding of their role in the food webs in different parts of the Atlantic Ocean.

Work at sea
The sampling and sorting will be carried out in cooperation with the CMarZ group (see 2.1).

2.8 PTEROPODS AND CEPHALOPODS

H. Ossenbrügge, U. Piatkowski, (IFM-GEOMAR)

Objectives
Pteropods are holoplanktonic molluscs of the Orders Thecosomata (shelled pteropods or sea butterflies) and Gymnosomata (naked pteropods). They occur in all marine environments from the poles to the equator, and from the surface to bathypelagic depths. Pteropods are typically open-ocean organisms, with sizes varying between 2 to 30 mm. Many of them are free-swimming snails whose foot is modified into a delicate wing. They float freely in the water, along with the currents. Approximately 120 species are known today. Gymnosomata are hunters, whereas Thecosomata are omnivorous mucus feeders. They can entangle planktonic food through a mucous web which can be up to 50 mm wide, many times larger than themselves. Most of the pteropods undergo more or less pronounced diel vertical

migrations, feeding at night near the surface and descending to greater depths during the day. The very fragile calcareous shells of the Thecosomata are bilaterally symmetric and vary widely in shape, making them an important tool for species identification. Our own recent studies near the Cape Verde Islands revealed an unexpected high diversity of pteropods in epipelagic and mesopelagic waters, indicating also distinct vertical distribution patterns. Scarcely anything is known about geographical distribution and ecology of these unusual molluscs in tropical Atlantic waters, although they can become quite abundant in mid-water plankton communities.

Planktonic cephalopods, and planktonic early life stages of nektonic, and benthic cephalopods, are distributed throughout all oceans. They occur from the surface to abyssal depths, and include epipelagic, mesopelagic, and bathypelagic species with spectacular forms such as the giant squid which can attain a total length of nearly 20 m, or the bioluminescent jewel squids, a prominent group of the tropical mid- and deep-water fauna. Most species have complex distribution patterns, perform pronounced diurnal vertical migrations, and many descend during ontogeny. Little is known about pelagic cephalopods in the open waters and the deep-sea of the tropical Atlantic Ocean, where many species are not well described, maybe even not yet discovered, although they form a key element of the pelagic food web in these waters. But quantitative distributional data on planktonic cephalopods are still scanty, because no device catches all developmental stages with equal efficiency, and because trawls that effectively catch adult cephalopods are non-quantitative. The smaller species and the early life stages of squids (Teuthida) and of several octopod groups are major components of tropical mid- and deep-water micronekton and macroplankton communities. They will be efficiently sampled by the MOCNESS which will be used during ANT-XXIV/1.

During the cruise we want to sample and identify pteropods and cephalopds from epipelagic to bathypelagic waters, analyze geographical and vertical distribution patterns, and contribute to issues such as systematic relationships, genetic diversity and biogeography. The investigations will provide new insights into the biogeography of these conspicuous animal groups from the tropical Southeast Atlantic Ocean.

We will also tackle heteropods and nudibranchs which occur in the samples.

Work at sea
The sampling and sorting will be carried out in cooperation with the CMarZ group (see 2.1).

2.9 PELAGIC FISHES

T. Sutton, C. Sweetman (HBOI)

Objectives
The employment of the large MOCNESS during ANT-XXIV/1 provides the opportunity to sample and census deep-pelagic fishes that are often missed by standard trawling procedures (i.e. smaller, but more numerous forms that pass through the mesh of fisheries-style trawling gear). The aim is to enlarge our knowledge on the assemblage structure, occurrence and distribution on meso- and bathypelagic fishes and the discovery of undescribed and very rare species, which is one of the most exciting features of deep-sea trawling.

Work at sea
The sampling will be carried out with the MOC-1 and MOC-10 in cooperation with the CMarZ group (see 2.1).

2.10 EDIA OUTREACH PROGRAMME

K. Milhahn (Journalist), S. Zankl (Photographer)

ANT-XXIV/1 is a dedicated CMarZ cruise and a media exposure with photos and written material including weblogs, articles and short documentations will be carried out during the cruise.

3. BIO-OPTICAL MEASUREMENTS: GROUND-TRUTHING FOR SATELLITE OBSERVATIONS

L. Bentama, B. Schmitt (AWI), S. Gehnke (GKSS)
Not on board: A. Bracher (AWI), R. Röttgers (GKSS)

Objectives
It has been estimated that marine phytoplankton contributes 30 to 60 % to global primary production. The large uncertainty range is a result of the lack of global information on phytoplankton absorption and light penetration depth, which cannot be supplied by the current ocean colour satellite sensors. The spectral resolution of these sensors is not sufficient to extract the relevant information. The variation of phytoplankton absorption in ocean waters also affects the retrieval of chlorophyll *a* concentrations (a measure of phytoplankton biomass) derived from satellite data, which are important input data used in primary production models. Results by Bracher et al. (2006) show that specific phytoplankton absorption spectra as well as information on the light penetration depth can be derived by combining information from measurements of the two satellite instruments, MERIS with high spatial, and SCIAMACHY with high spectral resolution (both operating on board of the European environmental satellite ENVISAT).

Besides the analysis of satellite data and applied model studies, field measurements in the open ocean of phytoplankton pigment composition, optical characteristics of phytoplankton and other water constituents, reflectance and underwater light measurements are highly precise input parameters for the validation of results from the analyses of satellite data and modelling.

Thus the aim of this research project is to improve estimates of global marine primary production and the distribution of major phytoplankton functional groups by using remote sensing data in combination with *in situ* measurements of ocean optics, phytoplankton productivity and composition and particulate organic carbon (POC). In particular, data will be collected during this cruise to improve our understanding of the oceans variability in optical properties and to improve/develop remote sensing algorithms for the investigated research area. Algorithms to retrieve POC from space are still very basic, but are of great importance for studies concerning biogeochemical cycles and the biological pump within the world's oceans because carbon and not chlorophyll are the bases for those studies. Through a better

knowledge of the sinks and sources of CO_2 in the ocean a contribution will be made to a better understanding of changes in the world's climate as well as to the understanding of the marine food web.

A close collaboration with the group from Lancaster University is planned to provide data about the phytoplankton concentration and composition, and phytoplankton iron limitation (by FRRF).

Work at sea

1. Water samples

Water samples will be taken frequently (every 6 hours) from beneath the ship (moon pool) and processed for various analyses:

- Water samples will be filtered onto GF/F filters for pigment analysis, particulate absorption measurements and POC.
- Water samples will be preserved for flow cytometry measurements later in the laboratory in Bremerhaven.
- Particulate absorption in suspension and absorption of Gelbstoff will be measured during the cruise using the point-source integrating-cavity absorption meter (PSICAM) (Röttgers et al. 2005).

2. Online and *in situ* Optical Measurements

- A FastTracka Fast Repetition Rate Fluorimeter (FRRF) will be used in a flow-through system with water continuously pumped from the moon pool to provide online data of chlorophyll fluorescence during the cruise.
- Remote sensing reflectance will be measured firstly from onboard the ship with a set of three radiometers and secondly in the water column (0-150 m) at the stations.

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Röttgers R, Schönfeld W, Kipp P-R, Doerffer R (2005) Practical test of a point-source integrating cavity absorption meter: the performance of different collector assemblies. Applied Optics 44 (26): 5549-5560.

4. PERSISTENT ORGANIC POLLUTANTS (POPS) IN AIR AND WATER

J. Barber, C. Benskin, C. Moeckel, J. Schuster (University Lancaster); S. Gehnke (GKSS)
Not on board: K. C. Jones (University Lancaster), C. Temme (GKSS)

Objectives

Several leading European groups of Environmental Chemistry are joining the RV *Polarstern* on ANT-XXIV/1 in 2007. Their common interest is the detection of trace organic contaminants, namely persistent organic pollutants (POPs), in remote regions of the Atlantic Ocean in order to further investigate the fate and behaviour of these compounds at global scale. The RV *Polarstern* has been found to be well suited to act as a clean ship for the sampling of these trace organic compounds. The chemical measurement programme during ANT-XXIV/1 will focus on the determination of selected POPs in air and water. The contaminants which are investigated can be subdivided into two major groups:

1. The "classical" POPs such as polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), hexachlorobenzene (HCB) and selected organochlorine pesticides.
2. "New" and emerging POPs like the polybrominated diphenyl ether (PBDEs) flame retardants and polyfluorinated compounds (PFCs).

Therefore, POPs can undergo long-range atmospheric transport (LRAT) with high volatile compounds condensing in colder (polar) regions and less volatile compounds condensing in warmer regions close to sources. This will probably not occur in one step, but in a number of steps of volatilization followed by deposition, according to seasonal fluctuations in temperature. The effect of this will be a relative enrichment of the more volatile compounds in cold areas, while less volatile compounds are enriched in moderate latitudes. Criteria for global fractionation behaviour of chemicals are various physical-chemical properties such as vapour pressure, the octanol-air partition coefficient (K_{OA}), the octanol-water partition coefficient (K_{OW}) and the Henry's Law Constant.

PCBs are a class of compounds with a variety of different physical-chemical properties. There are 209 congeners relative to the number of chlorine atoms on the molecule and the position that these atoms occupy. Therefore, with all these differences in physical-chemical properties, PCBs are ideal to investigate and find evidence of the global fractionation theory. These properties are very dependent on temperature and will therefore greatly influence the global transport of POPs.

Growth in interest on PBDE flame retardants has been as exponential as their apparent increase in the environment over the past 20 - 25 years in North America and Europe. Toxicological studies of limited PBDE congeners indicate that they are potential thyroid disruptors and developmental neurotoxicants. However, there is still very little information on PBDE contamination and its spatial trend over the regions of the world. The investigation which follows air sample collection on RV *Polarstern* will attempt to comprehensively understand the spatial and temporal trend of contamination by PBDEs in the atmosphere.

Polyfluorinated organic acids and their derivatives are produced by industry in very large quantities and are used for many purposes. Perfluoroalkyl sulfonates are used as surfactants

and for surface treatment in carpets, leather, paper, packaging and upholstery. In addition, some sulfonated and carboxylated PFCs have been used in or as fire-fighting foams, paints, alkaline cleaners, shampoos, and insecticide formulations. Due to the large production quantities and the persistence in the environment, polyfluorinated compounds are meanwhile globally distributed. Perfluorooctanesulfonic acid (PFOS) and perfluorinated carboxylic acids such as perfluorooctanoic acid (PFOA) have been detected in organisms from remote locations such as in blood of ringed seals, polar bears, mink, birds and fishes as well as in human blood.

Due to the findings of PFCs in numerous biota samples, it is of special interest to investigate their long-range transport. Two transportation processes from sources to remote locations have been proposed: On the one hand, PFCs could be transported by means of oceanic currents in the water phase due to their high polarity, especially since some of the PFCs have been found in North Sea and Arctic sea water. On the other hand, some precursors of perfluorinated sulfonic and carboxylic acids are highly volatile and can lead to an increased input of PFCs from the atmosphere. The investigation of the wide scale distribution of perfluorinated acids in the sea water of the North Sea and Atlantic Ocean is an ideal complementation to the simultaneous measurements in the atmosphere. ANT-XXIII/1 was especially suitable for these investigations as this cruise leg ranged from the likely sources (European continent) to remote areas where direct inputs are lacking.

Analysis of different classes of compounds can therefore help to provide ‚clues' about environmental processes. In previous studies we have investigated the latitudinal distribution of PCBs, PCDD/Fs, PAHs and HCHs on Atlantic cruises. More recently, we have become interested in observations made about the unique diel cycling of POPs in air over parts of the open ocean and the processes which could be controlling these phenomena. By combining short-term atmospheric samples with the collection of representative water samples across different regions of the Atlantic ocean, answers are sought as to whether atmospheric transport or degradation or the marine phytoplankton productivity are controlling the levels and air-water exchange and settling flux of POPs over the open ocean.

Work at sea

Air and water samples will be collected for analysis of POPs along the cruise journey, to allow further investigation of the broad roles of proximity to land masses and oceanic properties to be determined. Intensive air and water sampling will be carried out in regions of the ocean (20-0°N) in the North Atlantic and (0-15°S) in the South Atlantic. These regions have been shown to have a previously unobserved diurnal cycle of POPs in air during past cruises. The hypothesis of the biological pump influencing the atmospheric and seawater concentrations will be investigated by collecting air and water samples and biological parameters, such as chlorophyll pigments (divinyl and monovinyl chlorophyll) and fluorescence. These measurements will help us to understand how the changes in community, size and species of phytoplankton may have an influence in the atmospheric concentration. In turn, we will begin to better understand and quantify the role of oceans as sources/sinks of POPs.

5. COMPOSITION OF THE ATMOSPHERE AND RADIATION BUDGET AT THE ATMOSPHERE/OCEAN INTERSECTION

A. Wassmann, Y. Zoll (IFM-GEOMAR)
Not on board: A. Macke (IFM-GEOMAR)

Objectives

The net radiation budget at the surface is the driving force for most physical processes in the climate system. It is mainly determined by the complex spatial distribution of humidity, temperature and condensates in the atmosphere. The project aims at observing both the radiation budget and the state of the cloudy atmosphere as accurate as possible to provide realistic atmosphere-radiation relationships for use in climate models and in remote sensing. While similar experiments have been performed from land stations, only few data from measurements over ocean areas exist. The present project is part of the "Meridional Ocean Radiation Experiment" MORE which uses Atlantic transfers of various research vessels for the combined measurements of the atmospheric state.

A multichannel microwave radiometer will be applied to continuously retrieve temperature and humidity profiles as well as cloud liquid water path over the ocean. Time series of these profiles will show small scale atmospheric structures as well as the effects of the mean state of the atmosphere and its variability on the co-located measurements of the downwelling shortwave and longwave radiation. The atmospheric profiles will also be used to validate the satellite based profiles from the IASI instrument onboard the new European polar orbiting satellite MetOp. In the long run, based on the experiences of this and later Atlantic transects an autonomous measurement container is planned for operational atmospheric monitoring onboard commercial ships.

Work at sea

Upon departure from Bremerhaven the following instruments will be installed onboard RV *Polarstern* for continuous measurements:

1) Multichannel microwave radiometer HATRPO. The instrument requires occasional calibrations with liquid nitrogen as well as tipp-calibrations under calm sea and homogeneous atmospheric conditions.
2) Ceilometer including tilt measurement device for cloud bottom height measurements.
3) Whole sky imager for cloud structure measurements
4) Handheld sun photometer (Microtops) for aerosol and cloud optical thickness
5) inclinometer for sea surface tilt measurements

Occasional extra-radio soundings (ca. one per day) have to be performed close to the overpass times of the MetOp satellite. Synoptical observations will be done every hour. Most instruments require non or little maintenance. Only the microwave radiometer performance will be critically observed as this is the first time that such an instrument works under open ocean conditions.

Expected results

1) 2d structure of the clear sky atmosphere and corresponding net radiation budget.
2) Horizontal structure of the cloud water path and its effect on the downwelling shortwave and longwave radiation

3) Vertical structure of temperature and humidity as well as its variability for validation of IASI products
4) All results under mid-latitude, tropical and subtropical climate conditions.
5) Sea surface roughness (tilt angle distribution)

6. MAX-DOAS MEASUREMENTS OF ATMOSPHERE TRACE GASES FOR SCIAMACHY-VALIDATION

J. Helmschmidt (IUP)
Not on board: U. Platt, R. Sinreich (IUP)

Objectives
An important aspect of environmental sciences is the knowledge on trace gases and their concentration and distribution in the atmosphere. Tropospheric gases like NO_2, H_2O, HCHO, IO, BrO, O_4 and SO_2 are especially interesting due to their direct impact on humans. Stratospheric gases like O_3, NO_2, BrO, OClO and H_2O may influence the earth's radiation budget. Measurements of these species can be performed for instance by satellites, as by the instrument SCIAMACHY onboard ENVISAT launched into a polar orbit in March 2002. Figure 2 shows the mean distribution of tropospheric NO_2 between January 2003 and June 2004. To validate satellite-provided data, however, ground-based control-measurements done at locations beneath the satellite's orbit are necessary. In case of SCIAMACHY, measurements onboard RV *Polarstern* seem best suited for that purpose, because on the way to and from the Antarctica, the ship follows a polar course corresponding to ENVISAT's orbit.

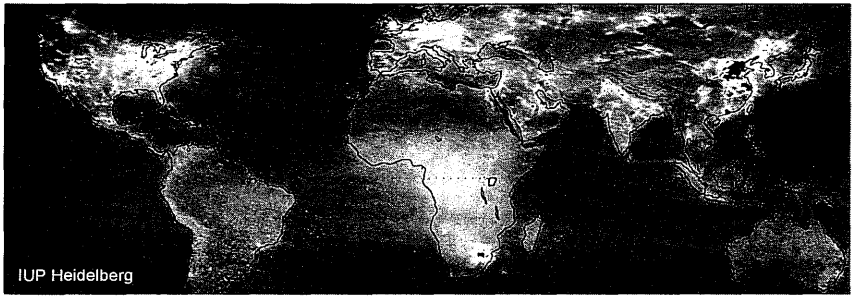

Fig. 2: Mean distribution of tropospheric NO_2 between January 2003 and June 2004 measured by the satellite instrument SCIAMACHY

The DOAS instrumentation
The method used by the satellite's instrument is the proven Differential Optical Absorption Spectroscopy (DOAS). For this principle, the fact is used that solar light passing through the atmosphere is not only strayed but also absorbed by gas molecules and will thereby yield absorption lines within the gained spectra which are characteristic for each gas compound.

From these lines, identity and amount of atmospheric trace gases can be obtained. For ground-based measurements, it is even possible to derive height profiles of the trace gases: light coming in vertical is dominated mainly by absorption of stratospheric gases because. Light coming in more horizontal contains more and more absorption of tropospheric gases due to the longer way of the sunlight through this sphere. This is the so-called Multi-Axis (MAX)-DOAS principle.

The validation instrument onboard RV *Polarstern* also applies the (MAX-)DOAS measurement principle of the satellites apparatus, of course. Thereby a moveable telescope which is able to point sequentially to the different vertical directions is mounted on a cardanic system to reduce the effect of the ship's movements (see Fig. 3). In its housing it contains not only a stepper motor for movement, but also protective shutters and HgNe- and Halogen calibration lamps. The incoming light is conducted to a cooled miniature Czerny-Turner spectrograph/CCD-detector unit (OceanOptics USB2000) by seven-fold glas fibres. The wavelength range of about 290 to 430 nm allows the retrieval of NO_2, BrO, SO_2, HCHO and others. Last, the gained spectra are stored in PC hard disk for the DOAS analysis. The instrument is working mostly automatically.

Results

For instance, measurements performed during the cruise ANT-XIX of RV *Polarstern* from Bremerhaven to Cape Town using a precursor of the nowadays instrumentation (same instruments, but another configuration of telescope units) feature the concentration of BrO and NO_2: The maxima were reached when the ship passed the English Channel with 3.1 ± 1.1 parts per trillion for BrO and 0.36 ± 0.13 parts per billion for NO_2. This was to be expected from the high air pollution in Europe. Furthermore an anti-correlation of BrO and NO_2 could be observed indicating a reservoir substance formed by the two gases (Diploma thesis J. Boßmeyer). On further cruises the ship-based DOAS instrumentation should gather data to investigate such events including other trace gases in combination with satellite results. Besides these measurements done mainly for validation purposes, gathering data in Antarctic seas is important for further atmospheric and also climate research.

Ship-based DOAS measurements have been carried out before in the years 1990, 1993 and from 2001 through 2007 with good success from the Heidelberg Institute of Environmental Physics.

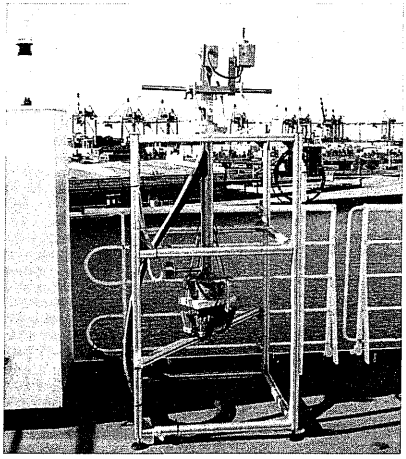

Fig. 3: The on-deck instrumentation of the MAX-DOAS instrument. The telescope unit is mounted on a cardanic system whereby the brush is used for braking the movement influenced by the ship's movement.

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7. SEA TRIAL AND TESTS OF THE NEW UPGRADED DEEP SEA SEDIMENT ECHO SOUNDER PARASOUND DS III-P70 DURING ANT-XXII/1

M. Boche, S. El Naggar, F. Niessen (AWI); T. Liebe, J. Rogenhagen (Laeisz), J. Ewert (Atlas Hydrographic)

The Deep Sea Sediment Echo Sounder "PARASOUND DS III-P70"; ATLAS HYDROGRAPHIC, Bremen, Germany; was upgraded from DS II to DS III-P70 during the last ship yard stay of RV *Polarstern* in Bremerhaven between 04.05.07 and 29.05.07.

Newly designed hard and software were installed and tested at harbour in Bremerhaven. The first operational test under real conditions at sea was carried out during the first part of the cruise ARK-XXII/1 between Bremerhaven and Tromsø between 29 May 2007 and 06 June 2007.

The final sea trial will be carried out during the cruise ANT-XXIV/1 between 26 October 2007 and 5 November 2007 in the Bay of Biscay at the former test location loc. 1 (45°50'N; 06°15' W) and loc. 2b (45°15' N; 04°35' W) to obtain the real deep sea conditions for the normal operation (Fig. 4). Water depths of more than 4,000 m are here required.

The mentioned location is also used in the past as test and calibration area for Hydrosweep and Parasound Echo Sounders of RV *Polarstern* (Fig. 5). Reference data are also available from this location and are here needed for comparison between the old and the new Parasound system.

The planned works are

- Complete and tune the final installation according to the claims found out during the first sea trial tests on ARK-XXII/1
- Operational checks under different transmission parameters (frequencies, power, sea states, water depth, etc)
- Sea trial and acceptance tests at location (about 48 hours in the Bay of Biscay), data analysis and validations
- Real operations between test locations and Las Palmas
- Disembarking the test teams in Las Palmas on 5 November 2007

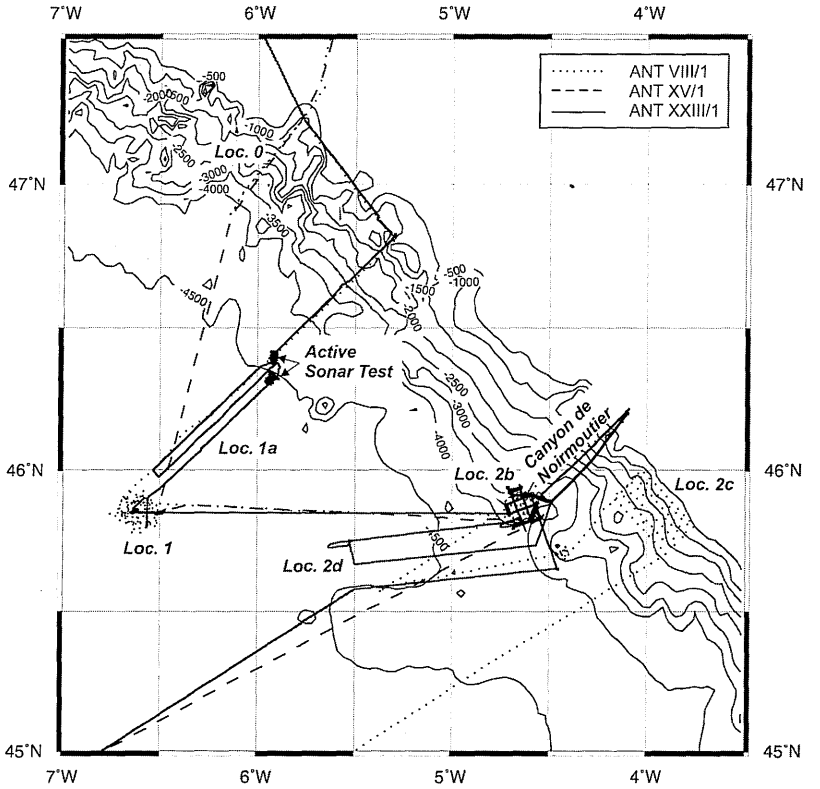

Fig. 4: Map of the former test locations in the Bay of Biscay for Hydrosweep and Parasound Loc. 1 and Loc. 2b will be used for sea trial of Parasound during ANT-XXIV/1

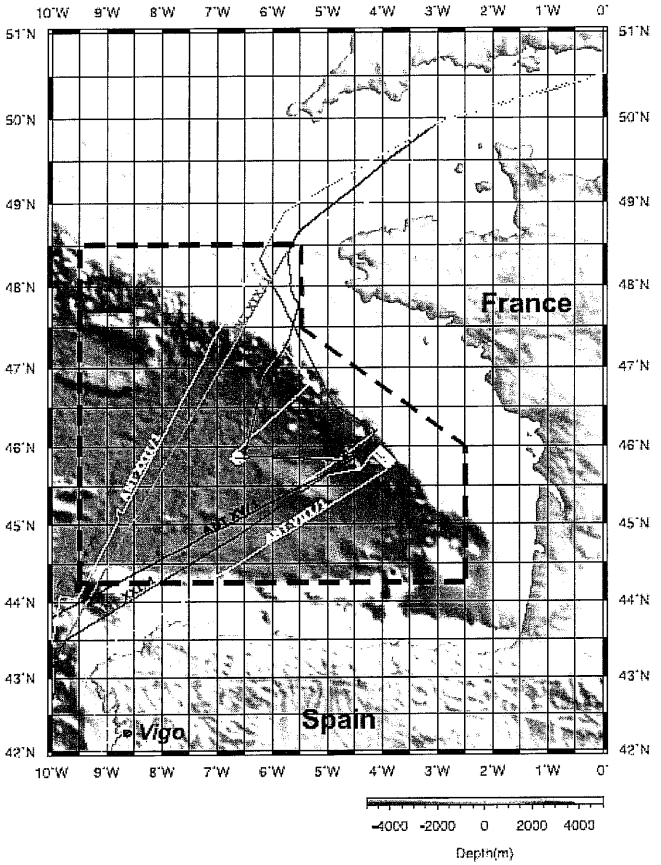

Fig. 5: Map showing the area for acoustic studies with Parasound including tracks studied during previous expeditions. The study area (broken line) is confined by the coordinates:

1) 48°30' N 9°30' W
2) 48°30' N 5°30' W
3) 47°30' N 5°30' W
4) 46°00' N 2°30' W
5) 44°15' N 2°30' W
6) 44°15' N 9°30' W

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UdeC	Estacion de Biologia Marina-Dichato Universidad de Concepcion Casilla 160-C Concepcion Chile
UniOvi BOS	Departamento de Biología de Organismos y Sistemas Universidad de Oviedo C/ Catedrático Rodrigo Uria s/n Oviedo 33071 Spain
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ZMA	Zoological Museum Amsterdam University of Amsterdam P.O. Box 94766 1090 GT Amsterdam The Netherlands

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Wiebe	Peter	WHOI	Biologist
Zankl	Solvin		Photographer
Zoll	Yann	IFM-GEOMAR	Student, meteorology

*disembarking in Las Palmas

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1.	Pahl,Uwe	Master
2.	Grundmann, Uwe	1.Offc.
3.	Ziemann,Olaf	Ch.Eng.
4.	Bratz, Herbert	2.Offc.
5.	Peine, Lutz	2.Offc.
6.	NN	2.Offc.
7.	Türke, Helmut	Doctor
8.	Koch, Georg	R.Offc.
9.	Kotnik, Herbert	2.Eng.
10.	Schnürch, Helmut	2.Eng.
11.	Westphal, Henning	3.Eng.
12.	Holtz, Hartmut	Elec.Tech.
13.	Rehe, Lars	Electron.
14.	Dimmler, Werner	Electron.
15.	Fröb, Martin	Electron.
16.	Feiertag, Thomas	Electron.
17.	Clasen, Burkhard	Boatsw.
18.	Neisner, Winfried	Carpenter
19.	Kreis, Reinhard	A.B.
20.	Schultz, Ottomar	A.B.
21.	Burzan, G.-Ekkehard	A.B.
22.	Schröder, Norbert	A.B.
23.	Moser, Siegfried	A.B.
24.	Pousada Martinez,S.	A.B.
25.	Hartwig-L., Andreas	A.B.
26.	Kretzschmar, Uwe	A.B:
27.	Beth, Detlef	Storekeep.
28.	Kliem, Peter	Mot-man
29.	Fritz, Günter	Mot-man
30.	Krösche, Eckard	Mot-man
31.	Dinse, Horst	Mot-man
32.	Watzel, Bernhard	Mot-man
33.	Fischer, Matthias	Cook
34.	Tupy, Mario	Cooksmate
35.	Völske,Thomas	Cooksmate
36.	Dinse, Petra	1.Stwdess
37.	Stelzmann, Sandra	Stwdss/KS
38.	Streit, Christina	2.Steward
39.	Schmidt, Maria	2.Stwdess
40.	Deuß, Stefanie	2.Stwdess
41.	Hu Guo, Yong	2.Steward
42.	Sun, YongSheng	2.Steward
43.	Yu, ChungLeung	Laundrym.

ANT-XXIV/2

28 November 2007 - 4 February 2008

Cape Town - Cape Town
Weddell Sea

Chief Scientist
Ulrich Bathmann

CONTENTS

1. ÜBERBLICK UND FAHRTVERLAUF

Ulrich Bathmann (AWI)

Am 28. Dezember 2007 wird das Forschungsschiff *Polarstern* von Kapstadt aus zum 2. Fahrtabschnitt ihrer 24. Antarktis-Expedition auslaufen. Während des Fahrtabschnittes wird sie als Basis für die Durchführung eines umfangreichen marinen Forschungsprogramms während des antarktischen Sommers dienen. Eine weitere wichtige Aufgabe ist der unterstützende eisbrechende Einsatz für die zwei Transportschiffe, die Material für die neue Neumayer III Station anliefern. Zusätzlich wird *Polarstern* so früh die Eisbedingungen es zulassen Neumayer II mit Proviant, Material und Treibstoff für die Sommerkampagne versorgen. Enden wird der Fahrtabschnitt am 4. Februar 2008 in Kapstadt.

