Expeditionsprogramm Nr. 78

FS POLARSTERN

ARK-XXII/1a

ARK-XXII/1b

ARK-XXII/1c

ARK-XXII/2

Koordinator:
Eberhard Fahrbach

Fahrtleiter:

ARK-XXII/1a:
Jörn Thiede

ARK-XXII/1b-c:
Michael Klages

ARK-XXII/2:
Ursula Schauer

ALFRED-WEGENER-INSTITUT FÜR POLAR- UND MEERESFORSCHUNG
MITGLIED DER HERMANN VON HELMHOLTZ-GEMEINSCHAFT DEUTSCHER FORSCHUNGSZENTREN E.V. (HGF)

BREMERHAVEN, APRIL 2007

EXPEDITIONSPROGRAMME No. 78

RV POLARSTERN

ARK-XXII/1a
29 May 2007 - 21 June 2007
Bremerhaven - Tromsø

ARK-XXII/1b
23 June - 9 July 2007
Tromsø - Longyearbyen

ARK-XXII/1c
10 July - 25 July 2007
Longyearbyen - Tromsø

ARK-XXII/2
28 July 2007 - 10 October 2007
Tromsø - Bremerhaven

Coordinator:
Eberhard Fahrbach
Chief Scientists:

ARK-XXII/1a:	Jörn Thiede
ARK-XXII/1b-c:	Michael Klages
ARK-XXII/2:	Ursula Schauer

STIFTUNG ALFRED-WEGENER-INSTITUT FÜR POLAR- UND MEERESFORSCHUNG
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1. ÜBERBLICK UND FAHRTVERLAUF

Jörn Thiede, Michael Klages (AWI)

Die FS *Polarstern* – Expedition ARK-XXII/1a-c (29.05.2007 – 25.07.2007; Bremerhaven – Tromsø – Longyearbyen – Tromsø) stellt einen Beitrag zu dem von der EU geförderten Projekt HERMES (Hotspot Ecosystem Research on the Margins of European Seas) dar, in dem marine Ökosysteme der Tiefsee erforscht werden. Das HERMES Projekt hat zum Ziel, neue Erkenntnisse zu Biodiversität, Struktur, Funktion und Dynamik verschiedenartiger Ökosysteme entlang des europäischen Kontinentalrandes zu erarbeiten. Diese Ergebnisse können dann in künftige Richtlinien einer europäischen Meerespolitik einfliessen. Der erste Arktisfahrtabschnitt des FS *Polarstern* zu Beginn des IPY (International Polar Year) ist in drei Unterabschnitte gegliedert, um so Untersuchungen an vier Ökosystemtypen entlang des nördlichen europäischen Kontinentalrandes durchzuführen. Mit HERMES wird erstmalig versucht, Tiefseeökosysteme in einem integrativen Ansatz europaweit zu untersuchen (Geosphäre, Hydrosphäre Biosphäre). Dabei werden ausgewählte, verschiedenartige Ökosysteme von Spitzbergen im Norden entlang des norwegischen Kontinentalrandes bis in das Schwarze Meer hinein studiert. Ein besonderer Schwerpunkt liegt dabei auf sogenannten "hot spots", stark physikalisch kontrollierten Systemen, die zudem durch vergleichsweise dynamische geologische und/oder hydrologische Randbedingungen, wie zum Beispiel instabile Kontinentalhänge, Tiefseegräben, Tiefwasserkorallen, kalte Sickerstellen oder sauerstofffreie, von Bakterien besiedelten Lebensgemeinschaften geprägt sind. Diese als wichtig identifizierten Systeme werden intensiv studiert, da sie entweder als besonders empfindlich gegenüber lokalen Störungen oder weltweiten Veränderungen eingestuft wurden, oder beispielswiese eine globale Bedeutung bezüglich des Kohlenstoffkreislaufs haben. Die Ziele von HERMES lassen sich durch fünf Kernfragen konkretisieren:

a) Erarbeitung eines besseren Verständnisses der natürlichen Faktoren, die Ökosysteme kontrollieren,
b) Verbesserung des Kenntisstandes zur Biodiversität und der Funktionsprinzipien von verschiedenartigen "hotspot" - Ökosystemen,
c) Verbesserung unserer Vorhersagekapazität hinsichtlich der Veränderung von Biodiversität und den funktionalen Abläufen in Ökosystemen vor dem Hintergrund globaler Umweltveränderungen,
d) Entwicklung von Konzepten und Strategien zur nachhaltigen Nutzung mariner Ressourcen,
e) Entwicklung der erforderlichen Rahmenbedingungen für Datenmanagement, Training, Nachwuchsausbildung und Öffentlichkeitsarbeit.

Für die Durchführung des Expeditionsprogrammes wird auf dem ersten Unterabschnitt der Reise (29.05.-21.06.07) das bemannte Tauchboot JAGO des IFM-GEOMAR aus Kiel an Bord sein, um an Kaltwasserkorallenriffen vor der norwegischen Küste zu arbeiten (Abb. 1.1). Während des zweiten und dritten Unterabschnittes wird das ferngelenkte Unterwasserfahrzeug "QUEST" des MARUM der Universität Bremen an Bord sein. Mit diesem Unterwasserfahrzeug werden gezielt Proben am Håkon-Mosby-Schlammvulkan, einer untermeerischen Quelle für Methanaustritt in 1250 m Wassertiefe, genommen (Abb. 1.2). Nach dem Wechsel der meisten wissenschaftlichen Fahrtteilnehmer um den 9. bzw. 10. Juli in Longyearbyen wird das FS *Polarstern* im Bereich des *Hausgarten* operieren (Abb. 1.2), einem von zehn Tiefseeobservatorien des von der EU geförderten Exzellenznetzwerkes ESONET (European Seas Observatory NETwork). Neben einem Standardprobennahmeprogramm (Aufnehmen und Ausbringen von Verankerungen, Freifall-Landern) wird

"QUEST" genutzt, um unter natürlichen Umgebungsgedingungen in der Tiefsee verschiedene Experimente durchzuführen, aber auch, um gezielt Sediment- und andere Proben aufzunehmen. Der Fahrtabschnitt ARK-XXII/1 wird am 25. Juli im Hafen von Tromsø enden.

SUMMARY AND ITINERARY

The RV *Polarstern* cruise ARK-XXII/1a-c (29 May 2007 – 25 July 2007; Bremerhaven – Tromsø – Longyearbyen - Tromsø) contributes to the EU funded Integrated Project HERMES (**H**otspot **E**cosystem **R**esearch on the **M**argins of **E**uropean **S**eas), aiming at research on ecosystems lying in the deeper ocean section. The project HERMES is designed to gain new insights into the biodiversity, structure, function and dynamics of ecosystems along Europe's deep-ocean margin to underpin the future development of a comprehensive European Ocean and Seas Integrated Governance Policy. This Arctic cruise leg of RV *Polarstern* during the first year of IPY (International Polar Year) is subdivided into three sub-legs to allow studies on four different ecosystem types along the Nordic margins within HERMES. It represents the first major attempt to understand European deep-water ecosystems and their environment in an integrated way (geosphere, hydrosphere, biosphere of a pan-European range). HERMES aims to compare and contrast selected environments around the European margin from the Svalbard continental margin, Norwegian margins to the Black Sea. In particular, HERMES will focus on hot spots that are strongly physically mediated and associated with dynamic geological and/or hydrogeological structures, such as unstable slope systems, canyons, deep-water corals, cold seeps and anoxic microbial systems. These important systems need to be urgently studied because of their possible biological fragility, global relevance to carbon cycling and/or susceptibility to catastrophic events and to global change. HERMES will address five key questions. Specifically, the main objectives of HERMES are:

- to better understand the natural drivers that control ecosystems,
- to better understand the biodiversity and ecosystem function of hot spot ecosystems,
- to forecast changes in biodiversity and ecosystem functioning linked to global change,
- to develop concepts and strategies for sustainable use of marine resources,
- to provide an integrated framework for data management, training, education and outreach.

The work plan is based on the use of the manned submersible JAGO (owned by IFM-GEOMAR, Kiel) during the first sub-leg (29 May – 21 June 07) for studies on cold water corals (Fig. 1.1). The work during the second and third sub-leg is based on the Remotely Operated Vehicle (ROV) "QUEST" of MARUM at Bremen University. The ROV is necessary for detailed studies at the Håkon Mosby Mud Volcano northwest of Norway at 1250 m water depth, an exceptional cold seep with anoxic microbial systems at high latitudes (Fig. 1.2). After exchange of scientific personnel in Longyearbyen around the 9 or 10 July, RV *Polarstern* will work in the area of the *Hausgarten* observatory (Fig. 1.2), one node within the European Seas Observatory Network (ESONET). Among a standard sampling programme including exchange of moorings and free falling landers, here the ROV will be used for various *in-situ* experiments at the central experimental site of *Hausgarten*. The cruise PS ARK-XXII/1 will end on 25 July at the port of Tromsø.

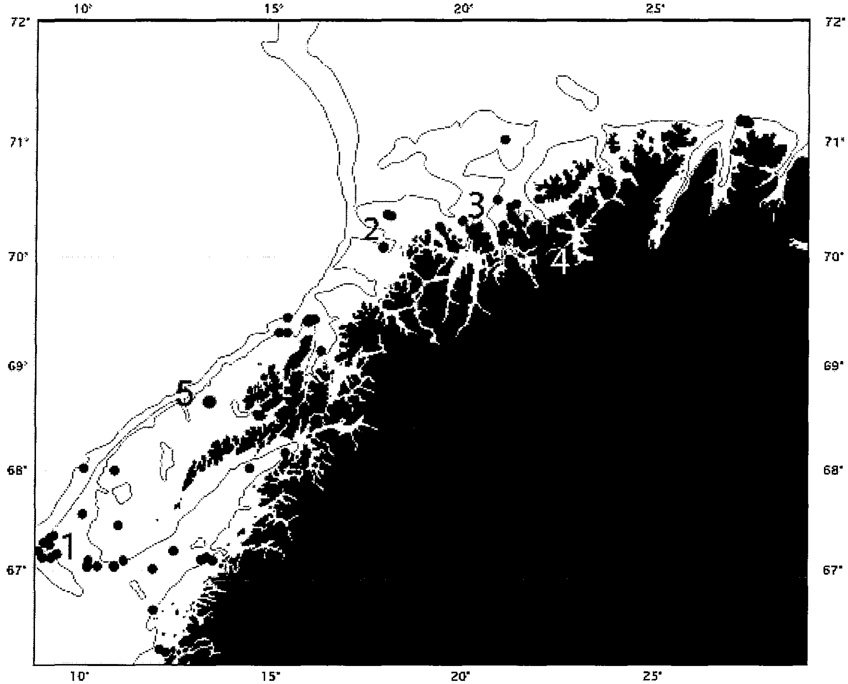

Abb. 1.1: Die geplanten Arbeitsgebiete während ARK-XXII/1a auf dem nördlichen norwegischen Kontinentalschelf. Zahlreiche Lophelia-Riffe (Punkte) sind von früheren Studien bekannt: Røst Reef (1), the Fugløydjupet reefs (2), the Fugløy reef (3) und die Floholmen site (5). Stjernsund reef im Alta Fjord (4) ist als Alternative bei schlechtem Wetter eingeplant.

Fig. 1.1: Map of planned and additionally possible sampling sites during ARK-XXII/1a at the northern Norwegian continental shelf. Numerous Lophelia reefs (red dots) are known from pre-site studies. Planned study sites are: Røst Reef (1), the Fugløydjupet reefs (2), the Fugløy reef (3). The Floholmen site (5) is also possible. Stjernsund reef in the Alta Fjord (4) is an alternative in case of bad weather.

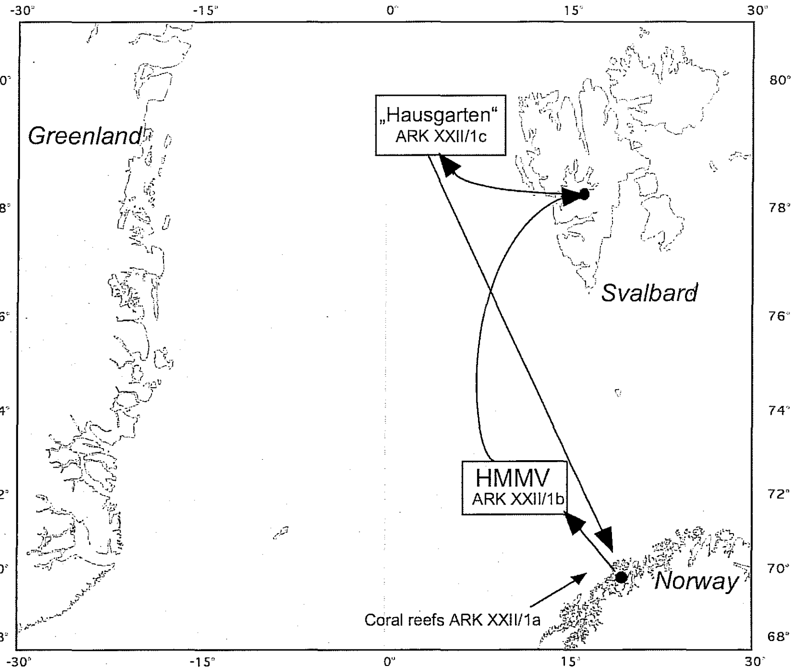

Abb. 1.2: Fahrtroute des FS Polarstern von Tromsø nach Longyearbyen und zurück während ARK-XXII/1b-c mit den Arbeitsgebieten „Håkon Mosby Mud Volcano“ und „Hausgarten“

Fig. 1.2: Cruise track of RV Polarstern from Tromsø to Lonyearbyen and back during ARK-XXII/1b-c into the working areas „Håkon Mosby Mud Volcano“ and „Hausgarten“

2. CRUISE LEG ARK-XXII/1A: BREMERHAVEN – TROMSØ (29.05. - 21.06.2007)

2.1 DIVERSITY OF SPONGE AND MICROBIAL COMMUNITIES ASSOCIATED WITH COLD WATER CORAL REEF HABITATS

Friederike Hoffmann, Nina Knab, Sandra Schöttner, Laura Wehrmann (MPI),
Paco Cardenas, CecileJolly, Christiane Todt (UiB), Christian Wild (LMU)

Microbes occur in every niche in the ocean and comprise a significant part of the global biomass. Recently also animal surfaces, tissues and exudates have been viewed as microbial habitats, which add microbial diversity to an ecosystem.

Biodiversity hot spots on continental margins like the deep water coral reefs and associated sponge accumulations have not yet been investigated for the nature of microbial niches in these settings. The microbial community structure and diversity of the different coral reef habitats (coral mucus, tissue and carbonate surface; sponge tissue; sea water; sediment) will be investigated, as well as their role in biogeochemical processes and nutrient cycling of the reef systems.

Objectives

1. Diversity of microbial communities associated with cold water coral reef habitats,
2. role of coral exudates on nutrient cycling on the reef,
3. biogeochemistry of reef-associated sediments with a special focus on sulfate reduction and calcification,
4. biodiversity of sponges associated to the reefs, and microbes associated to sponges.

Work at sea

Sampling

Collecting corals, coral mucus, carbonates, sediment cores and sponges from *Lophelia* reefs, and bottom water samples above the reef. Sampling will happen along reef transects by the manned submersible JAGO and by winch-operated tools (see Fig. 2.1a and 2.1b) at different sites off Northern Norway (see Fig. 1.1).

Experiments and analyses

Biodiversity of microbial communities associated with cold water coral reef habitats

- Molecular analyses of coral surface, mucus and tissue
- Molecular analyses of coral reef associated water and sediment

Role of coral exudates on nutrient cycling on the reef

- Biochemical characterisation of coral exudates
- Incubation experiments with coral exudates to determine microbial turnover and community change
- Transect sampling to assess the role of corals as ecosystem engineers via the release of DOM and POM

Biogeochemistry of reef-associated sediments

- Porewater geochemistry
- Carbon turnover rates
- Sulfate reduction rates
- Oxygen uptake rates
- Solid phase: Fe/S/C/N geochemistry

Biodiversity of sponges and associated microbes

- Sponge diversity: Qualitative and quantitative mapping of sponges on cold-water coral reefs
- Diversity of sponge-associated microbes by total cell counts and fingerprinting techniques

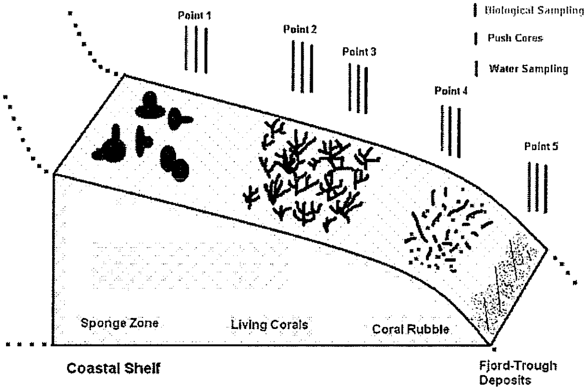

Fig 2.1a: Sampling of reef transect by JAGO-operated tools. At each point with push corer, biological sampling with manipulator arm, and water sampling.