Der wissenschaftliche Anteil der Expedition ist drei Projekten des Internationalen Polarjahres IPY gewidmet. SCACE - Synoptische Studie des Zirumantarktischen Klima- und Ökosystems - untersucht physikalische und biologische Zusammenhänge im antarktischen Zirkumpolarstrom (ACC) um die entsprechenden Mechanismen aufzuklären, die die Ozeanproduktivität und den Wassermassentransport bestimmen. SYSCO - Gekoppelte Systeme in der Tiefsee - untersucht den Einfluß der pelago-benthischen Kopplung in der Tiefsee in ausgewählten Gebieten zwischen der Subtropischen Konvergenz und dem antarktischen Kontinent. LAKRIS - Lasarev-See Krill Studie - bestimmt die Verteilungsmuster, Lebenszyklen und die Physiologie antarktischen Krills in der Lasarev-See.

Um die logistischen Aufgaben so früh wie möglich abzuarbeiten, wird *Polarstern* zielstrebig nach Neumayer dampfen und nur eine Station bei 56°S 0°O beproben. Ansonsten werden während der Anfahrt nur wissenschaftliche Untersuchungen durchgeführt, die die Schiffsgeschwindigkeit nicht beeinflussen. Diese Projekte umfassen die Beobachtung mariner Vögel (inkl. Pinguine) und Warmblüter, die von einer holländischen Forschergruppe von einem Beobachtungsposten auf dem Peildeck systematisch gezählt und bestimmt werden. Mit dem hinter dem Schiff gezogenen sogenannten Continous Plankton Recorder wird das Plankton aus dem Oberflächenwasser herausfiltriert und später während der taxonomischen Auswertung den geographischen Sammelpositionen zugeordnet.

Das IPY Programm SCACE wird durch duch die Programme CCMLAR - Konvention zum Schutz lebender antarktischer Resourcen - und das durch das BMBF geförderte LAKRIS komplettiert. Das übergeordnete Ziel von SCACE ist die synoptische Aufnahme biologischer und physikalischer Umweltparameter im ACC rund um den Kontinent im Rahmen von IPY, um diese mit historischen Daten zu vergleichen um Änderungen zu erkennen.

SCACE verbindet verschiedenste Disziplinen, um folgende Fragen zu beantworten:
- Welche physikalischen, biologischen und chemischen Prozesse regulieren die ozeanischen Systeme im Südozean und beeinflussen somit die Entwicklung des globalen Klimas?
- Wie sensibel reagieren die Prozesse im Südozean auf natürliche und anthropogen beeinflusste Störungen?

Der Südozean spielt eine zentrale Rolle in der Kontrolle des Systems Erde. Der ACC verbindet alle großen Ozeane miteinander, isoliert aber auch die Antarktis von diesen. Er

transportiert Wärme und Süßwasser und sorgt für die Verteilung gelöster Substanzen. Er ist Heimat verschiedenster Ökosysteme, die sich bei sich ändernden Klimaregime ggf. gegenseitig ersetzen. Auftrieb von Tiefenwasser fördert Makronährsalze in die lichtdurchflutete produktive Ozeanoberfläche und bildet so günstige Ausgangsbedingungen für eine umfangreiche Primärproduktion, die das Potential hat, atmosphärisches CO_2 zu binden. Ein Team aus Norwegen wird sich der Änderung des Karbonatsystems im Oberflächenwasser widmen, die durch diese Prozesse angetrieben wird.

Die Systeme des Südozeans sind ihrerseits aber auch sensibel gegenüber global wirkenden Änderungen. So werden wir eine der zahlenmäßig häufigsten Copepodenarten (*Oithona* spp) darauf hin untersuchen, wie flexibel sie auf Änderungen reagieren kann. *Oithona* ist weltweit verbreitet und es ist bisher unklar, um wie viel Arten es sich handelt und wo die Plastizität jeder Art je nach Verbreitungsgebiet gleich ist. Das Zooplankton des Zwischenwassers (Mesopelagials) ist vom Nahrungseintrag von oben abhängig, ansonsten jedoch an eine sehr gleichförmige Umgebung angepasst und somit für kleinste Änderungen hoch sensibel. Aber auch Organismen, die direkter Nutzung durch den Menschen zur Verfügung stehen werden, wie der antarktische Krill, werden während der Expedition intensiv untersucht.

Im Wesentlichen stammt unser Wissen über den antarktischen Krill aus nur wenigen Gebieten, insbesondere solchen um die Antarktischen Halbinsel. Neue Untersuchungen zeigen, dass die saisonalen Überlebensmechanismen von Krill regional variabel sind und dass weder die lokalen Umweltfaktoren noch die Reaktion von Krill darauf auf ein größeres umgebendes Gebiet extrapoliert werden dürfen. Mit dem LAKRIS-Projekt sollen Messungen, die im Rahmen von SO-GLOBEC und von CCAMLR (Convention for the Conservation of Antarctic Marine Living Resources) auf der Westseite der Antarktischen Halbinsel, im Südantillenmeer und im Indischen Sektor des Südpolarmeeres vorgesehen sind, durch detaillierte Untersuchungen in der Lasarev-See ergänzt werden.

Innerhalb des Wasserringes um die Antarktis gibt es unter anderem zwischen der Antarktischen Halbinsel und dem Nullgrad-Meridian, bzw. der Lasarev-See, ein Gebiet mit anscheinend erhöhten Konzentrationen von Krill. Ob diese offenbare Krillansammlung einem einzigen Krillbestand oder mehreren verschiedenen Beständen zuzuordnen ist, ist unklar. Strittig debattiert wird gegenwärtig auch, wie und ob dieser Bestand bzw. diese Bestände mit denen in anderen Abschnitten des Südpolarmeeres in Verbindung stehen. Untersuchungen in der Lasarev-See sollen zur Klärung dieser Fragen entscheidend beitragen.

Wenn Krill mit Meeresströmungen in das Weddellmeer eingetragen wird, dann am wahrscheinlichsten im Bereich der Lasarev-See, wo, zusammenfallend mit der Ostflanke des Weddell-Wirbels, südwärtige Strömungen angetroffen werden. Entlang des Nullgrad-Meridians kommt Krill zwischen dem 50. südlichen Breitengrad und der antarktischen Küste bei 70°S vor. Dies stellt die weiteste Nord-Süd-Verteilung von Krill im gesamten zirkumpolaren Südpolarmeer dar. Nördlich von 60°S ist Krill dem ostwärts versetzenden Zirkumpolarstrom unterworfen; Krill, der hier angetroffen wird, befindet sich also stromab der bekanntermaßen großen Bestände des Südantillenmeeres. Aus dem Bereich weiter südlich in Nähe des Kontinents, wo in der Lasarev-See westwärtige Strömungen vorherrschen, gibt es kaum Informationen über das Vorkommen von Krill-Larven. Diese müssten hier aber vorkommen, wenn eine Rezirkulation von Krill mit dem Weddell-Wirbel in das Südantillenmeeres postuliert wird.

SYSTCO ist ein weiteres großes IPY Programm der Expedition. Große Teile des Meeresbodens um die Antarktis zählen zur Tiefsee. Im Gegensatz zu den relativ gut bekannten

Schelfgebieten der Antarktis ist die Tiefsee noch so gut wie unerforscht. Erste Untersuchungen während des internationalen Projekts ANDEEP haben eine erstaunliche Artenvielfalt von Tiefseeorganismen gezeitigt. Basierend auf diesen Ergebnissen werden wir jetzt die Prozesse der atmosphärische-pelagische-benthischen Kopplung untersuchen. SYSTCO soll helfen die Rolle der Tiefsee des Südozeans im globalen Energiehaushalt, deren Funktion beim Klimawandel und beim Erhalt der biologischen Diversität aufzuklären.

Die Ziele von SYSTCO sind
- Prozessstudien in verschiedenen Tiefseegegenden in der Antarktis
- Aufklärung wie die pelago-benthische Kopplung dieser Systeme funktioniert.

Hierzu werden die eigenen Untersuchungen zu denen der anderen Arbeitsgruppen in Beziehung gesetzt, sodass
- der Einfluss der atmosphärischen CO_2-Konzentration auf das Karbonatsystem und somit auf die Produktion und den Export organischen Materials beleuchtet wird,
- und dessen Einfluss auf die Biologie abyssaler Schlüsselarten, auf das Recruitment benthischer Organismen in der Nephloid-Bodenschicht, auf Nahrungsmenge und -qualität für abyssale Organismen und deren Reaktion in Hinbilck auf Fraßökologie und trophische Interaktionen,
- der Einfluss der Bodentopographie, der Sedimenteigenschaften und der Biogeochemie des Meeresbodens und des Porenwassers auf benthische Organismen in der Gegenwart und der Erdgeschichte möglich wird. Die Aufnahme der Bathymetrie soll die Bildung von Mikrohabitaten aufklären helfen.

Unter dem Schirm des IPY Rahmenprogramms ICED (Integrated Circumpolar Ecosystem and Climate Dynamics), wird SCACE ein Transekt auf die Antarktis abarbeiten, dass von anderen Programmen auf anderen Forschungsschiffen in verschieden Regionen um den Antarktischen Kontinent ebenfalls durchgeführt wird. Solche synoptischen zirkumantarktischen Studien stellen die einzige Möglichkeit dar, einen Momentanzustand antarktischer Systeme vor dem Hintergrund hoher zwischenjährlicher Schwankungen aufzunehmen. Die enge Kooperation mit SYSTCO wird es erlauben die Kopplung von Prozessen in der Atmosphäre, in den oberen Wassermassen, im gesamten Wasserkörper bis in die Tiefsee aufzuklären.

ITINERARY AND SUMMARY

On 28 December 2007 RV *Polarstern* will leave from Cape Town for the second leg of her 24th expedition. During this cruise that will end in Cape Town on 4 February 2008, RV *Polarstern* will support an extensive marine research programme during the austral summer and will allocate ship time to support the logistic operations of two other ships that transport material for the construction of Neumayer III. In addition *Polarstern* will supply Neumayer II as early as possible in the season but depending on sea-ice conditions.

The scientific part of the cruise is part of three major IPY projects. SCACE aims to investigate the physical and biological patterns in the Antarctic Circumpolar Current to understand the temporal and spatial variability's that determine ocean productivity and water

mass transport. SYSCO-ANDEEP aims to understand the impact of pelagic-benthic coupling on deep-sea biota in distinct regions between the STC and the Antarctic continent. LAKRIS aims to reveal the life cycle pattern, distribution and physiology of Antarctic krill in the Lazarev Sea.

In order to access the working area for the logistic part of the cruise as soon as possible, RV *Polarstern* will head almost straight towards its first scientific position at 56°S 0°E and than continue to Neumayer II station. On the way to the Antarctic only such scientific activities will be performed that need no extra ship time.

The projects planned on the way south focus on observations of marine vertebrates and zooplankton. A Dutch team will visually observe penguins, seabirds and marine mammals from the upper bridge from out two wooden cabins. On the southward route from Cape Town another project scheduled and not requiring any ship time is the sampling of the near-surface zooplankton by use of the so-called Continuous Plankton Recorder (CPR).

The IPY programme SCACE, with addition of the CCMLAR programme and the BMBF funded LAKRIS programme will form one scientific backbone of the cruise. The overarching goal of SCACE is to use the outstanding chance provided by the IPY for an international collaboration to collect a unique data set that can serve as a benchmark for comparison with existing data to identify and quantify polar changes.

SCACE aims at welding together a broad range of ocean science disciplines in order to address currently elusive questions such as:

- Which physical, biological and chemical processes regulate the Southern Ocean system and determine its influence on the global climate development?
- How sensitive are Southern Ocean processes and systems to natural climate change and anthropogenic perturbations?

The Southern Ocean is critically involved in the machinery driving earth´s climate. The Antarctic Circumpolar Current (ACC) connects all the other oceans. Thus it plays a major role in the global transports of heat and fresh-water and the ocean-wide cycles of dissolved substances. It harbors a series of distinct ecosystems that displace each other with changing climate regimes. Upwelling of deep water masses results in an extraordinary high supply of plant macronutrients, which could sustain much higher primary production and hence CO_2 uptake than however observed. Thus, the Norwegian team will concentrate on the reaction of the carbonate system of the surface ocean to changes.

While the Southern Ocean thus exerts a control on earth's climate, it is itself sensitive to climatic changes, which may occur on various time scales and affect the biota. We will closely investigate one of the most important zooplankton specimens in the system, namely the cyclopoid copepod *Oithona* spp. These species have world-wide distribution and cope with extreme warm and cold environmental conditions similarly well. It is the focus of these studies to find out, if it is really the same species we are seeing. We will also investigate species' physiologyical reactions on changing environment. Zooplankton in the mesopelagic zone depends on food supply from above and therefore is subject to studies of species adaptation to very stable environmental conditions. There are, however, also direct anthropogenic influences on the ecosystem, namely by harvesting marine living resources such as krill.

Much of our knowledge of Antarctic krill originates from a few regions, such as the much-studied Antarctic Peninsula. But it is becoming increasingly clear that the seasonal survival mechanisms of krill are variable, so neither the local environment, (e.g. those along the Antarctic Peninsula) nor the response of krill to it can be extrapolated easily to a wider area. The LAKRIS project will complement the existing international research activities within SO-GLOBEC and CCAMLR (Convention for the Conservation of Antarctic Marine Living resources) along the west Antarctic Peninsula, Scotia Sea and in the Southwest Indian Ocean Sector.

Within the great current systems encircling Antarctica, there is a hotspot of krill density within a sector defined roughly by the Greenwich Meridian (i.e. the Lazarev Sea) and the west of the Antarctic Peninsula. Whether this hotspot itself contains one or several "stocks" of krill and whether these are connected with those in the rest of the Southern Ocean are currently topics of intense debate. Understanding krill survival at the seldom-studied eastern extremity of this hotspot may provide some clues in this puzzle.

The Lazarev Sea has been suggested to be the gateway through which the krill population enters the Weddell Gyre. At the 0° meridian krill distribution ranges from approximately 50°S to the Antarctic continent at 70°S - the widest latitudinal range throughout their entire circumpolar distribution. North of 60°S, krill are under the influence of the eastward-flowing Antarctic Circumpolar Current. They are thus downstream of the extensive Scotia Sea populations and reflect spawning success there. But south of 60°S, within the westwards flowing counter currents of the Lazarev Sea, there is little information on krill spawning and larval occurrence. If, however, the Weddell Gyre is the source of high krill densities in the Scotia Sea, then the westward moving water masses of the Lazarev Sea should seed substantial amounts of krill larvae into the system to sustain the large population observed at the northern outflow of the Weddell Gyre.

SYSTCO - system coupling in the deep-sea - will form the other large IPY programme operational during the cruise. Vast areas of the Southern Ocean surrounding the Antarctic continental shelf are deep sea. In contrast to our knowledge of the benthos in Southern Ocean shelf areas, corresponding data from the deep sea are still scarce. However, the pioneering investigations of ANDEEP aboard the *Polarstern* have revealed a remarkable biodiversity in the Southern Ocean deep sea.

We will now build on those results to elucidate the functioning of atmospheric, pelagic, and benthic systems of the Southern Ocean in a process oriented context. SYSTCO will help to understand the role of the Southern Ocean in global energy budgets, climate change, and the maintenance of the diversity of marine life on the Blue Planet.

SYSTCO is an ambitious programme designed to

- study processes in different realms of the biosphere in Antarctica and
- uncover how these systems are linked to each other (pelagic-benthic coupling processes)

Important objectives in the different realms are to connect own investigations with those of other expedition programmes, namely

- Atmosphere: to study surface fluxes, for example, of CO_2 and vertical profiles of fluxes in the atmospheric boundary layer.

- Water column and plankton: to define the influence of atmospheric processes on processes in the water column, the influence of the biogeochemistry of the surface water on primary productivity, the importance of the nanoplankton in the food web, and to describe vertical changes in the plankton community to abyssal depths.
- Benthos: to investigate the biology of abyssal key species, the role of the bottom-nepheloid layer for recruitment of benthic animals, the influence of the quantity and quality of food sinking through the water column on abyssal life, feeding ecology and trophic relationships of abyssal animals.
- Seabed characteristics: to study the effects of topography, sedimentology and biogeochemistry of sediment and pore water on benthic life in the present and past (palaeontology), to map bathymetry to understand microhabitat formation.

By coordination under the umbrella of the IPY lead project ICED-IPY (Integrated Circumpolar Ecosystem and Climate Dynamics), SCACE strives for performing in the same season and year sections that cross the ACC and extend to the Antarctic continent at several key longitudes. Such synoptic circumpolar assessment is the only way to document the current state of the polar environment without bias introduced by interannual variability. By close cooperation with the IPY project ANDEEP-SYSTCO, which is focused on benthic biology and geochemistry, the projects aim at also obtaining new insights into the coupling between processes in the productive near-surface euphotic zone and at the deep-sea sediments.

Fahrtroute und Stationen / Ships track and stations

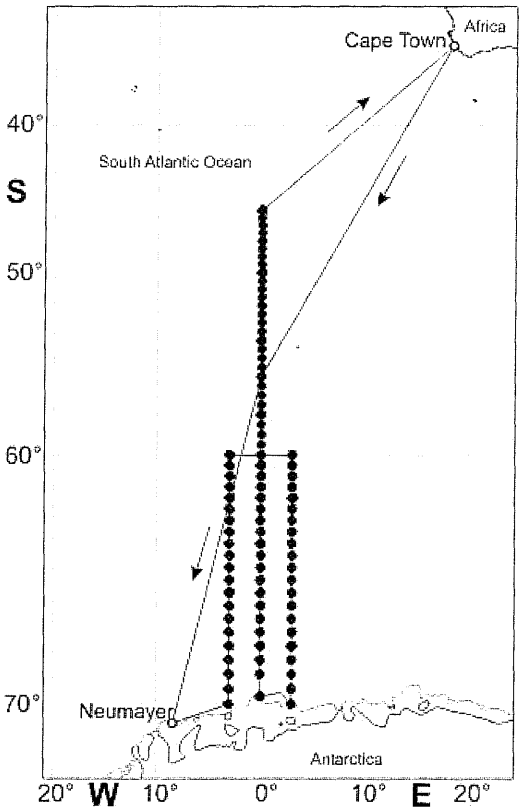

Fig. 1: Geplante Fahrtroute mit Stationen (hellere Punkte) und Positionen für andere Aufgaben (dunklere Punkte) während ANT-XXIV/2. Aufgrund logistischer Aufgaben (u.a. Versorgung Neumayer) wird nach dem Auslaufen Kapstadt fast direkt die deutsche Antarktisstation angelaufen.

Planned cruise track with positions for scientific sampling (lighter dots) and for other tasks (darker dots) during ANT-XXIV/2. After departure Cape Town we will head nearly directly to this German Antarctic station due to logistic reasons (e.g. supply Neumayer station).

2. PHYSICS OF BIOGEOGRAPHIC ZONATION IN THE ANTARCTIC CIRCUMPOLAR CURRENT - A CONTRIBUTION TO THE *SYNOPTIC CIRCUM-ANTARCTIC CLIMATE AND ECOSYSTEM STUDY* (SCACE)

D. Ewe, S. Maßmann, M. Olischläger, F. Richter, V. Strass (AWI); H. Leach (Univ. Liverpool); T. Witte (OPTIMARE)

Objectives

The physical and oceanographic measurements planned for *Polarstern* cruise ANT-XXIV/2 will form part of the IPY-Project Synoptic Circum-Antarctic Climate and Ecosystem study (SCACE). The overarching goal of SCACE is to use the outstanding chance provided by the IPY for an international collaboration to collect a unique data set that can serve as a benchmark for comparison with existing data to identify and quantify polar changes.

SCACE aims at welding together a broad range of ocean science disciplines in order to address currently elusive questions such as:

- Which physical, biological and chemical processes regulate the Southern Ocean system and determine its influence on the global climate development?
- How sensitive are Southern Ocean processes and systems to natural climate change and anthropogenic perturbations?

The Southern Ocean is critically involved in the machinery driving earth's climate. The Antarctic Circumpolar Current (ACC) connects all the other oceans. Thus it plays a major role in the global transports of heat and fresh-water and the ocean-wide cycles of dissolved substances. It harbours a series of distinct ecosystems that displace each other with changing climate regimes. Upwelling of deep water masses results in an extraordinary high supply of plant macronutrients, which could sustain much higher primary production and hence CO_2 uptake than however observed.

Although much progress has been made during the last decades in documenting the Southern Ocean hydrographic and biographic features, in quantifying fluxes and in understanding the dominating forcing, there is still a big gap in knowledge, especially with regard to the interaction of physical, chemical and biological processes. While this gap in knowledge is basically due to the remoteness of the area and its inhospitality for humans, it is also due to the fragmentation of research as carried out usually.

Work at Sea

The data base for this study will be collected at hydrographic stations, regularly spaced along the prime meridian south of 46° S and along two parallel sections running along 3°E and 3° W south of 60°S, respectively. A CTD (Conductivity, Temperature, Depth) sonde will be routinely deployed at the hydrographic stations and give vertical profiles of temperature, salinity and density. The CTD will hold additional instruments such as a chlorophyll-sensitive fluorometer to provide an indication of the abundance of phytoplankton and a transmissiometer to measure the attenuation of light. It will be attached to a carousel water sampler holding 24 bottles of 12 l volume each. The CTD carousel sampler will be the major tool for supplying the various scientific disciplines on board with water samples.

The CTD measurements shall be analysed together with measurements of horizontal currents in the top few hundred metres, to be recorded continuously with a vessel mounted ADCP (acoustic Doppler current profiler) installed in the ship's hull. Besides its major purpose, the ADCP shall be used as a detector for zooplankton abundance by evaluating the backscattered echo amplitude.

Within SCACE the physical and oceanographic measurements will be complemented by suite of chemical and biological measurements performed during the cruise. Data of zooplankton abundance derived from the net catches, for instance, will by used for calibration of the ADCP backscatter signal. Combined analysis of the physical, chemical and biological is hoped to result in a better understanding of the coupling between the different realms.

3. CARBON, OXYGEN AND NUTRIENT BIOGEOCHEMISTRY

K. Brown, J. Hauck, O. Hofmann, C. Neill, F. Pey (UiB);
Not on board: R. Bellerby (UiB)

Objectives
To measure the distributions of inorganic carbon, total alkalinity, oxygen and nutrients in the Weddell Sea and Antarctic shelf

Work at Sea
Underway pCO_2 and oxygen from the ships online seawater line. Sampling water column samples will be measured for inorganic carbon, total alkalinity, oxygen and nutrient concentrations. Ice samples will be collected and measurements of inorganic carbon, total alkalinity, oxygen and nutrients will be done.

Expected results
The work done will extend the long time series of measurements now collected by the group in the Southern Ocean. The new information will be used to determine the anthropogenic content, seawater pH and carbonate species distributions in the waters between South Africa and the Antarctic mainland. The shelf study will provide new information on the contribution upwelled deep water and its modification conditioning the water properties prior to high salinity shelf water production later in the season.

4. BIODIVERSITY IN THE SURFACE LAYER OF THE ANTARCTIC CIRCUMPOLAR CURRENT - A CONTRIBUTION TO THE *SYNOPTIC CIRCUM-ANTARCTIC CLIMATE AND ECOSYSTEM STUDY* (SCACE)

U. Bathmann, S. Herrmann (AWI); J. Kitchener (AAD)

Objectives

The survey is using the sensitivity of plankton to environmental change as early warning indicators of the health of Southern Ocean, as well as serving as a reference on the general status of the Southern Ocean for other monitoring programmes. The SO-CPR Survey is an independent project but together with CPR surveys in the northern hemisphere, it is a major survey and monitoring tool able to support GOOS. The SO-CPR Survey is not officially recognised as part of SO-GLOBEC, but contributes to GLOBEC internationally. The SO-CPR Survey is associated with the CPR Survey based at the Sir Alister Hardy Foundation for Ocean Science, Plymouth. Data acquired by partners in the SO-CPR Survey are shared between partners. In addition continuous chlorophyll measurements and discrete samples of phytoplankton will be collected to obtain productivity distribution pattern in the different water masses of the surface ocean.

The specific objectives are:

- Map the biodiversity and distribution of zooplankton, including euphausiid (krill) life stages, in the Southern Ocean.
- Assess the seasonal, annual and long term variability in abundance, species composition and distribution patterns of the Southern Ocean zooplankton communities.
- Similarly, assess the variability of abundance and development of krill larvae produced each year.
- Determine the patchiness and species composition of phytoplankton distribution.

Work at sea

The CPR can be towed from any vessel at speeds up to 23 knots and in conditions up to Force 12. They can be deployed and retrieved at normal ship's speed, although we often slow the ship to 3-5 knots for the final few metres of retrieval to prevent the CPR hit the stern. The CPR is towed 100 m aft of the ship, within the ship's wash, using wire of at least 12 mm diameter, and can be deployed from an A-frame, gantry, davit or similar. The unit cannot be towed in ice. The recorders can be towed continuously with no interruption to shipping schedules for 450 nautical miles before retrieval. They are purely mechanical, as they are driven by water passing over a propeller, and have no electronic components or power supplies that can fail. The mesh is advanced at a fixed rate of 1 cm per 1 nautical mile, regardless of ship's speed.

Thus, no dedicated ship time is required. CPR can be deployed and retrieved at normal ship speed; although brief swing to 3 - 5 knots is advisable for the final few metres of retrieval. No deviation is required from the scheduled cruise track. Tows will be conducted on the route south from Cape Town, commencing at 45°S and finishing at the krill survey area. Further tows are expected to be conducted on the return route to Cape Town commencing on departure from the krill survey area and finishing at 45°S.

The continuous measurements of chlorophyll fluorescence will be performed by means of a Turner design flow thru fluorometer that will be supplied by the Teflon clean running sea water system of *Polarstern*. Discrete plankton samples will be obtained from the Niskin bottles attached to the CTD frame from up to 10 water depth per station.

5. DISTRIBUTION AND BIOMASS OF KRILL AND ZOOPLANKTON: ACOUSTIC SURVEY

U. Bathmann, S. Krägefsky (AWI)

Objectives

Since the early assessments by the *Discovery* expeditions between 1930 and 1960 we know about the spacious distribution of substantial stocks of *Euphausia superba*. Commencing with the BIOMASS programme, the determination of krill catch quota by the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) is based on acoustic stock assessments.

Compared with, for example, the Antarctic Peninsula area, there is only rare information about the development in krill stock in the Antarctic waters of the Eastern Weddell Sea and the Lazarev Sea during the last decades.

To survey the spatial distribution of *Euphausia surperba* and the zooplankton, including possible prey organism of krill multifrequency acoustic measurements will be made by a Simrad EK60 scientific echosounder with the frequencies 38, 70, 120 and 200 kHz. Sampling and processing of acoustic data will be carried out in accordance to the CCMLAR standard procedures. E.g. using different scattering models and discrimination methods, additional data analysis will be performed, to account for current difficulties in interpretation of acoustic measurements. The echosounder has to be physically calibrated.

Work at sea

For comparison with and biological calibration of the acoustic survey data net samples of zooplankton will be taken with the multinet. Roughly 30 vertical net hols in the upper few hundred meters of the water column are planned using mesh sizes of 55 and 300 mm.

In addition, the Bongo Net will be employed to also catch larger zooplankton animals such as amphipods, which are able to swim fast enough to escape the multinet. Once on board, the net samples of zooplankton will be preserved using a 4 % solution of formol in sea water and then stored in Nalgene bottles. Gelatinous plankton like jelly fish will be sorted out before, with their biomass determined separately.

Beyond the purpose of calibration of the acoustic survey data the zooplankton net samples will be used for an investigation of the spatial distribution of different developmental stages of the various species.

6. KRILL DEMOGRAPHY AND POPULATION DYNAMICS

J. Edinger, M. Haraldsson, K. Stürmer, M. Vortkamp (BFA Fisch)
Not on board: V. Siegel (BFA Fisch)

Objectives

There have been very few attempts in the past to carry out standardized krill net sampling surveys to study seasonal aspects of krill distribution and demography in high latitude areas, which are covered by sea-ice during most of the year. Only one major exercise was conducted during the years 1983-85 by the international BIOMASS programme. The SIBEX surveys were carried out in the Antarctic Peninsula region and covered most of the annual cycle, however, sampling was mainly carried out in ice-free areas or in the marginal ice zone. The EPOS *Polarstern* study included the pack-ice region of the northern Weddell Sea from late winter to mid summer, but was more process orientated and less designed as a quantitative survey. The LAKRIS project started in austral autumn 2004 conducting a regular survey in the Lazarev Sea (3°E to °W) south of 60°S. Since the first survey a spring and winter survey have followed to collect data on the seasonal and interannual variability in the krill population.

The Antarctic ecosystem exhibits great spatial and temporal variability. Mesoscale, seasonal and interannual variability in abundance of Antarctic krill (*Euphausia superba*) impacts their dependent predator populations. Because of this variability over the multi-year (> 5 year) krill life span, long-term monitoring is essential to assess and understand the underlying physical and biological processes affecting krill recruitment success and population size. Information on seasonal and interannual abundance variations of short-lived salps (*Salpa thompsoni*) and biomass dominant other Euphausiacea species, sampled along with krill, provide additional insight on processes influencing the high latitude Lazarev Sea ecosystem. Included are studies on the distribution, abundance and demographic structure of krill and salps and abundance and distribution of other zooplankton taxa. Results from the various cruises will be compared with those from previous LAKRIS surveys to assess seasonal and between-year differences in krill demography and zooplankton composition and abundance over the studied period.

Experience gained through participation in other international programmes like BIOMASS has shown that standardization of equipment and methods is one of the most crucial steps for any successful work during the IPY 2008 field sampling period and later analytical work. The following net sampling protocols set out the procedures so that carrying out the cruise can collect comparable high quality data sets that will facilitate the establishment of a uniform and valuable database and allow for a simplified data exchange between CAML (Census Antarctic Marine Life) participants.

There are two primary objectives for the net sampling programme:

- to describe krill demography and large scale distribution patterns of size groups and maturity stages as well as regional recruitment indices,
- to collect quantitative data on other key zooplankton species, their quantitative distribution and abundance.