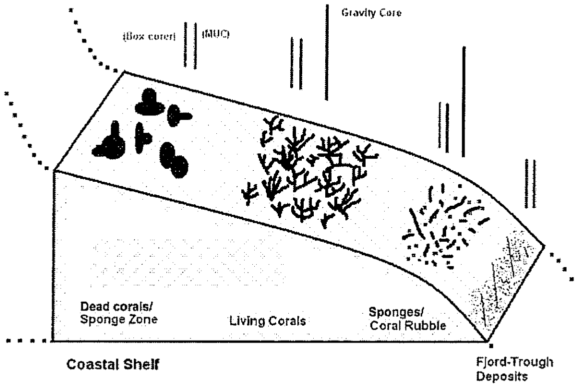

Fig 2.1b: Sampling of reef transect by winch-operated tools. At each point the multicorer and the giant box corer will be used. The longer bars indicate the operation of the gravity corer.

2.2 FLUXES OF PARTICULATE MATTER ON COLD WATER CORAL REEFS OFF THE LOFOTEN

Nora Hanelt, Autun Purser, Laurenz Thomsen, Unnithan Vikraim, Thomas Viergutz (JUB), Birgit Lessmann, University Bielefeld

Objectives and work at sea

Effects of elevated levels of particulate matter and sedimentation on cold-water coral ecosystems is a matter of great general interest for HERMES. Concern has often been expressed that increased levels of turbidity and sedimentation could have negative effects, e.g. as a result of re-suspension of sediments by trawling or other activities close to CWC-habitats, or as a result of eutrophication of overlying surface waters. Aim of the cruise is to study the coral reefs off the Lofoten by using a set of sensors (video, particle size, flow, turbidity, video) and samples (near-bottom water, surface waters) to get detailed information on fluxes of particulate matter through several coral-reefs. Information on particle dynamics will be used to estimate the importance of particle-aggregation, (bio)deposition and (bio)erosion for the coral reefs off the Lofoten. Samples within the reef, from ambient soft bottom communities and from surface waters will be used to trace back the origin of the particles entering the reef-systems. A close collaboration with the MPI group onboard will allow to further investigate the importance of coral-mucus for the material fluxes.

2.3 HERMES OUTREACH GROUP: "OUTREACH FOR SCHOOL PUPILS"

Rune Erlandsen, Aline Munyaruguru (JUB, Norwegian school pupils), Gesche Funk, Steffen Wittek (JUB, German school pupils), Nora Hanelt (JUB)

HERMES Outreach, in conjunction with the International Polar Year 2007/2008, AWI and Jacobs University Bremen will 'host' four school pupils from Norway and Germany on a research expedition onboard the famous research vessel and icebreaker RV *Polarstern*. The four school pupils will carry out their own research projects and assist the deep-sea researchers onboard the RV *Polarstern*. The pupils will also communicate to their school peers about their experiences, write expedition logs, conduct relevant scientific and investigative reporting, video-making and interviews that they put online. After the expedition, the pupils will continue their outreach efforts, for example by designing educational posters for distribution to schools, etc.

2.4 ANTHOZOAN DIVERSITY ASSOCIATED WITH COLD WATER CORAL COMMUNITIES

Manuela Fangueiro Ramos (USev)

Objectives

Anthozoans are one of the major components in benthic sessile communities in terms of both abundance and diversity, offering a good substratum (e.g. refuge, feeding, ...) to many other benthic mobile and sessile animal groups (crustaceans, polychaetes, echinoderms, ...). Cold water corals harbour a diverse invertebrate fauna as well as other anthozoan groups different from scleractinian (sea anemones s.l., soft corals, gorgonians, etc.). According to the previous investigations carried out by our research group in the University of Seville in Atlanto-mediterranean waters, as well as boreal-artic limits (Iceland) and Antarctic, our scientific objectives on board will be:

- To detect the presence of boundaries in the distribution of the anthozoan fauna at different taxa levels (family, genus, species) at different spatial scales, and try to identify associations,
- to evaluate the diversity of the different anthozoan groups associated with dead and living fields of cold water coral communities,
- to evaluate the potential origin of the anthozoan fauna according to the known distribution of genera/species in this and other biogeographical areas,
- to detect the presence of rare or poorly known anthozoan species,
- to evaluate the taxonomic utility of histological and cytological characters in scleractinian,
- to carry through the bank of tissues usable for molecular studies in anthozoans,
- to carry through the information about colour pattern of living anthozoan species that could be useful for other non-invasive sampling methods as ROVs.

Work at sea

Benthic cnidarians will be collected mostly by Van Veen and Maxi Box Corer. Hexacoral individuals will be relaxed with menthol in cold room and fixed in formaldehyde (morphological work) or absolute ethanol (molecular analysis). Octocoral colonies will be fixed in buffered formaline (pH 8-9) to avoid decalcification of their sclerites, some fragments will be also fixed in absolute ethanol for phylogenetic approaches. Photographs of the living specimens will be taken to ensure colour information that could be lost during fixation.

2.5 COLLECTING LIVE AND DEAD BIVALVES (ACESTA EXCAVATA) TOGETHER WITH ANTIPATHARIAN, GORGONIAN AND SCLERACTINIAN CORALS FOR SCLEROCHRONOLOGY

Jason Hall-Spencer, Marta Soffka, Tina Kirby (UPly)

Objectives

Our scientific objective is to collect live and dead bivalves (*Acesta excavata*) together with antipatharian, gorgonian and scleractinian corals for sclerochronology.

Work at sea

The samples will be preserved in alcohol so that the material is of use to geneticists, but the main aim is to examine the use of these samples to age them and record past water temperatures. We will enumerate the smaller species associated with the samples taken and, in addition, underwater film will be used to analyse the behaviour and distribution of macro organisms of the coral reef systems. The group is also heavily involved with the use of satellite monitoring of fishing effort and aims to make use of acoustic and visual seabed surveys to relate trawling/ long-lining effort to physical and biological effects on benthic ecology.

2.6 SEA TRIAL AND TESTS OF THE UPGRADED DEEP SEA SEDIMENT ECHO SOUNDER "PARASOUND DS III" DURING ARK-XXII/1

Gerhard Kuhn, Saad El Naggar, Frank Niessen (AWI), Martin Boche,Thomas Liebe (Laeisz), Jörn Ewert (ATLAS), Peter Gerchow (FIELAX)

Objectives

The Deep Sea Sediment Echo Sounder "PARASOUND DS III" of ATLAS Hydrographic, Bremen, Germany, will be upgraded from DS II to DS III during the last ship yard stay of RV *Polarstern* in Bremerhaven between 4 May 2007 and 29 May 2007.

Newly designed hard and software will be installed and tested at harbour in Bremerhaven. The operational test under real conditions at sea will be carried out during the first part of the cruise ARK-XXII/1 between Bremerhaven and Tromsø during the period of 29 May 2007 and 6 June 2007.

Work at sea

- Complete and tune the final hard and software installation under real condition (hardware checks, telegrams checks, data format, etc),
- operational checks under different transmission parameters (frequencies, power, data recording, etc),
- data analysis and validations,
- sea trial and acceptance tests at location (about 24 hours north-west of Tromsø),
- transfer of the test team to Tromsø via helicopter.

3. CRUISE LEG ARK-XXII/1B: TROMSØ – LONGYEARBYEN (23.06. - 09.07.2007)

3.1 GEOMICROBIOLOGICAL INVESTIGATIONS TOGETHER WITH HIGH RESOLUTION POREWATER PROFILING WITH MICROSENSORS AND INSITU MEASUREMENTS WITH BENTHIC CHAMBERS AND OPTODES

Frank Wenzhöfer (MPI)

Objectives

Mud volcanoes are very interesting systems, both from the biological and geological perspective. The rising mud and gas represents a window between the deep geosphere and the biosphere. Mud volcanism may be an important natural source of the greenhouse gas methane to the hydrosphere and atmosphere. Recent investigations show that the number of active submarine mud volcanoes might be much higher than anticipated, and that gas emitted from deep-sea seeps might reach the upper mixed ocean. Unfortunately, global methane emission from active submarine mud volcanoes cannot be quantified because their number and gas release are unknown. It is also unclear how efficiently methane-oxidizing micro organisms remove methane. With regard to the global climate change, the study of gas seeps at continental margins is an important contribution to our understanding and quantification of the methane cycle. The geological, chemical and biological investigation of gas seeps in polar regions and other areas of the world's ocean is a focus of research at the MPI, carried out in cooperation with several other national and international institutions within the framework of HERMES.

Only recently it has been discovered that mud volcano ecosystems are similar to those found at other types of cold seeps. Mud volcanoes like the HMMV are formed at tectonically inactive areas of continental margins and are generally connected to deep gas reservoirs. Methane and other gases are formed and may accumulate in deep sediment strata to build free or frozen gas reservoirs (gas hydrates). At mud volcanoes, sediment fluids, gas and mud is expelled from deep below forming mounds and crater at the seafloor. Methane oxidizing micro organisms profit from the rising gas and produce sulfide and carbonate – which are utilized by other organisms as energy source and substrate, respectively and are often densely populated by tube worms, clams and other symbiotic organisms. In gassy sediments a microbial symbiosis has been detected, which is able to consume methane by oxidizing it with sulfate. This symbiosis consists of archaea and bacteria, which can use the abundant sulfate in seawater instead of oxygen. Product of this reaction is sulfide which is used as energy source by the chemotrophic organisms (tube worms, clams, giant sulfur bacteria).

Since 2001 we have studied the HMMV in the framework of the BMBF/DFG Geotechnologien-funded project MUMM (Mikrobieller Umsatz von Methan in gashydrathaltigen Sedimenten), and since 2005 also within the EU project HERMES. The investigations at HMMV are carried out in cooperation with MPI, AWI, and IFREMER, and aim at an analysis of the main factors regulating the activity of the methanotrophic micro organisms and their contribution to biogeochemical fluxes at this mud volcano. Previous measurements at HMMV provided the first quantitative estimates of the *in-situ* composition, distribution and activity of methanotrophs in relation to gas emission. The HMMV hosts three key communities: aerobic methanotrophic bacteria (Methylococcales), anaerobic methanotrophic archaea (ANME-2) thriving below siboglinid tubeworms, and a previously undescribed clade of archaea (ANME-3) associated with bacterial mats. We found that the upward flow of sulphate- and oxygen-free mud volcano fluids restricts the availability of these electron acceptors for methane oxidation, and hence the habitat range of methanotrophs. This mechanism limits the capacity of the microbial methane filter at active marine mud volcanoes to < 40 % of the total flux.

Work at sea
For the RV *Polarstern* expedition ARK-XXI//1b during the International Polar Year we plan three main work packages with a focus to the hot spots at HMMV:
1) geomicrobiological investigations,
2) high resolution porewater profiling with microsensors,
3) *in-situ* measurements with benthic chambers and optodes.

3.2 GEOMICROBIOLOGY OF THE HMMV

Janine Felden, Stefanie Grünke, Gabriele Schüßler, Tomas Wilkop (MPI)

Objectives
Microbially mediated anaerobic oxidation of methane (AOM) is the major biological sink of methane in marine sediments. Hence, this process is crucial in maintaining a sensitive balance of our atmosphere's greenhouse gas content. However, a fundamental understanding of the associated biology is still lacking, consequently preventing a thorough biogeochemical understanding of an integral process in the global carbon cycle. Studies employing stable isotopes, radiotracers, modelling, and microbiological techniques have now established that methane in marine sediments is oxidized biologically under anoxic conditions. Although no anaerobic methanotroph has ever been isolated, biogeochemical studies have shown that the overall process involves a transfer of electrons from methane to sulfate. Accordingly, the isotopic and genetic signatures of the dominant microbial populations in environments enriched with methane proved that this transfer is mediated by a microbial consortium that includes archaea and sulfate-reducing bacteria.

The major aim of this study is the investigation of microbial sulfate reduction (SRR) and anaerobic methane oxidation (AOM) in methane enriched surface sediments of the HMMV, as well as sampling the sediments for microbiological and molecular analysis.

Work at sea
The focus of the microbiological investigations will be on the giant sulfide oxidizing bacteria covering parts of the HMMV and their micro diversity. Samples will be obtained from the sediment cores which were retrieved by the ROV and by multiple corer hauls and gravity cores. In parallel to the on board rate measurements, sub-samples are taken from cores to determine the total number of bacteria, to quantify different taxonomic groups of bacteria by fluorescence *in-situ* hybridisation (FISH, 16s rDNA clone libraries, DGGE) and to investigate the metabolic activity of methane consuming micro-organisms involved in sulfate reduction and methane oxidation under controlled laboratory conditions in microcosms. Furthermore, sediment sub-samples are obtained to investigate the distribution of lipid products derived from members of AOM consortia and their stable carbon isotopic composition which bears diagnostic information on the carbon source and/or metabolic carbon fixation pathway utilized by its producer. All these samples will be processed in the home laboratories of MPI.

3.3 HIGH RESOLUTION STUDIES WITH MICROSENSORS

Frank Wenzhöfer (MPI)

Objectives

The sediment of HMMV host three methane oxidizing communities: anaerobic methanotrophs (Beggiatoa mats), free living aerobic methanotrophs (Centre) and symbiotic aerobic methanotrophs. (Pogonophora fields). The methane originates from a deep source and the areas covered by the different microbial communities are relatively large. The centre of the vulcano shows relatively little microbial activity due to extremely high fluid flow rates. Surrounding this centre is a ring of Beggiatoa fields, covering anaerobic methane oxidizers, this sediment is soft and fine and contains high amounts of sulfide. The peak in methane oxidation capacity is at 1-3 cm under the sediment surface. Then there is an outer ring of pogonophora fields with relatively oxidized sediments. It is planned to investigate the transition between these sediments with high spatial resolution measurements using microsensors.

Work at sea

In-situ measurements will be done, using a profiler deployed by ROV QUEST, and *ex-situ*, i.e. on retrieved cores on board of the ship. The following sensors will be used: O_2, H_2S, pH, redox. This will improve insight into the carbonate chemistry inside the sediments. The redox sensor responds mainly to O_2, H_2S and Fe^{2+}, thus – together with porewater analyses - it may also give a hint to interesting iron chemistry in the anaerobic methane oxidizing zone. Most recordings will be done to approx. 15 cm depth, i.e. the standard length of a sensor. *Ex-situ* measurements will be done with the same type of sensors to observe the effects of experimental changes, e.g.

a) addition of nitrate, and sulfide to the water column to study the sulfide oxidation by Beggiatoa, nitrate reduction can be measured with N_2O sensors,
b) the effect of metabolic inhibitors on the iron chemistry (azide, cyanide, chloroform).

3.4 CHAMBERS AND OPTODES – IN-SITU INVESTIGATIONS OF TOTAL OXYGEN, METHANE AND SULFIDE FLUXES

Volker Asendorf , Janine Felden, Frank Wenzhöfer (MPI)

Objectives

Main aim of the chamber and optode work will be to quantify transport dynamics along a gradient of stations from sites colonized by Beggiatoa and Pogonophora towards sediments not influenced by methane seepage. From each chamber incubation, a series of water samples is taken at preset intervals that will be analysed for oxygen, nutrients, sulfide and methane concentrations. The Optodes serve to measure T, pH and oxygen in 2D in different areas characterized by different transport mechanisms (e.g. gliding Beggiatoa, pumping tube worms, degassing centre). A novel instrument will be tested to measure fluid flow in the sediments.

Work at sea

Benthic chambers follow the total exchange of solutes through the sediment water interface over time in an enclosed water volume. Therefore small support frames, capable of being operated by ROV's, are equipped with different chamber designs; small cores but several for simultaneous replication or one big rectangular (30 x 30 or 20 x 20 cm) or circular (ID 19 cm) chamber to cover a larger area. During the incubation a central stirrer mixes the overlying water simulating the hydrodynamic conditions. The O_2 concentration of the enclosed water is followed continuously by mini-electrodes while other compounds (DIC, methane, H_2S, nutrients) can be analyzed on retrieved water samples taken at pre-programmed time intervals during the incubation.

Seep ecosystems often display a great spatial and temporal heterogeneity not resolved by single point measurements with microsensors. The advent of planar optodes for imaging the spatial distribution of O_2 therefore provides a much more detailed insight into the O_2-dynamics and thus small-scale variations in biogeochemical processes of marine sediments. The technique allows continuous two-dimensional quantification of the O_2-distribution across the sediment–water interface at high spatial (~100 µm) and temporal resolution (seconds). For 2-dimensional O_2-distribution measurements in marine sediments an autonomous the *in-situ* planar optode module subsequently lowers the inverted periscope equipped with the planar O_2-sensor into the sediment ensuring initial alignment of the sediment surface with the centre of the planar optode. The obtained oxygen images cover an area of 7 x 5 and 15 x 10 cm with a spatial pixel resolution of ~106 and 208 µm, respectively. After placing the sensor foil in the sediment images can be recorded in intervals of seconds to hours for a total period of hours to days. Recently pH-foils have been developed which can now also be used for *in-situ* 2D seep ecosystem studies.

Advection in marine sediments can be in two directions with opposite effects on biogeochemical processes like AOM: out-flowing pore water will limit AOM to the upper sediment layer where sulfate penetrates, while bio ventilation will enhance influx of sulfate and push the zone of AOM downwards. Pore and fluid water flow can be measured by a novel instrument "Deep flow" injecting a fluorescent dye into the sediment and subsequently following the movement of the dye cloud through the sediment with optical fibres. The fluorescent dye is excited through the optical fibres, while also the emitted fluorescence is detected through these optical fibres. The device carries an array of several optical fibres (presently 12), placed at different depths in the sediment following the movement of the dye plume precisely in sediments over space and time. From those measurements pore water or fluid flow rates can be calculated. These rates are necessary to calculated flux rates from pore water solute gradients.

3.5 INVESTIGATIONS OF GAS HYDRATE AND HYDROCARBON IN-SITU INVENTORIES IN HÅKON MOSBY MUD VOLCANO DEPOSITS USING AUTOCLAVE CORE SAMPLING

Thomas Pape, Friedrich Abegg, Hans-Jürgen Hohnberg (RCOM)

Objectives

Recent studies conducted at the submarine Haakon Mosby mud volcano (HMMV) area revealed high concentrations of methane in sediments and near-bottom waters and occurrences of gas hydrates in shallow sediments. A conspicuous zonation of microbial habitats and activities at the HMMV indicated strong geochemical gradients existing in the sediments and on the seafloor.

The overarching objectives of the investigations are determinations of distribution, quantity, fabric, and structure of gas hydrates as well as estimations of *in-situ* inventories of low-molecular-weight hydrocarbons (LMWH; C1 through C6) present in deposits of the active HMMV. For this, the spatial extent of gas hydrate deposits in the HMMV sediments and the proportions of methane stored in the different phases (as gas, dissolved in interstitial waters, encapsulated in gas hydrates) will be assessed. Further, the compound specific concentrations of LMWHs, their inferred sources (microbial/thermo-catalytic), and the crystalline structure of gas hydrates will be determined. These investigations will help to understand the dynamics of LMWHs and gas hydrates at the HMMV.

Work at sea

The works at sea are predominantly directed to the recovery and quantitative degassing of pressurized sediment cores as well as sampling and preparation of gas hydrates and gas subsamples for onshore analyses. Intended sampling locations are well-known areas of gas hydrates occurrences at the HMMV and sites following transects along heat flow gradients including reference sites without high gas hydrate density.

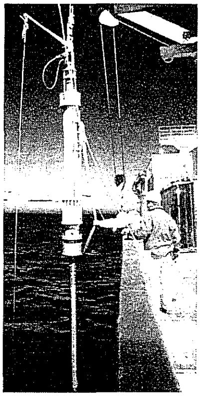

Fig. 3.1: Deployment of the Dynamic Autoclave Piston corer (DAPC)

Sampling will be performed using a Dynamic Autoclave Piston Corer (DAPC, Fig. 3.1), autoclave containers operated by the ROV QUEST, and conventional gravity corers. The DAPC allows for the preservation of *in-situ* pressures and temperatures in sediment cores and thus prevents dissociation of gas hydrates and degassing during core recovery. While one ROV-based autoclave container enables sampling of outcropping hydrates and other near-seafloor samples, other containers are designed to collect gas bubbles emanating from the seafloor within the gas hydrate stability field. Subsequent to their recovery autoclave samples will be degassed quantitatively in order to assess the total amounts of volatile hydrocarbons and gas hydrates. Subsamples of the gases released are stored for gas chemical analysis onshore. Sediments recovered by conventional gravity coring and gas hydrate pieces will be stored in liquid nitrogen immediately upon recovery until analyses onshore.

Work on land

The sample set to be investigated onshore comprises gravity cores, gas hydrates and gases. For determinations of gas hydrate depth distributions, fabric and intercalation with sediments, deep-frozen gravity cores will be scanned by computerized tomography (CT). Crystalline structures of individual gas hydrate samples will be examined using X-ray diffraction and kryo-Field Emission SEM. Gas chemical analyses of samples obtained by the DAPC, the autoclave containers and by controlled dissociation of gas hydrates will include measurements of LMWH distributions and of stable isotope ratios of hydrogen and carbon.

Expected results

Based on autoclave sampling technology, comprehensive data on spatial distributions of gas hydrates and on proportions of methane stored in different phases in sediments of the HMMW area in general will be obtained. Combined gas chemical and crystallographic approaches are expected to give information on the dynamics of gas hydrate generation and dissociation. The results will allow for an assessment of LMWH inventories at the HMMV and will contribute new information to the still sparse global data set on gas hydrate occurrences associated to active mud volcanoes.

3.6 SEDIMENT TEMPERATURE MEASUREMENTS AT HMMV

Tomas Feseker, Axel Nordhausen (MPI)

Introduction

The ascent of warm mud and fluids at mud volcanoes creates temperature anomalies close to the seafloor. Analyzing these anomalies provides information on the nature and strength of the mud volcano activity and helps to understand the relationship between fluid seepage, mud expulsion and the distribution of benthic communities. Repeated measurements at selected locations, long-term observation of sediment temperature changes and integration of geochemical observations are essential in order to determine the key processes that control the temperature distribution at mud volcanoes. Quantification of these processes will lead to improved estimates of methane discharge from the mud volcano.

Preliminary work

Sediment temperatures at HMMV have been studied in detail in the framework of several recent research cruises. During the ARK-XIX/3b cruise of RV *Polarstern* in 2003, a large number of sediment temperature measurements was obtained using a short-temperature lance operated by the ROV Victor 6000, autonomous temperature loggers mounted on the gravity corer, and a conventional heat flow probe. With temperatures reaching up to 25 °C half a meter below the seafloor, the results clearly showed a high level of mud volcano activity and suggested the presence of freshly expelled mud. Based on strongly curved temperature profiles from 3 to 15 m sediment depth, upward flow of porewater ranging from 0.8 to more than 4.2 m per year has been estimated for the central flat area, which agrees with the results of Microprofiler deployments. These findings lead to a long-term observation of sediment temperatures using a gravity corer equipped with temperature sensors and 5 short temperature probes between the cruises ARK-XXI/1b of RV *Polarstern* and AWI-ROV of RV *L'Atalante*, respectively, in 2005, and the *VICKING* cruise of RV *Pourquois Pas?* in 2006. The time series of temperature data revealed changes in sediment temperature of up to 10 °C in less than 2 weeks and point to pulsed episodic activity, possibly associated with deep circulation of seawater. Further observations during *VICKING* confirmed the presence of a strongly dynamic but persistent regime of fluid flow with episodic mud eruptions. Comparison of sediment temperature profiles from different locations within the central area suggests a three-dimensional pattern of fluid flow that may be related to the conical geometry of the shallow conduit deduced from interpretation of seismic data.

Planned work

During the ARK-XXII/2 cruise, sediment temperatures will be measured using short probes operated by the ROV QUEST as well as autonomous temperature loggers mounted on the gravity corer and the autoclave piston corer. The objective of the measurements in the course of the ROV dives is to repeat a pre-defined transect of temperature profiles across the central area of the mud volcano for comparison to previous observations and joint deployments of a temperature probe and the Microprofiler at selected locations, which will be used to constrain coupled models of heat transfer and solute transport in the sediment. Measurements from greater sediment depths are required to improve the understanding of three-dimensional flow in the conduit and will be obtained by using autonomous temperature loggers mounted on the gravity corer. Combining *in-situ* temperature measurements with the recovery of pressurized cores using the autoclave piston corer will provide new insights into the temperature effects of gas-related processes.

3.7 PERIODICITY IN THE ACTIVITY OF THE HÅKON MOSBY MUD VOLCANO (HMMV)

Carolina Perez-Garcia (Uitø)

Objectives
Located in the south western Barents Sea (72°N, 14° 44' E; 1250 m water depth) in the Håkon Mosby Mud Volcano (HMMV) is a 8 -10 m high and 1 kilometre wide circular structure in the Bear Island Slide. Analysis of the surface morphology revealed a central flat area and a hummocky periphery all surrounded by a circular moat as well as mud flows. Four locations for long gravity corer sampling above the mud flows and two authigenic carbonate samples are proposed to combine with sediment echosounder data (chirp) collected in order to provide a more profound insight into the periodicity of the expulsions of the volcano.

Work at sea
Sediment echo-sounder data (Chirp) collected during both the RV *Jan Mayen* cruise (2005) and the *VICKING* cruise (2006) have revealed four main seismic units (U1, U2, U3 and U4 from bottom to top) separated by three main seismic discontinuities (D1, D2 and D3, respectively) (Perez-Garcia et al, in prep.). The youngest unit U4 presents a stratified and reflective echo-character and its lower limit D3 is a surface of downlapping reflectors. Regionalize map of D3 shows a local distribution around the volcano and its limits correlates with the boundaries of the defined mud flows (Vogt et al., 1999). In addition, Milkov et al. (2004) distinguished between old mud flows and/or debris flows westward and recent mud flows south-westward the volcano. We suggest U4 as an autochthonous mud flows unit (Perez-Garcia et al., in prep.). From the four long gravity core locations proposed, we locate one sediment core above the area defined by old mud flows, one core in the half-way between the old and recent mud flows and two sediment cores at the recent mud flows. All sediment cores are seated approximately at the locations of high resolution chirp lines. Isopach map of the U4 reveal that the thickness of the unit is ~5 m at the desired locations, and thus well within the possible length of sediment coring operations. A sediment corer logger is to be used to measure the bulk physical and chemical properties of the gravity corers collected. Moreover, the two authigenic carbonate sample locations are in the hummocky area westward of the geometrical centre of the volcano. The dating and isotope measurements of those samples may provide an additional age control of major mud flows.

3.8 ADAPTIVE COMPETENCE AND ECOLOGY OF COLD-STENOTHERMAL FISHES IN POLAR REGIONS

Rainer Knust, Melanie Bergmann, Nils Koschnick, Gisela Lannig (AWI)

Objectives
Temperature affects all biological processes and is thus considered to be one of the most important abiotic factors shaping marine ecosystems. To allow a future assessment of climate driven changes it is therefore of paramount importance to determine the status quo. Representing the only deep-water connection between the North Atlantic and the Arctic Ocean, the Fram Strait belongs to the climatically sensitive areas of the world oceans. It was in this context that the long-term deep-sea station *Hausgarten* was established in 1999 (Soltwedel et al. 2005). Indeed, long-term heat transport measurements in the Fram Strait at 79°N have shown that a warming signal from the late 1990s is currently spreading in the interior Arctic Ocean. How could this affect the resident fauna?

The thermal tolerance range of aquatic organisms has been studied for decades. A recent comprehensive model of thermal tolerance argues that ectothermic animals (i.e. those which must conform to the environmental temperatures at which they live) inhabit an optimal temperature zone. By studying life performance in cold oceans our research focuses on how boundary conditions are defined from a physiological point of view and what metabolic processes and capacities are responsible for temperature adaptation thereby affecting thermal tolerance. The adjustment of aerobic scope, reflected by mitochondrial densities and capacities is identified as a crucial step in thermal adaptation, and mitochondrial enzyme levels are an important determinant of aerobic capacity for ATP production. Recent research has shown that adjustments of aerobic capacities differ between cold-acclimated boreal and cold-adapted polar ectotherms resulting in enhanced mitochondrial matrix enzymes (citrate synthase, NADP+-dependent isocitrate dehydrogenase) over respiratory chain capacities and might support enhanced anabolic processes in cold-adapted compared to cold-acclimated animals. Indeed, temperature-dependent growth performance of Antarctic eelpout in the laboratory revealed highest growth rates at 4° C compared with 12° C for the boreal species. This indicates a mismatch between optimum and ambient habitat temperature likely to be a relict of the deep-sea origin of the genus Pachycara. Thus, thermal biology and tolerance are important physiological traits that determine whether a species survives temperature challenges and how it is affected by climate change. Changes in the abundance of key species that shape benthic assemblages may in turn affect population dynamics of prey organisms and thus benthic communities. It is thus also important to understand the ecology and functional ecological role of potential key predators. Although analyses of camera observations indicate that demersal fish belonging to the eelpout family (Zoarcidae) constitute an important fraction of the shallower *Hausgarten* and Håkon Mosby Mud Volcano megafauna, little is known to date about their physiology and functional ecological role.

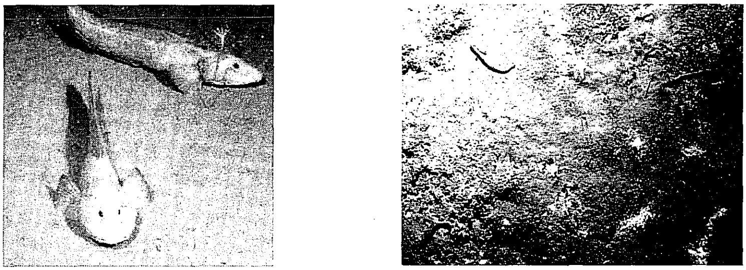

Fig. 3.2: Lycodes frigidus at central Hausgarten (2400 m, left photograph) and L. squamiventer at Håkon Mosby Mud Volcano (1250 m, right photograph)

Work at sea

Our work onboard will focus on the basic mechanisms that allow Arctic fish to maintain a high aerobic capacity as well as the capacity for growth and reproduction in the cold. Our studies will concentrate on eelpout. Zoarcids are widely distributed. They are abundant in the Southern Polar Region (e.g. Antarctic eelpout, *Pachycara brachycephalum*), in temperate latitudes (e.g. North Sea eelpout, *Zoarces viviparus*) and in the Northern Polar Region (e.g. Arctic eelpout, *Lycodes squamiventer, L. frigidus*). Thus, these species are ideal model organisms to study the differences between seasonal and latitudinal cold adaptation as well as between Southern and Northern Polar Region cold adaptation.

On board RV *Polarstern* we intend to catch Artic eelpout by means of an ROV slurp gun, baited bottom traps and traps attached to a benthic lander at water depths between 1000 and 2500m. Alive fish will be maintained in an aquarium container for a later transport to the laboratories in Bremerhaven. Samples for further studies on physiological parameters, populations dynamics and ecology, stable isotopes, growth and fecundity and food uptake will be taken from killed fishes and stored at -80° C until analysis in Bremerhaven.

3.9 INVESTIGATIONS ON THE BENTHIC FORAMINIFERAL FAUNA AND THEIR ISOTOPES OF THE HÅKON MOSBY MUD VOLCANO (HMMV)

Jutta Wollenburg (AWI)

Objectives and work at sea

In 2001, with the aid of the ROV Victor 6000 pushcores from the typical HMMV habitats have been taken for investigations on the benthic foraminiferal fauna and the isotopic signature of their tests. Three years later samples from multiple corers were taken to complete the fragmentary data set. However, despite the use of a digital system, the samples from 2001 differed significantly from those of 2004, especially the transmission electron microscope analyses on the younger material were disappointing. Therefore, I would like to get a few cores (pushcores or multiple cores) to improve our data set on ultra-structure analyzes for a satisfying closure of the running DFG project. However, my principal interest is a new proposal on experimental investigations on methane-related benthic foraminiferal faunas, submitted to the DFG for funding. For this project, autoclaves, pushcorer etc. for the use at the HMMV have been designed during the last 1.5 years. Three autoclaves were built and will be operated during this years cruise, QUEST will take the autoclaves (one per dive) to the seafloor, fill it with a pushcore, close it, and take it back onboard with the seafloor bottom pressure (125 bar). In the subsequent months the unique action of these autoclaves will enable us to carry out *in-situ* experiments on deep-sea benthic foraminifera and their associated fauna and flora. The dimensions of the autoclaves on the one hand are adapted to the HMMV environment, on the other hand, the outer dimension and handling match an older version that has already been handled by QUEST during a previous expedition, thus we expect no technical problems. Six additional pushcores (alternatively multiple core liners) will be transferred in pressure-free mesocosms for comparison with the autoclaves.