Work at Sea

The CCAMLR (Convention on the Conservation of Antarctic Marine Living Resources) Working Group as well as the CAML IPY steering group recommended the use of a standard type of net to avoid potential variation in catchability and selectivity of nets during krill centered survey activities. The most appropriate type of net presently available is the RMT8+1 (Rectangular Midwater Trawl). This net shall be used as the standard net for target and random hauls. The net has a mesh size of 4.5 mm. The net will be equipped with a calibrated flowmeter to estimate the filtered water volume as accurately as possible, and a real-time time-depth-recorder (TDR) to follow the track of the net.

At each station a quantitative standard double oblique tow will be conducted from the surface down to 200 m (or to within 10 m of the bottom at stations shallower than 200 m). Such a depth range is considered to be the best compromise between the time available for sampling and the likely vertical depth range of krill. During the hauls a constant ship's speed of 2.5 ± 0.5 knots is suggested. It is recommended to maintain a wire speed of 0.7 to 0.8 m/sec during paying out and of 0.3 m/sec during hauling. The net mouth angle is remarkably constant during hauling within the speed ranges given above. When the net reaches maximum depth, the winch should be stopped for about 30 seconds to allow the net to stabilize before starting to retrieve the net. If the net is hauled from the stern of the ship then the propeller of the ship should be stopped when the net reaches a depth of 15 to 20 m; this is to minimize the effects of the propeller action on the net operation and avoids damage of the samples. The total time of the net haul from surface to bottom to surface should be approximately 40 minutes.

The use of a real-time TDR is essential to maintain a smooth net trajectory and control the maximum fishing depth. Calibrated flowmeters will be used to give a measure of net speed during the haul as well as the total distance travelled. The flowmeter should be mounted outside the net opening to avoid clogging which may reduce the efficiency. The dependence of mouth angle to net speed has been investigated for the RMT system.

The quantitative study of the krill population will be carried out along three parallel meridional transects which will extend from the continental coast into oceanic waters as far north as 60°S. Net samples will be taken every 30 nautical miles along each transect. This standardized station grid will also enable us to investigate the horizontal and vertical distribution of krill as well as estimate the actual krill biomass in the area by net sampling and hydro-acoustics.

Samples will be sorted immediately after the haul. Antarctic krill, salps and other Euphausiid species will be sorted quantitatively and length measurements will be taken from representative sub-samples. Additional information will be collected from sex and maturity stages of euphausiids according to the classification established by Makarov and Denys. These measurements will serve the interpretation of the success of the current reproductive season and the status of the spawning stock, but will as well give us some indication on the survival rate of recruits in the population spawned in the previous year.

The description of krill demographic parameters and the investigation of population dynamics of the stock will be the major focus of the krill net sampling programme to the Lazarev Sea in austral summer 2008. However, the collection of quantitative macro-zooplankton data will also play an important role during the current field campaign. The zooplankton data will be a subset of the internationally collected survey data by several CAML IPY participants around the entire Antarctic continent. These data will serve to establish a possible concept for

bioregionalisation of the pelagic system of Southern Ocean. Such analyses will be carried out during planned joint workshops and will try to delineate bioregions at the broad scale. This work will be an important contribution to the achievement of a range of scientific, management and conservation objectives, including large-scale ecological modelling, ecosystem-based management and the development of an ecologically representative system of potential marine protected areas.

7. BIOLOGY OF OITHONA SIMILIS (COPEPODA: CYLOPOIDA) IN THE SOUTHERN OCEAN

U. Bathmann, B. Wend (AWI)

Objectives

Oithona similis belongs to the order of cyclopoid copepods. It is highly abundant through-out many parts of the world ocean and is supposed to be a cosmopolitan species. The work on this cruise is part of a project that challenges whether *O. similis*, a key species in three chosen study areas (Southern Ocean, Arctic Ocean and North Sea), is indeed a cosmopolitan species. A further goal is a better understanding of its life cycle (or the ones of the existing cryptic species) including feeding habits and generation times of the developmental stages.

Work at sea

Samples will be collected with Niskin bottles mounted on a CTD and additionally a towed multinet (55 µm) will be used. Samples will be taken out of the epipelagic layer down to a depth of 250 m. They will partly be preserved in formalin for further morphological identifications of species, reproduction in the field as well as feeding habits and in ethanol for genetic examinations. These examinations will be done at the home laboratory.

On board experiments with living animals will be conducted dependent on the numbers of animals found at each station. These experiments aim on the determination of egg production, egg development, nauplii hatching and stage duration. Moreover experiments on the feeding behaviour are planned by placing adults of *O. similis* (or eventually existing cryptic species) in small bottles containing unfiltered natural seawater, from which large zooplankton will be removed. All experiments will be conducted with 10 individuals per vial. To examine the feeding preferences a control bottle containing no copepods will be used and furthermore a sample of the sea water will be preserved in acidic lugol prior to the beginning of the experiment. After 24 hours all individuals will be removed and a part of them will be preserved in ethanol to perform genetical experiments and the rest will be conserved in formalin for morphological investigation as well as for gut content analysis in the home laboratory. This procedure allows to control whether cryptic species exist.

8. CARNIVOROUS ZOOPLANKTON IN THE MESOPELAGIC FOOD WEB OF THE SOUTHERN OCEAN

U. Bathmann, S. Kruse (AWI)

Objectives

Carnivorous zooplankton taxa contribute to a great extent to marine zooplankton biomass and are therefore believed to have a significant predation impact on the zooplankton community of the Southern Ocean. Chaetognaths are one of the most important carnivorous plankton taxa in Antarctic meso- and bathypelagic waters. Swarming amphipods are also able to control mesozooplankton-standing stocks. Consequently, carnivores may contribute significantly to the downward carbon flux due to marked diel vertical migrations and due to production of fast-sinking faecal pellets. Pronounced variations in the food web dynamics of plankton communities, depending highly on factors like season, climate and location, can be expected. In order to understand the role of carnivorous zooplankton taxa like chaetognaths and amphipods, comprehensive seasonal and geographical studies on little known mesopelagic taxa are required. During this cruise, distribution and abundance of deep-living carnivores, their feeding habits and predation impact as well as their role in the carbon cycle will be investigated in the Lazarev Sea. Special attention will be given to the depth range between 500 and 3000 m. As the expedition ANT-XXIII/6 already provided information about the winter situation, this expedition shall complete the existing picture of the carnivores in this area. Among the chaetognaths the focus will lie on the species *Eukrohnia hamata* and the two deep water species *E. bathypelagica* and *E. bathyantarctica*. In addition the amphipods *Cyllopus lucasii*, *Primno macropa* and *Lanceola sp.* will be of special interest.

Work at sea

Investigations on board RV *Polarstern* will be done by a combination of sampling and experimental approaches. Stratified sampling will be performed from down to 2,000 m with a Multinet (100 µm, 5 nets; depth intervals: 2,000-1,500 m, 1,500-1,000 m, 1,000-750 m, 750-500 m, 500-0 m). Chaetognaths being in a good condition will be sorted out of these samples for feeding and respiration experiments. Additional specimens will be picked for C/N analysis, gut content as well as for lipid and fatty acid analysis, which will be quickly stored at -80° C for further analysis in Germany.

Further samples will be taken by means of a RMT 1 and RMT 8 (rectangular midwater trawl) from down to 3,000 m water depth. This kind of sampling is of high importance for obtaining amphipods, as they cannot be caught with a Multinet. The RMT cod-end will be modified in such a way that the animals are neither too compactly and concentrated nor fallen dry. The water volume in the cod-end comprises approximately 26 l. Therefore, animals damaged by the net sink to the bottom of the cod-end, while the major portion stays alive in the cod-end bucket. Actively swimming specimens will be sorted for feeding and respiration experiments as mentioned before for the chaetognaths. Additional samples will be frozen (-80°C) for later analysis in the home laboratories.

For the feeding experiments chaetognaths as well as amphipods will be placed in containers with seawater and will be allowed to defecate. After a certain starvation period, one day for the chaetognaths and two days for the amphipods, feeding experiments will be conducted by offering different prey to the chosen carnivores. To determine digestion time the containers

will be checked continuously until defecation. The digestion time is needed to calculate the daily feeding rate and to draw conclusions about the predation impact.

The faecal pellets produced will be used to estimate the role of the zooplankton in the carbon flux. Therefore, measurements of the sinking velocities will be conducted in a Plexiglas cylinder (1 m) filled with filtrated seawater at ambient temperature. Moreover, the size and the C/N-ratio of additional pellets will be investigated (home laboratories).

For the respiration experiments the species will be kept in 0,5 or 1 l bottles depending on the size of the specimens. The oxygen consumption rate will then be measured according to the Winkler-method in subsamples of water from these bottles and compared to the oxygen content of the water in the control bottles (without animals). Individuals from different depth intervals will be compared to get information on their activity.

9. GEOCHEMICAL INVESTIGATIONS AT THE SEDIMENT-WATER INTERFACE

O. Sachs, E. Sauter (AWI)

Objectives

The AWI geochemistry group participates in the *Polarstern* ANT-XXIV/2 cruise to study compare organic carbon (C_{org}) fluxes reaching the seafloor of the target area as well as the interactions between geochemical microgradients and benthic organisms. This work not only comprises the main field phase of the DFG project DOMINO (Dynamics of benthic Organic Matter fluxes In polar deep-Ocean environments) but also acts as an interface between the two main projects ANDEEP-SYSTCO (ANtarctic benthic DEEP-sea biodiversity: colonisation history and recent community patterns - SYSTem Coupling) and SCACE (Synoptic Circum-Antarctic Climate-processes and Ecosystem study), both, as DOMINO does, contributing to the IPY programme ICED (Integrating Climate and Ecosystem Dynamics).

On the one hand, the quantification of organic carbon influx onto the sediment surface is projected to better constrain carbon export to the seafloor as an "end member" of the biological pump. On the other hand the measurement of geochemical microgradients exhibits a tool to describe the geochemical milieu around benthic organisms and, thus, to explain faunal communities and their ecologic and metabolic characteristics.

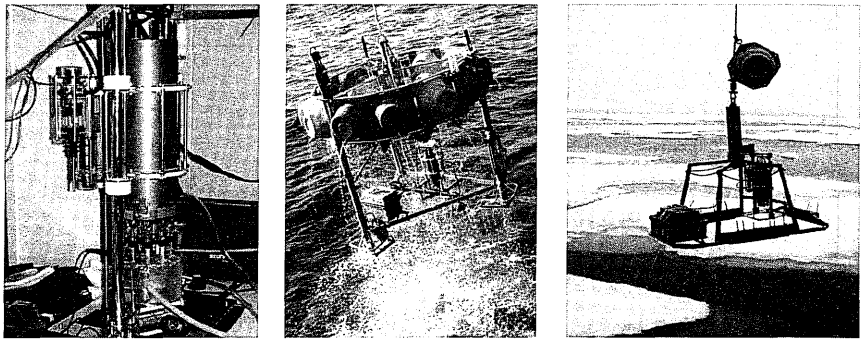

Fig. 9.1: Microprofiler (a), free falling lander system (b), and wire-driven profiler (c)

Most of the organic carbon arriving at meso and oligotrophic sediments is remineralized right below the sediment/water interface, consuming dissolved oxygen as a primary electron acceptor. In addition, oxygen functions as a final oxidant for anaerobic pathways. Thus, the measurement of the pore-water oxygen distribution provides a suitable tool for the determination of C_{org} fluxes through the sediment/water interface and of C_{org} remineralization rates. Beside the quantification of oxic respiration rates by *in situ* chamber or laboratory core incubation, O_2 microelectrodes have proven to be an appropriate tool to determine diffusive oxygen fluxes via the measurement of the pore water O_2 depth distribution in very high resolution. In order to avoid sampling and pressure artifacts during core retrieval it is highly desirable to measure O_2 microprofiles *in situ*, i.e. at the sea floor (Sauter et al., 2001).

Only little data, mostly measured *ex situ*, exist for high latitudes beyond 60°N or S. During ANT-XXI/4 we had the opportunity to measure *in situ* fluxes at the Polar Front (Sachs et al., submitted). Up to now, only little is known also about the total amount of organic carbon remineralized and fixed within surface sediments of the Southern Ocean.

During this cruise the main focus will therefore be put on the *in situ* measurement of O_2 microprofiles and a complementing sediment and bottom water sampling programme to be conducted during the ANDEEP-SYSTCO benthos stations.

Work at sea

In this study *in situ* microprofile measurements will be performed by means of an autonomously working microprofiler (Fig. 9.1a) able to drive microsensors for O_2, pH, and H_2S as well as a resistivity probe into the sediment with a minimal vertical resolution of up to 0.1 mm. The profiler can either be mounted into a free falling lander system (Fig. 9.1b) co-equipped e.g. with a video camera, an acoustic doppler velocimeter and/or a water sampler. In case the lander deployment is too difficult due to ice or sea stage, the microprofiler can be mounted into a wire-driven frame (Fig. 9.1c).

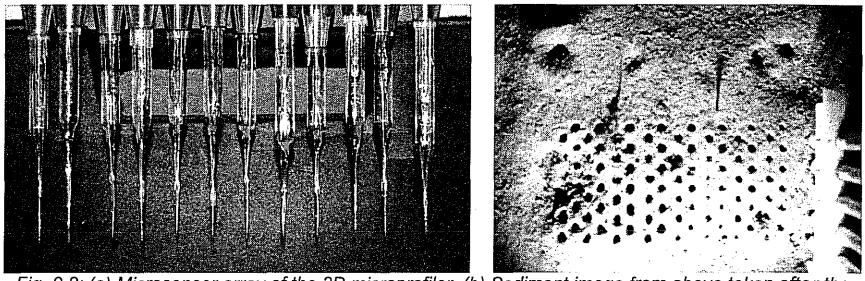

Fig. 9.2: (a) Microsensor array of the 3D microprofiler. (b) Sediment image from above taken after the measurement during ARK-XXII/1c. According to the small scale bottom topography, the penetration depth of the sensors is different, which can be seen by the different diameter of the individual holes.

In order to further resolve 3D gradients around biogenic structures, the development of a special 3D deep-sea microprofiler was initiated at the AWI. This system was designed to allow new insights into spatial small scale variabilities generated by benthic organisms. The new device is not restricted to lower sensors vertically into the sediment but is able to displace its sensor array (up to 12 microsensors, Fig. 9.2a) horizontally in order to measure cascades of microprofiles over a target area of ~30 x 35 cm (Fig. 9.2b). Together with a sequence of photographs taken prior, during and after the measurements, this allows the 3D reconstruction of the pore water oxygen distribution for descriptive geochemical habitat characterization e.g. around biogenic structures, as well as for 3D pore water modelling. The system was deployed for the first time during the ARK-XXII/1c cruise in the AWI *Hausgarten* area and is now projected to work in the Southern Ocean for the first time.

In situ measurements will be complemented by *ex situ* measurements of microprofiles, sediment, pore water and bottom water sampling for the determination of other geochemical parameters like C_{org}, C/N ratio and nutrient profiles. Sediment sampling will be performed by a conventional multicorer whereas water samples from the near-bottom zone will be taken by a special bottom water sampler allowing the collection of water from 6 levels within the lower most two meters above the sea floor (Fig. 9.3).

In addition, the sea floor surrounding the sampling and measuring locations will be characterized hydroacoustically while approaching and leaving the site using Parasound and Hydrosweep. This is for both purposes, 1) to have a control about water depth and bottom topography and 2) for later correlation acoustic data with surface sediment parameters.

Expected results

Our contribution is to be seen as the interface between the water column investigations projected in SCACE and the benthos biology work of ANDEEP-SYSTCO: The sea floor as the final recipient of deep carbon export stands between pelagic production and particle sedimentation on the one hand and the utilization of carbon resources by the benthic fauna on the other side. Therefore we hope not only to get the opportunity to perform repeated measurements at the same spot in order to estimate seasonal and episodic variabilities of fluxe. It is also hoped from this cruise that we gain new insights into small scale heterogeneities of benthic oxygen distribution in relation to benthic habitats which is the link to the ANDEEP bioregionalization approach. From the geochemical point of view we will expand the still small data base of high quality benthic flux measurements in the Southern Ocean. This enables us to improve budget considerations in respect to organic carbon influx

to the seafloor as well as the chance to improve transfer functions to correct existing laboratory measurements.

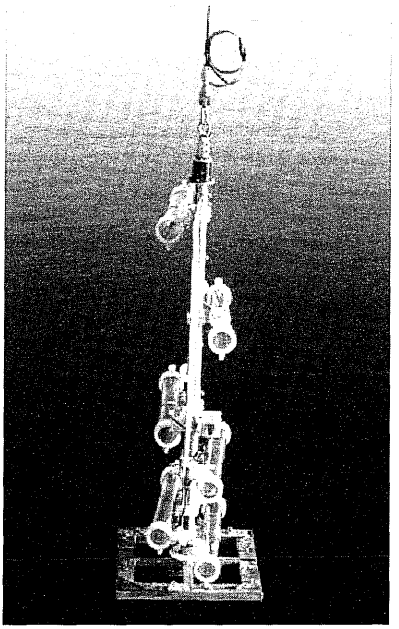

Fig. 9.3: Bottom water sampler

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10. ANDEEP-SYSTCO (SYSTEM COUPLING) IN THE SOUTH ATLANTIC OCEAN BENTHIC FORAMINIFERA OF THE DEEP SOUTHERN OCEAN: DIVERSITY AND BIOGEOGRAPHY

D. Fontaine (University Geneva)
Not on board: J. Pawlowski (University Geneva)

Background and objectives

Benthic foraminifera are a dominant faunal element in the deep-sea and high latitude settings. These amoeboid protists are highly diversified and abundant, yet they are often overlooked in biological studies because they are unfamiliar organisms, which are difficult to extract from sediment samples and to identify. As a result, the contribution of foraminifera to deep-sea benthic diversity is poorly known, although mounting evidence suggests that it is substantial.

Recent developments in molecular systematic have provided new tools for studying foraminiferal diversity (Pawlowski, 2000; Pawlowski *et al.*, 2003). Molecular studies have revealed a high genetic diversity in some benthic (Holzmann & Pawlowski, 1997; Tsuchiya *et al.*, 2003) and planktonic (De Vargas *et al.*, 1999) foraminiferal morphospecies. Genetic analysis of some common Antarctic deep-sea species showed surprisingly low level of molecular diversity and strong similarity to the Arctic populations (Pawlowski *et al.*, 2007). This is in agreement with bipolarity observed in some planktonic foraminifera (Darling *et al.*, 2000) but contrasts with strong genetic differentiation of shallow-water benthic species (Pawlowski *et al.*, in prep.). Extremely high eukaryote diversity was found within enigmatic foraminifera-like Komokiaceans, although their relationship to other foraminifera was not definitely established (Lecroq *et al.*, in prep.).

The main objective of this project is to examine the diversity of foraminifera in deep-sea Antarctic sediments. Using material collected during this cruise, we aim to answer following questions
(1) How many deep Southern Ocean species are globally distributed?
(2) Are deep-sea species less variable genetically than shallow-water taxa?
(3) Do deep-sea benthic foraminifera possess planktonic dispersal stages? and
(4) What are the phylogenetic origins of foraminifera-like Komokiacea?

Work at sea

During RV *Polarstern* cruise ANT-XXIV/2, we will collect surface sediment samples from a wide range of water depths and sites in the Weddell Sea using the multicorer or box corer. For molecular studies, multicores and subsamples of box cores will be sieved immediately after collection and living foraminifera hand picked under a binocular microscope. Some specimens will be photographed and their DNA will be extracted. Others will be deep-frozen for further DNA analysis. Some sediment samples will preserved in ethanol for later molecular study. Additionally, plankton samples will be collected to search for dispersal forms (larval stages, propagules) of deep-sea benthic taxa.

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11. THE LINK BETWEEN STRUCTURAL AND FUNCTIONAL BIODIVERSITY OF THE MEIOBENTHOS IN THE ANTARCTIC DEEP SEA

K. Guilini (University Gent)
Not on board: Ann Vanreusel,M. Raes (University Gent)

Objectives

The overall aim of this study is to identify the role of meiofauna in the C flow through benthic deep-sea sediments of the Antarctic in relation to their biodiversity. In order to unravel the link between meiofaunal biodiversity and function, it is essential to reveal the interactions in the benthic food web and the trophic position of different meiofauna taxa and functional groups at locations with contrasting food input. Many studies have illustrated the high biodiversity of small benthic taxa in the deep sea. However it remains unclear what drives this high local biodiversity. As for many systems a relation with productivity of the system has been hypothesized but correlation with water depth and other associated environmental factors often hampers to unravel the link between biodiversity and food input. At the transition of the South Atlantic into the Southern Ocean strong climatic and trophic gradients exist. A latitudinal gradient at similar water depths between 47°S and 69°S would allow to estimate the variation in local biodiversity in relation to changing productivity levels.

Work at sea
The importance of meiofauna taxa in the C turnover in deep-sea sediments is still an unknown factor limiting detailed C modelling of the benthic boundary layer. Despite their high numerical dominance and potential high reproductive turnover rates there is little evidence that nematodes are strong agents in the carbon mineralization but indirectly they may interact with microbiological activities (by grazing on bacteria populations). Through enrichment experiments food pulses to the deep-sea sediments will be simulated by offering different labelled food items (especially phytodetritus and bacteria). In this way the C uptake by meiobenthic taxa in response to a specific food input, and the importance of different meiobenthos taxa in the C cycle will be estimated. Although the meiofauna standing stock in deep-sea sediments is closely linked to the degree of organic matter input and consequently the surface primary production as shown by previous studies their response to seasonally varying deposition of phytodetritus is often delayed in time, in addition to the fact that in stead of increase in densities at the surface of the sediments, subsurface maxima in densities appear. Although still restricted so far, evidence for a microbial related feeding activity rather than using fresh phytodetritus as food source is growing. In order to test if deep-sea nematodes show more preference for microbial related food sources enrichment experiments with different potential 13C labelled food sources will be performed. Natural biomarker analysis (stable isotopes and fatty acids) of selected taxa will unravel their degree of selectivity and food preferences for particular components of the deep-sea ecosystem.

12. ON THE FUNCTIONAL BIODIVERSITY AND ECOLOGY OF MACROBENTHIC ABYSSAL KEY SPECIES WITH FOCUS ON THE ISOPODA, MOLLUSCA AND POLYCHAETA

A. Brandt, L. Kramer, T. Riehl, L. Würzberg (ZIM); S. Brix, B. Ebbe (DZMB);
M. Schüller (LMU); H. Robert (RBINS)

Objectives
Very little is known about the ecology and role of deep-sea fauna in the trophodynamic coupling and nutrient cycling in oceanic ecosystems. This project examines the trophic structure and functioning of the abyssal macrobenthic community of the Southern Atlantic Ocean, focusing specifically on the role of the Isopoda, Mollusca and Polychaeta including 1) general feeding biology, 2) bentho-pelagic coupling, 3) the reproduction of certain key species, and 4) population genetics of selected abundant key species. Epibenthic sledge samples from three previous *Polarstern* expeditions (ANDEEP I-III) and new epibenthic sledge and sediment core samples taken on the RV *Polarstern* expedition ANT–XXIV/2 will be analysed. A variety of methods will be used including gut content analysis, functional morphology of target species as well as biochemical measurements. The latter include analyses of lipid classes, biomarkers, quantification of nucleic acids (RNA:DNA ratios), and examination of stable isotopic signatures of epifaunal animals and surrounding sediments.

The results will be compared and combined with the findings of research groups examining other aspects of the southern ocean food web or biogeochemistry of the sediment. Combining the comprehensive datasets concerning diversity and colonisation patterns

available from ANDEEP I-III and this planned study focusing on food web dynamics allows us, for the first time, to better understand the trophodynamic role of deep-sea fauna in the ecology of the Southern Atlantic Ocean.

Work at sea

We will start our analyses with the alcohol fixed samples from the ANDEEP I-III expeditions and determine key abyssal species. Of these species we will then analyse the biomass using he wet weight and conversion factors. We also plan first analyses of the mouthparts and foregut (including the gut contents) in the laboratory before we start with the expedition, in order to obtain some ideas on the general feeding biology of the key species (e.g. suspension feeders, deposit feeders, scavengers, predators, etc.).

The identification of key species prior to the expedition will allow us to more quickly identify and collect them from the new SYSTCO samples in the coolroom.

During ANT-XXIV/2 we plan to sample 5 stations on our way south from Cape Town, and revisit two of the most interesting stations on our way back to the north. In total, we hope to be able to obtain 7 stations (see Fig. 12.1), including epibenthic sledge samples, which will serve as a basis for the above-described investigations. The positions of the stations are preliminary and could be changed if satellite data indicates noteworthy peaks in primary production. This current adjustment would allow us to obtain information about a possible benthic reaction to events in the water column.

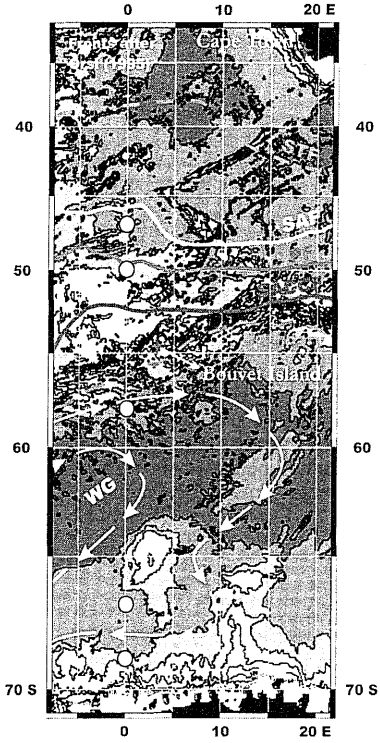

Fig. 12.1: 7 deep-sea stations are planned during SYSTCO (ANT-XXIV/2). Time permitting two interesting stations will be revisited.

- **Station 1**: 0°W 47°S, 4000 m (north of the Polar Front)
- **Station 2**: 0°W 50°S, 3500 m (in the Polar Front)
- **Station 3**: 0°W, 58°S, 4,200 m (south of the Polar Front, at the border to the Weddell Gyre
- **Station 4**: 0°W, 67°S, 4,700 m (is a revisit of the ANDEEP station 59, south of Maud Rise)
- **Station 5**: 0°W, 69°S, ca. 2,000 m (bathyal station)

As soon as the samples will be on board, they will be sorted in a coolroom or container by the most important taxa and key abyssal species of these groups, in order to freeze it immediately for the further described treatment in the laboratories in Hamburg (ZIM and IHF). At each station we will also take sediment samples which will be worked up either directly by a sedimentologist on bord or - if this is not possible - later in Germany in close collaboration with the Alfred Wegener Institute for Polar and Marine Research.

Those isopod specimens from the expedition ANT-XXIV/2 which will not be used for biochemical analyses, will be studied with regard to the functional morphology of the mouthparts, gut contents or they will be available for other projects dealing with systematic or phylogenetic investigations. For molecular genetic studies concerning phylogenetic relationships or population genetics of selected key species, we will extract DNA on board after precooling of the samples at -20°C for at least 48 hours. These results will be compared with those obtained from the isopod material from the previous ANDEEP expeditions.

Our data and those which will be obtained on primary production and abundances and biomasses of important pelagic species (in cooperation with U. Bathmann and colleagues)

will help to identify potential links between these two ocean realms and possibly document the processes critical to bentho-pelagic coupling.

13. QUANTITATIVE INVESTIGATIONS ON THE BIODIVERSITY AND BIOGEOGRAPHY OF MACROBENTHOS UNDER DIFFERENT NUTRITIONAL REGIMES

B. Ebbe (DZMB)

Scientific background and objectives

Macrobenthic biodiversity has been studied during the preceding ANDEEP expeditions and first results have been published. As the overwhelming majority of species was found to be rare and patchily distributed, it can be expected that additional samples will yield more new species and additional material of rare species. Any taxonomic information will be shared with the Census of Antarctic Marine Life (CAML).

The SYSTCO expedition offers the opportunity to collect quantitative samples under different nutritional conditions from the same place (before and during or after a plankton bloom). Possible changes in density and species composition as well as changes in reproductive features will provide helpful data to support the investigations to be undertaken with material from the epibenthic sledge by Brandt et al. (above) and make comparisons with results from the CeDAMar companion project CROZEX. If organisms are found to be reproductively active, plankton data will be examined with regard to larvae, especially of polychaetes.

Work at sea

Two box core samples will be taken at each station. If the sediment is soft enough, vegematic boxes consisting of 25 subcores will be used to yield 25 subsamples with a surface of 10x10 cm. At least ten of these, amounting to 0.1 m^2, will be sieved through 0.3-mm sieves, fixed in formalin and after 48 hours (if feasible) transferred to 70 % ethanol for storage. Organisms will be picked, sorted, enumerated and identified at the lab after the end of the expedition. Other subcores can be used by other participants as needed and will be processed according to the respective protocols.

A survey of the sediments before employing the box corer will be done with the SPI camera system which will provide surface and profile images of the seafloor. SPI images will be particularly helpful in finding fluff layers indicating the arrival of fresh material from the water column. Profile images will provide information on the degree of bioturbation, depth of the oxygenated layer, and grain size.

14. THE ROLE OF SPONGES IN THE BENTHIC-PELAGIC COUPLING IN BIOTOPES OF THE DEEP WEDDELL SEA AND ADJACENT AREAS

N. Brenke (FIS); M. Schrödl, E. Schwabe (LMU); V. Wadley (AAD)
Not on board: Dorte Janussen (FIS)

Background and objectives

According to our findings from ANDEEP I-III, the sponge fauna of the deep Weddell Sea differs substantially from that of the adjacent areas in being richer, more diverse and the fact that sponges of some groups may become very large for deep-sea conditions. We found large faunal variability between stations, but it is unknown whether this is due to differences in the water chemistry and food supply, bottom sedimentology and topography, or simply a result of insufficient sampling. Probably more than one factor controls the distribution of sponges and associated benthic organisms. In the further course of Antarctic deep-sea investigations, we can expect to identify key associations of sponges characteristic of various ecological zones. These communities probably do not represent a long-term, stable system, but rather stages within a cycle of ecosystems; and successions of ecosystems in time, are likely to be found in a larger area also as a succession in space.

Scientific questions central for this research project are:

- What kind of consortia of animals are associated with sponges in the Antarctic deep sea?
- Do especially the larger sponges control the occurrence and diversity of other organisms?
- Which are the key associations of Antarctic deep-sea sponges and which processes lead to the present Antarctic fauna??
- How closely are the Antarctic shelf and deep-sea sponge species related at a molecular level, and how closely related with representatives from other deep-sea areas?
- Is the apparently patchy distribution of most sponge taxa a function of ecological successions in time?

Work at sea

- Sampling, documentation, preliminary identification and quantification of sponges from all benthic sampling gears.
- Fixation for histological and electron microscopic investigations and freezing of sub-samples for molecular biology and FISH-analysis of the micro-infauna.
- Skeletal preparation and preliminary identification of the main sponge taxa represented.
- In cooperation with DZMB: Separation of tissue samples from the bigger sponges for meio-infauna investigations.
- In cooperation with other groups (optional): Sampling of bottom water and surface sediment samples and their fixation for microbial investigation. Search for sponge larvae within plankton.

Work at home institution

- Taxonomic identification and description of the sponge fauna. Quantification of the sponge communities from different localities and depths.

- In cooperation with DZMB: Sorting and quantification of major taxonomic groups of meiofauna found on and in sponges.
- Investigations of the microbial communities within the sponge tissues and of the bottom water samples (in cooperation with Chinese and German partners).
- Molecular investigations and comparison of selected shelf and deep-sea representatives of sponge taxa.
- Possibly identification of key communities of sponges and associated organisms for different habitates of the deep Weddell Sea area.

15. DIVERSITY, ORIGIN AND EVOLUTION OF THE DEEP-SEA ANTARCTIC ANTHOZOAN FAUNA

M. Conradi (DFZ)

Background

It is already well known that Anthozoans are one of the major components in benthic sessile communities in terms of both abundance and diversity. Despite of this, the Antarctic athozoan fauna is still poorly known, and most of our knowledge comes from the continental shelf, while deep-sea fauna is perhaps not as diverse as that living on the shelf but is much less known and unpredictable.

The last ANDEEP cruise, among other sampling stations, extensively prospected the deep Weddell Sea in the limits of 4,000-5,000 m depth, showing an interesting anthozoan asemblange (*Umbellula*+*Galatheanthemum*+Antipatharia), with clear influence of deep-sea bottoms from surrounding oceans. In the proximity of the Antarctic Peninsula deep-sea fauna becomes more diverse but still differentiable from that of the shelf.

Anthozoans are one of the most interesting benthic sessile animal groups to study the importance of the possible immigrant - or emigrant- ways and relict Cretaceous stock conforming the extant Antarctic fauna.

Scientific objectives

- To detect the presence of boundaries in the distribution of deep-sea anthozoans at different taxa levels (family, genus, species).
- To evaluate the potential origin of the deep-sea Antarctic anthozoan fauna according to the known distribution of genera/species in this and other biogeographical areas.
- To detect undescribed species that could help to the understanding of the relationship between Antarctica and other deep-sea bottoms and continental shelf in the past and in the present.
- To continue to build up the bank of tissues usable for molecular studies (already initiated since EASIZ III).
- To sustain the study of the reproductive pattern in Antarctic Anthozoans (already initiated since EASIZ-I).

Work at sea
Anthozoans will be extracted from all samples, most likely the Agassiz trawl will prove to be most useful to catch these organisms.

16. MEIOBENTHOS AND THEIR ROLE IN THE DEEP ANTARCTIC FOOD WEB

A. Henche, G. Veit-Köhler (DZMB)

Objectives
Biomarkers such as stable isotopes and fatty acids can be traced throughout food webs and thus are suitable for the understanding of trophic positions and food resource selectivity of marine species. Detailed analyses of fatty acid, fatty alcohol and wax ester compositions can elucidate similarities between taxa and reveal indications of feeding behaviour and food sources. The advantage of applying lipid compositions to feeding studies is that trophic lipid markers integrate longer time periods than conventional methods and feeding experiments verified the concept of trophic marker lipids using algae and copepods of known lipid composition. But generally, benthic species have relatively low lipid contents as compared to herbivorous zooplankton species and do not rely on depot lipids in the same way. Often fatty acids of the available food sources dominate the fatty acid composition of the species, masking potential taxon-specific patterns and emphasising the intensity of the pelago-benthic coupling. Therefore stable isotope ratios $\delta^{13}C$ and $\delta^{15}N$ will be used as an additional tool which can contribute to the determination of food sources and selectivity in meiofauna organisms, even at species level.

Meiofauna can significantly contribute to the regulation of benthic turnover and serve as food for secondary consumers. The role of meiofauna in the deep Weddell system as trophic link between sedimented organic matter and higher level consumers is another question that will be investigated in this study. It will be clarified whether there exists a coupling of meiofauna with higher trophic levels or if, on contrary, meiofauna in the deep Weddell system represents an energy-sink only accelerating decomposition. This and the determination of total meiofaunal standing stock at the investigated sites will be a crucial contribution to the generalised energy-flux model and food web study - a common objective of the ANDEEP-SYSTCO cruise.

Work at sea
Sediment samples taken with the multicorer (MUC) as well as residual sediment from deployments of other devices will be sieved and decanted, meiobenthic animals will be picked out and frozen for fatty acid and stable isotope analysis. The meiofauna will be sorted to the lowest taxonomic level possible. Nevertheless, very high numbers of these animals are necessary. Sediment cores will be fixed in formalin for the determination of meiofaunal standing stock as well as frozen for sediment analysis.

Additionally, the collection of benthic animals of groups other than meiofauna will be supported and intensified. For that reason the DZMB additionally provides a -80°C freezer, dry shippers and laboratory material.

Expected results
This work will be part of the first deep-sea food web study in the Antarctic. The benthic realm as a very diverse part of the Weddell system will be sampled and investigated from meio- to megafauna thus perfectly complementing the already existing food web study of the Weddell continental shelf area.

17. MARINE TOP PREDATORS AND THEIR PREY - 'SCRATCHING THE SURFACE'

M. van Dorssen, B. Feij, H. Flores, J.A. van Franeker, A. Meijboom
(IMARES)

The ANT-XXIV/2 expedition (November 2007-February 2008) is the third *Polarstern* cruise into the Lazarev Sea in which IMARES participates with research that links quantitative assessments of top predators with the density of prey in the surface layer of the seasonal sea ice zone. Earlier expeditions in the Lazarev Sea Krill Study (LAKRIS) in which we participated were conducted in autumn (ANT-XXI/4, Mar-May'04) and winter (ANT-XXIII/6, Jun-Aug 2006). We aim for a full coverage of seasonal changes. The ANT-XXIV/2 expedition represents our opportunity to study the summer situation.

Objectives
1. To improve quantitative assessment of distributional patterns of marine birds and mammals in the Southern Ocean, further documenting high abundances in sea ice areas and,
2. to start a top-down survey of the food web structure that could explain high predator abundance in sea ice, which we believe to be largely triggered by ice algae concentrating higher food web levels in the poorly studied upper layer of surface water.

Both objectives have high relevance for policies in conservation and management, especially in the light of potential effects of global climate change on the extent and characteristics of the Antarctic sea ice zone.

Methods and work at sea
Top predator censuses
Censuses of marine birds and mammals are conducted from 'open' observation posts installed on the bridge roof (Peildeck). Distribution and abundance of top predators is determined by international standard census methods, using band-transect and snapshot methods for birds (Tasker et al. 1984), supplemented with line-transect elements for marine mammals (Buckland et al. 2001). Ship based predator surveys are conducted whenever the ship is transecting under daylight conditions. In addition to ship based surveys, in the sea ice areas, helicopter surveys will be used to maximize coverage. Although ecology of individual species has our strong interest, our basic aim is to supply an integrated picture of abundance and food requirements of the whole community of warm-blooded top predators.

To achieve this, density figures for individual species are translated to daily food requirements per km^2, which then can be summed for all species together.

Surface fishing

In our opinion, the surface layer and its link to sea ice is of critical importance to the Antarctic food webs. Unfortunately, the standard fishing techniques or bioacoustics are not well adapted to reflect animal abundance in the surface layer of the ocean, especially not where this layer is covered by sea ice. We therefore have spent considerable effort on the construction of a special net to sample fish and zooplankton residing in the upper water layer, even when directly under sea-ice. The scraping off of the under ice fauna is reflected in our project's name *'Scratching the Surface'*. We built a special heavy-framed but floating net that can 'roll' along the undersurface of sea-ice: SUIT = *Surface and Under-Ice Trawl*. The net can be operated from the rear gangway of *Polarstern* and shears sidewards to starboard away from the ship's trackline. Because of the heavy steel frame, floaters and wheels, the construction weighs ± 1,000 kg. The netframe-opening is square with sides of about 2.2 m and has a 'slide-out' system for heavy lumps of ice. The net is made of a shrimp-net type (7 mm half mesh) and about 13 m long. The rear three meters of the net are lined with 0.3 mm mesh, ending in a large codend bottle. Based on experiences with the SUIT-net in the 2004 and 2006 expeditions, we have made further improvements to the design of frame and net.

Net catches will, as much as possible, be immediately identified, measured and processed while fresh during the cruise itself. Subsamples will be stored in various ways suitable for the later analyses of e.g. energy-density and contents of stomachs/guts, both needed to make stepwise additions to food web analysis and productivity estimates.

For our 'food web' objective, we aim to collect new data on consumption when possible. We aim for gut content analysis of organisms caught with the SUIT net. Seabird diets can be studied without harm to animals by stomach flushing. For this we will mostly use birds accidentally landed on the ship. On an opportunistic basis, we may also sample faeces from seals or other marine mammals. Prey remains from predator stomachs will be used to reconstruct original mass and energy consumption of different types of prey. SUIT net catches will be used to estimate energetic values of prey groups relevant to the top predators.

Expected results

As experienced in earlier SUIT deployments during ANT-XXI/4 and ANT-XXIII/6, we expect that our surface fishing will produce significant new results on abundance and diversity of marine life in the surface layer of the Southern Ocean. The role of seasons will further assist in beginning to understand the processes that are involved and their overall meaning for Antarctic food webs and their populations of top predators. We closely co-operate with, and benefit from other research conducted during the interdisciplinary LAKRIS expeditions. Our detailed information on the surface layer biology is complementary to results obtained by standard fishing for krill with e.g. RMT nets or the bioacoustics programme. We continuously improve our net design with also the aim to catch under-ice organisms in such a good condition that they are beneficial to a range of experimental work by colleagues on board. Ultimately it is the goal of these expeditions to all contribute to improved ecosystem understanding in which all levels from physics to biology are integrated.

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5.	Hring, Igor	2.Offc.
6.	Fallei, Holger	2.Offc.
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8.	Koch, Georg	R.Offc.
9.	Kotnik, Herbert	2.Eng.
10.	Schnürch, Helmut	2.Eng.
11.	Westphal, Henning	3.Eng.
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13.	Rehe, Lars	Electron.
14.	Dimmler, Werner	Electron.
15.	Fröb, Martin	Electron.
16.	Feiertag, Thomas	Electron.
17.	Clasen, Burkhard	Boatsw.
18.	Neisner, Winfried	Carpenter
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30.	Fritz, Günter	Mot-man
31.	Krösche, Eckard	Mot-man
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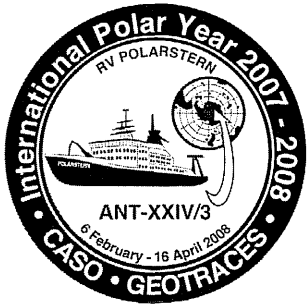
ANT-XXIV/3

6 February - 16 April 2008

Cape Town - Punta Arenas
Weddell Sea, Drake Passage

Chief Scientist
Eberhard Fahrbach



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1. ÜBERBLICK UND FAHRTVERLAUF

Eberhard Fahrbach (AWI)

Am 6. Februar 2008 wird das Forschungsschiff *Polarstern* von Kapstadt zur Antarktisreise ANT-XXIV/3 auslaufen. Zunächst wird der Kurs bis 15°E nach Westen führen. Dort wird *Polarstern* nach Südwesten drehen und der Laufbahn des *Jason-1*-Satelliten folgen. Mit dem Thermosalinographen und dem Acoustic Doppler Current Profiler (ADCP) sollen Temperatur, Salzgehalt und die Meeresströmung vom fahrenden Schiff aus erfasst werden, während der Satellit mit einem Altimeter die Auslenkung der Meeresoberfläche misst. Die Messungen vom fahrenden Schiff aus werden während der gesamten Reise ausgeführt. Entlang der Kurs-Linie werden vertikal profilierende Driftkörper (Floats) ausgelegt, Verankerungen mit Bodendruckmessern (PIES) ausgetauscht und Stationen mit einem Reinstwasserschöpfer-System ausgeführt, um eine Vielzahl von Spurenstoffen im Meerwasser zu messen, die Aufschlüsse über biogeochemische Kreisläufe geben und zur Verbesserung der Wassermassencharakterisierung herangezogen werden können. Um die Bedeutung des atlantischen Sektors des Südlichen Ozeans als Quelle oder Senke im globalen Kohlenstoffkreislauf abzuschätzen, werden die Komponenten des CO_2-Systems gemessen.

Bei 51°S wird *Polarstern* den Meridian von Greenwich erreichen. Dann führt der Kurs direkt nach Süden. CTD-Messungen (conductivity, temperature, depth) sollen während der gesamten Reise an etwa 210 hydrographischen Stationen mit Wasserschöpfern zur Bestimmung der Konzentration von gelösten Nährstoffen, Sauerstoff, Spurenstoffen und CO_2 ausgeführt werden. An der CTD-Sonde wird ein ADCP (L-ADCP, lowered Acoustic Doppler Current Profiler) befestigt sein, um Strömungsprofile über die gesamte Wassersäule zu messen. Die endgültige Anzahl der Stationen muss dem Fortgang der Arbeiten angepasst werden. Da keine Reservezeit zur Verfügung steht, können Zeitverluste durch unvorhergesehene Ereignisse oder zu langsamen Fortschritt der Arbeiten nur durch die Reduktion der Stationszeit aufgefangen werden.

Um quasi-kontinuierliche Messungen zu erhalten, erfolgt die Aufnahme und Auslegung von Verankerungen. In die Verankerungen werden Strömungs-, Temperatur- und Leitfähigkeitsmessgeräte, Schallquellen zur Ortung von Driftkörpern (Floats) und Eisecholote (upward looking sonar, ULS) zur Messung der Eisdicke eingebaut. Ferner sollen Floats vom Typ NEMO (Navigating European Marine Observer) ausgebracht werden. Im Rahmen eines Projekts von Steve Riser, University of Washington, ist geplant 40 APEX Floats auszulegen. Zur Quantifizierung des Süßwassereintrags durch Eisberge soll im südlichen Weddellmeer ein Eisberg mit einem Satellitensender ausgestattet werden, der mit dem Hubschrauber auf Eisbergen abgesetzt wird. Biologische Untersuchungen haben das Ziel, die Rolle von Viren in polaren Ökosystem zu bestimmen und die Konsequenzen der biochemischen Veränderungen im Ozean für bestimmte Phytoplanktonarten abzuschätzen.

Bei etwa 62°S müssen die Arbeiten auf dem Meridian von Greenwich unterbrochen werden, um am 28. Februar bei der Neumayer-Station anzukommen. Die Versorgung muss erfolgt sein, bevor die Sommermannschaft mit dem Flugzeug die Station verlassen hat. Nach dem Abschluss der Versorgungsarbeiten wird *Polarstern* zurückdampfen und die Arbeiten am Meridian von Greenwich wieder aufnehmen. Nachdem die Arbeiten auf dem Meridian von Greenwich abgeschlossen sind, wird *Polarstern* in Richtung Kapp Norvegia ablaufen.

Die nächste Phase der Arbeiten findet im eigentlichen Weddellmeer zwischen Kapp Norvegia und der Nordspitze der Antarktischen Halbinsel statt. Auf einem Schnitt erfolgen CTD-Stationen mit Probennahmen für Spurenstoffe und die Aufnahme und Auslegung von Verankerungen und Driftkörpern. Am 30. März wird die Jubany-Station mit dem Dallmann-Labor zum Abtransport von Material und zum Austausch von Personal auf der *Polarstern* angelaufen.

Der letzte Teil der Reise führt in die Drake-Passage, wo Verankerungen aufgenommen und wieder ausgelegt werden sollen. Begleitend erfolgen CTD-Messungen und Probennahmen zur Spurenstoffmessung.

Während der gesamten Reise werden, soweit es die Zeit erlaubt, Infrarot-Beobachtungen von Warmblütlern ausgeführt, die zur Weiterentwicklung eines automatischen Ortungssystems dienen.

Die wissenschaftlichen Arbeiten werden durch ein Programm der Öffentlichkeitsarbeit und des Lehrer-Programms des IPY begleitet.

Die Reise wird am 16. April 2008 in Punta Arenas enden. Die Fahrtroute ist in Abbildung 1.1 dargestellt.

Das Ziel der ozeanographischen Arbeiten besteht darin, die Bedeutung des atlantischen Sektors des Südlichen Ozeans für die großräumigen klimatischen Bedingungen besser zu verstehen. Die Intensität und Struktur der thermohalinen Zirkulation, der Einfluss der Ozeanschichtung auf das Meereis und die Wirkung als Quelle oder Senke für das Treibhausgas CO_2 bestimmen die Rolle des Ozeans für das Klima.

Im atlantischen Sektor des antarktischen zirkumpolaren Wassergürtels wird die globale Zirkulation durch die Variationen der Bildung von Antarktischem Bodenwasser beeinflusst. Messungen im Tiefen- und Bodenwasser des Weddellmeers haben gezeigt, dass sich seine Eigenschaften im Zeitraum der letzten 10 bis 15 Jahren merklich verändert haben. Zum Ende der 80er Jahre fanden eine Erwärmung und die Salzgehaltszunahme des von Norden einströmenden Zirkumpolaren Tiefenwassers statt. Im weiteren Verlauf wurde die Temperaturzunahme in den tieferen Schichten des Boden- und Tiefenwassers sichtbar und breitete sich bis in das westliche Weddellmeer aus. Inzwischen hat sich das Zirkumpolare Tiefenwasser wieder deutlich abgekühlt, im Bodenwasser hält die Erwärmung aber noch an. Gleichzeitig mit der Erwärmung im Weddellmeer wurde eine Temperaturzunahme in der Tiefe des Einstroms von Zirkumpolaren Tiefenwasser auch weiter nördlich im zirkumpolaren Wassergürtel beobachtet. Im Südatlantik wurde ein Temperaturanstieg im Antarktischen Bodenwasser im Vemakanal gemessen, der darauf hin deutet, dass die Veränderungen in der Antarktis überregionale Auswirkungen haben.

Die Variationen in den verschiedenen Meeresgebieten können hypothetisch als Teile einer längerfristigen Wirkungskette interpretiert werden. Die Wassermassencharakteristik des Einstroms aus dem Zirkumpolarstrom in das Weddellmeer hängt von den Konvergenzbedingungen an der Weddellfront ab. Der Zustrom kann seine Intensität oder Wassermassen-Eigenschaften ändern. Er erfolgt allerdings nicht nur im östlichen Weddellmeer, wie früher angenommen, sondern auch schon westlich des Meridians von Greenwich. Vermehrter Einstrom kann zur Erwärmung im Weddellmeer führen.

Der verstärkte Einstrom von warmem, salzreichem Wasser wirkt sich auf die Stabilität der Wassersäule aus und kann zur Polynja-Bildung beitragen. Da die Entstehung der großen Weddellmeer-Polynja in den 70er-Jahren des letzten Jahrhunderts noch nicht geklärt ist, kann nicht ausgeschlossen werden, dass sie durch Veränderungen im Einstrom von Zirkumpolarem Tiefenwasser ausgelöst wurde, indem die Stabilität der Wassersäule abnahm. Fluktuationen des Einstroms könnten durch die Variation der atmosphärischen Antriebsbedingungen ausgelöst werden, die z. B. im Rahmen der Antarktischen Zirkumpolaren Welle, des Südlichen Annularen Modes oder des Antarktischen Dipols auftreten. Andererseits könnten aber auch lokale Veränderungen der Antriebskräfte im Weddellmeer von Bedeutung sein.

Die Wassermassenformation erfordert, dass warmes, salzreiches Wasser in größerer Tiefe in den antarktischen Bereich einströmt, dort durch Auftrieb in der Antarktischen Divergenz an die Oberfläche kommt und im Kontakt mit der Atmosphäre abgekühlt wird, bis die Dichtezunahme das Absinken ermöglicht. Der Süßwassergewinn durch Niederschlag und durch den Zustrom von Schmelzwasser vom Kontinent, der zum Teil durch das Abbrechen von Eisbergen erfolgt, führt aber zur Dichteabnahme, die erst durch Salzfreisetzung bei der Meereisbildung kompensiert werden muss, bevor die Boden- oder Tiefenwasserbildung einsetzen kann. Daher ist der Salz- oder Süßwasserhaushalt von besonderer Bedeutung.

Im Rahmen globaler Programme haben unsere Messungen das Ziel, einen mittleren Zustand des Weddellmeer-Systems und dessen Veränderlichkeit zu charakterisieren, um über die regionalen Untersuchungen hinaus, globale Zusammenhänge zu beschreiben. Ferner sollen die Daten zur Validierung regionaler Modelle herangezogen werden. Da sich gezeigt hat, dass merkliche Veränderungen des Systems über einen Zeitraum von Dekaden erfolgen, erfordert die Untersuchung der Ursache und der Auswirkungen dieser Fluktuationen Wiederholungsmessungen hoher Qualität über einen entsprechenden Zeitraum.

Das direkte Ziel der Untersuchungen ist es, einen Zusammenhang zwischen den Fluktuationen der atmosphärischen Bedingungen, der Eigenschaften der Wassermassen und den Meereisbedingungen nachzuweisen. Mit den Messungen sollen die in den vergangenen Jahren im Weddellmeer beobachteten Veränderungen weiter verfolgt werden, um ihren zeitlichen Verlauf und ihre räumliche Verteilung zu erkennen. Um die Ursache der Veränderungen zu bestimmen, sollen die Fluktuationen des Antarktischen Zirkumpolarstroms südlich von Südafrika gemessen werden, wobei die Intensität und die Lage seiner südlichen Strombänder und der Übergang zum nördlichen Stromband des Weddellwirbels von Bedeutung sind.

Im Weddellmeer sollen die Messungen zeigen, ob die Polynja-Bildung westlich der Maudkuppe durch den Einstrom von Zirkumpolarem Tiefenwasser begünstigt wird, oder ob der lokale atmosphärische Antrieb dominiert. Im Falle der Polynja-Bildung soll gemessen werden, wie die Eigenschaften des Weddellmeer-Tiefenwassers durch tiefe Konvektion verändert werden.

Die physikalischen Untersuchungen werden durch ein Programm zur Messung von Spurenstoffen erweitert, die zur Wassermassencharakterisierung herangezogen werden. Damit wird die Abschätzung der Wassermassenbildungsraten ermöglicht.

Spurenmetalle wie Eisen, Zink, Kupfer, Mangan, Nickel und Kobalt spielen alle lebenden Zellen und Organismen eine bedeutende Rolle. Im Ozean sind ihre Konzentrationen aber sehr gering. Die Prozesse, die die Verteilung dieser Stoffe bestimmen, sind aber noch

weitgehend unbekannt. Das Ziel der GEOTRACES-Untersuchungen ist es, die Verteilungen einer Vielzahl dieser Stoffen zu messen und damit die relevanten Prozesse zu verstehen. Die geringe Konzentration und die hohe Gefahr der Verschmutzung der Proben erfordern den Einsatz eines besonders entwickelten Probennahmesystems des NIOZ.

Der Beitrag des atlantischen Sektors des Südpolarmeers als Quelle oder Senke im globalen Kohlenstoffkreislauf wird in einem Projekt zur Messung von Nährstoffen und den Komponenten des CO_2-Systems bearbeitet.

Das Hauptprogramm der Reise erfolgt im Rahmen des Internationalen Polarjahres 2007/2008 (IPY). Das IPY 2007/2008 steht unter der Schirmherrschaft der ICSU und der WMO. Es soll durch eine weltweite Koordination der Kräfte und die Intensivierung der Aktivitäten zu einer quasi-synoptischen Aufnahme der Bedingungen in beiden Polargebiete führen, die als Grundlage der Bewertung der gegenwärtig ablaufenden Veränderungen dienen wird. Im GEOTRACES-Projekt werden Spurenstoffe und biogeochemische Prozesse untersucht. Das CASO-Projekt (Climate of Antarctica and the Southern Ocean) setzt Arbeiten des früheren WECCON-Projekts (Weddell Sea convection control) fort. Es begann mit dem World Ocean Circulation Experiment (WOCE) als von 1989 bis 2001 Untersuchungen im Weddellmeer ausgeführt wurden, die zum besseren Verständnis der Wassermassentransformation und Zirkulation beigetragen haben. Diese Messungen wurden anschließend im *Climate Variability and Predictability* (CLIVAR) Programm des *World Climate Research Programme* (WCRP) der UNESCO fortgesetzt. Die Arbeiten in der Drake-Passage erfolgen im Rahmen des französischen DRAKE-Projekts, das ebenfalls ein Beitrag zum IPY-Projekt CASO ist. Die globale Bedeutung der regionalen Prozesse wird im IPY-Projekt BIAC (*Bipolar Atlantic Thermohaline Circulation*) berücksichtigt. Im Norden schließen die Messungen an die Arbeiten des BONUS-GOODHOPE-Projektes an. Die Untersuchungen bei der Maudkuppe und des Antarktischen Küstenstroms finden im Rahmen des von SCOR (Scientific Committee of Oceanographic Research) betreuten iAnzone Programms statt, das einen Beitrag zum *Climate and Cryosphere* (CLIC) Programm des WCRP liefert und im IPY mit dem Projekt SASSI *Synoptic Antarctic Shelf Slope Interactions Study* vertreten ist. In diesem Programm ist besonders die Ausbringung der Upward Looking Sonars (ULS) und der Verankerungen an der Küste von Bedeutung. Die ULS sind ein Beitrag zum *Antarctic Sea Ice Thickness Projects* (AnSITP). Das Ausbringen der Floats erfolgt im Rahmen des internationalen *Argo*-Programms, das zum *Gobal Ocean Observing System* (GOOS) beiträgt. Im Rahmen der internationalen Programme erfolgt besonders enge Zusammenarbeit mit dem Bjerknes Centre in Bergen, Norwegen, und dem British Antarctic Survey (BAS), der am Verankerungsprogramm beteiligt ist. Die gesamte Expedition ist ein Beitrag zum MARCOPOLI-Programm der Hermann von Helmholtz-Gemeinschaft Deutscher Forschungszentren (HGF).

SUMMARY AND ITINERARY

Polarstern will leave on 6 February 2008 from Cape Town for the cruise ANT-XXIV/3 to Antarctica. First, she will steam to the west up to 15°E where she will turn to the southwest and follow up the ground track of the *Jason-1* satellite. Temperature, salinity and ocean currents will be measured with a thermosalinograph and the acoustic Doppler current profiler (ADCP) from the mowing vessel, whereas the satellite will observe the sea surface elevation with an altimeter. Along the tack line floats will be deployed, moorings with bottom pressure sensors (PIES) will be exchanged. Samples will be taken to measure the content of trace substances in the sea water. The measurements will help to understand biogeochemical cycles and give further information on water masses and circulation. The components of the CO_2 system will be measured to elucidate the role of the Southern Ocean in the global CO_2 cycle.

At 51°S *Polarstern* will reach the Meridian of Greenwich from whereon the course will be to the south. It includes measurements by the CTD probe (Conductivity, Temperature, Depth) and the recovery and redeployment of moorings. At approximately 210 hydrographic stations water samples will be taken to determine the concentration of dissolved nutrients, oxygen, trace substances and CO_2. Biological investigations aim to determine the role of viruses in polar ecosystems and the impact of changes of biochemical conditions in the ocean on phytoplankton.

The final number of stations must be adapted to the progress of work. Since there is no spare time, time losses due to unexpected events or slower progress as expected have to be compensated by reduction of station time.

An essential part of the programme consists in the recovery and redeployment of moorings. They contain current meters, temperature and conductivity sensors, sound sources to locate floats and upward looking sonars (ULS) to measure the sea ice thickness. Additionally NEMO floats (Navigating European Marine Observer) will be deployed. On request of Steve Riser, University of Washington, we will deploy up to 40 additional APEX floats along the ships transect. To asses the freshwater input by icebergs an iceberg will be equipped with a satellite transmitter which will be deployed with an helicopter on the berg.

At approximately 62°S the station work on the Meridian of Greenwich has to be interrupted to reach the Neumayer Station on 28 February. The supply has to be accomplished before the summer crew has to leave the station in order to reach the last flight back to Cape Town. After the supply operation *Polarstern* will steam back and continue the station work along the Meridian von Greenwich.

The next phase of the cruise will take place between Kapp Norvegia and the northern end of the Antarctic Peninsula. CTD stations, trace substance sampling and the deployment of moorings and floats will continue. On the 30 March Jubany Station and the Dallmann Laboratory will be visited to take material on board and to exchange scientific personnel on *Polarstern*. After the call to Jubany Station the final part of the cruise will consist in the recovery and redeployment of moorings in Drake Passage and a hydrographic section with sampling of traces substances.

During the whole cruise infra red observations will be carried out as much as time allows. The project aims to develop a system to automatically locate marine mammals.

The scientific work will be accompanied by a public relation project which includes the work of a writer and a participant of the IPY teacher programme.

The cruise will end on 16 April 2008 in Punta Arenas. The cruise track is displayed in figure 1.1.

The physical oceanography programme intends to investigate the role of the Southern Ocean in the global climate system. Here we focus on the Atlantic sector including the Weddell Sea. The Antarctic ocean contributes through atmosphere-ice-ocean interaction processes to the variability of the climate system. The ice cover has a strong control on the albedo and on the ocean-atmosphere heat exchange. At the same time the advective heat supply from the ocean controls the ice cover. Atmosphere-ice-ocean interactions lead to water mass conversion which occurs in the open ocean and on the shelves. Whereas the shelf processes affect a reservoir limited through the shallow water depth and the cross frontal transports at the shelf edges, open ocean processes can affect deeper layers directly if the stability of the water column is weak. A major contribution of the global deep and bottom water formation occurs in the Weddell Sea. It is controlled by the transport of source waters into the Weddell Sea, processes within the Weddell Sea, and the transport of modified water out of the Weddell Sea.