3.10 EXPLORATION OF MEIOFAUNA AND TROPHODYNAMICS IN DIFFERENT MICROHABITATS

Katja Guilini (UGent)

Project description

Since 2003, meiofauna is being studied at the Håkon Musby Mud Vulcano (HMMV) by Van Gaever et al. (2006). We want to continue this research with a focus on nematodes which dominate the community and show extreme differences in the diversity and density and a great distinctness between different microhabitats (centre, microbial mats, Pogonophora field and outer rim). Although their dominant presence and the fact that the first evidences indicate chemosynthetically derived food sources for some species, little is known on their true function as possible trophic link in the food chain, the role of their biodiversity and the link between both aspects. In collaboration with the NIOO-CEMO institute (The Netherlands), we want to gain data for a model which could contribute to the clarification of the bentho-pelagic link. Other questions which remain largely unanswered till now are formulated in the objectives of this project.

Objectives
In order to better understand the function and driving forces of their presence, the following key questions are addressed:

- What is driving the biological patchiness at seeps? Therefore the meiofauna patchiness will be investigated in relation to the possible food sources and the biogeochemical and microbiological processes.
- What is the trophic position of the meiofauna? Hence the trophic interactions between meiobenthic organisms and their potential food sources will be studied based on stable isotope and fatty acid analyses. Experiments will be performed and samples will be collected from different microhabitats in order to unravel different trophic interactions and potential selectivity for certain food sources with as main emphasis the position of the meiofauna in the benthic food web.
- How do endobenthic organisms thrive in extreme conditions of cold seeps? Here the adaptations among the thriving species to the extreme living conditions will be further dealt with.
- What is the origin of seep-meiofauna species? Therefore the fauna from different seep locations worldwide will be investigated in addition to the fauna from adjacent less extreme sites in order to estimate the importance of local adaptation and the distribution of taxa.

Work at sea
At the HMMV *in-situ* and in vitro experiments will be performed in which different ^{13}C labelled potential food sources will be added to benthic cores. Both experimental set-ups consider a time-series in which the response of the meiofauna community will be investigated and the uptake of food will be traced through the different benthic compartments. In order to identify the uptake and potential food selectivity stable isotope and fatty acid analyses will be performed after returning to the lab. For the experiments onboard, samples will be collected with a video-guided Multicorer (MUC) and incubated in a cold room at *in-situ* temperatures. The use of a video-guided ROV allows sampling of different microhabitats and deployment and recovery of the *in-situ* experiment cores. The sediment cores will be sliced on board. Samples for community analysis will be preserved on 4 % formaldehyde, while the samples for biochemical analysis will be stored at -20°C.

3.11 SEEP FINDER MODULE

Volker Karpen, Michael Hofbauer (JUB)

Objectives and work at sea
Novel sensor packages for long-term deployments have been developed to study the dynamics of cold seeps. Methane seeps at passive and active margins are often associated with the occurrence of fluid flow. Online flow chambers have the ability to detect active discharges *in-situ* . A module, which contains a methane sensor as well as an optical seep meter will be deployed at the Håkon Mosby Vulcano. It is planned to measure methane and fluid flow to discover the distribution and activity of seepage.

3.12 DEEP-SEA MEIOBENTHIC COMMUNITIES BETWEEN 70° AND 80°N FROM THE ARCTIC SEAS

Gustavo Fonsecca (AWI)

Objectives and work at sea

The Arctic Seas are characterized by two main flows: the North Atlantic current (NAC) in the eastern side and the East Greenland current (EGC) in the western. The NAC is a few degrees warmer and richer in nutrients than the EGC and, consequently, supports a much higher primary production at its euphotic zone. The primary production in the Arctic occurs in seasonal blooms in which a minor part sinks towards the deep seafloor. All the organic material deposited in the deep seafloor is within a short period (weeks to months) consumed by its inhabitants and it is believed to be the main factor structuring deep-sea benthic communities. Given this, our main objective during the cruise ARK-XXII/1b onboard of RV *Polarstern* is to sample 6 multiple cores (MUC) between Norway (70°N) and Spitzbergen (80°N) at 2000 m water depth. This sampling is comparable to the sampling performed one year before along the EGC on board of the RV *MARIA S. MERIAN* cruise MSM/2. From each MUC 4 sub-samples for each biotic (meiofauna, chloroplastic pigments and microbial biomass) and abiotic parameter (water content and grain size) will be taken. In addition to the description and comparison of the benthic system from these two sets of samples, we will have the opportunity to investigate changes in the meiobenthic community structure along two different latitudinal gradients. These samples will also be used for molecular and morphological taxonomical proposes. These studies are part of the PhD thesis carried out by Gustavo Fonseca at the deep-sea research group at AWI.

3.13 CHARACTERISATION OF CHEMOSYNTHETIC EPIFAUNA (COMPOSITION, DIVERSITY, AND FOOD WEB), BY IMAGING AND SAMPLING OF THE DIFFERENT "HABITATS“

Carole Decker, Benedicte Ritt (IFREMER)

Objectives

Main scientific objectives are the characterisation of chemosynthetic epifauna (composition, diversity, and food web) by imaging and sampling of the different "habitats" (microbial mats, pogonophoran fields, muddy areas) that we have started to sample during the *VICKING* cruise. For that purpose we need grab and slurp gun samples. Habitat mapping is another important objective to follow, as HMMV was regularly surveyed from 2002 or 2003.

4. CRUISE LEG ARK-XXII/1C: TROMSØ – LONGYEARBYEN (10.07. - 25.07.2007)

4.1 MULTIDISCIPLINARY INVESTIGATIONS AT THE ARCTIC DEEP-SEA LONG-TERM OBSERVATORY HAUSGARTEN

Thomas Soltwedel, Lennart Bittermann, Marlen Blume, Anne Grave, Christiane Hasemann, Ulrich Hoge, Normen Lochthofen, Juri Okolodkov, Anja Pappert, Burkhard Sablotny (AWI), Katarzyna Anna Grzelak (IOPAS), Christophe Rabouille, Bruno Bombled (LSCE)

The marine Arctic has played an essential role in the history of our planet over the past 130 million years and contributes considerably to the present functioning of the Earth and its life. The past decades have seen remarkable changes in key arctic variables, including a decrease in sea-ice extent and sea-ice thickness, changes in temperature and salinity of arctic waters, and associated shifts in nutrient distributions. Since arctic organisms are highly adapted to extreme environmental conditions with strong seasonal forcing, the accelerating rate of recent climate change challenges the resilience of arctic life. The stability of a number of arctic populations and ecosystems is probably not strong enough to withstand the sum of these factors which might lead to a collapse of subsystems.

To detect and track the impact of large-scale environmental changes in a the transition zone between the northern North Atlantic and the central Arctic Ocean, and to determine experimentally the factors controlling deep-sea biodiversity, the Alfred Wegener Institute for Polar and Marine Research (AWI) established the deep-sea long-term observatory *Hausgarten*, which constitutes the first, and until now the only open-ocean long-term station in a polar region.

Objectives

Hausgarten observatory includes 15 permanent sampling sites along a depth transect (1000 - 5500 m) and along a latitudinal transect following the 2500 m isobath crossing the central *Hausgarten* station (Fig. 4.1). Multidisciplinary research activities at *Hausgarten* cover almost all compartments of the marine ecosystem from the pelagic zone to the benthic realm, with some focus on benthic processes. Regular sampling as well as the deployment of moorings and different free-falling systems (bottom lander) which act as local observation platforms, have taken place since the observatory was established in summer 1999. Frequent visual observations with towed photo/video systems allow the assessment of large-scale epifauna distribution patterns as well as their temporal development. To determine the factors controlling deep-sea biodiversity, a number of biological short- and long-term experiments are carried out using the Remotely Operated Vehicle (ROV) "QUEST 4000".

Work at sea

Hydrographic data will be assessed using a CTD-system, equipped with water samplers. Water samples will be analysed for bio-optical parameters for the validation of satellite data. Organic matter produced in the upper water layers or introduced from land is the main food source for deep-sea organisms. To characterise and quantify organic matter fluxes to the seafloor, we use moorings carrying sediment traps. To assess the recycling of carbon and to calculate the fluxes of solutes across the sediment water interface, we perform *in-situ* oxygen measurements at the seabed. Virtually undisturbed sediment samples are taken using a video-guided multiple corer. Various biogenic compounds from the sediments are analysed to estimate activities (e.g. bacterial exoenzymatic activity) and total biomass of the smallest sediment-inhabiting organisms. Results will help to describe ecosystem changes in the benthal of the Arctic Ocean. The quantification of benthic organisms from bacteria to megafauna is a major goal in biological investigations. Large-scale distribution patterns of mega/epifauna organisms are assessed using an Ocean Floor Observation System (OFOS), equipped with a video camera and a still camera. Different free-falling devices carrying various biological experiments (colonisation of hardsubstrates, food enrichment to attract the small sediment-inhabiting fauna) will be used to determine the factors controlling deep-sea biodiversity. By means of the ROV "QUEST 4000" we will terminate these experiments.

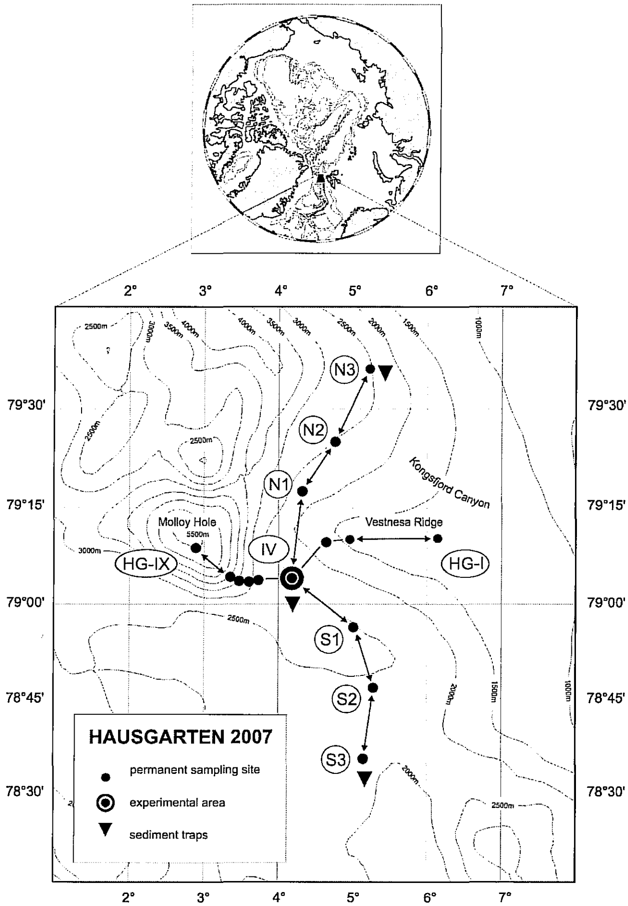

Fig. 4.1: The deep-sea long-term observatory Hausgarten *in the eastern Fram Strait*

4.2 STUDIES ON DEGRADATION RATES OF ORGANIC MATTER ON A DEPTH GRADIENT REACHING FROM SHALLOWER WATERS OFF THE WEST COAST OF SVALBARD TO A DEEP (5500 M) ARCTIC TROUGH

Anders Tengberg, Madeleine Nilsson (UGoteborg)

Objectives

The Arctic is not only essential to the global ocean circulation through formation of deepwater it makes up an important marine ecosystem which has only been sporadically studied. Our research group has developed and used state of the art *in-situ* investigation techniques (autonomous bottom landers) for more than 10 years to study biological, chemical, and physical processes at the seafloor and in sediments. We have successfully worked in several International projects using our landers in water depths from 20 - 5200 m. During the ARK-XXII/1c we will use a unique combination of technology to study the degradation rates of organic matter (important when assessing the regional and global carbon cycle) on a depth gradient reaching from shallower waters off the West Coast of Svalbard to a deep (5500 m) Arctic trough (*Hausgarten* station) which is known for its high sediment accumulation rates and exceptionally high fauna abundance and variability.

Work at sea

Material and methods

To study biological, chemical and physical processes at the seafloor one of our bottom landers (see Fig. 4.2) will be equipped with about 30 different sensors (to measure water currents, oxygen concentration, particle content in the water, salinity, temperature and depth). It will also be equipped with a video camera which has the ability to "scan" the seafloor. The main focus of these studies will be to look at the carbon turnover and burial rates in these Arctic sediments. To study these we propose to compare three different techniques, all carried to the bottom and back by our lander (see Fig. 4.2).

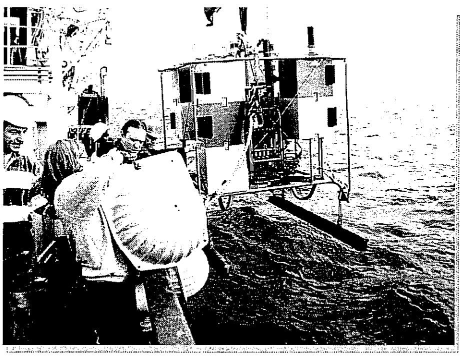

Fig. 4.2: The big autonomous Göteborg lander being deployed in the Baltic Sea within the frames of a European research project. This lander has been successfully deployed more than 100 times in water depths ranging from 20-5200 m

1. <u>Incubations</u>*:* We will measure the total carbonate (TCO_2) and nutrient production as well as the oxygen consumption *in-situ* by making parallel chamber incubations of the sediment and the overlying water. The lander is autonomous and will sink to the seafloor. There three chambers will be gently pushed into the sediment leaving about

20 cm of overlying water. The incubations start when lids are closed and stirrers start to mix the chamber water. During incubations, which generally lasts for 36 - 48 hours the oxygen concentration will be continuously monitored in the enclosed water using oxygen optodes and samples (ten from each chamber) will be automatically collected into syringes. The water samples will be analysed on-board once the lander has been recovered. The evolution in solute concentrations with time gives information about the degradation and burial of organic matter.

2. Planar Optode: A so-called planar optode will be used to obtain the oxygen concentration in two dimensions in the sediment and at the sediment-water interface. A planar optode is like an "inverted periscope" which is gently inserted into the sediment. Through a special optical technique, called luminescence quenching, it is possible to obtain high resolution oxygen images. Our group was the first to develop this technology for *in-situ* studies and this will, to our knowledge, be the first time that it is applied in the deep sea. From the oxygen images oxygen concentration gradients (profiles) can be extracted. About 600 oxygen profiles can be extracted from each image and from the profiles the sediment oxygen consumption can be calculated, which gives and independent estimate of carbon turnover rates.

3. Oxygen gradients in the bottom water: Oxygen optodes will be mounted at different levels above the bottom. These sensors will be logged at 2 s intervals. We anticipate that these measurements will reveal a gradient with lower concentrations closer to the bottom. Together with information about the currents we anticipate that this oxygen gradient can be used also to calculate the oxygen consumption of the bottom.

4.3 GEOCHEMICAL INVESTIGATIONS AT AWI HAUSGARTEN

Eberhard Sauter, Oliver Sachs (AWI)

Objectives and work at sea

In close co-operation with the AWI deep-sea group (Soltwedel et al.) we plan to proceed our geochemical investigations of the sedimentary and near-bottom environments at the *Hausgarten* area west of Svalbard.

For this purpose the main *Hausgarten* station at 2500 m water depth as well as two other selected sites will be sampled by ROV-push cores, multi corer, and bottom water sampler.

Vertical gradients of nutrients, C_{org} content, C/N ratio, porosity and other geochemical parameters are planned to be determined from surface sediment samples in order to characterize the geochemical milieu for benthic life. Oxygen gradients will also be measured from bottom water samples in order to quantify interfacial solute fluxes and rates of near-bottom respiration.

Special emphasis is laid on the exact measurement of oxygen micro gradients below the sediment water interface and in vicinity of organisms and biogenic structures. It is hoped that those gradients give new insights into the metabolistic interaction between macro fauna and their next environment. For this purpose both a ROV-operated deep-sea microprofiler (Fig. 4.3) as well as a newly developed lander-based 3D microprofiler will be deployed at several locations of the *Hausgarten* region.

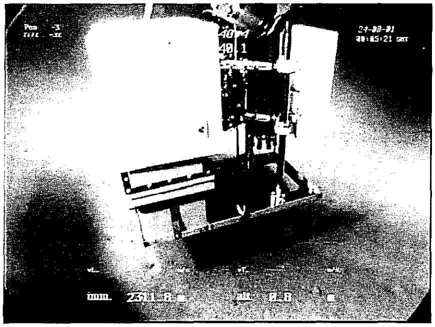

Fig. 4.3: The in-situ O_2 microprofiler (MIC) being deployed at a measuring location by ROV "VICTOR 6000"

One specific task is to measure within and outside an *in-situ* current channel deployed during cruise ARK-XIX at the seafloor to investigate benthic respiration and interfacial solute exchange under changing bottom current regimes. This work is planned to be conducted together with colleagues from CNRS.