Water samples will be taken to investigate the role of trace elements in biogeochemical processes. Every living cell and organism needs the trace metals iron, zinc, copper, manganese, nickel and cobalt roughly in that order for many functions, notably as co-factors in enzymes. Within the oceans their concentrations are very low, and recently it was discovered that iron is limiting plankton ecosystems in some 40 % of the oceans, notably the Southern Ocean. Moreover the roles of Fe, Zn as well as Cu, Mn, Ni, Co as a co-limitation of plankton at any given time and place in the oceans is yet to be pursued. Zinc is the co-factor in carbonic anhydrase for CO_2 metabolism, the most common enzyme in the biosphere. Together with the key role of iron in photosynthesis, Zn will strongly control the response of ocean biota to the future High-CO_2 world, notably the biosynthesis of shells and coral reefs.

The processes controlling oceanic distributions hence availability of trace metals in the oceans still are poorly understood. Organic complexation, adsorptive scavenging on settling particles, river input and atmospheric dust input from land as affected by desertification, dissolution within reducing marine sediments, pressure-cooker chemistry of rocks and seawater in hydrothermal vents, ocean circulation and mixing, these all play a role. In fact these processes are valid topics of research in themselves.

For unravelling these processes there is a suite of other trace elements and isotopes to be considered serving as sometime source tracers, sometime internal clocks, and sometimes as tracers or analogs for ocean water mixing and circulation, also in past oceans. During the cruise water samples will be taken by a special ultra-clean sampling system from NIOZ which will allow to determine the distributions trace elements and isotopes and to understand the controlling factors.

The main programmes occur in the context of the International Polar Year 2007/2008 (IPY). The IPY 2007/2008 was established under the auspices of ICSU and WMO. It aims to coordinate forces globally to achieve a quasi-synoptic survey of the conditions in both polar

areas to obtain a benchmark for future changes. In the GEOTRACES project the role of traces substances in the context of biogeochemical cycles is investigated. The contribution to the CASO project (*Climate of Antarctica and the Southern Ocean*) aims to investigate processes which occur in the Atlantic Sector of the Southern Ocean and Drake Passage.

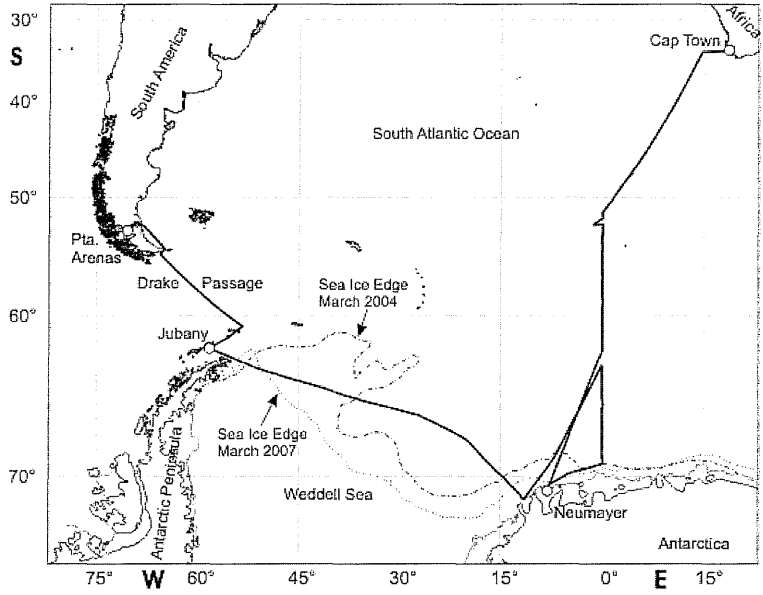

Abb. 1.1: Die Fahrtroute der Polarstern während der Reise ANT-XXIV/3 vom 6. Februar bis zum 16. April 2008. Der Rand der Meereisausdehnung im März 2004 und im März 2007 ist jeweils als strichpunktierte und gepunktete Linie angegeben.

Fig. 1.1: Cruise track during Polarstern leg ANT-XXIV/3 from 6 February to 16 April 2008. The sea ice edge for March 2004 and March 2007 is displayed as dotted und dashed lines.

2. CASO: CLIMATE OF THE ANTARCTIC AND THE SOUTHERN OCEAN

2.1 DECADAL VARIATIONS OF WATER MASS PROPERTIES IN THE ATLANTIC SECTOR

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Objectives

The densest bottom waters of the global oceans originate in the Southern Ocean. Production and export of these dense waters constitute a vital component of the global climate system. The formation of dense water in polar areas is controlled to a large extend by the delicate balance between supply of fresh water through precipitation and melt of continental and sea ice and the extraction of freshwater by sea ice formation and evaporation. Therefore the Southern Ocean's part of the global freshwater cycle links continental and oceanic conditions. It consists in the transport of freshwater from the continent through melting of ice shelf and icebergs and is strongly mediated by redistribution of freshwater through the highly variable and moving sea ice cover on which snow is accumulated as well as by the oceanic circulation. Coupled models predict an intensification of the freshwater cycle in the context of global warming. Observations of the freshening of Subantarctic Mode, intermediate and deep waters suggest that the intensification is ongoing.

Dense waters are produced at several sites near the continental margins of Antarctica. Quantitatively the most important region for dense water formation may well be the Weddell Sea, however other areas provide significant contributions as well. The basic mechanism of dense water generation involves upwelling of Circumpolar Deep Water which is relatively warm and salty into the surface layer where it comes into contact with the atmosphere and sea ice. The newly formed bottom water is significantly colder and slightly fresher than the initial Circumpolar Deep Water which indicates heat loss and the addition of freshwater. Since freshwater input in the upper oceanic layers is prohibitive to sinking through increasing stability of the water column, it has to be compensated by salt gain through fresh water extraction. The upwelled water is freshened by precipitation and melting of glacial and sea ice. Freshwater of glacial origin is supplied from the ice shelves or melting icebergs. Ice shelves melt at their fronts and undersides related to the oceanic circulation in the cavity. Iceberg melting depends highly on the iceberg drift and can supply freshwater to areas distant from the shelves as the Antarctic frontal system. Due to the spatial separation of major freezing and melting areas of sea ice cooling and salt release during sea-ice formation cause the compensation of the freshwater gain and subsequently the density increase which is needed for bottom water formation. Significant parts of the salt accumulation occur on the Antarctic shelves in coastal polynyas. Since extreme heat losses can only occur in ice free water areas, the polynyas are areas of intense sea ice formation. Offshore winds compress the newly formed sea ice and keep an open sea surface in the polynyas. The cold and saline water accumulated on the shelves can descend the continental slope and form deep and bottom waters.

The properties and volume of the newly formed bottom water underlies significant variability on a wide range of time scales, which are only poorly explored due to the large efforts needed to obtain measurements in ice covered ocean areas. As for the atmospheric driving forces, the sea ice and upper ocean layers, seasonal variations are partly known and normally exceed in intensity the other scales of variability. However the spatial distribution pattern of the variability is only poorly resolved e.g. seasonal cycles of sea ice thickness are only available at a few sites. An estimate of the sea ice mass as a baseline to detect change is still not possible due to the missing measurements of sea ice thickness. Longer term variations of the atmosphere-ice-ocean system as the Antarctic Circumpolar Wave, the Southern Hemispheric Annular Mode and the Antarctic Dipole are only poorly observed and understood. Their influence on or interaction with oceanic conditions are only guessed on the basis of models which are only superficially validated due to lack of appropriate measurements.

The extreme regional and temporal variability represents a large source of uncertainty when data sets of different origin are combined. Therefore circumpolar data sets are needed of sufficient spatial and temporal coverage. At present such data sets can only be acquired satellite remote sensing. However, to penetrate into the ocean interior and to validate the remotely sensed data, an ocean observing system is needed, which combines remotely sensed data of sea ice and surface properties with *in situ* measurements of atmospheric, sea ice and oceanic properties.

To achieve further progress significant steps occurred in the development of appropriate technology and logistics. Oceanic properties are measured under the sea ice which required the development of under-ice acoustic ranging and data transmitting systems. To construct from the achievable observations a comprehensive circumpolar view, model assimilations have to be done which require the development of appropriate models.

During IPY a set of meridional transects will be occupied in one season to provide the first synoptic snapshot of the circulation, stratification and biogeochemical status of the Southern Ocean. At a minimum, each of the "chokepoint" sections between Antarctic and the southern hemisphere continents should be occupied, plus one or more additional lines in each basin. ANT-XXIV/3 will cover the African chokepoint in the Atlantic Sector of the Southern Ocean, the Weddell Sea and Drake Passage. The northern part of the section south of Africa will be covered by BONUS-GOOD HOPE. Of special interest will be the possibility to detect and estimate the transport of newly-formed dense bottom waters flowing westward along the continental slope, to better understand the connections between known deep water sources and the locations where deep water leaves the slopes to flow north. The ANT-XXIV/3 cruise will provide 4 sections (Greenwich Meridian, Kapp Norvegia, Joinville Island, Drake Passage) on which the coastal current has significantly different properties. However, here there are still uncertainties with the ship time. If it will not be available, the present cruise track has to be rediscussed. The African choke point includes measurements with moored Pressure Inverted Echosounders (PIES) which are simultaneously a contribution to the GRACE project. The PIES need to be recovered and redeployed.

The CASO project (*Climate of Antarctica and the Southern Ocean*) takes up work which had started in the WECCON project (*Weddell Sea convection control*). It aims to investigate processes which occur in the Atlantic Sector of the Southern Ocean and Drake Passage in cooperation with the Bjerknes Centre for Climate Research in Bergen, Norway and the British Antarctic Survey (BAS). In the framework of iAnZone, a programme associated to SCOR (*Scientific Committee of Oceanographic Research*) and its IPY SASSI project

(*Synoptic Antarctic Shelf Slope Interactions Study)* observation occur in the area of Maud Rise and the Antarctic Coastal Current. The observations occur jointly with the IPY GOOD-HOPE project which covers the northern part of the Atlantic sector of the Southern Ocean. The global impact of the regional Processes will be considered in the BIAC (*Bipolar Atlantic Thermohaline Circulation*) IPY project. The cruise occurs in the context of the MARCOPOLI programme of the Hermann von Helmholtz Association of German Research Centres (HGF). It is a contribution to the *Climate Variability and Predictability* (CLIVAR) and the *Climate and Cryosphere* (CliC) projects of the *World Climate Research Programme* (WCRP). The ULS are a contribution to the *Antarctic Sea Ice Thickness Project* (AnSITP). The deployment of floats occurs in the framework of the international *Argo* programme which contributes to the *Global Ocean Observing System (*GOOS).

Work at sea

The *Polarstern* cruise ANT-XXIV/3 will complement the efforts during the International Polar Year 2007/2008 to obtain *in situ* observations in the Atlantic sector of the Southern Ocean in order to allow a circumpolar view. Time series stations with moored instruments will provide measurements in the deep and the surface layers and of ice thickness. For this purpose moorings with current meters, temperature and salinity sensors as well as upward looking sonars will be recovered and redeployed. The cruise concentrates to three major areas: the Greenwich Meridian, the Weddell Sea and Drake Passage.

Ship borne meridional transects are needed to determine water mass properties including tracer concentrations. They will occur along the Greenwich Meridian, across the Weddell Sea and Drake Passage (Fig. 1.1). The ship borne surveys in summer are imbedded in the time series measurements with moorings, drifters and floats to derive the effect of the seasonal variability on transfer processes and to avoid the aliasing effect on longer term observations. Moorings will be recovered (Fig. 2.1) and redeployed (Fig. 2.2). The spreading of floats is able to extend the data from the sections over larger parts of the area.

Profiling floats will be deployed. The float system has to complement *Argo* in ice-fee and under-ice condition to reach a global coverage. Moorings with sound sources for under ice navigation will be recovered and redeployed. The IPY set the goal of achieving at least the 3° X 3°sampling of the global array throughout the southern hemisphere oceans south of 30°S, for the full duration of the IPY (March 2007 to March 2009). Acoustically tracked floats will provide profiles and current velocities from key ice-covered seas. The floats will be programmed to continue to profile and store data beneath ice. Once the floats detect open water, the stored profiles will be transmitted. While the position of the sub-ice profiles is not known without acoustic navigation, the floats can survive the winter and the stored profiles provide a statistical description of winter stratification.

The international *Argo* programme aims at observing global ocean upper temperature and circulation by means of free floating *Argo* floats. Globally, approximately 2800 of such regularly undulating platforms are in operation. During the past years, the AWI pushed technological developments to extend the operational rage of Argo floats into seasonally ice-covered regions. To this end and with additional support by the EU project MERSEA and the BMBF Project German *Argo* the so-called NEMO float (Navigating European Marine Observer) was developed and tested, which are now fully operational. During ANT-XXIV/3, up to 18 NEMO floats and an overhauled APEX floats will deployed in the Weddell Sea. In

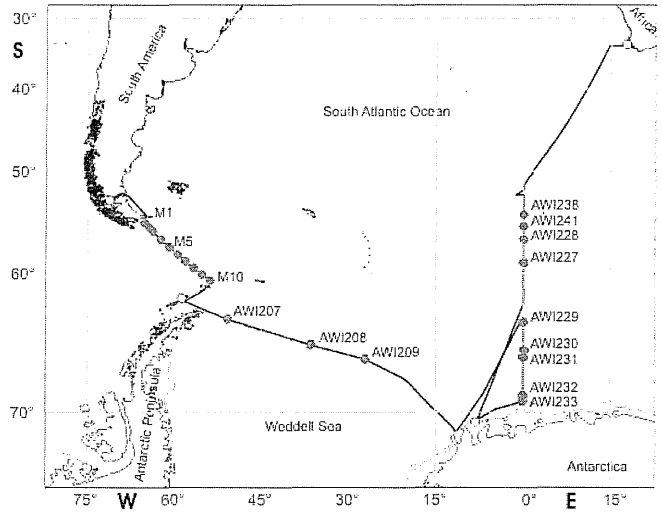

Fig. 2.1: The locations of moorings to be recovered during ANT-XXIV/3

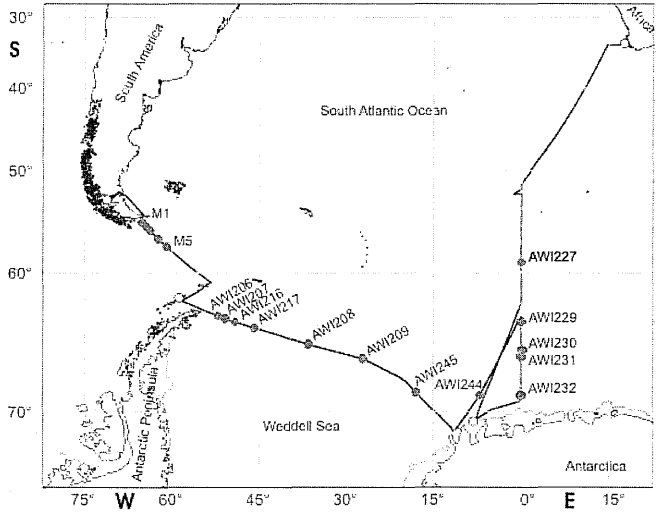

Fig. 2.2: The locations of moorings to be deployed during ANT-XXIV/3

addition, on request of Steve Riser, University of Washington, we will deploy up to 40 additional APEX floats along the ships transect.

To obtain position for the CTD profiles collected by the abovementioned floats during the winter season, the installation of a RAFOS sound source array is necessary. The travel time of sound signals of moored sound sources (1- 12) will be recorded by the free drifting floats. Using times of arrival of signals of two or more sources, the position of the receiver, i.e. the float, may be determined retrospectively.

The present state of planning for the installation of the RAFOS array is displayed in figure 2.3. At this time, sound sources at positions 01, 02, 03, 04, 05, 06, 07, und 08 are deployed. During ANT-XXIV/3, sound sources at positions 01, 02, 04, 05 und 06 shall be recovered, while sound source deployments will occur at positions 01, 02, 09, 11, 04, 10 und 06.

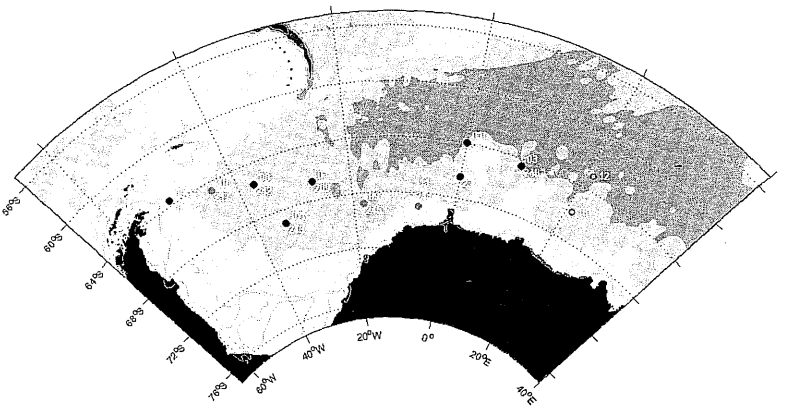

Fig. 2.3: Planned sound source array. Numbers next to the dots indicate sound source codes and corresponding mooring numbers.

Additional work will be probably executed concurrently during a Norwegian cruise onboard *G.O. Sars*. During that cruise, sound source 03 shall be recovered, and new sound source mooring shall be deployed at positions 03, 12, und 13.

Since 2002, the GRACE satellite mission has observed the gravity field of the Earth with unprecedented accuracy. Gravity field products provided by the GRACE Science Data System allow assessing both the static geoid, as well as time-varying signals associated with changes of global water mass distribution.

To detect temporal variability of oceanic currents and mass transports, it is critical to validate the space-born GRACE data by both observed and modelled Ocean Bottom Pressure (OBP) time series. In the framework of a joint BMBF (German Ministry for Education and Research) project, an OBP database is established by the Alfred Wegener Institute (AWI) to collect all available observations of OBP recorders deployed at the sea floor.

During ANT-XXIV/3, up to 6 PIES will be deployed (ANT-3,5,7,9,11, and 13). Optionally 2 - 3 of these will be equipped with up to 2 PopUp modules for early data transmission (after 1 year).

2.2 MONITORING THE ACC TRANSPORT THROUGH DRAKE PASSAGE

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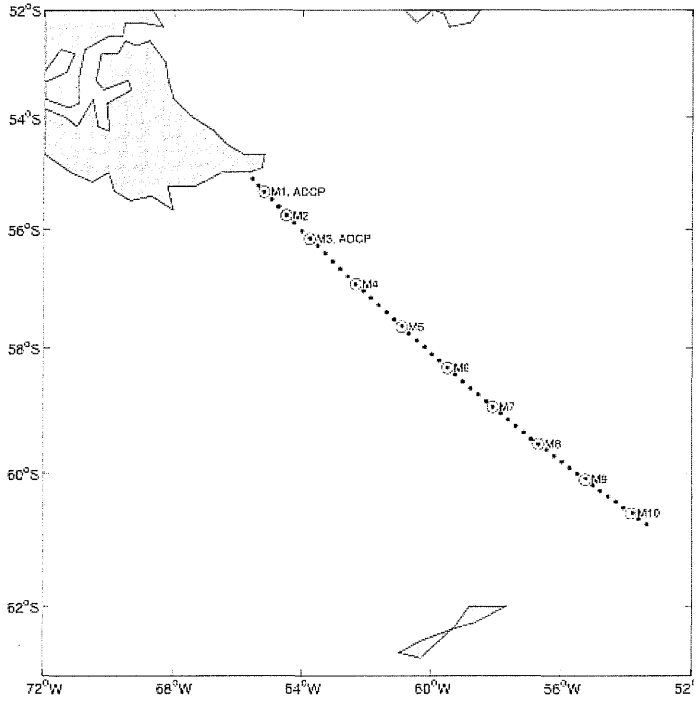

Fig. 2.4: Planned route and station locations for Drake cruise. M1 to M10 are mooring locations. Dots are planned hydrological stations. The final number of hydrological stations will be adjusted to the progress of work. Time losses due to unexpected events or slower progress than expected will be buffered by a reduction of station time.

Objectives
Monitoring the Antarctic Circumpolar Current (ACC) transport is essential for understanding the coupling of this major current with climate change. The main objective of the expedition is to monitor the magnitude and variability of the ACC through Drake Passage. Therefore one of the main task of the expedition is the deployment of a mooring array below track 104 of altimetric satellite Jason-1 for at least two years.

The *in situ* time series of currents through the Passage coupled with the satellite altimetric observations should provide estimations of variations of the mass transport on time scale from month to interannual. We should be able to produce a continuous time series of transport through Drake Passage starting in 1992. Then we shall examine the mechanisms responsible for the variability of the transport. Hopefully the comparison of this 16-year-long time series with the time series obtained by ISOS at the end of the 1970 will provide information on the changes in 30 years.

A proper use of the altimetric data requires a better understanding of the altimetric signal in these high latitudes. Therefore an important technical objective is a precise validation of the altimetric signal. In particular, the rough sea state and atmospheric conditions require a precise examination of the corrections to be applied for the ocean response to the atmospheric pressure and the sea state effects on the altimetric measurements.

High frequencies and transients: Another difficulty resides in the fact that time scales are small in the ACC. The satellite time sampling (10 days) may lead to serious aliasing problems. We shall therefore estimate potential aliasing (from the *in situ* data) and combine several satellites (to improve the time resolution) and use data assimilation models. Another objective is to document eddies and transient structures to improve our understanding of their interactions with mean current and their role for the transport of properties across the current.

Water masses: Water masses enter Drake Passage where they undergo substantial modifications. Our objectives concerning water masses are the following:
- identify precisely water masses, their sources and trajectories,
- quantify mixing by small scale structure analysis (CTD Thorpe method, LADCP shear method) and multiparameter analysis,
- Study climate change in water masses.

Work at sea
The 10 subsurface current meter moorings (M1 to M10) deployed during ANT-XXII/3 will be recovered. 5 new moorings will be installed at locations M1 through M5. Each mooring carries 3 current meters and seacats. M1 and M3 carry an upward-looking ADCP on top.

A proper use of the altimetric data requires a validation of the altimetric signal. For that the upward-looking ADCPs on moorings M1 and M3 will provide valuable data for validation.

Another technical objective is the improvement of our knowledge of the geoid in the area. For that gravimetric measurements will be performed using *Polarstern* gravimeter.

To complement the mooring array, we shall perform a high resolution CTD/LADCP station section.The distance between adjacent stations will be less than 20 km with a closer spacing

in the frontal regions. The hydrographic stations will gather water samples at different levels for tracers.

Temperature, salinity and ocean currents will be measured with the thermosalinographs and acoustic Doppler profiler from the moving vessel. During the whole cruise, the ship-borne gravimeter KSS-31 and GPS will be operated.

Expected Results

The data to be gathered will provide

- new information on the velocity field at Drake Passage (time scales, vertical structure, transients, mean flow) 30 years after ISOS (from currentmeters and full depth LADCP),
- new full depth high resolution hydrography with tracers 16 years after last similar cruise (METEOR A21) thus information on variability in water mass characteristics,
- a better understanding of the altimetric signal in the Drake Passage,
- an improvement of the geoid in the area,
- a precise documentation of the mass and volume transport through DRAKE on the mean and variability,
- new estimates of mixing.

2.3 DYNAMICS AND TRANSPORT OF THE ANTARCTIC CIRCUMPOLAR CURRENT IN DRAKE PASSAGE

Not on board: Teresa Chereskin (SIO/UCSD); Kathleen Donohue, Randy Watts (URI)

Objectives

The Southern Ocean is especially sensitive to climate change, responding to winds that have increased over the past 30 years and warming significantly more than the global ocean over the past 50 years. The ACC is the pulse of the Southern Ocean, and the Drake Passage choke point is not only well suited geographically for measuring its time-varying transport, but observations and computer models suggest that dynamical balances which control its transport are particularly effective through the Drake Passage. This project contributes to the International Polar Year (IPY) through its transport line monitoring of the ACC in Drake Passage. The observations will resolve the seasonal and interannual variability of the total ACC transport, its vertical structure partitioned between barotropic and baroclinic components, and its lateral structure partitioned among the multiple jets comprised by the ACC. Moreover, Drake Passage is a region of high mesoscale variability. The mesoscale eddies are thought to play a mediating role in transferring momentum from the circumpolar winds that drive the ACC, down through the water column to the seafloor, where topographic form stresses regulate its long-term transport. Measurements in the local dynamics array will quantify eddy exchanges with the mean current and density structure, and they will quantify the mean vorticity balance in order to test hypotheses regarding the dynamical balances that govern the ACC.

Work at sea

This study will deploy a transport line and local dynamics array of Current Meters and Pressure-recording Inverted Echo Sounders (CPIES) moored for a period of 4 years to quantify the transport and dynamics of the Antarctic Circumpolar Current (ACC) in Drake

Passage. Data will be collected annually by acoustic telemetry, leaving the instruments undisturbed until recovered.

2.4 MEASUREMENT OF TRACE GASES (CFCS, HELIUM ISOTOPES, NEON)

M. Gebler, A. Gronholz, O. Huhn (IUP)
Not on board: M. Rhein (IUP)

Objectives
The Weddell Sea is the main supplier for Antarctic Bottom Water (AABW) to the World Ocean. Weddell Sea Deep and Bottom Water are formed by interaction of mid-depth water masses with several shelf water masses (e.g. glacial melt water or Ice Shelf Water) and by entrainment of external water masses. Changes in its formation rates - caused by environmental changes, e.g. the decay of ice shelves or warming mid-depth water - could modify the strength and variability of the Meridional Overturning Circulation (MOC) and, thus, affect climate and climate change. Changes in the AABW formation process and in the amount of AABW formed might also influence the anthropogenic carbon uptake of the deep ocean.

The deep and bottom water formation in the Weddell Sea and its variability will be studied by using time series of CFC inventories inferred from this cruise and from historical data. The combined hydrographic, CFC and noble gas data will allow to distinguish different source water masses, that contribute to deep and bottom water formation, and how they reflect changing environmental conditions. Further insight in the variability of the export of deep and bottom water out of the Weddell gyre across the Greenwich Meridian and through the South Scotia Ridge system as well as the import of easterly sources is expected from the continuation of the CFC time series in 2008. The role of the Southeast Pacific Deep Slope Water in the transport of the Atlantic Circumpolar Current will be studied through a noble gas/CFC and lADCP repeat through Drake Passage.

Methods
Chlorofluorocarbons (CFCs) are gaseous, anthropogenic tracers that enter the ocean by gas exchange with the atmosphere. The evolution of these transient tracers in the ocean interior is determined by their temporal increase in the atmospheric and by the formation and mixing processes of intermediate, deep and bottom water.

The applied methods using CFCs as age tracers and include transit time distributions (TTDs, or age spectra). By applying a "mean age" and a "width of the age", this dating method accounts for advection and mixing, other than the "concentration age" approach, which accounts - as a first approach - for advection only. Additionally, a tracer free dilution can be applied. This improves the estimates of ventilation rates significantly. Necessary to derive the parameters of the TTDs is to use different transient tracer observations, i.e. different observed age tracers or/and tracers at different observation times (i.e. time series).

The total inventories of CFCs in deep and bottom water reflect the accumulation of CFCs carried by its surface near source water masses. Together with the known atmospheric CFC evolution, CFC inventories and their changes allow estimating the renewal or formation rates of recently formed bottom water. Furthermore, with the available time series from various sections allows to investigate its variability and, possibly, its relation to changing environmental (boundary) conditions (ice shelf decay, surface water warming, etc.).

Using stable tracers like helium isotopes and neon, additional to temperature and salinity, allow one to carry out a Optimum Multiparameter (OMP) analysis to estimate the contributions of the parent source water masses to the formation of deep water masses. Herein helium and neon are ideal tracers for glacial melt water or ISW, and the 3He/4He isotope ratio is a tracer for deep water from the Pacific.

Work at sea
About 1,500-2,000 CFC samples are planned for the three subsections of the cruise. Water samples from the rosette system will be stored in glass ampoules. Either they will be analyzed directly on board or they will be sealed off after a CFC free headspace of nitrogen has been applied. In both cases the CFC measurement uses a purge and trap sample pre-treatment followed by gas chromatographic (GC) separation on a capillary column and electron capture detection (ECD).

Approximately 500 samples for helium isotopes and neon are planned for the cruise to guarantee a sufficient vertical and horizontal resolution. The samples will be taken in the Drake Passage (~200) to determine the South Pacific Deep Slope Water signal and at special locations at the section across the Weddell Sea (~300) to determine the relative contributions from the various bottom water sources. The samples for helium isotopes and neon are stored in sealed copper tubes (50 ml). The noble gas samples are analysed in the IUP Bremen mass spectrometry lab afterwards with a sector field and quadrupole mass spectrometer system.

3. GEOTRACES

General Objectives
One major aim of international GEOTRACES (http://www.geotraces.org) is:

> "*To determine global ocean distributions of selected trace elements and isotopes, including their concentration, chemical speciation, and physical form, and to evaluate the sources, sinks, and internal cycling of these species to characterise more completely the physical, chemical and biological processes regulating their distributions*".

The International Polar Year (IPY) is an excellent opportunity to study Trace Elements and Isotopes in the Arctic and Antarctic Oceans. An international suite of vertical sections in the polar oceans is integrated in the IPY project No. 35 (http://www.ipy.org/development/eoi/proposal-details.php?id=35) entitled: "*International Polar Year GEOTRACES: An international study of the biogeochemical cycles of Trace Elements and Isotopes in the Arctic and Southern Oceans*". In context of this IPY-GEOTRACES, two Polarstern cruises are scheduled in the Arctic Ocean (ARK-XXII/2; 2007) and Antarctic Ocean (ANT-XXIV/3; 2008) respectively.

Data Management
All data of Isotopes and Trace Metals will be reported into the worldwide database of the GEOTRACES programme. Within the GEOTRACES Scientific Steering Committee, Dr. Reiner Schlitzer (AWI) is the SSC-member responsible for the database, and will be able to correspond regularly with other SSC members Michiel Rutgers van der Loeff (AWI) and Hein de Baar (NIOZ).