4.4 EXPLORATION OF MEIOFAUNA AND TROPHODYNAMICS IN DEEP-SEA SEDIMENTS.

Katja Guilini (UGent), Dick van Oevelen (NIOO-CEME)

Project description
The meiofauna community at the *Hausgarten* site has already been studied over a long time period and at different depths by Eveline Hoste (UGent) in collaboration with the Alfred Wegener Institute. We want to continue this research and collaboration (with T. Soltwedel and I. Schewe) with a focus on nematodes which dominate the community and show a relatively high diversity. Although their dominant presence and the fact that they are assumed to play a crucial role as trophic link in the food chain, little is known on their true function in deep-sea sediments, the role of their high biodiversity and the link between both aspects. This lack of knowledge hinders adequate modelling of the bentho-pelagic link, which could be of substantial importance to predict the effect of potential changes in food availability due to climate change. In collaboration with the Netherlands Institute of Ecology (NIOO-CEME) we want to put gathered data in a model which could contribute to the clarification of the bentho-pelagic link.

Objectives
In order to better understand the function and driving forces of their presence, the following key question is addressed:

What is the trophic position of the meiofauna? Hence the trophic interactions between meiobenthic organisms and their potential food sources (phytodetritus, bacteria, ...) will be studied based on stable isotope and fatty acid analyses. *In-situ* and *in-vitro* experiments will be performed and samples will be collected in order to unravel different trophic interactions and potential selectivity for certain food sources with as main emphasis the position of the meiofauna in the benthic food web.

Work at sea
At the *Hausgarten* site *in-situ* and *in-vitro* experiments will be performed in which different ^{13}C labelled potential food sources will be added to benthic cores. In both experimental set-ups

the response of the meiofauna community will be investigated and the uptake of food will be traced through the different benthic compartments. The *in-vitro* experiment will consider a time-series. In order to identify the uptake and potential food selectivity stable isotope and fatty acid analyses will be performed after returning to the lab. For the experiments onboard, samples will be collected with a video-guided Multicorer (MUC) and incubated in a cold room at *in-situ* temperatures. The use of a video-guided ROV allows deployment and recovery of the *in-situ* experiment cores. The sediment cores will be sliced on board. Samples for community analysis will be preserved on 4 % formaldehyde, while the samples for biochemical analysis will be stored at -20° C.

4.5 QUANTIFICATION OF THE AT-SEA DISTRIBUTION OF SEABIRDS AND MARINE MAMMALS

Claude R. Joiris (VUB)

Objectives

The aim is to quantify the at-sea distribution of seabirds and marine mammals in the Greenland Sea, as a function of the main hydrological parameters (water temperature, salinity) allowing to identify the main water masses (Atlantic water, polar water, pack ice) and fronts structures between water masses and ice edge.

Transect counts will take place when RV *Polarstern* is sailing, since at stations seabirds can be massively attracted by ships.

This expedition is part of a long term study in both polar regions - mainly the European Arctic seas - started in 1973 (C R Joiris).

Data will be discussed as reflecting food availability, i.e. the ecological structure of the whole water column. Another aspect will be the historical evolution in numbers since 1973 and the numerous expeditions in between, with special attention to climate change and possible changes in pack ice extend.

The main aims are:

- To improve the knowledge and understanding of the factors influencing their distribution, such as hydrology (water masses, fronts, ice edge, pack-ice); when available, data on the other biological compartments will be integrated in an interdisciplinary interpretation: phyto- and zooplankton, fish etc. In order to allow such a discussion, data will be translated in density, biomass, and calculated food intake, taking differences in diet into account.
- To complete the study of the ice conditions on their distribution: 2005 provided data during a period of very pour ice conditions (NAO), with an apparent breeding failure of one of the most numerous species of the region: little auk *Alle alle* of Jan Mayen. This new expedition should provide more data on the topic; on the longer term, these data will be integrated in a model allowing to foresee probable consequences of global warming on the ecology of polar seas.
- A first attempt to detect long term changes can be made as well, since we are the only team accumulating data - obtained with the same methodology - in the Norwegian and Greenland seas since 1973 (more than 15 expeditions, of which 12 were analyzed in a synthetic paper: Joiris, 2000).

5. BETEILIGTE INSTITUTE/ PARTICIPATING INSTITUTES ARK-XXII/1 A-C

	Adresse Address
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DWD	Deutscher Wetterdienst Hamburg Abteilung Seeschifffahrt Bernhard-Nocht Str. 76 20359 Hamburg / Germany
FIELAX	FIELAX, Gesellschaft für wissenschaftliche Datenverarbeitung mbH Schifferstr. 10-14 27568 Bremerhaven / Germany
HeliTransair	HeliTransair Flugplatz 63329 Egelsbach / Germany
IFM-GEOMAR	Leibniz-Institut für Meereswissenschaften IFM-GEOMAR Düsternbrooker Weg 20 24105 Kiel / Germany
IFREMER	Institut Français de Recherche pour l'Exploitation de la Mer BP70 29280 Plouzane / France
IOPAS	Institute of Oceanology PAS Polish Academy of Sciences Powstancow Warszawy 55, P.O. Box 68 81–712 Sopot / Poland
JUB	Jacobs University Bremen Campusring 1 28759 Bremen / Germany

	Adresse Address
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MPI	Max Planck Institute for Marine Microbiology Celsiusstr. 1 28359 Bremen / Germany
NIOO - CEME	Netherlands Institute of Ecology Centre for Estuarine and Marine Ecology Korringaweg 7, Yerseke 4400 AC Yerseke / The Netherlands
Oeckltv	Oecklfilmtv Produktionen Mainzer Strasse 28 50678 Köln / Germany
Oktopus	Oktopus GmbH Kieler Straße 51 24594 Hohenwestedt / Germany
OPTIMARE	OPTIMARE Am Luneort 15a 27572 Bremerhaven / Germany
RCOM	Research Centre Ocean Margins University of Bremen P.O. Box 330440 D-28334 Bremen / Germany
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UPly	Department of Marine SciencesUPly University of Plymouth Plymouth Devon, PL4 8AA / United Kingdom
USev	Biodiversidad y Ecología de Invertebrados Marinos Departamento de Fisiología y Zoología Facultad de Biología Universidad de Sevilla Reina Mercedes 6 41012 – Sevilla / Spain
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6. FAHRTTEILNEHMER / PARTICIPANTS

6.1 FAHRTTEILNEHMER / PARTICIPANTS ARK-XXII/1A

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Brauer	Jens	Helitransair (1a-c)
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Schauer	Jürgen	IFM-GEOMAR

6.2 FAHRTTEILNEHMER / PARTICIPANTS ARK-XXII/1B

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Abegg	Friedrich	RCOM
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Buldt	Klaus	DWD
Decker	Carole	IFREMER
Felden	Janine	MPI
Feseker	Tomas	MPI
Fonsecca	Gustavo	AWI
Grünke	Stefanie	MPI
Guilini	Katja	UGent
Hofbauer	Michael	JUB
Hohnberg	Hans-Jürgen	RCOM
Karpen	Volker	JUB
Klages	Michael	AWI
Knust	Rainer	AWI
Koschnick	Nils	AWI
Lannig	Gisela	AWI
Laurent	Melina	UParis
Müller	Eugen	DWD
Nordhausen	Axel	MPI
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Perez-Garcia	Carolina	UiTø
Ritt	Benedicte	IFREMER
Sablotny	Burkhard	AWI
Schüßler	Gabriele	MPI
Wenzhöfer	Frank	MPI
Wilkop	Tomas	MPI
Wollenburg	Jutta	AWI
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Bergenthal	Markus	MARUM
Duessmann	Ralf	MARUM
Meyer	Jörn Patrick	MARUM
Ratmeyer	Volker	MARUM
Rehage	Ralf	MARUM
Reuter	Michael	MARUM
Seiter	Christian	MARUM

6.3 FAHRTTEILNEHMER / PARTICIPANTS ARK-XXII/1C

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Bauerfeind	Eduard	AWI
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Blume	Marlen	AWI
Bombled	Bruno	LSCE
Buldt	Klaus	DWD
Cathalot	Cecile	LSCE
Grave	Anne	AWI
Grzelak	Katarzyna Anna	IOPAS
Guilini	Katja	UGent
Hasemann	Christiane	AWI
Hoge	Ulrich	AWI
Joiris	Claude.	VUB
Klages	Michael	AWI
Knust	Rainer	AWI
Koschnik	Nils	AWI
Lannig	Gisela	AWI
Lochthofen	Normen	AWI
Monsees	Matthias	OPTIMARE
Müller	Eugen	DWD
Nilsson	Madeleine	UGoteborg
NN		IOPAS
NN (Engineer)		AWI
NN-OFOS Technician		Oktopus
Oevelen	Dick van	NIOO-CEME
Okolodkov	Juri	AWI
Pappert	Anja	AWI
Rabouille	Christophe	LSCE
Sablotny	Burkhard	AWI
Sachs	Oliver	AWI
Sauter	Eberhard	AWI
Schewe	Ingo	AWI
Soltwedel	Thomas	AWI
Sterk	Wilfried	VUB
Tengberg	Anders	UGoteborg
Outreach & Education		
Bauer	Michael	Germany
Eggermont	Mieke	Belgium
Smaadahl	Thale	Norway
QUEST Team:		
Duessmann	Ralf	MARUM
Franke	Phillip	MARUM
Ratmeyer	Volker	MARUM
Rehage	Ralf	MARUM
Reuter	Michael	MARUM
Schmidt	Werner	MARUM
Seiter	Christian	MARUM
Zarrouk	Marcel	MARUM

7. SCHIFFSBESATZUNG / SHIP'S CREW

Name of Ship: RV *POLARSTERN*
Nationality: GERMAN
Bremerhaven-Tromsø 29 May 2007 - 25 July 2007

No.	Name	Rank
1.	Pahl,Uwe	Master
2.	Grundmann, Uwe	1.Offc.
3.	Ziemann,Olaf	Ch.Eng.
4.	Bratz, Herbert	2.Offc.
5.	Röder, Thomas	2.Offc.
6.	Hering, Igor	2.Offc.
7.	Schneider, Marcel	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.	Vehlow, Ringo	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.

ARK-XXII/2

28 July - 10 October 2007

Tromsø - Bremerhaven

Chief scientist: ***Ursula Schauer***

Contents

1. ÜBERSICHT UND FAHRTVERLAUF

Ursula Schauer (AWI)

Die Expedition ARK-XXII/2 ist ein zentraler Beitrag zum Internationalen Polarjahr 2007/08 (IPY 2007/08). Sie trägt insbesondere zu zwei im IPY-Wissenschaftsplan aufgeführten Zielen bei:

"1. Status: to determine the present environmental status of the polar regions"

und

"2. Change: to quantify, and understand, past and present natural environmental and social change in the polar regions; and to improve projections of future change"

(The Scope of Science for the International Polar Year; http://www.ipy.org)

ARK-XXII/2 folgt der Strategie, dass diese Ziele nur in Kooperation mit anderen Expeditionen erreicht werden können. Gemeinsam mit den zeitnah stattfindenden Expeditionen

- NABOS (mit russischem Eisbrecher)
- NORDIC LSBI (IB Kapitan Dranitsyn und RV Ivan Kireev);
- LOMROG (IB Oden);
- AGAVE (IB Oden);
- SOFIADEEP (RV Maria S Merian)
- Drift des französischen Schiffes TARA und der russischen Eisstation NP 35
- AARI-Expedition (Academic Fedorov)
  (siehe http://www.asci-ipy für eine Übersicht)

wird erstmals während des IPY 2007/2008 eine synoptische Aufnahme des physikalischen, chemischen und biologischen Zustands des gesamten Arktischen Ozeans in einer Phase rasanten Klimawandels durchgeführt. Für die Bewertung der zur Zeit beobachteten Veränderungen, wie der Verringerung des Meereises, der Erwärmung der Wasserschichten, der Verschiebung der Ozeanzirkulation mit den entsprechenden Auswirkungen auf das Vorkommen von Stoffen, die über die Flüsse eingetragen werden, als auch den durch Ozean- und Eisorganismen produzierten sowie der Lebewesen selbst ist eine solche umfassende Gesamtaufnahme als Ausgangspunkt für Langzeitbeobachtungen notwendig. Insbesondere liefert ARK-XXII/2 Beiträge zu folgenden IPY-Projekten:

SPACE (Synoptic Pan-Arctic Climate and Environment Study, IPY-EoI #18),
GEOTRACES: Spurenstoffe in der Arktis (IPY-EoI #45),
iAOOS (Integrated Arctic Ocean Observing System, IPY-EoI #80)
(siehe http://www.ipy.org/development/eoi/index.htm)

sowie zu dem deutsch-russischen Projekt auf der bilateralen Liste gemeinsamer Forschungsvorhaben VERITAS (Variability and Export of Riverine Matter into the Arctic Ocean and late (Paleo-) Environmental Significance). Gleichzeitig ist ein Großteil der Arbeiten Bestandteil des durch die EU geförderten *Integrated Programmes* DAMOCLES (Developing Arctic Modelling and Observing Capabilities for Long-term Environment Studies).

ARK-XXII/2 übernimmt dabei die Aufnahme im Eurasischen Sektor der Arktis. Um insbesondere dekadische Veränderungen zu erfassen, ist die Expedition so konzipiert, dass Schnitte früherer Expeditionen, wie *Oden* 1991, FS *Polarstern* 1993, FS *Polarstern* 1995 und FS *Polarstern* 1996 wiederholt werden. So können räumliche und zeitliche Variabilität unterschieden und damit erstmalig gleichzeitig die Entwicklung ozeanographischer, eisphysikalischer, sowie biologischer und biogeochemischer Parameter über eine Dekade erfasst werden. Zusätzlich wird ein geologisches Programm zur Untersuchung der Verteilung von Flusswasser und seiner Fracht bei unterschiedlichen Klimabedingungen durchgeführt.

Die Schnitte erstrecken sich von den Schelfgebieten der Barents-, der Kara- und der Laptewsee über das Nansen- und das Amundsenbecken bis ins Makarowbecken. Auf allen Schnitten werden Messungen und Beprobungen zur Dicke und RADAR-Rückstreueigenschaften des Meereises, zu Eigenschaften und Zirkulation der Wassermassen, zum Austausch zwischen den Schelfmeeren und den tiefen Becken, zu Zyklonen in der zentralen Arktis, zu den Transportwegen von natürlichen Spurenstoffen in der Arktis; zur chemischen Zusammensetzung von gelösten organischen Substanzen und deren Rolle als Marker für Wassermassen, zur Auswirkung der abnehmenden Meereisbedeckung und – dicke auf die Lebensgemeinschaften im und unter dem Packeis, zu Mechanismen der Verbreitung und der Anpassungsstrategien des Zooplanktons im Arktischen Ozean und zur Biodiversität polarer Tiefsee-Eukaryoten durchgeführt. Nördlich der Karasee werden zusätzlich Sedimentproben zur Bestimmung der spätquartären Veränderlichkeit des Flusswasserausstroms und der Vereisungsgeschichte genommen.

Die Reise beginnt am 28. Juli 2007 in Tromsö. Der erste Schnitt führt entlang 34°E von der Barentssee bis ins Amundsenbecken; von dort geht es nach Osten, um je einen Schnitt westlich und östlich der St. Annatroges zu bearbeiten. Entlang dieser Schnitte werden Sedimentkerne genommen, um durch geologische Untersuchungen die Rolle des sibirischen Flußwassereintrags im Holozän zu untersuchen. Ein nächster Schnitt führt über den Lomonosowrücken ins Makarowbecken und kreuzt damit Ausbreitungswege des Atlantikwassers und des Süßwassers aus den sibirischen Festlandsabflüssen. Ein langer Schnitt führt zurück in die Laptewsee. Von dort aus wird die Rückreise durch die Nordostpassage angetreten. Am 10. Oktober 2007 wird die Expedition in Bremerhaven enden.

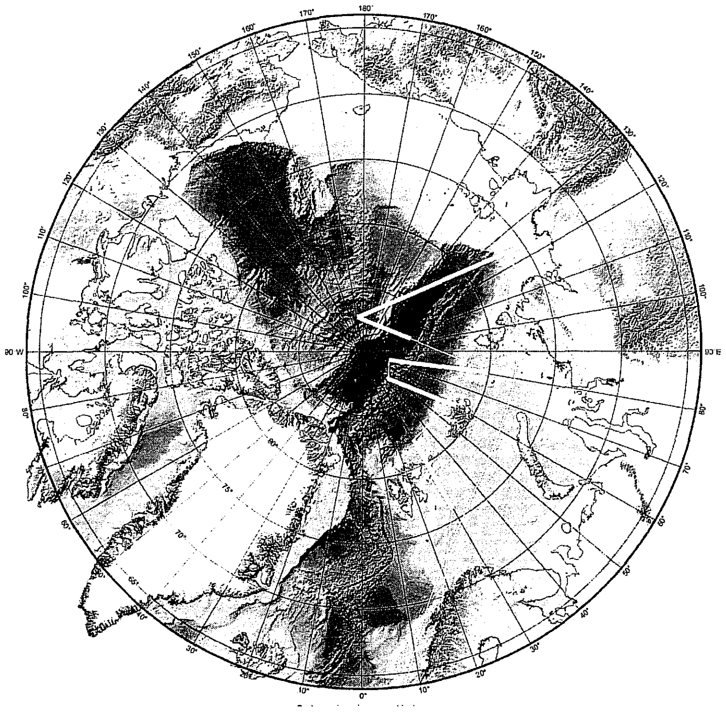

Abb. 1: Arbeitsgebiet und Fahrtroute während ARK-XXII/2. Die Reise beginnt am 28. Juli in Tromsö und endet am 10. Oktober 2007 in Bremerhaven.
Fig. 1: Planned cruise track für ARK-XXII/2. The journey starts on 28 July in Tromsø and ends on 10 October 2007 in Bremerhaven.

Der genaue Verlauf der Reise ist abhängig von russischer Forschungspolitik bezüglich der Forschungsgenehmigung für die russische Wirtschaftszone und der Möglichkeit die Nordostpassage zu durchfahren.

ITINERARY AND SUMMARY

The expedition ARK-XXII/2 is a central contribution to the International Polar Year 2007/08 (IPY 2007/08). In particular it serves two objectives formulated in the IPY science plan:

> "1. *Status: To determine the present environmental status of the polar regions"*
>
> *und*
>
> "2. *Change: To quantify, and understand, past and present natural environmental and social change in the polar regions; and to improve projections of future change"*
>
> (The Scope of Science for the International Polar Year; http://www.ipy.org)

ARK-XXII/2 follows the strategy that these goals can only be achieved in co-operation with other expeditions. For the first time a synoptic survey of the physical, chemical and biological state of the entire Arctic Ocean will be carried out conjointly with other expeditions that take place at the same season

- NABOS (with a Russian icebreaker)
- NORDIC LSBI (IB Kapitan Dranitsyn and RV Ivan Kireev),
- LOMROG (IB Oden),
- AGAVE (IB Oden),
- SOFIADEEP (RV Maria S Merian),
- Drift of the French vessel TARA and the Russian icestation NP 35,
- AARI-Expedition (Academic Fedorov),
  (see http://www.asci-ipy for an overview)

in a phase of rigorous climate change. For the assessment of the presently observed concurrent decrease in sea ice, warming of the upper ocean and the shifts in ocean circulation with the respective impacts of distribution of matter that is imported by river runoff and produced by ocean and ice organisms as well as on the biota itself such a comprehensive survey is necessary as a baseline for long-term observations.

In particular ARK-XXII/2 contributes to the following IPY projects:

> SPACE (Synoptic Pan-Arctic Climate and Environment Study, IPY-EoI #18),
> GEOTRACES: Geotraces in the Arctic (IPY-EoI #45),
> iAOOS (Integrated Arctic Ocean Observing System, IPY-EoI #80)
> (see http://www.ipy.org/development/eoi/index.htm),

as well as to the German-Russian project which is part of the bilateral list of joint research programmes VERITAS (Variability and Export of Riverine Matter into the Arctic Ocean and late (Paleo-) Environmental Significance). During the same time a large part of the work will be the implementation of the EU funded *Integrated Programmes* DAMOCLES (Developing Arctic Modelling and Observing Capabilities for Long-term Environment Studies).

In the context of IPY, ARK-XXII/2 takes its share in covering part of the Eurasian sector of the Arctic. In order to enable detection of decadal change the expedition is designed to repeat large-scale sections that were made in the nineties of the last century, such as *Oden* 1991, RV *Polarstern* 1993, 1995 and 1996. In this way spatial and temporal variations can be distinguished which is a prerequisite to assess the development of water masses, circulation, sea ice, as well as biological and biogeochemical parameters. During the same time a geological programme serves to investigate the distribution input from of river runoff at different climate conditions.

This work will be carried out along CTD sections (see map) which extend from the shelves of the Barents, Kara and Laptev seas across the Nansen and Amundsen Basin into the Makarov Basin. On all sections measurements will be carried out and samples will be taken to investigate thickness and back-scatter of sea-ice, properties and circulation of water masses, exchange between shelf seas and deep basins, cyclones in the central Arctic, transport pathways of natural trace elements and isotopes, chemical composition of dissolved organic matter and their role as markers of water masses, and the impact of decreasing sea ice on the organisms and ecosystems in and below the sea ice, the mechanisms of spreading and adaptations strategies zooplankton and the eukaryotic diversity in fine fractions of deep-sea sediments. North of the Kara Sea, in addition to that sediment cores will be taken for the determination of the Late Quaternary variation of river runoff and of the Eurasian Arctic glaciation history.

The cruise will start on 28 July 2007 in Tromsø. The first section runs along 34°E from the Barents Sea into the Amundsen Basin; from there we will proceed eastwards to take sections both west and east of the St. Anna Trough to get the Atlantic Water boundary current upstream and downstream of the confluence of the Fram Strait and the Barents Sea branch. Along these two sections sediment samples for geological investigations will be taken. The work continues along a section extending into the Makarov Basin thus crossing the pathways of Atlantic Water returning to the Fram Strait as well as that of river water from the Siberian shelves. The work will finish with a long section back to the Laptev Sea. From there we will get back along the Northern Sea Route and return to Bremerhaven where RV *Polarstern* will arrive on 10 October 2007.

2. SEA ICE

2.1 SEA ICE THICKNESS MONITORING IN THE TRANS POLAR DRIFT

Stefan Hendricks, Lasse Rabenstein, Volker Thor Leinweber (AWI)

Objectives
The Arctic summer sea ice extent has decreased by 8 % per decade for the past 30 years.

By using satellite technology the sea ice cover is easy to observe. Huge areas will be overflown several times a month. Observations of sea ice thickness is a completely different problem and a much more complicated task. At present there is no satisfying method to measure sea ice thicknesses with a high degree of accuracy from space. Therefore, in 1991, the AWI started to measure ice thicknesses in the Trans Polar Drift using electromagnetic (EM) induction sounders, first solely on the ground but from 2004 on with the so-called EM Bird which is mounted beneath a helicopter. Measurements were done during RV *Polarstern* cruises in 1991, 1996, 1998, 2001 and 2004. This time series shows a 20 % thinning of level sea ice in the Trans Polar Drift in the last 13 years. During ARK-XXII/2 intensive helicopter EM-Bird operation shall continue the ice thickness time series of the years 1991-2004.

Sea ice can be classified in many ways. For EM-Bird measurements the classification in level ice and deformed ice is of interest. Level ice is flat and grows thermodynamical whereas deformed ice grows by wind and ocean driven forces. The EM-Bird works accurately over level ice but underestimates ice thicknesses of deformed ice by up to 50%. The goal is to improve our understanding of the processes which are responsible for the underestimation of the ice thickness in deformed ice. Therefore an extensive ground truth study for the EM-Bird is planned. Thus comparison of *in-situ* and EM datasets of a highly three dimensional sea ice structure shall be possible. These datasets will be used as a basis for theoretical modelling of the effects of deformed ice on helicopter EM measurements. The modelling studies will investigate the possibility to retrieve more quantities, e.g. the porosity of deformed ice, from recent and upcoming datasets.

Work at sea

- Regular flights of 1 to 2 hours duration with the EM-Bird, laser altimeter and a nadir-looking digital video camera.
- *In-situ* ice thickness measurements in deformed ice using electrical hand drillers with EM-Bird overflights at the same time.
- Ice thickness profiles using a Geonics EM-31 (ground based EM sounder) drilled ice-cores and geometrically corrected levelling of the ice surface (freeboard measurement) during 1 to 2 hour-long stations, with collection of ice-cores for determination of temperature and salinity profiles through the ice.
- Standardised hourly visual ice observations.

2.2. MELT POND DISTRIBUTION IN THE EASTERN ARCTIC DURING LATE SUMMER

Stefan Kern, Andreas Winderlich (IfM HH), Stefan Hendricks, Lasse Rabenstein (AWI)

Objectives

Melt ponds form on Arctic sea ice every summer but have been observed on only very few occasions on Antarctic sea ice. They are on average about 10 m^2 in size and half to over one meter deep. The coverage of sea ice with melt ponds is quite variable. They can cover more than 40 % of the sea ice, while other sea ice areas may be basically free of melt ponds. Degree of sea ice deformation, snow load at the beginning of the melt period, and number of pond formation-drainage cycles, can explain this variability in coverage.

By their low albedo melt ponds strongly influence the surface albedo of sea ice. The unknown fraction of sea ice covered by melt ponds makes an accurate estimation of the surface albedo distribution of Arctic sea ice during summer a difficult task. Melt ponds are also known to cause (typically) an underestimation of the sea ice concentration derived from satellite microwave radiometry during summer.

Remote sensing techniques relying on data in the visible and infrared (IR) frequency range are severely hampered by the quasi-permanent cloud cover during Arctic summer. Satellite microwave radiometry, which is independent of daylight and clouds, suffers from a coarse spatial resolution (O(10 km)). Active microwave sensors enable a much finer spatial resolution (O(10 m) to O(100 m)) and by this are better suited to identify melt ponds and to get the melt-pond fraction on sea ice. Analysis of data from sensors operating in C-Band at

5.3 GHz or Ku-Band at 13.4 GHz have led to first encouraging results. However, with just one frequency or polarization, identification of melt ponds and estimating their distribution is complicated by signal ambiguities between the melt-pond surface and the surrounding sea ice.

Our aim during the expedition is to find the optimal frequency/polarization/incidence angle combination for melt-pond identification and estimation of their spatial distribution using a helicopter-borne Scatterometer in combination with video and IR-camera imagery.

Work at sea
We will carry out (with focus on the first half of the expedition):

- Helicopter-borne measurements of the radar backscatter of melt-pond covered sea ice at frequencies of 1.0 GHz (L-Band), 2.4 GHz (S-Band), 5.3 GHz (C-Band), 10.0 GHz (X-Band) and 15.0 GHz (Ku-Band) at both like- (vertical VV, horizontal HH) and both cross-polarizations (HV, VH), at incidence angles of 20 – 65 ° using the Multi_Scat instrument of the IfM Hamburg.
- Simultaneous helicopter-borne video imagery and IR-temperature measurements along the same track.
- *In-situ* measurements of surface and sub-surface ice parameters (temperature, salinity, porosity, surface roughness) and meteorological measurements (air temperature, wind speed and direction).
- Acquisition of AVHRR imagery.

All these measurements will be carried out as simultaneous as possible to overpasses of relevant satellite sensors (ALOS Palsar, L-Band; Envisat ASAR, C-Band; TerraSAR-X, X-Band; AVHRR, MODIS), data of which will be acquired as well. The final goal is to develop an algorithm with which the melt-pond distribution (or alternatively the surface albedo distribution) can be inferred from multi-frequency / multi-polarization spaceborne active microwave observations.

2.3. THIN-ICE THICKNESS ESTIMATION IN THE EASTERN ARCTIC DURING FALL

Stefan Kern, Andreas Winderlich (IfM HH), Stefan Hendricks, Lasse Rabenstein (AWI)

Objectives
The Arctic sea ice cover is shrinking in extent and seemingly also in thickness. Model scenarios indicate a considerably reduced if not even a vanishing summer sea ice cover until 2100. The associated shorter freezing season and more open water to re-freeze during fall suggest larger areas of thin ice than we have now. In contrast to thick (say above 80 cm) sea ice, thin sea ice allows a considerably larger ocean-atmosphere heat exchange during winter. Ice formation on the ice underside is larger for thin than for thick ice, resulting in more brine release into the ocean. Thin ice is where frost flowers grow, which are believed to substantially influence the lower troposphere halogen chemistry.

Existing methods to identify small thin sea ice areas (leads) are based on data from satellite active microwave sensors (e.g. Radarsat-1 SAR); polynyas, which typically comprise a larger thin ice area than leads, can be monitored using satellite microwave radiometry. To estimate its thickness usually additional information (numerical model or additional satellite data from a different frequency range) is required. Satellite altimeter observations are not accurate enough to get estimates of the thin-ice thickness because they measure the freeboard height of the sea ice.

Our aim during the expedition is to find the optimal frequency/polarization/incidence angle combination for unambiguous thin-ice identification and estimation of its thickness using a helicopter-borne scatterometer in combination with video and IR-camera imagery, helicopter-borne ice thickness sensing using the EM-Bird of the AWI, and *in-situ* measurements of the ice properties (e.g. surface roughness, temperature, salinity, grain-size profiles). The latter measurements will be used to improve numerical modelling of the radar backscatter of thin sea ice to optimize and better understand current thin-ice thickness retrieval techniques. EM-Bird ice thickness and IR-camera data will be used to develop and evaluate the thickness retrieval method. The final goal is to develop an algorithm with which satellite active microwave data can be used to reliably estimate an ice thickness of only a few centimeters. Only these data offer the spatial resolution in combination with the independence regarding daylight and weather influences that is required for this task.

Work at sea

We will carry out (with focus on the second half of the cruise):

- Helicopter-borne measurements of the radar backscatter of thin (below 30 cm) sea ice at frequencies of 1.0 GHz (L-Band), 2.4 GHz (S-Band), 5.3 GHz (C-Band), 10.0 GHz (X-Band) and 15.0 GHz (Ku-Band) at both like- (vertical VV, horizontal HH) and both cross-polarizations (HV, VH), at incidence angles of 20 – 65° using the Multi Scat instrument of the IfM Hamburg.
- Simultaneous helicopter-borne video imagery and IR-temperature measurements along the same track.
- Quasi-simultaneous measurements of the ice thickness using the EM-Bird of the AWI along the same track.
- *In-situ* measurements of sea ice (see above) and meteorological parameters.
- Acquisition of AVHRR imagery

All these measurements will be carried out as simultaneously as possible to overpasses of relevant satellite sensors (ALOS Palsar, L-Band; Envisat ASAR, C-Band; TerraSAR-X, X-Band; AVHRR, MODIS).

2.4. ARCTIC SEA ICE FAUNA – COMMUNITY COMPOSITION, FEEDING ECOLOGY AND ENVIRONMENTAL PHYSIOLOGY

Rainer Kiko, Maike Kramer, Stefan Siebert, Alice Schneider (IPÖ)

Objectives

Sea ice covers large areas of the polar oceans: in the Arctic, approx. 7 Mio km^2 are covered with ice in summer time, 14 Mio km^2 in winter time. This ice cover plays a crucial role not only for geophysical processes, but also for the biology in the polar regions. Sea ice is not a solid block, but a matrix permeated with brine channels, which vary in diameter from micrometers to centimeters. These brine channels make up one habitat for a special community, the sympagic (ice-associated) community. It comprises viruses, bacteria, fungi, microalgae, protozoans and small metazoans. With an average temperature below -1.9° C and temperature extremes of approx. -22° C, the brine channels represent one of the coldest environments on earth. Salinity in the brine channels is coupled to the environmental temperature and rises when temperatures drop below the freezing point, as only water and not the contained solutes crystallize. The brine salinity can vary between approx. S = 220 at -22° C ice temperature and S = 2 - 3 during meltwater flushing in summer near 0° C.

Our studies will focus on sea ice metazoans (also called sympagic meiofauna), multicellular animals in the size range of about 20 µm to 2 mm, as well as on under-ice amphipods. The meiofauna, which has been found in arctic sea ice so far, comprises mainly of copepods, rotifers, turbellarians and nematodes. While sea ice algae have received considerable attention since the beginning of biological sea ice studies, sympagic meiofauna has been studied only recently. Community composition in the arctic pack ice and the factors influencing it are still not fully understood, especially as seasonality is concerned. Virtually nothing is known about the feeding ecology of sympagic meiofauna. These animals are however expected to play an important role in the sympagic ecosystem and in cryo-pelagic coupling, being a potential mediator of biomass and energy from algae, bacteria and protozoans to higher trophical levels. It is thus important to improve our knowledge on the community composition and ecology of sympagic meiofauna in order to understand their role in the functioning of the polar ecosystems. What enables sympagic metazoans to survive at low temperatures down to approx. -6° C is another interesting question for our working group.

The predicted loss of perennial sea ice in the Arctic Ocean will lead to major changes, if not destruction of an ecosystem, which is nearly as large as Australia (7 Mio km^2) (Intergovernmental Panel on Climate Change, 2007). Species dependent on perennial arctic sea ice will probably be extinguished at the end of the current century. Therefore, studies on all topics of sea ice biology are urgently needed, especially on the identification of endangered species, description of their life cycles and physiology and on the collection of genetic information (even complete genomes). Furthermore the observation and modelling of changes in the whole ecosystem, which might occur due to a change from perennial to seasonal sea ice cover are of high importance.