3.1 TRACE ELEMENTS INVESTIGATED BY THE NIOZ TEAM

H. de Baar, L. Gerringa, A. Hoogstraaten, M. Klunder, P. Laan, R. Middag, S. Ober, J. van Ooyen, W. Polman, C.E. Thuroczy (NIOZ); A.C. Alderkamp (University Groningen/Stanford University)

In GEOTRACES we have defined 6 key trace metals (Table 3.1) which, together with additional metals Co, Ni, Ag will be investigated in IPY-GEOTRACES subprojects. The distribution and biological availability of Fe (sub 1) is strongly controlled by its physical-chemical speciation (sub 2) within seawater, where colloids and Fe-organic complexes are dominant actors. For phytoplankton growth, Cu (sub 4) at the cell wall acts in reductive dissociation of Fe-organic complexes, hence facilitates Fe uptake. This may partly explain the nutrient-type distribution of Cu in the oceans. The external sources of Fe into the oceans are either from above (dust) and below (sediments) and will be constrained by Al and Mn (sub 3) for aeolian dust input and sedimentary redox cycling sources, respectively. The Fe enhances phytoplankton growth, which in turn strongly controls the biological pump for uptake of CO_2 from the atmosphere into polar oceans. The increasing CO_2 in polar ocean waters may affect phytoplankton ecophysiology, with key links of metals Fe (sub 1-2) in the overall photosynthetic apparatus and Zn (sub 4) in carbonic anhydrase and respectively, where Cd and Co (sub 4) may substitute for Zn in the latter carbonic anhydrase.

Tab. 3.1: The 6 trace metals with high priority in GEOTRACES. Many more trace metals to be measured during GEOTRACES, yet these 6 to be measured on all sections. Moreover Co, Ni, Ag of our subproject 4.

Fe	Iron	Most important essential micronutrient
Al	Aluminium	Tracer of Fe inputs (from mineral dust and elsewhere)
Zn	Zinc	Second important micronutrient; co-factor in carbonic anhydrase; toxic at high concentrations; environmental pollutant worldwide
Mn	Manganese	Tracer of Fe inputs and redox cycling; Fe-Mn in superoxide dismutase
Cd	Cadmium	Essential micronutrient; paleoproxy for phosphate in seawater; toxic at high concentrations; environmental pollutant worldwide
Cu	Copper	Essential micronutrient (toxic at high concentrations); toxic at high concentrations; environmental pollutant worldwide
Co	Cobalt	Essential micronutrient; co-factor vitamin B12
Ni	Nickel	Essential micronutrient; in urease
Ag	Silver	Analog of both Cu and Si; paleoproxy for nutrient silicate; environmental pollutant

Subproject 1: Distributions, Sources, Sinks of dissolved Fe and Fe(II) in Polar Oceans

Very little data exists on Fe in waters of the Antarctic Ocean. There is some data for Fe (or other trace metals) in surface waters of the Arctic Ocean, and very little at depths below ca. 1,000 metres. Thus ANT-XXIV/3 aims for two complete sections on distributions of Fe (and other trace metals) in the Antarctic Ocean. On the other hand we know that dissolved Fe is the key limiting nutrient for phytoplankton growth, hence the complete ecosystem and carbon budget and CO_2 exchanges in the Southern Ocean. Since the 1988 European Polarstern Study the role of Fe in ecology of the Southern Ocean has been investigated, including the Fe distributions, speciation, sources and sinks. Nevertheless in an exhaustive synthesis of all then existing ocean Fe data uncertainty remained as to the actual, correct, concentration of Fe in ocean waters. Thus total dissolved Fe is a top priority in GEOTRACES.

Subproject 2: Physical and Chemical Speciation of Dissolved Fe in the Polar Oceans

Dissolved (<0.2 micron) Fe in seawater in fact consists of several sizes fine colloidal Fe next to an operationally defined soluble (<smallest size cutoff ultrafiltration) pool. Moreover organic Fe(III)-complexes exist within both the colloid pool(s) and the soluble pool. Implications are twofold. Firstly within surface waters, the colloid fractions cannot be assimilated unless first dissolved by photoreduction into bio-available Fe(II) state. Similarly not all Fe(III)-organic complexes are available, where again photoreduction serves to make Fe more suitable for plankton uptake. Moreover others observed reductive dissociation of the Fe(III) complex by a Cu-containing protein (sub 4) at the cell wall. Secondly dissolved Fe in the deep ocean appears controlled by competition between two pools. Global ocean Fe models postulate the soluble Fe(III)-organic maintaining Fe in solution, while the colloids are removed towards the seafloor. Major focus is the until now hardly measured distribution between deep ocean colloid and organic complexed Fe pools.

Subproject 3: Dissolved Al and Mn as Source Tracers for Fe in Polar Oceans

For the world oceans, the initial hypothesis of Fe coming from above has been challenged by upwelling supply from below where reducing marine sediments are the ultimate Fe source. Dissolved Al in surface waters is a tracer of aeolian dust input and indeed very high in the Mediterranean where dissolved Fe is also high due to dust supply from the adjacent Sahara and Egypt arid regions. The dissolved Al and dissolved Fe also co-vary on a transect from the Canary Basin to Gibraltar. Data of Al is scarce in polar seas, and IPY GEOTRACES aims to fill this gap for better assessment of dust input. Elevated dissolved Mn and Fe in reducing environments render dissolved Mn a source tracer for Fe from below, i.e. from reducing sediments. Our combined Mn-Fe data, also with natural radiotracers (see below section on Radium Isotopes for margins, ^{227}Ac from deep seafloor) will quantify the Fe 'from below' source.

Subproject 4: Involvement of Co, Ni, Cu, Zn, Ag, Cd in Biological Cycles in Polar Oceans

The first row transition metals (Mn, Fe, Co, Ni, Cu, Zn) are essential for every living cell, in the sea and on land. Co is co-factor in vitamin B12, which most phytoplankton cannot synthesize hence needs to be provided in ocean waters. Zinc is in carbonic anhydrase for CO_2 fixation by algae. Substitution of cobalt Co or cadmium Cd in carbonic anhydrase may occur under Zn deficiency stress. Also a specific Cd-based carbonic anhydrase exists in a certain diatom. These enzyme functions may partly explain the co-variance in the oceans of

Zn with silicate (sub 5), and Cd with phosphate. Also nickel Ni co-varies with both phosphate and silicate, and copper Cu resembles silicate, albeit less due to deep ocean Cu removal (akin to deep ocean Fe removal in sub-2). The second row metal silver (Ag), despite having no biological function, also correlates with silicate. The thus far small (Cd, Ni, Cu) or very small (Zn, Ag) ocean data sets suggest interaction of Zn and Ag with the diatoms-and-Si cycle, and all (Ni, Cu, Zn, Ag, Cd) with the general ocean carbon cycle. The parallel measurements of nutrients (nitrate, phosphate, silicate) and alkalinity allows our study of metal-nutrient co-variances. With regards to the trace metals Cd, Cu, Ni and Zn this allows synergy and internal consistency with the project of Peter Croot (IFM-GEOMAR).

Subproject 5: Trace Metal Input by Aerosols

The input of airblown dust particles (aerosols) into surface waters will be assessed by collection of marine aerosols in combination with a settling model and estimation of partial dissolution of aerosol components into surface seawater. This project is in collaboration with Dr. Alex Baker (University of East Anglia), relying on his expertise and equipment. There is a close link with the above subproject 3 where distributions of Al in surface waters are determined as independent tracer for aerosol input.

Subproject 6: Dynalife: Dynamic Light Conditions and Fe Limitation

The DYNALIFE project focuses on the interactions between DYNAmic light conditions and Fe limitation experienced by Antarctic phytoplankton. It is evident that light availability plays a major role in defining where and when the different phytoplankton taxa bloom. The light climate phytoplankton experience can be highly dynamic, as a result of diel cycles, changes in cloud cover and wind driven mixing of the upper layer of the ocean. These alternations between low and high light require regulation and acclimation of light harvesting, photosynthesis, and photoprotective pigments in the phytoplankton. In response to low light algae maximize their light harvesting capacity and photosynthetic efficiency. Yet, high light may cause damage to the photosystems leading to photoinhibition and therefore requires synthesis of protective pigments. Southern Ocean ecosystem model results indicate taxon-specific differences in photoinhibition may be a key factor in determining the distribution of a taxon. And, indeed, experiments with Antarctic phytoplankton in the laboratory have identified taxon-specific differences in photoacclimation and photoinhibition at different light conditions that contribute to explaining the observed distribution. In addition, iron (Fe) limitation of the algal communities in the Southern Ocean is now well documented, and directly affects the quantity and efficiency of the photosystems. Thus, Fe-limitation directly affects photoacclimation and photoinhibition.

The objectives of this cruise are three-fold:
1) to determine if Antarctic phytoplankton experience photoinhibition when they reside near the surface,
2) to determine if the photoacclimation and photoinhibition is related to iron limitation and
3) to determine if the photoacclimation and photoinhibition is related to the depth of the mixed layer.

Subproject 7: Iron interactions with the Southern Ocean in a high-CO_2 World
B. Bontes, I. Neven (University of Groningen)

Since the beginning of the anthropocene atmospheric CO_2 levels have risen from 280 ppm to 370 ppm. This is higher than any CO_2 concentration experienced on Earth in at least 400,000

years and a further increase up to 750 ppm by the year 2050 becomes increasingly inevitable. Along with rising atmospheric CO_2 comes a continuing invasion of CO_2 into the world oceans (particularly in polar areas), which is predicted to cause a drop of pH by 0.3 - 0.4 units. As a result only half of the pre-industrial carbonate ion concentration [CO_3^{2-}] might remain (Feely et al. 2004). With the biological pump overriding CO_2 outgassing from upwelling deep waters, the Southern Ocean is an important sink for anthropogenic CO_2. Thus, making the local phytoplankton community an important player within the global climate system.

Surface ocean pH and CO_2 changes in turn might have large impact on representatives of the major bloomforming taxonomic classes: diatoms, nanoflagellates, and haptophytes (mainly Phaeocystis antarctica) in the Antarctic Ocean proper (> 50°S), and coccolithophorids in the sub-Antarctic region (< 50°S) of the Southern Ocean. We are going to study the effects of different pCO_2 in Southern Ocean seawater on the growth and vitality of several (large and small) pre-cultured diatom species (Fragilariopsis kerguelensis, Chaetoceros dichaeta, Corethron sp., Chaetoceros brevis) as well as the *in situ* algal community.

Iron limitation is directly affecting the efficiency of photosynthetic fixation of dissolved CO_2, thus the working hypothesis is that at controlled conditions of low Fe versus high Fe the response of the plankton community to different CO_2 conditions will be a function of the Fe availability.

Work at Sea

Sampling strategy

Highest priority is given to the sampling of complete (24 or more depths) sampling of vertical profiles throughout the complete (4 - 5 km depth) water column at deep water stations. Spacing of the overall 24 samples would be more closely together in the upper 1,000 metres, where the strongest vertical gradients of trace metals as well as major nutrients are expected. Optional adjustments of sampling depths in relation to water mass hydrography while maintaining some coherence of 'standard depths' between stations. Occasionally even two hydrocasts (overall 48 depths) may be pursued at one station. Overall the aim is to collect such deep profiles of 24 (some 48) samples at ca. 15 stations, shiptime permitting. In addition when the ship is at shallower sites of the continental shelf and slope, the 24 sampling depths would be spaced over the complete, shallower water column. Underway sampling of surface waters with the torpedo at any time when possible and provided that the shipboard analists have time to process and either directly analyze or store such samples. Samples will be taken at "large stations" and "super stations" (Fig. 3.1)).

Ultraclean sampling

The overall clean sampling and shipboard filtrations will be supervised by Patrick Laan, with assistance by the PhD students Maarten Klunder, Rob Middag and Charles-Edouard Thuroczy.

The novel titanium frame for rapid ultraclean sampling at 24 depths will be used at each station of the GEOTRACES grid. The system was tested successfully at sea in November 2005, will be tested again in April 2007 (aboard RV *Pelagia*). The CTD and bottle closing technology will be done by Sven Ober. The accompanying large winch (Kley-France) with 17 mm kevlar cable will be operated by Marcel Bakker. One spare titanium frame wih 24 spare samplers, CTD etc as well as various spare parts of the Kley winch will be stored in container NIOZ-25.

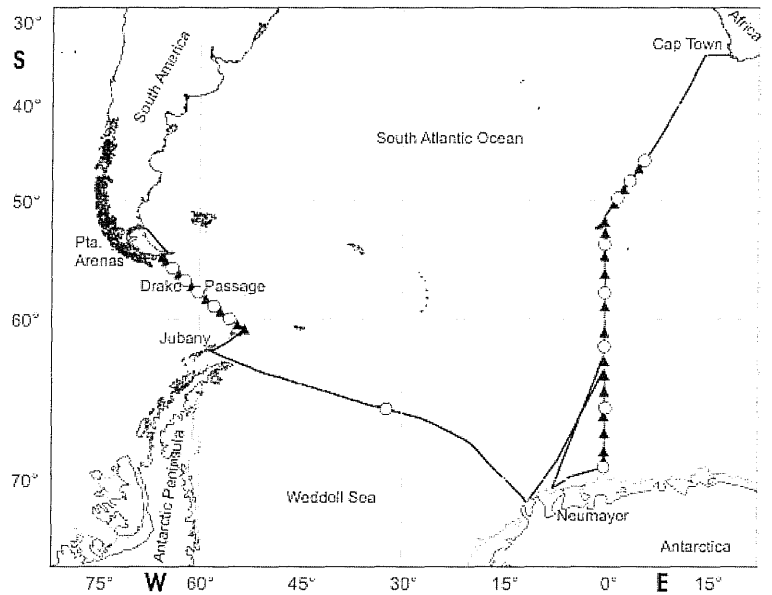

Fig. 3.1: Location of planned GEOTRACES stations during ANT-XXIV/3. According to the use of in situ pumps "large stations" (triangles) and "super stations" (open circles) are distinguished.

Upon recovery the complete frame with its 24 samplers will be placed inside its home laboratory. This is the ultraclean laboratory container NIOZ-7 to be placed on the aft-deck (Arbeitsdeck) at starboard front position. Once the frame is placed inside this container, the seawater will be filtered over filtration cartridges by pressurizing each sampler with nitrogen gas from cylinders. The filtered seawater is collected in pre-cleaned bottles. Crates filled with these bottles are brought into the adjacent clean analytical container NIOZ-28 for shipboard analyses, or brought to containers NIOZ-27 or NIOZ-41 elsewhere on the ship as mentioned below, or stored in container NIOZ-35 for analyses afterwards at the home laboratories.

Moreover samples will be collected underway when the ship is travelling between stations, where a torpedo will be towed alongside the ship at aft starboard side parallel to the aft deck. From the foreward clean inlet of the torpedo a tubing is led to a clean pump and then into the clean analytical container NIOZ-28 placed on the aft-deck, at amidship frontal position adjacent to NIOZ-7.

Subproject 1: Dissolved iron

Maarten Klunder and Patrick Laan will measure Fe directly on shipboard by Flow Injection Analysis (FIA) in clean container NIOZ-28, and afterwards in stored samples at the home laboratory. The Fe analyses will include daily runs of an internal IPY-GEOTRACES certification standard of iron in seawater (600 ml bottles as collected during April 2007

Pelagia cruise), and occasional runs of a certified SAFe standard of which only a small number of standard bottles is available. The similar shipboard detection method of reduced Fe(II) species (Rijkenberg et al., 2005) may, or may not, also be pursued on shipboard.

Subproject 2: Physical and chemical speciation of dissolved iron

Loes Gerringa and Charles-Edourd Thuroczy will work in second analytical container NIOZ-27 (placed inside the ship). Here the filtered seawater will be passed over an ultrafiltration unit as to isolate the colloids size class of dissolved iron. The ultrafiltrate comprises the 'truly dissolved' iron and in this fraction the truly dissolved iron concentration, as well as the dissolved organic complexed iron fraction will be detected. Voltametry in combination with the above mentioned FIA will be applied to unravel the organic complexed iron pool in seawater.

Subproject 3: Dissolved Al and Mn as source tracers for iron

Rob Middag will do the shipboard FIA measurements of both dissolved Al and dissolved Mn in clean container NIOZ-28. In the case of unforeseen lack of time or otherwise, the shipboard detection of Al will be given highest priority, such that some parallel samples for dissolved Mn will be stored for afterwards analyses at the home laboratory. Briefly it is well documented that samples for dissolved Mn can be stored without risk of contamination, while for Al there have been reports of contamination during storage due to trace amounts of Al still coming from the plastic of the storage bottles. Otherwise we have rigorously cleaned our storage bottles according to SAFE protocols, where recently it was demonstrated that over 2 years storage this did prevent Al contamination (Bruland, Smith, Dec. 2006, pers. comm.).

Subproject 4: Involvement of Co, Ni, Cu, Zn, Ag, Cd in biological cycles

Sample bottles of one litre each will be filled with filtered seawater for measurements afterwards in the home laboratory of Co, Ni, Cu, Zn, Cd as well as dissolved Fe. Latter dissolved Fe as a duplication hence confirmation/verification of the direct shipboard detection in above subproject 1. All seawater sample bottles will be placed in plastic crates and stored in NIOZ-38 storage container. The home laboratory measurement of this suite of trace metals will be done by High-Resolution Inductively Coupled Plasma Mass Spectrometry (HR-ICP-MS) with preceding in-line column pre-concentration of the metal elements from seawater. With regards to the trace metals Cd, Cu, Ni and Zn this allows synergy and internal consistency with the project of Dr. Peter Croot (IfM-GEOMAR).
Another set of small 60 ml bottles will be collected and stored for afterwards measurement of dissolved silver Ag in the laboratory of collaborator Dr. Eric Achterberg, National Oceanography Centre, Southampton, UK.

Another set of small bottles of sub-samples will be brought to container NIOZ-41 (placed in foreward Ladenraum) for shipboard analyses of major nutrients nitrate, silicate and phosphate by Jan van Ooijen with the auto-analyzer. Recently the NIOZ nutrients group participated in an international intercalibration of nutrients in seawater by more than 30 laboratories, where eventually only the NIOZ team had all its reported values of variables within the standard deviations of the median values of all participating laboratories.

The state-of-the-art accuracy envisioned for the major nutrients as well as Alk/DIC (see below) will allow the best possible property-property plots of latter biological cycling variables versus the "nutrient-type" trace metals Co, Ni, Cu, Zn, Ag, Cd. Here it is hoped a more

specific co-variance of one trace metal versus only one nutrient (Si, N, P, Alk, DIC) variable can be unraveled with statistical significance. For example is the commonly mentioned Cd-phosphate covariance really true or does Cd in fact correlate more closely with nitrate (when excluding O_2 minimum zones where nitrate deviates). Similarly is the silicate-type distribution of both Zn and Ag true and demonstrating involvement in the opal cycle of diatom frustules, or would one or both metals in fact better correlate with Alkalinity, i.e. the $CaCO_3$ cycle. Moreover the trace metals can be plotted versus one another just as well, for example to assess apparent fractionations within the oceans of, for example, the two group 1b metals Cu and Ag, or the two group 2b metals Zn and Cd.

Subproject 5: Trace Metal Input by Aerosols

Maarten Klunder and Rob Middag will collect marine aerosol samples and further process these samples on shipboard.

Subproject 6: Dynalife: Dynamic Light Conditions and Fe Limitation

Anne Carlijn Alderkamp will collect water containing *in situ* phytoplankton from the surface and from the base of the mixed layer in a trace metal clean fashion. Subsamples from each sample will be filtered and stored at -80°C for analysis of the pigment composition (HPLC, Groningen), and phytoplankton composition (microscopy). Each sample will then be incubated in triplicate under incident light conditions (surface light) and 10 % of incident light conditions (low light) in a deck incubator. At regular intervals samples will be taken to determine 1) the percentage of viable cells by cytox staining and flow cytometry and 2) the photoacclimation and photoinhibition status by Pulse Amplitude Modulated (PAM) fluorometry. To test the effect of repair of the photosystem reaction centers on the photoinhibition, a second incubation will be exectuted as described above with the addition of lincomycin. Lincomycin inhibits transcription of chloroplast encoded proteins such as the D1 reaction center protein, which is a crucial component of PSII with a high turnover rate. In addition, to test the effect of prevailing iron conditions, a second sample will be collected from the bottom of the mixed layer, and incubated for 24 hrs under *in situ* temperature and 10 % of incident light conditions with (+Fe) and without (-Fe) the addition of iron. On the next day, both +Fe and -Fe samples will analyzed for pigments and community composition and incubated under *in situ* light, low light, with and without lincomycin.

Subproject 7: Iron interactions with the Southern Ocean in a high-CO_2 World
B. Bontes, I. Neven (University of Groningen)

Babette Bontes will perform growth experiments with cultures of the above pre-cultured diatom species at three CO_2 concentrations (190, 370 and 750ppm). Growth, photosynthetic efficiency, organic carbon and nutrient dynamics will be measured. The same experiments will be done with *in situ* algae (pre-filtered). These experiments will take place in bottles at 2 degrees (in a container) and in deck incubations under *in situ* light and temperature conditions.

Ika Neven is going to carry out short-term $14CO_2$ disequilibrium experiments on the cultures mentioned above and the *in situ* phytoplankton community to estimate the extent of bicarbonate (HCO^{3-}) uptake and the role of external carbonic anhydrase in inorganic carbon uptake of Southern Ocean phytoplankton.

References

Rijkenberg, M., Fischer, A., Kroon, J., Gerringa, L., Timmermans, K., Wolterbeek, H,. de Baar, H. (2005): The influence of UV irradiation on the photoreduction of iron in the Southern Ocean, Mar.Chem., 93(2-4), 119-129.

3.2 TRACE ELEMENTS INVESTIGATED BY THE IFM-GEOMAR TEAM

O. Baars, K. Bluhm, P. Croot, M. Heller (IFM-GEOMAR)
Not on board: Rob Sherrell (Rutgers University)

Background and general objectives

In the High Nutrient Low Chlorophyll waters of the Southern Ocean the supply of iron controls primary productivity and thus the cycling of other key bio-elements (Co, Ni, Cd and Zn). While recent work has focused on the role of iron, it is now clear, mostly through at sea incubation experiments and laboratory studies, that other elements may also play a role in controlling the species composition of the phytoplankton and importantly the rates at which macronutrients are consumed by phytoplankton. These changes in rates of uptake are then reflected as differences in the nutrient ratios, or metal to nutrient ratios, of the phytoplankton themselves. A further complicating factor is the chemical speciation and bioavailability of these bio-elements may also undergo changes as a function of phytoplankton growth fuelled by the supply of iron. Understanding of these processes is then critical for investigations into primary productivity of the Southern Ocean and the sources and sinks for major nutrients. Unfortunately at the present time their have been only a limited number of studies on the distribution of these elements in the Southern Ocean, and even less studies examining the chemical speciation of these elements. Recent studies have also indicated that sub-optimal Zn concentrations may greatly influence Si and N uptake rates by phytoplankton while the Co containing vitamin B12 may be present in the Southern Ocean at potentially limiting concentrations for some diatom species - however for both elements direct evidence is still missing. Thus presently we urgently require a comprehensive study encompassing the chemical speciation and distribution of the already identified key bio-elements (Co, Ni, Cd and Zn) over a range of different Fe and macronutrient conditions. Overall such a study will not only improve our understanding of trace metal biogeochemical cycling in the Southern Ocean but also greatly increase our understanding as a whole of nutrient biogeochemistry in this key climatic region.

As part of the GEOTRACES contribution to ANT-XXIV/3 the IFM-Geomar Aqueous Trace Oxidant and Metal Speciation Laboratory (ATOMSLab) has 3 main research areas funded by the DFG:

1. Does Fe control the biogeochemical cycling, speciation and distribution of Cd, Zn, Ni and Co in the Southern Ocean?
2. Development of a budgetary scheme for Cd, Zn, Ni and Co in the Southern Ocean, including both concentrations of various inorganic and organic pools, size ranges and the fluxes between them.
3. What controls trace metal solubility (Fe, Al and Ti) in the ocean?

The overall aim of this work is to combine the results of the objectives listed above into a comprehensive model of the key processes affecting the biogeochemistry of the Cd, Zn, Co, Ni and Ti in the Southern Ocean.

Subproject 1: Cadmium and Zinc Speciation and Distribution in the Southern Ocean

Objectives
The key objective here is to obtain new data on Zn and Cd speciation across the Southern Ocean. Further to this there are two key questions we wish to examine:

- How does the organic complexation and free metal concentrations of Zn and Cd vary with Fe distribution?
- Does Particulate Cd:P increase in high productivity regions?

Work at sea
Cadmium and Zinc speciation measurements will be undertaken using anodic stripping voltammetry with a thin-mercury film rotating disk electrode as used in our early work during EIFEX (ANT-XXI/3). Water samples will be divided into the following phases by filtration: Soluble (Vivaflow 10kDa ultrafiltration), Colloidal (Retentate of Ultrafiltration), Dissolved (0.2 µm filtration), Particulate (collection on Quartz and/or Polycarbonate filters) and Unfiltered (no filtration). Mass balances will be constructed to ensure sampling integrity. Trace metal samples collected in this manner will be analysed using established methods in our laboratory in Kiel (Soluble, Dissolved, Colloidal and Unfiltered) and in the laboratory of Prof. Dr. Rob Sherrell (Rutgers University) for particulate samples.

Subproject 2: Cobalt and Nickel organic complexation in the Southern Ocean

Objectives
For the GEOTRACES work during this cruise we seek to examine the following critical questions for these elements in the Southern Ocean:

1. What is the contribution of inert Co(III) complexes to the total dissolved Co pool?
2. What is the dissociation rate of the natural Co(II) ligands in seawater?
3. Do inert Ni complexes exist in the Southern Ocean?
4. Does Ni in surface waters vary according to iron supply or N source?

Work at sea

Cobalt speciation will be measured using a variant of the published nitrite catalysed methods employing oxime ligands as used in our laboratory previously. Nickel speciation can be accomplished using the same ligands but in the absence of nitrite At sea measurements of Co will be made using flow injection analysis based on the Co catalysed chemiluminescence of gallic acid. Water samples will be divided into the following phases by filtration: Soluble (Vivaflow 10kDa ultrafiltration), Colloidal (Retentate of Ultrafiltration), Dissolved (0.2 µm filtration), Particulate (collection on Quartz and/or Polycarbonate filters) and Unfiltered (no filtration). Mass balances will be constructed to ensure sampling integrity. Trace metal samples collected in this manner will be analysed using established methods in our laboratory in Kiel (Soluble, Dissolved, Colloidal and Unfiltered) and in the laboratory of Prof. Dr. Rob Sherrell (Rutgers University) for particulate samples.

Subproject 3: Iron Distribution and Speciation in the Southern Ocean

In collaboration with the group of Hein de Baar from NIOZ we will examine the solubility of iron in water samples from the Southern Ocean. This study will seek to determine the processes (complexation, scavenging, redox state) that contribute to the distribution of iron in deep waters and in the long term transport of iron through the deep ocean.

Objectives
What controls the solubility of dissolved iron in deep waters?

Work at sea
Samples will also be collected and stored frozen for the later determination of iron solubility back in the laboratory in Kiel using radiotracers, FIA measurements and voltametric analysis as recently performed during ANT-XXIII/9 in the Weddell Sea and Kerguelen Plateau. This study will complement work within the BMBF project SOPRAN (D-SOLAS) which examines iron cycling in the surface ocean under the Saharan dust plume.

Subproject 4: Titanium and Aluminium Distribution and Speciation in the Southern Ocean

Objectives
The processes controlling the solubility of the dust enriched elements Al, Fe and Ti is poorly understood nor quantified. These 3 elements share similarities in their chemistry regarding their principal sources to open ocean regions (dust deposition) and most importantly in their ability to form strongly hydrolysed species under ambient seawater conditions which are poorly soluble. However these elements do differ in the apparent influences of organic complexation and particle scavenging rates. By examining and comparing the distribution and speciation of these elements in the Atlantic Ocean under a wide regime of dust deposition regimes a more complete picture of the processes and rates affecting Al, Fe and Ti biogeochemistry can be made contributing to an improved model for trace metals cycling in ocean biogeochemistry.

1. To investigate the distribution and partitioning between soluble, colloidal and particulate phases of Al and Ti in the open ocean in the Southern Ocean.
2. Determine the solubility and speciation of Ti in seawater under ambient open ocean conditions. Investigate the potential role of organic complexation of Ti in the open ocean.
3. Determine the solubility and speciation of Al in seawater under ambient open ocean conditions. Investigate the kinetics of Al reactions in seawater and the interaction between Al and organic matter.

Work at sea
Titanium and Aluminium concentrations and speciation measurements will be undertaken using anodic stripping voltammetry with a hanging mercury drop electrode as recently developed in our laboratory in Kiel. Further seawater samples will be collected at sea and frozen for later solubility measurements to be performed in Kiel.

3.3 ISOTOPES

M. R. van der Loeff, I. Vöge, NN (AWI); P. Cai (XU)

Background and General Objectives
Uranium-series radionuclides are powerful tracers for the rate of transport processes in the ocean. We wish to measure the distribution of U-series isotopes along the Zero meridian and in the Drake Passage. The sampling will be coordinated with sampling of other trace elements. This joint sampling allows us to directly apply the information on particle dynamics (aggregation, disaggregation and particle sinking rates) and terrigenous input that we will obtain from the distribution of thorium isotopes and ^{231}Pa, to the transport of other tracers. Similarly, we will be able to confront the results on water mass ventilation and upwelling, as we will derive from ^{230}Th/^{231}Pa and ^{227}Ac distributions, with hydrographic data and the conclusions drawn from other tracers described in parallel proposals (Nd/Hf isotopes; freons). The data will be interpreted along with other tracer data in (inverse) GCM models. We expect that this approach will improve our ability to use a set of tracers as more reliable proxies for past ocean climate.

Subproject 1: ^{234}Th as tracer of export production of POC
P. Cai (XU), M. R. van der Loeff, I. Vöge (AWI)

Objectives
1) To acquire accurate estimates of upper ocean POC export fluxes,
2) to infer the export fluxes of some particle-reactive elements/compounds (i.e., Fe, Al, Mn, Cu, Cd, Ni, Zn, and Ag) that will be measured by other researchers in the same regions,
3) to carry out the intercomparison of POC export studies between ^{234}Th/^{238}U and ^{210}Po/^{210}Pb methods.