This cruise will give us the opportunity to study the sympagic meiofauna community in the high Arctic over a huge area during late summer, especially as their feeding ecology and environmental physiology are concerned. Furthermore, comparative studies on the meio- and macrofauna communities of first-year and multi-year ice will be conducted in order to assess potential changes in the marine ecosystem due to global warming and arctic sea ice retreat.

Our studies on the community composition of sympagic meiofauna will accomplish our data sets from previous cruises, allowing assumptions about spatial heterogeneity and seasonality in the sea ice habitat. Experiments and analysis concerning feeding ecology, in combination with mathematical models, will give information about the pathways of energy and matter through the sympagic ecosystem and give an idea about the role of sympagic meiofauna within the high arctic food web.

Our work should result in the establishment of one Arctic sympagic species as a model system for research on cold acclimation and adaptation of sea ice inhabiting meiofauna organisms and in a better understanding of mechanisms allowing their survival at low temperatures.

Comparing species diversity and abundances of sea ice organisms in first-year and multi-year pack ice will give us valuable insights in potential changes of sea ice communities due to climate change processes in the Arctic Ocean.

Work at sea
The sympagic meiofauna community will be analysed qualitatively and quantitatively, and the sea ice habitat will be characterized in terms of several environmental parameters. For this, several ice cores, cut in sections for vertical resolution, and pump samples of under-ice water will be taken at each station. Ice cores will be used for meiofauna countings, and for determination of *in-situ* temperature, bulk salinity, chlorophyll a (chl a) and phaeopigment (phaeo) content. Under-ice water will be analysed for meiofauna, *in-situ* temperature, salinity profiles, chl a and phaeo content. Sorting and counting of meiofauna may partly be conducted on alive samples onboard the vessel, but mainly on formalin fixed samples at the home laboratory. Abundances of under-ice amphipods will be estimated from under-ice video images.

Meio- and macrofauna will also be collected for various experiments and analyses concerning feeding ecology and environmental physiology. Individuals will be isolated alive from bottom sections of ice cores, from slush found in the gap layer between rafted floes, from ice pieces collected by ice fishing, and from under-ice water and zooplankton net samples. Part of the experiments will already be conducted onboard. For further experiments in our home laboratory, cultures of sympagic meio- and macrofauna and sympagic algae will be established during the cruise.

In order to gain information about the role of sympagic meiofauna for the sympagic food web, we will conduct feeding experiments with dominant sympagic meiofauna species as predators or grazers and different sympagic meiofauna, protozoans or ice algae as food. In basic predator-prey experiments, only one prey taxon will be offered to the predators and the influence of prey concentration on the predation rate (functional response) will be studied. Additionally, in food-choice experiments, several prey taxa will be offered to the predators at the same time, and preference for particular prey will be studied. Grazing experiments on ice algae will be conducted not only in suspensions of algae but also on surfaces, in order to simulate *in-situ* conditions. Countings of fixed algae and analysis of fixed faecal pellets will be performed at the home laboratory. Further, *in-situ* grazing activity of sympagic copepods will be studied. For this, bottom sections of ice cores will be stained with an inert dye, which is then taken up by the copepods and allows for determination of *in-situ* gut retention times. The average chl a content in the guts of each species analysed will be determined by gut fluorescence measurements at the home laboratory. From these, *in-situ* grazing rates can be estimated.

For gut content analyses, meiofauna organisms will be isolated quickly from the ice and fixed in picric acid formaldehyde (PAF). At the laboratory, the animals will be cut, and the gut content will be inspected with a scanning electron microscope (SEM). Due to the quick fixation, gut content analyses will reveal *in-situ* diets.

For the biochemical analyses of fatty acids as well as stable carbon and nitrogen isotopes, sympagic meiofauna organisms will be sorted alive onboard, and stored deep-frozen (-80° C) until analysis in the laboratory. Several fatty acids are not produced by the animals themselves, but are taken up with their food. Fatty acids can thus present information about the diet consumed *in-situ*. The stable isotope ratios of carbon ($\delta^{13}C$) and nitrogen (($\delta^{15}N$)

provide a time-integrated measure of the trophic position in a certain food web, and can also provide information on the major carbon source of an organism.

During this cruise, adaptations of sympagic species to low temperatures and high salinities will be analysed with physiological and molecular-biological methods. For this purpose we will determine the supercooling points of whole animals (sympagic and pelagic) and the thermal hysteresis and osmolarity of their hemolymph after different temperature and salinity incubations. This will show, if these organisms are isoosmotic to their habitat and whether they use antifreeze agents to avoid intracellular ice formation. Furthermore we will determine tolerated temperature extremes for these species. Comparison of sympagic with pelagic organisms hopefully will show, why some pelagic organisms cannot survive within sea ice and which physiological mechanisms are needed to survive within the ice.

The transcription of DNA to mRNA is the first step of protein synthesis. Proteins are the main effectors of physiological functions and adaptations. As protein synthesis is energy demanding, it is very important for the cell to control the first synthesis step very precisely. Therefore gene expression analysis allows us to get a first insight into physiological adaptation mechanisms responsible for the survival of sympagic species.

For this purpose, organisms of the same species will be isolated from the sea ice and incubated at -1.2° C (S = 25) and at -3.1° C (S = 55). From these two populations, mRNA will be isolated and differentially expressed transcripts will be isolated using a molecular biological technique called "Suppression Subtractive Hybridisation" (SSH). Thereafter, these differentially expressed transcripts will be sequenced and furthermore characterised with different molecular-biological methods, e.g. real-time PCR or Micorarray analysis.

Comparison with the Antarctic sympagic copepod species *Stephos longipes*, for which an analogue SSH –cDNA library already exists, will allow us to identify the mechanisms which sympagic organisms at both poles have developed, in order to survive within the ice.

3. OCEANOGRAPHY

Benjamin Rabe, Serge Pisarev, Ursula Schauer, Andreas Wisotzki (AWI)
Bert Rudels (FIMR), Takashi Kikuchi, Sebastian Mechler (OPTIMARE)

Objectives

The circulation and water mass properties of the Arctic Ocean have been largely affected by the climate change of the past decades. In turn it is assumed that the Arctic Ocean itself might exert a considerable feedback on global climate due to the role of sea ice in the radiation budget and due to the dramatic water mass conversions associated with cooling and both freezing and melting that directly or indirectly influence the Atlantic-wide meridional overturning circulation.

In particular, the intermediate waters were considerable warmer and saltier in the nineties of the last century than during the decades before which was caused by advection of warmer water from the North Atlantic. In the same time, during a more cyclonic atmospheric pattern (high NAO index), the fresh water that is supplied to the Arctic Ocean by continental runoff (10 % of the global runoff), precipitation, and Pacific water inflow underwent strong variations in supply, storage and circulation pattern.

The additional heat of the recently intruded Atlantic waters might have contributed to the decrease in sea ice while flowing through the central Arctic along the continental slopes and ridges. However, much of this heat is isolated from the surface by the fresh water layer of the river-run-off and only where the fresh water layer is diverted from the Atlantic layer or where Atlantic water can upwell at the shelf edge heat can be released. This was the case in the Eurasian Arctic during the cyclonic atmospheric state of the nineties, when the river water entered the basins further in the east so that more Atlantic water heat might have been lost than before.

We do not know the present development. While the first warm water anomalies of the nineties still travel through the Arctic Ocean new pulses of even warmer Atlantic water arrived in Fram Strait. In the same time the atmospheric circulation pattern returned to a more anticyclonic state and observations in the Canadian part indicate a hydrographic relaxation to historic conditions.

In order to understand the processes behind these changes and to disentangle variations that follow the atmospheric oscillation patterns and trends that point to enduring climate change we will repeat hydrographic sections that were taken in the Eurasian Basin in the 1990s during the Oden 1991 as well as RV *Polarstern* 1993, 1995 and 1996.

Work at sea

Along all sections hydrographic stations will be taken at a distance of about 20 - 40 km. The casts will be carried out with either a conventional CTD/rosette water sampler or with the ultra-clean system of the GEOTRACES programme (chapter 5). Both systems use Seabird components (SBE 9+ and SBE32) with double temperature and conductivity sensors. In areas with heavy ice, the sections will be extended by helicopter-borne XCTD casts. Along the transects, the velocity field of the upper 400 m will be measured with a ship-borne 150 kHz broadband ADCP.

In order to provide year-round measurements of temperature, salinity, velocity and under-ice turbulence, ice-tethered platforms (ITPs) with various instrumentation will be deployed:

- 3 ITPs (Ice-Tethered Profilers) equipped with Seabird CTDs that will sample temperature and salinity profiles once per day between the surface and 800 m water depth,
- 1 ITAC (Ice-tethered Acoustic Current profiler) consisting of a RDI ADCP (75 kHz, Long Ranger) that measures the velocity profile of the upper 500 m once per day,
- 1 OFB (Ocean Flux Buoy, from Tim Stanton, Naval Postgraduate School) that measures turbulent fluxes of heat and salt immediately below the ice.

These platforms contribute to the "International Arctic Ocean Observation System" (iAOOS) that aims at a persistent observation network. In our cruise, contributions come through the EU-funded Integrated Project "DAMOCLES" (Developing Arctic Modelling and Observing Capabilities for Long-term Environment Studies) and the BMBF-funded Project "North-Atlantic".

4. 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 RV *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).

4.1 A- TRACE ELEMENTS DURING ARK-XXII/2 EXPEDITION

Karel Bakker, Maarten Klunder, Patrick Laan, Rob Middag, Sven Ober, Charles-Edouard Thuroczy (NIOZ).

Objectives
In GEOTRACES we have defined 6 key trace metals (Table 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. 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 Arctic Ocean. There hardly is any data for Fe (or other trace metals) in surface waters of the Arctic Ocean, and no data at all below ca. 1000 metres depth. Thus ARK-XXII/2 aims for the first-ever data on distributions of Fe (and other trace metals) in the subsurface waters of the Arctic Ocean, and the first systematic study also for the surface waters. 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 (EPOS; de Baar et al, 1990, 1995; Buma et al., 1991) the role of Fe in ecology of the Southern Ocean has been investigated, including the Fe distributions, speciation (sub 2), sources (sub 3) and sinks (Nolting et al., 1991; Loscher et al., 1997; de Baar et al., 1999; Hoppema etal, 2003). Nevertheless in an exhaustive synthesis of all then existing ocean Fe data (deBaar & deJong, 2001) 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 (Nishioka et al., 2005). Moreover organic Fe(III)-complexes exist within both the colloid pool(s) and the soluble pool (Boye et al., 2005 a, b). Implications are twofold. Firstly within surface waters, the colloid fractions cannot be assimilated unless first dissolved by photoreduction (Rijkenberg et al., 2005) 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 (Rijkenberg et al.,2006). Moreover others observed reductive dissociation of the Fe(III) complex by a Cu-containing protein (sub 4) at the cell wall (Peers et al., 2005; Maldonado et al., 2006). Secondly dissolved Fe in the deep ocean appears controlled by competition between two pools. Global ocean Fe models (Parekh et al., 2004, 2005) 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 (Martin,1991) has been challenged by upwelling supply from below (de Baar et al.,1995) 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 (Hydes et al., 1987) where dissolved Fe is also high (Saager et al.,1993) 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 (Kramer et al., 2004). 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 (Saager et al., 1987; Schoemann et al., 1998) render dissolved Mn a source tracer (Buciarelli et al., 2001; Laes et al., 2007) for Fe from below, i.e. from reducing sediments. Our combined Mn-Fe data, also with natural radiotracers (see below section on Isotopes, where ^{228}Ra for margins, ^{227}Ac for 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 (de Baar & La Roche, 2003). 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.

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 in the central Arctic Ocean basin. Spacing of the overall 24 samples would be more closely together in the upper 1000 meters, 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 permitted by the chief scientist and officers, and provided that the shipboard analists have time to process and either directly analyze or store such samples.

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 with 24 spare samplers, CTD etc. as well as various spare parts of the Kley winch will be stored in container NIOZ-35.

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 traveling 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 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 (500 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

Charles-Edourd Thuroczy will also work in clean container NIOZ-28. 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 analytical container NIOZ-27. Inside this container a flow bench will be placed to create a clean working area. 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-35 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.

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 Karel Bakker 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.

Another set of sub-samples will be collected in glass bottles and given to Sven Ober for 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. When inevitable due to either unexpected instrument problems or lack of time, instead some samples for Alk/DIC will be stabilized and stored for analyses afterwards at the NIOZ home laboratory. The Alk/DIC dataset with nutrients will be reported to the international ocean CO_2 databases, notably EU CarboOcean and GLODAP.

The state-of-the-art accuracy envisioned for the major nutrients as well as Alk/DIC 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.

4.2 B- ISOTOPES

4.2.1 Subproject 1: ^{234}Th as tracer of export production of POC

Pinghe Cai (XU), Michiel Rutgers van der Loeff (AWI)

Objectives

1) To acquire accurate estimates of upper ocean POC export fluxes in the Arctic Ocean;
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 (see section on trace metals above; and
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. A 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 in this cruise. For every 3 stations, large sinking particles will be collected at a depth of ca 100 m either by deployment of *in-situ* pumps or by collection of a large volume sample with an entire Rosette cast and subsequent filtration from a 1-m^3 tank on deck using size-fractionated filtration. Nitex screens 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.

4.2.2 Subproject 2: Tracing flux of particulate organic matter with Polonium-210 and Lead-210

Oliver Lechtenfeld (AWI)

Background

Polonium-210 (^{210}Po) and Lead-210 (^{210}Pb) are produced by stepwise radioactive decay of Uranium-238 in seawater. ^{210}Po (138 days half life) and ^{210}Pb (22.3 years half life) have high affinities for the particles within. In seawater those radionuclides are present in dissolved form and adsorbed onto particles. Following adsorption onto particle surfaces, ^{210}Po especially is transported into the interior of cells where it bonds to proteins. In this way, ^{210}Po also accumulates in the food chain. ^{210}Po is therefore considered to be a good tracer for POC, and traces particle export over a timescale of months. ^{210}Pb adsorbs preferably onto structural components of cells, biogenic silica and lithogenic particles, and is therefore a better tracer for more rapidly sinking matter. In combination with Thorium-234 the ^{210}Po-^{234}Th tracer pair can be used to distinguish POC and silica flux. This work is coordinated by Jana Friedrich, AWI.

Objectives

Our goals in the GEOTRACES activities during ARK-XXII/2 is (1) to get a better insight into Po binding sites in organic matter and (2) to trace pathways of particulate and dissolved matter leaving the Siberian Shelf.

1) We will investigate to which extent TEP can play a role in extending ^{210}Po as a proxy for POC and whether TEP and $^{210}Po/^{210}Pb$ data can be related. This work will be done in collaboration with Maya Robert and Uta Passow (AWI). We further look into the distribution of ^{210}Po on POC and in different plankton assemblages.

2) The pathways of particulate and dissolved matter will be followed by the combined use of ^{210}Po and ^{234}Th as a tracer pair (and perhaps ^{210}Pb) for particle flux (collaboration with Pinghe Cai). This information gathered from water column will be complemented with the results of the ^{210}Po-^{210}Pb study in sea ice (group of Pere Masque) to provide a more thorough picture of particle transport from the shelf to the open sea and from surface to depth.

Work at sea
^{210}Po and ^{210}Pb will be sampled in surface water (taken from the ship's sea water supply) and in shallow depth profiles (up to 200 m depth, taken from CTD rosette Niskin bottles) in 20 l samples for dissolved and particulate fractions and 5 l samples for the total fraction. These samples will be complemented by a few deeper profiles (800 m depth from CTD rosette Niskin bottles). The filtered samples for Po will be sub-sampled for TEP. The ^{210}Po, ^{210}Pb and TEP analysis will be done at AWI.

4.2.3 Subproject 3: ^{231}Pa and ^{230}Th in the Arctic

Kate Lepore (UCD)

Objectives
The distribution 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 sediment cores to evaluate patterns of particle flux and boundary scavenging. Cooperation partner: Brad Moran (URI).

Work at sea
^{231}Pa and ^{230}Th sampling requires collection of 1 l seawater each for unfiltered (total) and 1 l each filtered (<0.4 µm) seawater. All seawater samples are stored acidified, without addition of any tracers. Particulate matter will be collected by CTD-rosette (~20 l), transferred to pre-cleaned 12 l carboys, and pressure filtered through 0.4 µm, 90 mm diameter, Teflon filters using compressed N_2 (~5-10 psi overpressure). Sample manipulation and processing will be conducted in a clean-air hood (HEPA filtered).

Sediment cores will be sliced and ~1 gram sediment samples stored in plastic containers.