Work at sea
^{234}Th and POC samples will be collected and processed during this cruise. Ideally about one depth profile of ^{234}Th will be sampled per day. An aliquot of 4-l of seawater will be collected at 0, 25, 50, 75, 100, 150, 200 m. A total of 50 profiles are expected to be achieved on this cruise. At selected ("super") stations, large sinking particles will be collected at several depths by deployment of *in situ* pumps using size-fractionated filtration. Nitex screens of various mesh size (10 and 50µ) with particulate matter are ultrasonicated and the suspension is filtered through a 25 mm precombusted QMA filter. The particulate and the total ^{234}Th samples will be counted onboard using RISO beta counters mounted in the geochemistry container.

Subproject 2: analysis of multiple thorium isotopes and ^{231}Pa
M. R. van der Loeff, I. Vöge, NN (AWI); P. Cai (XU)

Objectives
The distributions of ^{231}Pa and ^{230}Th are controlled by particle flux and boundary scavenging. Activities stored in marine sediments can therefore help to reconstruct particle flux patterns in the past. Moreover, changes in the water column distribution of these isotopes can be interpreted as indication of changes in water mass ventilation and in particle flux. We wish to determine ^{231}Pa and ^{230}Th in filtered and unfiltered (total) seawater, suspended particulate matter, and surface sediments to evaluate patterns of particle flux and boundary scavenging.

The distribution of multiple Th isotopes over particulate and dissolved phase can be used to derive adsorption and desorption rates. When the particles are separated according to grain size before analysis (e.g. with a 50 µ screen), the isotopes can be used to constrain the settling velocity of small and large particles in the upper 100 m of the water column. If the distribution of Th isotopes is obtained over various size fractions it is possible to derive aggregation and disaggregation rates.

Work at sea
^{231}Pa and ^{230}Th analysis requires collection of 20 l of filtered (<1 µm) seawater. All seawater samples are stored acidified, without addition of any tracers.

Sediment cores obtained with the minicorer will be sliced and stored in plastic containers.
In conjunction with Subproject 1, size-fractionated particulate material will be collected with *in situ* pumps to be analyzed for ^{234}Th beta counting, and subsequently for ^{231}Pa, ^{230}Th and ^{232}Th in the home laboratory. In the vicinity of the Antarctic Peninsula, ^{228}Th will be included in the analyses.

Subproject 3: Importance of marine polysaccharides for radionuclides cycling
M. Robert (AWI), not on board: J. Friedrich (AWI)

Background
Dissolved organic matter (DOM) forms the largest pool of organic material in the marine environment. The colloidal fraction of the DOM is highly reactive and thus, plays a large role in biological, physical and chemical processes. Due to their high molecular weight, polysaccharides belong to the colloidal organic matter (COM). These substances are mainly released by marine phytoplankton and bacteria. Some of these exopolymers can abiotically aggregate to form particles called transparent exopolymer particles (TEP). TEP are very sticky and consequently a key controlling factor in vertical fluxes as they glue together diverse particles. This occurs via aggregation and leads to the formation of large marine aggregates. The sticky nature of TEP is linked to the presence of a high fraction of acidic polysaccharides with sulphate ester groups, which give the ability to form cations bridges and hydrogen bounds, especially with trace elements.

Thorium-234 (^{234}Th), Lead-210 (^{210}Pb) and Polonium-210 (^{210}Po) are produced by radioactive decay of Uranium-238 in seawater. ^{234}Th (24 days half life), ^{210}Po (138 days half life) and ^{210}Pb (22.3 years half life) are known for their high affinities to particles and aggregates. In seawater these radionuclides occur both in dissolved form and adsorbed onto particles. In the COM pool, the Polonium (Po) distribution differs from Thorium (Th) and Lead (Pb). Whereas Th and Pb seem to have a higher partitioning coefficient in polysaccharide-enriched COM than in the bulk COM, Po seems to have a much higher partitioning coefficient in bulk COM than in polysaccharide-enriched COM. This selective complexation points to the importance of the chemical composition of marine particles in controlling the scavenging of particle reactive radionuclides in particular and trace elements in general in the ocean.

Objectives
The aim of the project is to get a better insight into Th, Pb and Po binding to aggregates and TEP, and its contribution to the transport of particle reactive radionuclides. We will investigate to which extent TEP can play a role in extending ^{210}Po as a proxy for particulate organic substances transport and whether TEP and ^{210}Po/^{210}Pb data can be related. Alternatively, the Th behavior with TEP will be investigated.

Work at Sea
^{210}Po and ^{210}Pb will be sampled in surface water (taken from the ship's sea water supply) and several depth profiles down to 800 m depth on the Zero Meridian and Drake Passage transects (from CTD rosette Niskin bottles) in 20 l samples for dissolved and particulate fractions. Additional samples (10 l) will enable to determine TEP concentrations in the same fractions. A central topic will be aggregation experiments to link the formation of aggregates and distribution of ^{234}Th, ^{210}Po, ^{210}Pb and TEP in the COM in waters of different primary productivities (Polar Front on the Zero Meridian transect, low productivity Weddell Sea water and high productivity waters near the Antarctic Penninsula (near Jubany) The ^{234}Th, ^{210}Po, ^{210}Pb and TEP analysis itself will be done back at AWI.

Subproject 4: Radium isotopes and ^{227}Ac
M. R. van der Loeff (AWI)

Objectives
Four radium isotopes are supplied to the ocean by contact with the continent or (deep-sea)-sediments: ^{223}Ra, (half-life 11.4 d); ^{224}Ra (3.7 d), ^{226}Ra (1620 y) and ^{228}Ra (5.8 y). The distribution of these isotopes in seawater has been shown to be most helpful to evaluate shelf-basin exchange and water residence times. On the Zero meridian we expect extremely low concentrations of all but the long-lived ^{226}Ra. We will concentrate the Radium sampling programme in the area around the Antarctic Peninsula where Ra isotopes are most informative on shelf-water interaction (Hanfland, PhD thesis 2002; Dulaiova, pers. comm.). Like Ra isotopes, ^{227}Ac is released from sea sediments, but its main source is in deep-sea sediments. This tracer is therefore especially useful to study deep water mixing and ventilation.
Cooperation partners: Claudia Hanfland (AWI)

Work at sea
^{222}Rn in surface water will be measured semi continuously by gas-water exchange in the ship's seawater supply using a RAD7 analyser. Large volume surface water samples will be collected for radium isotopes using the Polarstern's seawater intake, filtered through a 1 µm cartridge filter. For ^{228}Ra/^{226}Ra, 1-2 m^3 of filtrate is passed over MnO_2-coated polypropylene cartridges. The isotope ratio is quantified in the home laboratory by Soxhlet leaching and subsequent gamma spectroscopy; ^{226}Ra is quantified by occasional coprecipitation of Radium on $BaSO_4$ from 20-L samples. ^{226}Ra in other samples will be interpolated from a relationship we expect to derive between ^{226}Ra and dissolved silicate.

For short-lived radium isotopes, the filtrate is transferred to 250 L tanks. Each sample is pumped at <1 l/min using an electric *in situ* aquarium pump (in each drum) though MnO_2-impregnated acrylic fiber to scavenge radium isotopes. Fibers are dried using compressed air, and short-lived ^{223}Ra and ^{224}Ra measured at-sea using RaDeCC detectors. Longer-lived ^{228}Ra will be measured on the fibers by gamma counting ^{228}Ra/^{226}Ra ratio in the shore-based lab and/or by recounting the ^{224}Ra activity after ingrowth of ^{228}Th. For occasional deeper (i.e. below surface) sampling, large-volume samples require multiple (2-3) CTD casts and filling barrels or, if time allows, the deployment of *in situ* pumps.

The analysis of ^{227}Ac requires 60-l samples. Such samples will be collected on deep water profiles with the Rosette (when time permits), or produced by combining samples from several CTD/Rosette casts.

Subproject 5: Nd and Hf isotopes
NN, not on board: M. Frank (IfM-GEOMAR)

Objectives
The subject of our proposed study is a detailed investigation of the distribution of neodymium (Nd) and hafnium (Hf) isotopes in dissolved and particulate form in the water column of the Atlantic sector of the Southern Ocean. Nd isotopes have been shown to be a powerful geochemical tracer for present and past water mass mixing and source provenance tracing in the ocean. The combination with Hf isotopes was applied successfully for the characterization of continental weathering regimes. Both isotope systems have been used for the reconstruction of water masses in the Southern Ocean on various time scales in the past from marine sediments. So far there are, however, nearly no data for the water column of the Southern Ocean, which severely restricts the reliable application of this combination of tracers for present day studies and reconstructions of the past. In the frame of the international GEOTRACES programme we will collect large volume water samples from the surface ocean and from depth profiles at selected stations during ANT-XXIV/3.

Work at Sea
We will collect large volume water samples (100-120 litres for surface waters and 50-60 litres at depth) under trace metal clean conditions from the towed fish and from the CTD rosette. The samples will be collected in 20 l collapsible plastic bottles and will be filtered through a 0.45 µm filter, which will also be collected. After that the water samples will be acidified with ultrapure HCl to a pH of 2. Then a FeCl3 solution will be added and the dissolved metals will be coprecipitated at a pH between 7 and 8 using ammonia. Most of the supernate will be discarded and the samples will be taken to the home lab in 2 litre bottles for further chemical treatment and preparation for mass spectrometric analyses.

Expected results
We will determine the isotope composition of Nd and for the first time Hf in dissolved and particulate form to characterize the isotope composition of the different Southern Ocean water masses, their sources and mixing relationships. This will enable new insights into the influence of Antarctic weathering processes on the geochemical composition of the Southern Ocean and will allow a more reliable application of the Nd/Hf isotope systems for reconstructions of past weathering regimes and past ocean circulation.

Subproject 6: Rare Earth Elements
M. R. van der Loeff, (AWI)

Objectives
The varying REE-pattern is transferred to the ocean via processes such as riverine inputs, dust inputs, or leaching of shelf sediments and ice drifted sediments. In addition to selective weathering, elemental fractionation may also occur during aqueous transport, where natural particles and colloids are of great importance. The REE concentrations coupled with the Nd isotopic ratios (subproject 5) are powerful tracers to investigate scavenging processes and to predict the fate of elements brought from the continent. The REE's residence times on the order of 1,000 years make them ideal tracers for water masses as it allows for long distance transport while preventing complete homogenisation.

Work at sea
Samples will be collected for REE in dissolved or particulate form. For dissolved REE 1 l of seawater will be collected in surface waters and at deep stations using the NIOZ Titanium-

Rosette. Particulate REE in surface waters will be collected by the ship's seawater pump and a continuous flow centrifuge. At least 1,000 l of seawater will be centrifuged at a rate of about 500 - 1,000 l per hour at 16,000 g.

Subproject 7: Iron isotopic fractionation near the Antarctic Peninsula
samples collected for M. Staubwasser, Köln.
Cooperation partners: P. Croot (IFM-GEOMAR), M. R. van der Loeff, D. Abele (AWI), H. de Baar (NIOZ)

Objectives
On the occasion of our visit to Jubany we plan a cooperation with the IPY project ClicOPEN (Doris Abele; EoI#193; full proposal #34) on the issue of iron stress on near-shore ecosystems of the Antarctic Peninsula. We will have the opportunity to link the high coastal Fe concentrations with semi continuous surface-water profiles to the growth-limiting concentrations far offshore. Such a transect is especially interesting for studies of Fe isotopic composition, which can be measured at far better precision at these elevated concentrations and thus will allow to identify any isotope fractionation during early Fe uptake. We will therefore take samples for Fe isotopic composition studies (cooperation with Michael Staubwasser, University Köln).

Work at sea
Near Jubany we will make five shallow casts with the ultraclean Rosette, probably 3 on the approach of Jubany and 2 after our visit. At five depth horizons 20-l samples will be collected for iron isotope analysis. In parallel the distribution of dissolved trace metals will be determined.

Subproject 8: $\delta^{13}C$ of particulate organic material in the Southern Ocean
A. Huber (AWI), not on board: D. Wolf-Gladrow, U. Passow, C. De La Rocha (AWI)

Objectives
The Southern Ocean may have been essential for the drawdown of atmospheric CO_2 during glacial periods. In order to reconstruct the state of the Southern Ocean during glacial periods and the processes responsible for altered states various paleo-proxies including $\delta^{13}C_{org}$, $\delta^{15}N$, $\delta^{30}Si$, have been proposed and applied. A major problem for the application of $\delta^{13}C_{org}$, as a paleo-proxy is its large variation in the Southern Ocean and the unknown origin of isotopically very light organic material ($\delta^{13}C_{org}$ below -30 ‰). Our goal is to identify the phytoplankton species responsible for this light material, to look for variations under various growth conditions, and to investigate the relationships between $\delta^{13}C_{org}$ to other paleo-proxies based on consistent data sets. The work will contribute to the international programme GEOTRACES (2006).

Work at sea
We will collect field samples of size fractionated particulate organic matter in Southern Ocean surface waters. A minimum of 50 - 80 µg of carbon per filter is required for the measurement of $\delta^{13}C_{Corg}$. At a chlorophyll concentration of 0.5 - 2 µg L^{-1} and a carbon:chlorophyll ratio of 40 g g^{-1} filtration of 20 to 40 l of seawater will collect enough material for $\delta^{13}C_{Corg}$ measurements of samples fractionated into 5 size classes. This has been confirmed by measurements performed within an earlier fractionation experiment. The amount of water filtered will of course be determined at each station according to the chlorophyll concentration, which is measured online as fluorescence.

In order to separate different plankton groups we will fractionate suspended particulate material sequentially into 5 size classes: 0.2 - 1.2 µm, 1.2 - 5 µm, 5 - 20 µm, 20 - 100 µm and > 100 µm. The large diatoms (*Corethron* sp., *Fragilariopsis kerguelensis*) common in the Southern Ocean will be collected in the > 100 µm fraction, whereas the smaller diatoms like *Pseudonitzschia* sp. and many protozoa will be collected in the 20 - 100 µm fraction. Copepods caught in the large size fractions will be hand picked off the filters. Flagellates of *Phaeocystis antarctica* and other flagellates will dominate the 5 - 20 µm fraction. Bacterioplankton (0.2 - 1.2 µm) and picoplankton (1.2 - 5 µm) will dominate the two respective smallest fractions. These size fractions will be used for our initial test sampling conducted in the beginning of 2007 (see above).

4. DISSOLVED CARBON DIOXIDE IN THE ANTARCTIC OCEAN

B. Bontes, S. Ober, H. Slagter, (NIOZ); S. van Heuven (University of Groningen)
Not on board: M. Hoppema (AWI)

Objectives

We will validate the net uptake of CO_2 by the Southern Ocean versus field data of the longest existing (since 1984) ocean record of combined data of CO_2, transients CFCs, hydrography and nutrients, at the zero meridian. The 1984 AJAX and 1990 FS Meteor expeditions with high-quality data by others (Takahashi, Weiss, Chipman) were followed by successive Polarstern sections with excellent data in 1992, 1996 and 1998, 2002, 2005 by our group jointly with M. Hoppema, E. Fahrbach (AWI) and the transient tracers (CFC's, 3H) team of Bremen (M. Rhein). This next cruise, ANT-XXIV/3; IPY 2008, will enable us to compute an anticipated increase of anthropogenic CO_2 in the AAIW during the 24 year time period of our time series.

Work at Sea

Autonomous underway pCO_2 in surface waters

The new pCO_2 system permanently installed on *Polarstern* will collect data of pCO_2 in surface waters as well as marine air. The collected data will contribute to the global dataset (Takahashi and co-workers) for assessment of CO_2 exchange between ocean and atmosphere.

Underway DIC in surface waters

One coulometry unit kindly provided by C. Neil (University of Bergen) will semi-continuously determine the DIC in surface waters. This system is already used and operational in the preceding expedition ANT-XXIV/2 where C. Neil is one of the shipboard scientists. The combination of DIC in surface waters with the above pCO_2 in surface waters allows valuable computation of other variables, notably pH and Alkalinity.

Alkalinity and DIC along vertical profiles
Samples will be collected from hydrocast along vertical profiles in glass bottles for shipboard analyses of Alkalinity and total Dissolved Inorganic Carbon (DIC) by Vindta analyzer instrument in container NIOZ-27. Accuracy will be pursued by daily analyses of certified standards of DIC/Alk in seawater provided by the Scripps laboratory of Prof. Andy Dickson. The Alk/DIC dataset with nutrients will be reported to the international ocean CO_2 databases, notably EU CarboOcean and GLODAP.

5. MARINE BIOLOGY

5.1 THE SIGNIFICANCE OF VIRUSES FOR POLAR MARINE ECOSYSTEM FUNCTIONING

C. Brussaard, C. Evans (NIOZ)

Objectives
Microbial communities (phytoplankton, bacteria, Achaea, heterotrophic protozoa and viruses) comprise the majority of the biomass in the oceans and drive nutrient and energy cycling, thereby supporting also the polar ecosystems. The emergent awareness that the response of ecosystems to climate change depends largely on the response of the underlying microbial community, that phytoplankton productivity is of vital importance to the global climate system, and that viruses are major players influencing biodiversity and biogeochemical processes, underlines the need to elucidate the ecological role of viruses in polar ecosystems. Despite the likely importance of viruses in polar aquatic ecosystems, the ecological role of viral mediated mortality or polar microbes (phytoplankton in particular) and the quantitative significance of polar viruses with respect to climate and global environmental change are barely studied.

The GEOTRACES cruise allows for the first time a detailed and comprehensive study to focus on viruses and viral mediated processes in Antarctic environments. As part of the GEOTRACES-IPY activity programme, this projects' objectives are

1) to examine the abundance and composition of viruses and their hosts (prokaryotes and phytoplankton) in Antarctic marine environments,
2) to compare the significance of viruses and their impact on microbial mortality and geochemical cycling in the aquatic polar ecosystems (Arctic versus Antarctic), and
3) to unravel the impact of climate and global environmental change on the ecological role of viruses and their activities.

Work at sea
Algal abundance: Small volume samples will be ideally analysed directly fresh on board (using flow cytometry). If not possible the samples will be fixed, snap frozen in liquid nitrogen and stored at -80 °C. Analysis will then be done at the home laboratory.

Viral and bacterial abundance: Small volume samples will be fixed with glutaraldehyde, snap frozen in liquid nitrogen and stored at -80 °C. Samples will be analysed back at NIOZ using the nucleic acid stain SYBR Green and flow cytometry according to the methods of Brussaard (2004) and Marie et al (1999) for viruses and bacteria respectively.

Viral diversity: Larger volume samples (at least 10 l) for viral diversity will concentrated by a 30 kDa ultrafiltration. Samples will be stored at -80 °C freezer and analysed at the NIOZ by PFGE.

Algal and bacterial richness: Several liters of sample will be passed through a 1 and 0.2 µm filter which will then placed in cryovials, snap frozen and stored at -80 °C. The analysis of the samples by DGGE will be done at NIOZ depending on the other results of the other variables.

Viral and grazing induced mortality of algae: Whole water will combined with either 30 kDa filtered water (virus and grazer-free) or 0.2 um filtered water (grazer-free) in triplicate over a dilution series and incubated at *in situ* temperature and light conditions (deck incubator). Samples for algal enumeration will be taken from all incubations at the start of the assay and after 24 h incubation, analysed fresh ideally using flow cytometry. From these results algal growth, microzooplankton grazing and viral lysis rates will be calculated.

Viral induced mortality of bacteria: Rates of viral induced mortality of bacteria will be determined by viral reduction assay. Briefly, the bacterial community will be concentrated by tangential flow filtration and resuspended in viral free water generated by 30 kDa ultrafiltration. The production of viruses will be followed by sampling for bacterial and viral abundance over a 12 h period (subsampling every 3 h).

Secondary production: We will make measurements to determine the rate of secondary production using the radiolabelled Leucine incorporation technique. Live and dead (fixed) subsamples of whole water will be incubated at *in situ* temperature for 4 h with 3H-Leucine with an activity of approximately 20 µCi. After the incubation period the samples will be killed with the addition of formalin and stored until later analysis by liquid scintillation at the NIOZ.

Lysogenic viral infection of bacteria: Rates of lysogenic infection of the bacteria will be determined by the addition of Mitomycin C, inducing lytic production of any lysogenic phase which will be followed by subsampling for viruses and bacterial hosts.
Grazing of algae, bacteria and cyanobacteria: Grazing will be assessed by following the uptake of fluorescently labelled prey added to whole water and incubated at *in situ* temperature and light for 24 h.

Virus Isolation: We will attempt to isolate algal viruses for future laboratory work. Samples will be collected from depths within the euphotic zone at a variety of stations.
Viral burst size: samples for analyses by TEM for viral burst size of bacteria will be taken, fixed, flash frozen and stored at -80°C (or fixed and stored at 4°C).

5.2 PHYTOPLANKTON MEASUREMENTS

V. Garçon, M. Lacombe (CNRS LEGOS)

Objectives
The ocean is getting acidified in response to atmospheric CO_2 increase. The impact of such an acidification on primary producers is usually investigated through laboratory experiments or coupled physical/biogeochemical modelling. What is the *in situ* state of the ocean with respect to pH conditions and distribution of the various phytoplanktonic groups? This knowledge is a prerequisite for both carrying out proper models outputs validation, and establishing the present state.

We are interested in the Polar frontal Region of Drake Passage by two major phytoplanktonic functional types: diatoms (siliceous phytoplankton) and coccolithophorids (calcareous phytoplankton). Our main objective is to investigate the relationship between the variations of acidification level (pH and alkalinity) and of distribution of these two groups.

Work at sea
We will sample across the Polar Front from the Niskin bottles and then perform filtrations for further determination of pigments composition by HPLC (on land) and for further species identification and quantification of diatoms and coccolithophorids biomass by microscopy (on land). 500 samples will be collected for HPLC determination and 750 for microscopy speciation (diatoms and coccolithophorids).

Expected results
The distribution of the two phytoplanktonic groups will be established in the Polar Frontal region. By comparing with the pH and alkalinity conditions of the surface water masses, it will be possible to derive a relationship linking chemistry of seawater and the phytoplanktonic speciation.

5.3 SILICATE MEASUREMENTS WITH CYCLIC VOLTAMMETRY

V. Garçon, M. Lacombe (CNRS LEGOS)

Objectives
The Drake Passage is an important entry point for several water masses from the Pacific into the Atlantic ocean. They are carried by the Antarctic Circumpolar Current (ACC) around the Antarctic continent and thus can enter the South Atlantic and Weddell Sea. Our objective is to compare the present picture of water mass mixing with that of the Drake Cruise in 2006 (ANT-XXIII/3), and in particular the SPDW (South Pacific Deep Waters) spreading. We will also document water mass mixing along the Greenwich meridian.

Work at sea
We will sample for silicates determinations at each CTD station along the ZERO-DRAKE transects (along the Greenwich meridian and across Drake Passage). The samples will be analyzed on board by cyclic voltammetry with a glassy carbon electrode, the reference electrode being an Ag/AgCl electrode (Metrohm). Electrochemical measurements will be carried out with a newly developed autonomous submersible potentiostat. The distribution of silicate will give us information of SPDW spreading across Drake Passage, as compared with the WOCE A21 and ANT-XXIII/3 cruises. These data will also be compared with the classical

silicate determinations carried out by colorimetry by the dutch group (NIOZ) all along the ZERO-DRAKE cruise transects.

6. MAPS: MARINE MAMMAL PERIMETER SURVEILLANCE

O. Boebel, O. Klatt (AWI)

Objectives
MAPS focuses on the development of automated methods for the detection of marine mammals in the vicinity of ships, *Polarstern* in particular, using both visual and acoustic techniques.

Work at sea
Two Infrared cameras will collect snippets (short movies) of whale blows, which thermally clearly stand out against the cold sea surface. These will serve to improve on existing pattern recognition algorithms, particularly, to reduce the number of false positives. A portable listening station and sonobuoys will be used to collect hydroacoustic records along the cruise track. The analysis of the embedded marine mammal vocalizations, with special focus on the spatial distribution of the various call types and local dialects, will be used in the development of PAM (passive acoustic monitoring) systems, which rely on *in situ* detection algorithms.

7. BETEILIGTE INSTITUTE/ PARTICIPATING INSTITUTES

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9. SCHIFFSBESATZUNG / SHIP'S CREW

No.	Name	Rank
1.	Schwarze, Stefan	Master
2.	Spielke, Steffen	1.Offc.
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4.	Peine Lutz	2.Offc.
5.	NN	2.Offc.
6.	NN	Doctor
7.	Hecht, Andreas	R.Offc
8.	Minzlaff, Hans-Ulrich	2.Eng.
9.	Sümnicht, Stefan	2.Eng.
10.	Schaefer, Marc	3.Eng.
11.	Scholz, Manfred	Elec.Tech.
12.	Nasis, Ilias	Electron
13.	Verhoeven, Roger	Electron.
14.	Muhle, Helmut	Electron.
15.	Himmel, Frank	Electron.
16.	Loidl, Reiner	Boatsw.
17.	Reise, Lutz	Carpenter
18.	Guse, Hartmut	A.B.
19.	Stutz, Hein-Werner	A. B.
20.	Winkler, Michael	A.B.
21.	Vehlow, Ringo	A.B.
22.	Hagemann, Manfred	A.B.
23.	Schmidt, Uwe	A.B.
24.	Bäcker, Andreas.	A.B.
25.	Wende, Uwe	A.B.
26.	Preußner, Uwe	Storekeep.
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28.	Voy, Bernd	Mot-man
29.	Elsner, Klaus	Mot-man
30.	Hartmann, Ernst-Uwe	Mot-man
31.	Pinske, Lutz	Mot-man
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33.	Silinski, Frank	Cooksmate
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39.	Gaude, Hans-Jürgen	2.Steward
40.	Möller, Wolfgang	2.Steward
41.	Huang, Wu-Mei	2.Steward
42.	Yu, Kwok Yuen	Laundrym.

ANT-XXIV/4

18 April - 20 May 2008

Punta Arenas - Bremerhaven

Chief Scientist
Andreas Macke

CONTENTS

1. ÜBERBLICK UND FAHRTVERLAUF

Andreas Macke (IFM-GEOMAR)

Am 18. April 2008 wird das Forschungsschiff *Polarstern* die Rückreise von Punta Arenas nach Bremerhaven antreten. Die Fahrt wird zur kontinuierlichen Untersuchung atmosphärischer und ozeanischer Eigenschaften sowie der Energie- und Stoffflüsse zwischen Ozean und Atmosphäre genutzt. Folgende Projekte werden durchgeführt:

Autonome Messplattformen zur Bestimmung des Stoff- und Energieaustausches zwischen Ozean und Atmosphäre (OCEANET)
Um die experimentelle Erfassung von Stoff- und Energieaustausch zwischen Ozean und Atmosphäre auf eine solide Basis zu stellen, ist im Rahmen dieses Projektes mittels der Vernetzung der Expertisen des IFM-GEOMAR (CO_2-/O_2-Flüsse, photosynthetischer Status, Energiehaushalt, Fernerkundung), des GKSS Forschungszentrums („FerryBox" und Fernerkundung der marinen Biologie mit ENVISAT/MERIS), und des AWI Bremerhaven (CO_2-System, marine Infrastruktur von *Polarstern*) die Weiterentwicklung und Erprobung autonomer Messsysteme geplant, die langfristig für den operationellen Betrieb an Bord verfügbarer Fracht- und Forschungsschiffe vorgesehen sind.

Fernerkundung der Aerosol-Zusammensetzung (in der Atmosphärensäule)
Die Hauptziele sind die Charakterisierung des Aerosols in der Atmosphärensäule, der Konsistenztest mit begleitenden breitbandigen Strahlungsflüssen sowie die Erfassung der zeitlichen Entwicklung von Aerosoleigenschaften um Aerosol-Wolken-Wechselwirkungen und meridionale Gradienten des troposphärischen Aerosols zu erforschen.

MAX-DOAS-Messungen atmosphärischer Spurengase zur SCIAMACHY-Validierung
Zur Validation von Satellitenprodukten sind bodengebundene Kontrollmessungen unterhalb des Satellitenorbits notwendig. Im Falle von SCIAMACHY sind die Messungen an Bord von *Polarstern* bestens geeignet, da das Schiff auf seinem Weg zwischen Arktis und Antarktis einer Strecke folgt, die dem Orbit des ENVISAT-Satelliten entspricht.

Schiffsgetragene ADCP-Messungen des äquatorialen Strömungssystems
Schiffsgetragene ADCP-Messungen mit *Polarstern* erhöhen die Verfügbarkeit von Strömungsabschnitten und erlauben so das Studium von intrasaisonaler bis saisonaler Variabilität des Transports der Hauptströmungszweige. Darüber hinaus werden sie als Referenzdaten für Verankerungsbeobachtungen am Äquator bei 23°W genutzt.

Satellitenvalidation: Bio-optische und atmosphärische Studien
Das Ziel dieses Forschungsprojektes ist es, die Abschätzung der globalen marinen Primärproduktion sowie die der Verteilung der wesentlichen funktionalen Gruppen des Phytoplanktons durch eine Kombination von Fernerkundung und *in situ* Messung der ozeanischen Optik, der Produktivität und Komposition des Phytoplanktons und des partikulären organischen Kohlenstoffs zu verbessern.

ITINERARY AND SUMMARY

On 18 April 2008 *Polarstern* will start its return from Punta Arenas to Bremerhaven. The cruise will be utilized for continuous investigations of atmospheric and marine properties as well as for energy and material fluxes between ocean and atmosphere. The following projects will be carried out:

Autonomous measurement platforms for energy and material exchange between ocean and atmosphere (OCEANET)
In order to provide a solid basis for the observational monitoring of energy and material exchange between ocean and atmosphere it is planned to develop an autonomous observation system for operational use onboard available cargo- and research vessels. The project is based on a network of expertise from IFM-GEOMAR (CO_2-/O_2-fluxes, photosynthetic status, energy budget, remote sensing), the GKSS research centre (ferry box, remote sensing of marine biology with ENVISAT/MERIS) and AWI-Bremerhaven (CO_2-system, marine infrastructure of *Polarstern)*.

Remote sensing of (atmospheric column) aerosol composition
The main goals are to characterize aerosol column properties, check their consistency with associated measurements of broadband radiative fluxes, and to monitor temporal evolution of aerosol properties in order to explore aerosol-cloud interactions and to establish meridional gradients of tropospheric aerosols.

MAX-DOAS-measurements of atmospheric trace gases for SCIAMACHY-Validation
To validate satellite-provided data ground-based control-measurements done at locations beneath the satellite's orbit are necessary. In case of SCIAMACHY, measurements onboard *Polarstern* seem best suited for that purpose, because on the way to and from the Antarctica, the ship follows a polar course corresponding to ENVISAT's orbit.

Shipboard ADCP-measurements of equatorial current system
Shipboard ADCP measurements with *Polarstern* will enhance the availability of current sections and thus allow in the future to address the intraseasonal to seasonal variability of the transports of the main current branches. Furthermore, they will be used as a reference data set for the moored observation at the equator at 23°W.

Satellite ground truth: bio-optical and atmospheric studies
The aim of this research project is to improve estimates of global marine primary production and the distribution of major phytoplankton functional groups by using remote sensing data in combination with *in situ* measurements of ocean optics, phytoplankton productivity and composition and particulate organic carbon (POC).

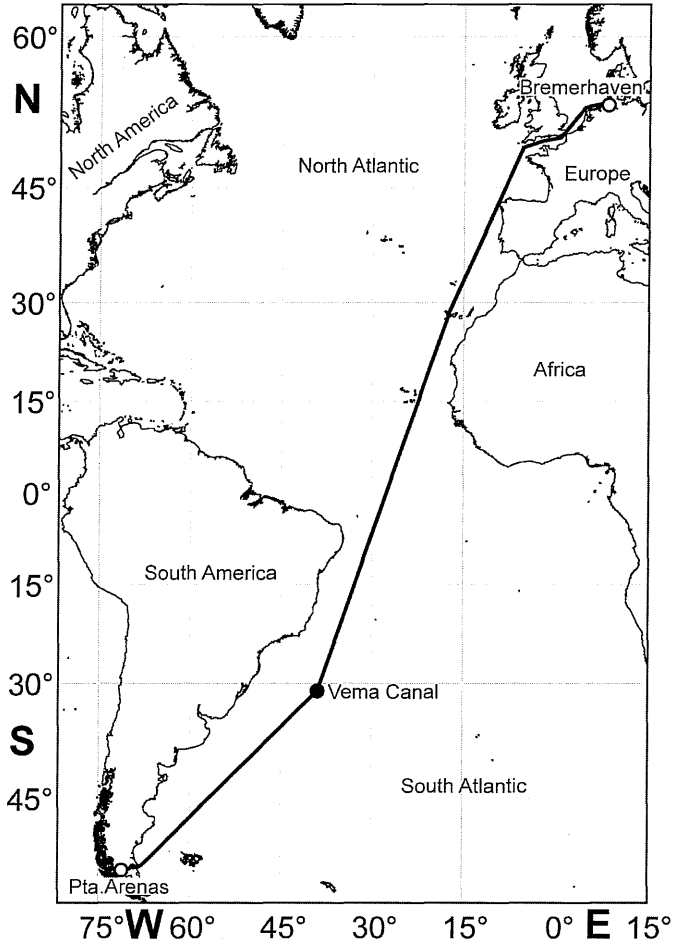

Abb. 1: Fahrtroute ANT-XXIV/4
Fig. 1: Cruise track on ANT-XXIV/1

2. AUTONOMOUS MEASUREMENT PLATFORMS FOR ENERGY AND MATERIAL EXCHANGE BETWEEN OCEAN AND ATMOSPHERE (OCEANET)

2.1 AUTONOMOUS MEASUREMENT PLATFORMS FOR ENERGY AND MATERIAL EXCHANGE BETWEEN OCEAN AND ATMOSPHERE (OCEANET): ATMOSPHERE

K. Bumke, M. Hieronymi, J. Kalisch, A. Macke, Y. Zoll, (IFM-GEOMAR); B. Pospichal (IGMK); Stefan Kinne (ZMAW)

Objectives

a) Radiation & remote sensing

The net radiation budget at the surface is the driving force for most physical processes in the climate system. It is mainly determined by the complex spatial distribution of humidity, temperature and condensates in the atmosphere. The project aims at observing both the radiation budget and the state of the cloudy atmosphere as accurate as possible to provide realistic atmosphere-radiation relationships for use in climate models and in remote sensing. While similar experiments have been performed from land stations, only few data from measurements over ocean areas exist. The present project is part of the "Meridional Ocean Radiation Experiment" MORE which has used Atlantic transfers of various research vessels for the combined measurements of the atmospheric state since 2004. The main project behind this cruise is the WGL-PAKT Initiative OCEANET.

A multichannel microwave radiometer will be applied to continuously retrieve temperature and humidity profiles as well as cloud liquid water path over the ocean. Time series of these profiles will show small scale atmospheric structures as well as the effects of the mean state of the atmosphere and its variability on the co-located measurements of the downwelling shortwave and longwave radiation. The atmospheric profiles will also be used to validate the satellite based profiles from the IASI instrument onboard the new European polar orbiting satellite MetOp. Atmospheric aerosol optical thickness will be measured by means of hand held sun photometer. If available, stand-alone sun-photometer (CIMEL) will be operated under calm sea conditions. In the long run, based on the experiences of this and later Atlantic transects an autonomous measurement container is planned for operational atmospheric monitoring onboard commercial ships.

b) Air-sea interaction and fluxes

Great emphasis has to be put on air-sea fluxes of momentum, sensible and latent heat to improve numerical models of weather forecast and climate simulations since oceans cover 71 % of the earth's surface. The fluxes of sensible and latent heat are also of importance for the energy budget of the ocean and the atmosphere. Due to the steady increase of many trace gases in the atmosphere like CO_2, *in situ* gas flux measurements are required to establish parameterizations that provide flux estimates in climate models.

To estimate the turbulent fluxes of momentum, sensible heat, latent heat, and CO_2 a sonic-anemometer and an open path LiCor will be mounted. Measurements are taken at a sampling rate of 20 Hz (LiCor) respectively 30 Hz (sonic-anemometer) allowing to derive the fluxes by applying the inertial dissipation method. This method relies on measurements at high frequencies, less distorted by the motion and the superstructure of the ship than the

covariance technique. Additional measurements of the sea surface temperature (SST) in combination with observations of the standard meteorological parameters and measurements of the CO_2 content in ocean and atmosphere at a lower data rate performed by marine chemist (see section 2) flux parameterizations can be derived.

To measure the SST a system of an upward and a downward looking radiometer is used. The measured brightness temperatures of the ocean and the atmosphere are also of interest for the estimates of the net radiation budget.

Work at sea

Upon departure from Punta Arenas the following instruments will be installed onboard *Polarstern* for continuous measurements:

1) Multichannel microwave radiometer HATRPO. The instruments requires occasional calibrations with liquid nitrogen as well as tipp-calibrations under calm sea and homogeneous atmospheric conditions.
2) Ceilometer including tilt measurement device for cloud bottom height measurements
3) Whole sky imager for cloud structure measurements
4) Handheld sun photometer (Microtops) for aerosol and cloud optical thickness
5) Inclinometer for sea surface tilt measurements
6) Sonic anemometer USA-1 to measure the wind components and temperature
7) LiCor to measure water vapour and CO_2
8) M-100 absorption hygrometer to measure water vapour
9) System of a KT-4 and a KT-19 radiometer to measure SST and the brightness temperature of the atmosphere

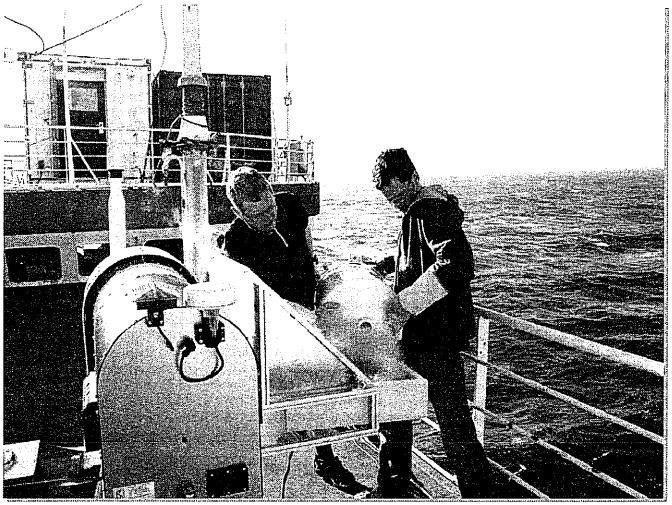

Fig. 1: Calibration of the HATPRO microwave radiometer with liquid nitrogen

Occasional extra-radiosoundings (ca. one per day) have to be performed close to the overpass times of the MetOp satellite. Synoptical observations will be done every hour, aerosol optical thickness measurements every 30 minutes (under direct sun conditions). Most instruments require non or little maintenance. Only the microwave radiometer performance will be critically observed as this is the first time that such an instrument will work under open ocean conditions.

Turbulence measurements should take place on a mast or similar device close to the bow to minimize the flow distortion by the ship's superstructure.
Most instruments require only little maintenance.

Expected results
1) 2d structure of the clear sky atmosphere and corresponding net radiation budget
2) Horizontal structure of the cloud water path and its effect on the downwelling shortwave and longwave radiation
3) Vertical structure of temperature and humidity as well as its variability for validation of IASI products
4) Aerosol optical thickness for clear-sky conditions
5) Sea surface roughness (tilt angle distribution)
6) Turbulent fluxes of momentum, sensible, and latent heat
7) Flux of CO_2 between ocean and atmosphere
8) Flux parameterizations for measured fluxes (It is expected that this necessitates more data than those which will be gained during this planned cruise)

All results under mid-latitude, tropical and subtropical climate conditions.

2.2 AUTONOMOUS MEASUREMENT PLATFORMS FOR ENERGY AND MATERIAL EXCHANGE BETWEEN OCEAN AND ATMOSPHERE (OCEANET): OCEAN

M. Gehrung, NN (GKSS); T. Steinhoff, NN (IFM-GEOMAR)
Not on board: A. Körtzinger (IFM-GEOMAR), F. Schroeder (GKSS), M. Hoppema (AWI), H. Zemmelink (NIOZ)

Objectives
This project is part of the WGL-PAKT-Initiative OCEANET which aims to combine the existing expertise of IFM-GEOMAR, GKSS and AWI to further develop, test and install on *Polarstern* autonomous instrumentation for measurement of exchange of energy and matter between the atmosphere and the surface ocean. The long term goal of this initiative is to provide operational approaches for unattended operation on "Voluntary Observing Ships".

The oceanic component of this study focuses on the marine carbon cycle in the surface ocean which is of high climate relevance but at the same time susceptible to climate change. The surface ocean's CO_2 source/sink function is maintained by a complex interaction of physical and biological processes. A deconvolution of these driving forces requires both a rather comprehensive observational approach as well as high spatial and temporal coverage. These requirements can only be met with multi-parameter observational approaches that can be operated in unattended mode on platforms such as merchant vessels.

During this first OCEANET cruise the feasibility of autonomous underway measurements will be assessed for a wide range of instruments for measurement of physical (temperature, salinity, turbidity), chemical (CO_2 partial pressure, pH, oxygen, total gas tension, nutrients), and biological parameters (chlorophyll a, photosynthetic parameters).

Work at sea

Measurements will be made continuously on pumped surface seawater using the following approaches:

- Autonomous continuous measurements of basic parameters in surface waters (T, S, turbidity, chlorophyll a, dissolved oxygen, and pH) with a FerryBox system (GKSS)
- Autonomous continuous measurements of CO_2 partial pressure in surface waters (AWI, NIOZ)
- Autonomous continuous measurements of dissolved oxygen and total gas tension in surface waters (IFM-GEOMAR)
- Nutrient measurements in surface waters along the transect at high spatial resolution (GKSS)
- Comparison of algal profiles (chlorophyll a) concentration along the transect using different methods (fluorometry, absorption) (GKSS)
- Continuous measurements of phytoplankton activity and physiological state of the algae along the transect (GKSS).

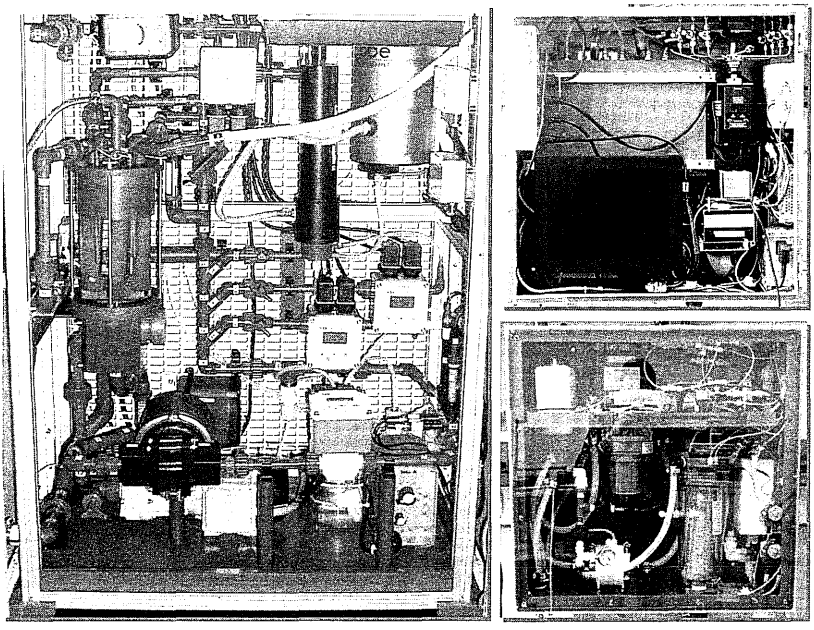

Fig. 2: Autonomous underway instruments that will be operated during ANT-XXIV/4 include the 'Ferrybox' system (left) and a pCO_2 system (dry box – top right; wet box – bottom right).

Expected results
The expected outcome of this cruise will be twofold.

Firstly, the consortium will gain experience in the operation of sophisticated multi-parameter instrumentation under the favourable conditions of a research vessels on the basis of which the feasibility of operation under the more demanding conditions of VOS-type operations will assessed and further improvements will be made.

Secondly, we will acquire a first high-quality data set along the meridional surface transect through the Atlantic Ocean that can be used to demonstrate the potential of high resolution multi-parameter observations for climate-relevant observations in the surface ocean.

3. MAX-DOAS-MEASUREMENTS OF ATMOSPHERIC TRACE GASES FOR SCIAMACHY-VALIDATION

Not on board: R. Sinreich (University Heidelberg)

Introduction:
An important aspect of environmental sciences is the knowledge on trace gases and their concentration and distribution in the atmosphere. Tropospheric gases like NO_2, H_2O, HCHO, IO, BrO, O_4 and SO_2 are especially interesting due to their direct impact on humans. Stratospheric gases like O_3, NO_2, BrO, OClO and H_2O may influence the Earth's radiation budget. Measurements of these species can be performed for instance by satellites, as by the instrument SCIAMACHY onboard ENVISAT launched into a polar orbit in March 2002. Figure 3 shows the mean distribution of tropospheric NO_2 between January 2003 and June 2004. To validate satellite-provided data, however, ground-based control-measurements done at locations beneath the satellite's orbit are necessary. In case of SCIAMACHY, measurements onboard *Polarstern* seem best suited for that purpose, because on the way to and from the Antarctica, the ship follows a polar course corresponding to ENVISAT's orbit.

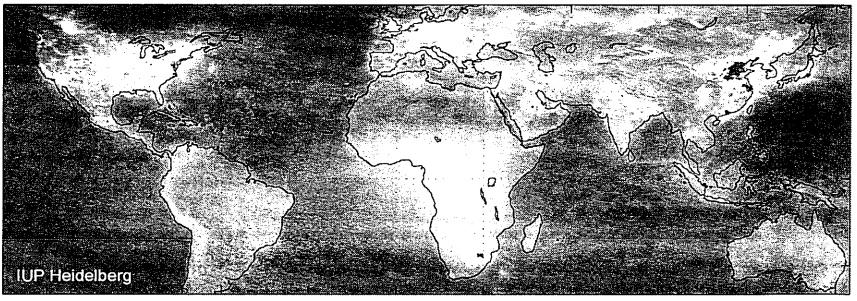

Fig. 3: Mean distribution of tropospheric NO_2 between January 2003 and June 2004 measured by the satellite instrument SCIAMACHY.

The DOAS instrumentation

The method used by the satellite's instrument is the proven Differential Optical Absorption Spectroscopy (DOAS). For this principle, the fact is used that solar light passing through the atmosphere is not only strayed but also absorbed by gas molecules and will thereby yield absorption lines within the gained spectra which are characteristic for each gas compound. From these lines, identity and amount of atmospheric trace gases can be obtained. For ground-based measurements, it is even possible to derive height profiles of the trace gases: light coming in vertical is dominated mainly by absorption of stratospheric gases because. Light coming in more horizontal contains more and more absorption of tropospheric gases due to the longer way of the sunlight through this sphere. This is the so-called Multi-Axis (MAX)-DOAS principle.

The validation instrument onboard *Polarstern* also applies the (MAX-)DOAS measurement principle of the satellites apparatus, of course. Thereby a moveable telescope which is able to point sequentially to the different vertical directions is mounted on a cardanic system to reduce the effect of the ship's movements (see Fig. 4). In its housing it contains not only a stepper motor for movement, but also protective shutters and HgNe- and Halogen calibration lamps. The incoming light is conducted to a cooled miniature Czerny-Turner spectrograph/CCD-detector unit (OceanOptics USB2000) by seven-fold glas fibres. The wavelength range of about 290 to 430 nm allows the retrieval of NO_2, BrO, SO_2, HCHO and others. Last, the gained spectra are stored in PC hard disk for the DOAS analysis. The instrument is working mostly automatically.

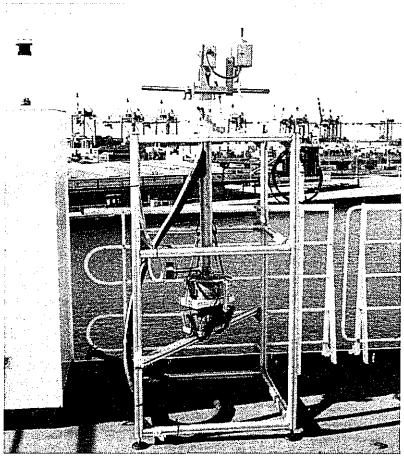

Fig. 4: The on-deck instrumentation of the MAX-DOAS instrument. The telescope unit is mounted on a cardanic system whereby the brush is used for braking the movement influenced by the ship's movement.

Results

For instance, measurements performed during the cruise ANT-XIX of *Polarstern* from Bremerhaven to Cape Town using a precursor of the nowadays instrumentation (same instruments, but another configuration of telescope units) feature the concentration of BrO and NO_2: The maxima were reached when the ship passed the English Channel with

3.1 ± 1.1 parts per trillion for BrO and 0.36 ± 0.13 parts per billion for NO_2. This was to be expected from the high air pollution in Europe. Furthermore an anti-correlation of BrO and NO_2 could be observed indicating a reservoir substance formed by the two gases (Diploma thesis J. Boßmeyer). On further cruises the ship-based DOAS instrumentation should gather data to investigate such events including other trace gases in combination with satellite results. Besides these measurements done mainly for validation purposes, gathering data in Antarctic seas is important for further atmospheric and also climate research.

Ship-based DOAS measurements have been carried out before in the years 1990, 1993 and from 2001 through 2007 with good success from the Heidelberg Institute of Environmental Physics.

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4. REMOTE SENSING OF (ATMOSPHERIC COLUMN) AEROSOL COMPOSITION

S. Kinne (MPI-Meteorology)

Objectives

Atmospheric aerosol introduces one the largest uncertainties in our understanding of anthropogenic climate change. Aerosol originates from different sources, has a lifetime of a few days and spans several orders of magnitude in size. Thus, an appropriate regional and seasonal representation in (global) modelling is a challenge.

To capture characteristic aerosol properties and its variability, remote sensing tools are employed. Remote sensing from space provides aerosol data, however, mainly in a qualitative way (due to uncertain background noise and retrieval assumptions). Quality data are usually provided by (long-term) ground remote sensing networks, such as AERONET, where sky-radiance data allow estimates on all relevant aerosol optical properties (amount, absorption, size and shape). Since all AERONET sites are landlocked, the statistics on aerosol data over oceans is relatively sparse. Samples of sun-photometry measurements during the voyage will add to the over-ocean data-base for aerosol optical depth (AOD), size and absorption (via radiance-field inversion techniques) and provide insights on the meridional distribution in April.

Aerosol, moreover, interacts with other drivers of anthropogenic change, in particular aerosol interacts with clouds. This is important, since clouds are the main modulators of the Earth's climate. High temporal observations of aerosol prior and past the passing clouds allow the examination of aerosol-cloud interactions.

Work at sea
Upon departure from Punta Arenas the following instruments will be installed onboard *Polarstern* for intermittant and continued measurements (note, continued CIMEL measurements can provide data on cloud properties):

1) oversee automatic CIMEL sun-photometer measurements
2) conduct supplementary Microtops handheld sun-photometer sampling
3) perform real-time closure studies for consistency of aerosol properties and associated broadband (solar) fluxes

Expected results
1) Improved record on aerosol optical properties over oceans as function of latitude
2) new insights through correlation with associated atmospheric properties (e.g. wind, cloud micro- and macrophysics).

5. SHIPBOARD ADCP-MEASUREMENTS OF EQUATORIAL CURRENT SYSTEM

Not on board: P. Brandt (IFM-GEOMAR)

Introduction / expected results
While for the near-surface flows seasonal cycles could be determined from drifter currents and altimetry, reliable transports and seasonal cycle analyses of the subsurface flows from the interior tropical Atlantic that could serve as a calibration base for model simulations have not become available. Recently, however, time series from moored ADCPs were obtained within the context of the Pilot Research Moored Array in the Tropical Atlantic (PIRATA) [Servain et al., 1998, Brandt et al. 2006]. The mooring activity was continued in the frame of the BMBF project Nordatlantik. Within this project a current meter mooring array was deployed at 23°W for the first time in August 2006. While the moored instruments will yield multi-year current observations at fixed positions, ship sections are needed to resolve the complicated structure of the equatorial current system.

Shipboard current observations were used to obtain mean transports of the primary equatorial current branches, particularly the Equatorial Undercurrent (EUC) at 35°W (Schott et al., 2003) and 26°W (Brandt et al. 2006). However, the available ship sections are up to now not conclusive concerning the seasonal cycle of EUC transports (Hormann and Brandt, 2006). Shipboard ADCP measurements with *Polarstern* will enhance the availability of current sections and thus allow in the future to address the intraseasonal to seasonal variability of the transports of the main current branches. Furthermore, they will be used as a reference data set for the moored observation at the equator at 23°W.

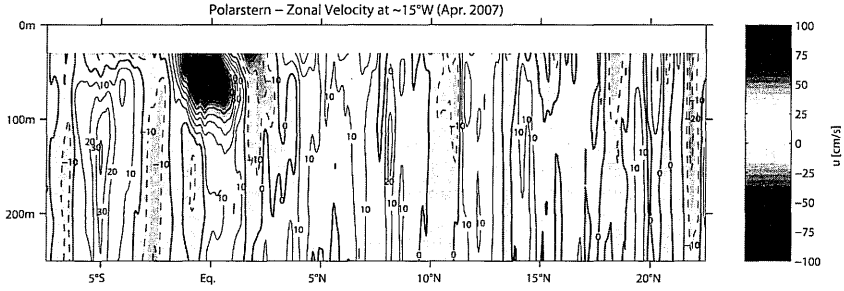

Fig. 5: Zonal current velocity along a meridional section at 15 to 20°W during Polarstern cruise ANT–XXIII/10 in April 2007. Most prominent is the equatorial current system with the Equatorial Undercurrent (EUC) at 50 m depth at the equator (up to 1 m/s) and the South Equatorial Undercurrent (SEUC) at 100 to 200 m depth at 5 S (up to 0.4 m/s). Further north there are several eastward and westward current bands mainly associated with the enhanced eddy field in the region.

The Shipboard ADCP / work at sea

Polarstern is equipped with a shipboard 150 kHz Ocean Surveyor ADCP. Velocity data were acquired during *Polarstern* cruises ANT-XXII in June 2005 (Brandt et al. 2006) and ANT–XXIII/10 in April 2007 (Fig. 5). The velocity data obtained after processing were of good quality. Depth range is 200 to 250 m for the whole cruise. Thanks to frequent purposeful deviations from a straight cruise track, the transducer misalignment - which is an essential factor in data processing - could be determined quite well. Those purposeful deviations prove most suitable if the time intervals between course changes are 10 minutes at least and course changes are 10 degrees at least. During the second cruise in April 2007, heading data were available from the Laser-navigation-platform. This heading resulted in slightly lower data quality compared to previous cruise in June 2005, when the heading from the ASHTECH array were used. It is thus recommended to store heading information from both the Laser-navigation-platform and the ASHTECH array together with the ADCP data. The ADCP should run as long as possible, i.e. outside the 200 nm zone. Frequent purposeful deviations from the course should be performed in the region 10°S to 20°N twice daily.

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6. SATELLITE GROUND TRUTH: BIO-OPTICAL AND ATMOSPHERIC STUDIES

B. Schmitt (AWI), L. Bentama (GKSS); A. Theis, Hagen Schulte in den Bäumen, M. Taylor (IUP)

Bio-optical measurements

Objectives

It has been estimated that marine phytoplankton contributes 30 to 60 % to global primary production. The large uncertainty range is a result of the lack of global information on phytoplankton absorption and light penetration depth, which cannot be supplied by the current ocean colour satellite sensors. The spectral resolution of these sensors is not sufficient to extract the relevant information. The variation of phytoplankton absorption in ocean waters also affects the retrieval of chlorophyll *a* concentrations (a measure of phytoplankton biomass) derived from satellite data, which are important input data used in primary production models. Results by Bracher et al. (2006) show that specific phytoplankton absorption spectra as well as information on the light penetration depth can be derived by combining information from measurements of the two satellite instruments, MERIS with high spatial, and SCIAMACHY with high spectral resolution (both operating on board of the European environmental satellite ENVISAT).

Besides the analysis of satellite data and applied model studies, field measurements in the open ocean of phytoplankton pigment composition, optical characteristics of phytoplankton and other water constituents, reflectance and underwater light measurements are highly precise input parameters for the validation of results from the analyses of satellite data and modelling.

Thus, the aim of this research project is to improve estimates of global marine primary production and the distribution of major phytoplankton functional groups by using remote sensing data in combination with in-situ measurements of ocean optics, phytoplankton

productivity and composition and particulate organic carbon (POC). In particular, data will be collected during this cruise to improve our understanding of the oceans variability in optical properties and to improve/develop remote sensing algorithms for the investigated research area. Algorithms to retrieve POC from space are still very basic, but are of great importance for studies concerning biogeochemical cycles and the biological pump within the world's oceans because carbon and not chlorophyll are the bases for those studies. Through a better knowledge of the sinks and sources of CO_2 in the ocean a contribution will be made to a better understanding of changes in the world's climate as well as to the understanding of the marine food web.

Work at sea

1. Water samples

Water samples will be taken frequently (every 6 hrs) from beneath the ship (moon pool) and at the stations from CTD/rosette casts and processed for various analyses:

- Water samples will be filtered onto GF/F filters for pigment analysis, particulate absorption measurements and POC.
- Water samples will be preserved for flow cytometry measurements later in the laboratory in Bremerhaven.
- Particulate absorption in suspension and absorption of Gelbstoff will be measured during the cruise using the point-source integrating-cavity absorption meter (PSICAM) (Röttgers et al. 2005).

2. Online and In Situ Optical Measurements

- A FastTracka Fast Repetition Rate Fluorimeter (FRRF) will be used in a flow-through system with water continuously pumped from the moon pool to provide online data of chlorophyll fluorescence during the cruise.
- A second FastTracka FRRF will be attached to the CTD to take measurements in the water column
- Remote sensing reflectance will be measured firstly from onboard the ship with a set of three radiometers and secondly in the water column (0 - 150 m) at the stations.

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7. LIFE IN COLD OCEANS: ACTIVITY DEPENDENT ON EXTRACELLULAR ION REGULATION?

A. Wittmann (AWI)

Objectives

The physiological fundamentals of temperature dependent distribution limits in cold oceans are addressed as a precondition to understand ecological performance and ecosystem function. Our work focuses on the specific role of extracellular ion concentration in setting limitations to lifestyle and life history evolution.

The biogeography of marine crustaceans in cold oceans is related to the combined effects of extracellular Mg2+ levels [Mg2+]e and low temperature, which act synergistically to slow muscular activity in the cold.

We attempt to develop quantitative knowledge of the temperature dependent effects of magnesium on animal life cycle resulting from changes in physiology performance, larval development, and growth rate. Within the crustacean phyla this work will focus on the lithodid crabs. They are suitable for such studies since they have a wide distribution range north and south of the Antarctic convergence and thus covering a broad temperature regime. Ovigerous females of *Lithodes santolla* will be caught at about 15 to 30 m depth using commercial fishery traps in the Argentine Beagle Channel. The crabs will be kept in aquaria at 6±0.5° C in the Centro Austral de Investigaciones Cient ficas (CADIC) in Ushuaia. These lithodids will be transported with *Polarstern* to Bremerhaven and finally to the marine biological laboratory in Helgoland

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4.	Peine Lutz	2.Offc.
5.	NN	2.Offc.
6.	NN	Doctor
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9.	Sümnicht, Stefan	2.Eng.
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11.	Scholz, Manfred	Elec.Tech.
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13.	Verhoeven, Roger	Electron.
14.	Muhle, Helmut	Electron.
15.	Himmel, Frank	Electron.
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17.	Reise, Lutz	Carpenter
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19.	Stutz, Hein-Werner	A. B.
20.	Winkler, Michael	A.B.
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22.	Hagemann, Manfred	A.B.
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30.	Hartmann, Ernst-Uwe	Mot-man
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