4.2.4 Subproject 4: Radium isotopes and ^{227}Ac

Michiel Rutgers van der Loeff, Tobias Roeske (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. The distribution of ^{228}Ra can add information on circulation time to the other tracers of fresh water and continental inputs (like δ^{18}O, fluorescence, Ba, nutrients) (Rutgers van der Loeff et al., 1995; Hansell et al., 2004). Like Ra isotopes, ^{227}Ac is a 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), Brad Moran (URI).

Work at sea
^{222}Rn will be measured semi continuously by gas-water exchange in the ship's seawater supply using a RAD7. Large volume surface water samples will be collected for radium isotopes using the RV *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 120 l tanks. Each sample is pumped at <1 L/min using an electric (110 V) *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.

4.2.5 Subproject 5: The role of sea ice in the transport of trace elements and isotopes in the Arctic Ocean

Patricia Camara (UAB)

Objectives
Sea ice is an important agent for the transport and dispersion of sediments and dissolved or particulate chemical species in the Arctic Ocean, with origin in the ice formation areas or by enrichment during its transit. This transport has several implications: i) its relative importance in the global ocean in terms of fluxes in the Arctic and export to the Atlantic Ocean; ii) the basic mechanisms that regulate the incorporation of TEIs to ice and, particularly, to entrained sediments; and iii) the final fate of sediments and TEIs by release during transit and, specially, in main ablation areas such as the Fram Strait. Altogether modulated by the mechanisms that regulate the TEIs-sediments-ice-water interactions and within a frame of changing conditions in the Arctic Ocean. Radionuclides, both of natural and artificial origin are a group of relevant TEIs in the GEOTRACES programme, as potential chronometers of environmental processes and because of the knowledge of their source terms.

This project attempts to first identify and quantify the processes that regulate the distribution of a suite of radionuclides (^{7}Be, ^{137}Cs, ^{210}Po, ^{210}Pb, ^{230}Th, ^{231}Pa, ^{234}Th and Pu) in the Arctic Ocean, and in particular in relation to the sea ice dynamics and its response to changing environmental conditions; secondly, to determine how these TEIs can be used as tracers of present and past oceanographic conditions and for studies of contaminant dispersion. We intend to

- Determine the relative importance of the processes by which this suite of TEI is accumulated by sea ice: in formation areas, by interception of atmospheric fluxes or by interaction with the surface waters of the ocean.
- Determine the mechanisms and efficiency by which these TEI associate with particulate matter transported by sea ice and the degree of adsorption or desorption to/from particulate matter once released from sea ice in the water column.
- Establish a reference distribution of the selected TEIs in the Arctic Ocean as a baseline to evaluate past and future changes.
- Investigate the feasibility of TEIs as tracers of processes in the Arctic Ocean, such as: estimation of transit times and origin of sea ice; quantification of the role of sea ice in the transport of particulate matter and chemical species through the Arctic Ocean; evaluation of the relative importance of fluxes derived by release of sediments and TEI by melting during transit in the Central Arctic and in the Fram Strait; and use of the $^{231}Pa/^{230}Th$ ratio as a paleocirculation proxy in the Arctic Ocean.

Our work at UAB will focus on the study of the role of sea ice in the transport of radionuclides (namely ^{210}Pb, ^{210}Po, ^{7}Be, ^{234}Th, ^{239}Pu, ^{240}Pu, ^{137}Cs, Ra, ^{129}I) in the Arctic, with special emphasis on those associated to sea ice sediments, with the aim of using them as tracers of several processes. This includes:

- Investigating what is the actual importance of the interaction with sea water in respect to scavenging of particle reactive radionuclides from sea water by sea ice sediments in comparison to atmospheric inputs during transit and concentrations in sediments in sea ice formation areas. Potential use of some of the radionuclides as tracers of transit times of sea-ice.
- Estimate the actual balance of these isotopes in the Arctic, and in particular in respect to understanding the importance of release of sea ice sediments and associated isotopes during transit in the Arctic and in ablation areas such as the Fram Strait

Coordination at UAB: Pere Masque.

Work at sea

Samples to be collected are:

- Sea ice cores (whole cores and/or profiles),
- sea ice sediments,
- atmospheric input (collectors-snow and aerosol filters) during the cruise,
- water column profiles and bottom sediments in selected stations.

We will also investigate the role that sea ice sediments plays on the transport of ^{230}Th and ^{231}Pa and the implications it may have on the use of the Pa/Th proxy in the Arctic. For that we will analyze Th and Pa in sea ice sediments collected during the cruise and will carry adsorption/desorption experiments onboard.

4.2.6 Subproject 6: Rare Earth Elements, ^{10}Be and the isotopic composition of Nd (ε_{Nd})

Tobias Roeske (AWI)

Objectives

Rare Earth Elements (REE) and the isotopic composition of Nd are important water mass tracers. The varying REE-pattern and isotopic signature of Nd 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 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 1000 years make them ideal tracers for water masses as it allows for long distance transport while preventing complete homogenisation. Especially Nd isotopes are useful in paleoceanography, as their isotopic signature is preserved in ferromanganese nodules, foraminifera, and Fe-Mn oxide coatings of sediments.

Beryllium isotopes (cosmogenic ^{10}Be and lithogenic ^{9}Be) give additional information on inputs and water mass sources. Cooperation partners: Per Andersson (National Museum of Natural History, Stockholm, Sweden) and Martin Frank (IFM-GEOMAR, Kiel).

Work at sea

Samples will be collected for REE in dissolved or particulate form and in sea ice sediments. With dirty ice and filtered seawater experiments will be undertaken regarding the exchange between the particulate phase and seawater.

For dissolved REE 1 l of seawater will be collected in surface waters and at deep stations using NIOZ's Titanium-Rosette. Particulate REE in surface waters will be collected by the ship's seawater pump and a continuous flow centrifuge. At least 1000 l of seawater will be centrifuged at a rate of about 500 - 1000 l per hour at 16,000 g. Sea ice sediments will be sampled by coring. Cores will be sliced and melted aboard in parallel with similar experiments on radionuclides (Patricia Camara).

An experiment will be done to investigate the desorption/dissolution of REE and fractionation of the isotopic composition of Nd from particles of dirty ice with filtered surface water. Dirty ice will be added to this water and after melting the water will be filtered. The results will be compared to the same water with no dirty ice added to test the contribution of sea ice sediments to the isotopic signature of Nd and the REE-pattern.

Up to 15 10-l samples of filtered seawater will be collected from surface water and CTD/Rosette casts in the Russian shelf region. These samples will be treated later for Neodymium analysis in Stockhom. In addition, ^{10}Be and ^{9}Be will be extracted from the same water samples to be analysed in Kiel (IFM-GEOMAR).

4.2.7 Subproject 7: Barium as river water tracer

Tobias Roeske, AWI

Objectives

Barium has been shown to be a powerful tracer to distinguish river water masses from Eurasian and American origin (Taylor et al., 2003). In combination with other tracers of fresh water components (salinity, $\delta^{18}O$, fluorescence, ^{228}Ra, nutrients) it will be possible to obtain an overview of the distribution of the various fresh water sources during our expedition as a contribution to the EU programme DAMOCLES.

Work at sea

Small (15 ml) samples will be taken from the Rosette casts along with the sampling for $\delta^{18}O$ and nutrients. Analysis will be done by isotope dilution ICP-MS at AWI.

4.2.8 Subproject 8: Anthropogenic radionuclides ^{129}I, ^{99}Tc, ^{137}Cs and Pu

Patricia Camara (UAB)

Objectives

The main source of ^{129}I and ^{99}Tc is their release by reprocessing plants of nuclear fuel. The sources (Sellafield, La Hague) are well known. ^{137}Cs and Pu isotopes have also been released by fallout, and the isotopic composition of Pu differs among the various sources. The distribution of these tracers is used to model the arctic circulation and especially the relative contributions of Atlantic and Pacific water masses. Cooperation partners: Michael Karcher (AWI/OASYS), Claudia Hanfland (AWI), Pere Masque (UAB), Brad Moran (URI), John Smith (BIO).

Work at sea

1-l samples for ^{129}I are collected from the CTD-rosette and stored with no special requirements (e.g., at room-temperature) until shore-based analysis. When possible, samples will be collected in conjunction with ^{137}Cs. For ^{99}Tc, 5-l samples are collected from the CTD-rosette and stored in plastic canisters with no special requirements. For ^{137}Cs and Pu isotopes, 35-l samples will be collected from surface waters and on water profiles at selected stations in the Russian shelf area. ^{137}Cs will be collected with the ammonium molybdophosphonate (AMP) method (to be analysed at UAB) and in parallel on KCFC resin (to be analysed at BIO).

4.2.9 Subproject 9: Phyto- and Protozooplankton ecology in the water column

Lilith Kuckero (AWI)

Objectives

Since the 1990s phyto- and protozooplankton ecological investigations on biomass, species composition, productivity, and related biochemical parameters as chlorophyll a, particulate organic carbon/nitrogen (POC/N), carbonate, and biogenic silica have been carried out in arctic waters mainly in the Fram Strait area. During the years 1993 – 1996 sampling was also conducted above Amundsen, Nansen Basins. During this cruise, about 10 – 15 years later, the same investigations will be done for comparison with the old data to understand eventual changes due to a changing environment. Specific questions addressed: Are there regional differences in the seasonal distribution patterns of phyto- and protozooplankton, POC/N, carbonate and biogenic silica in the ice covered Arctic Ocean? A comparison of the results from 1993 -1996 with 2007 will be carried out. What is the influence of the respective abiotic factors? Which are the most remarkable features? How important is the sea ice and biological processes within it for the pelagic food web? What changes can we measure? Coordination at AWI: Eva Nöthig.

Work at sea

Water will be sampled with the rosette sampling system attached to the CTD. Subsamples will be taken from the surface layer at 4 different depths (appr. 5, 20, 40, 80m) down to 100 m water depth (in coordination with the ^{234}Th- and ^{210}Po-based studies on export production), and about 6 samples below 100 m down to the bottom according to the CTD profile and the requirements of the geochemists at selected stations for the following parameters:

Species abundances (watersamples, ca. 200 ml fixed with buffered formalin), chlorophyll a and phaeopigments (0.5 to 1 litre of water will be filtered on Whatman GF/C glass-fibre filters), POC/N, carbonate, biogenic silica (for each 2 - 4 litres) will be filtered on precombusted Whatman GF/C glass-fibre filters and cellulose acetate filters, respectively, stored deep frozen for later analyses in the home laboratory.

4.3 METHANE SUPER-SATURATION IN POLAR SHELF WATER AND THE MARGINAL ICE ZONE - IN SITU PRODUCED OR SUPPLIED BY SUBMARINE SEEPS

Ellen Damm, Ingrid Vöge (AWI)

Objectives

Recent change in the Arctic alters water mass formation and convection, which may have profound effect on natural biogeochemical cycles in seawater. Especial feedback effects to pathways of climatically relevant biogases like methane will loom large in the equation of change. The present marine methane cycle is influenced mainly by atmospheric methane transported by downward diffusion and convective ventilation into the deeper ocean, by fossil methane released from gas venting sites at the sea floor, microbial *in-situ* methane production in the upper ocean and microbial oxidation in the whole water column. With this expedition we expect to expand the knowledge about the changing of the methane background signal by methane, released from active gas venting sites and the methane *in-situ* production in the upper water column and to quantify these processes. The aim of our investigations is to estimate the balance between the pathways and the resultant isotopic fractionation processes as well as the methane budget in different water currents related to background concentrations and super-saturations.

The planned investigations contribute to a better understanding of:

- Pathways of methane in the hydrosphere in relation to water transformation during summer;
- the influence of seasonal ice coverage to the exchange of methane at the ocean atmosphere boundary and therefore to the role of the seasonal ice covered marginal Arctic Ocean as a sink or source for atmospheric methane;
- submarine gas vents as potential sources for methane plumes in the water column;
- the incorporation of fossil methane into the recent marine carbon cycle.

Work at sea

The investigations continue to the work on methane distribution in the water column performed in the Barents Sea during ARK-XIX and ARK-XXI in 2003 and 2005, respectively.

Water sampling will be done with the rosette in different water depths for a number of stations along transects. Water samples will be collected in Niskin bottles mounted on a rosette sampler from bottom water depths up to the surface (0.5 m). The dissolved gases will be immediately extracted from the water and analysed for methane by gas chromatograph equipped with a flame ionization detector (FID) on board ship. Gas samples will be stored for investigations of the $\delta^{13}CCH4$values in the home laboratory. Furthermore at each station samples for the analyses of DMSP (p), DMSP (d) will be taken and analyzed in the home lab.

4.4 DISSOLVED ORGANIC MATTER IN THE ARCTIC OCEAN

Sally Walker (Texas A&M)

Scientific Background

Findings of the last 15 years have indicated significant environmental changes in the Arctic Ocean (Search SSC, 2001) including a general warming trend, changing surface water distribution, and decreasing sea ice cover. More recently, major changes in the global hydrological cycle have been suggested leading to increased precipitation, and decreased surface water salinities in high latitude oceans (Curry et al., 2003) potentially contributing to increased freshwater discharge in Eurasian rivers (Peterson et al., 2002). Concern has risen as to how these changes might effect the heat budget of the Arctic Ocean, the fate of soil organic carbon stored in tundra and taiga soils, the global thermohaline circulation, and the general climate in the northern hemisphere. In order to predict effects of environmental changes in the Arctic Ocean we need to develop a better understanding of how physical and biogeochemical processes in the Arctic Ocean are linked to continental run-off and atmospheric forcing. The large freshwater discharge and the extended shelf areas play an important role by influencing water mass modification on the shelf and stratification in the open Arctic Ocean. A halocline layer effectively separates the cold and fresh surface layer from the warm and salty Atlantic layer in wide areas of the Arctic Ocean. Although the role of this halocline is critical to the Arctic system we do not understand how the halocline is formed and sustained much less how it responds to changes of freshwater discharge and sea ice formation.

I was recently funded by NSF to investigate the formation of the Arctic Halocline by using organic tracers and *in-situ* fluorescence. We found elevated levels of terrestrial DOM and associated fluorescence in halocline waters which is very intriguing and suggests the involvement of river water in halocline formation. Unfortunately, we also found that the fluorescence signal can not be attributed to the terrestrial source alone, rather there seem to be several sources involved. The *in-situ* probe is very general and does not allow any further distinction of the fluorescence signal. With the samples collected during the ARK-XXII/2 we hope to unravel some of these different sources by using a new method combining high resolution spectrofluorometry and parallel factor analysis. With this new method we will be in a much better position to determine source waters involved in halocline formation which is critical for our understanding of climate change the Arctic Ocean system.

Work at sea

During leg 2 of ARK-XXII on RV *Polarstern* we basically plan two things. First, we will monitor *in-situ* fluorescence at every station and depth. For that purpose we will mount the fluorescence sensor on the CTD unit to be lowered to the bottom of the ocean at every station. This will give us real time information on the horizontal and vertical distribution of fluorescence which is caused by certain organic compounds dissolved in seawater. Second, based on the fluorescence signal we will select our sampling location and depth and collect between 1 and 20 l of seawater at several depth levels. We plan to collect about 120 samples during the cruise. Each sample will be split into subsamples to determine the following parameters: dissolved organic carbon (DOC), dissolved organic nitrogen (DON), optical properties (absorbance and fluorescence), carbohydrates, lignin phenols, stable carbon (DOC), nitrogen (nitrate). Water samples will be frozen and transported to the home laboratory for further analyses which will take about 1 year to complete. Some of the analyses planned for these samples are novel to Arctic Oceanography and will allow significant new insight. We are especially excited about the combination of 3 dimensional fluorescence and parallel factor analysis, especially in combination with new tracers such as nitrogen isotopes in nitrate.

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5. MARINE BIOLOGY

5.1 ZOOPLANKTON INVESTIGATIONS

Kristina Barz, Adrian Basilico (AWI), Ksenia Kosobokova (SIO), Antoine Nowazyk (LOB)

Objectives

The zooplankton work focusses on four aspects:
(1) the Atlantic Inflow,
(2) the reproductive biology and strategies of mesopelagic copepods,
(3) trophodynamic relationships in the arctic pelagic food web and
(4) the makrozooplankton.

1. A large amount of zooplankton is advected into the Arctic Ocean with the inflow of Atlantic water. The copepod *Calanus finmarchicus* is a key species in the North Atlantic and can be traced in most parts of the Arctic Ocean, where it is expatriated and can be used as a passive tracer for Atlantic inflow waters. With increasing temperatures this species may colonize the Arctic Ocean and thus have a profound effect on the carbon flux and trophic web there. On transects perpendicular to the shelf slope and across the ridges the vertical and horizontal distribution of advected Atlantic species will be studied. In experiments the survival potential of *C. finmarchicus* in relationship to lipid content and gonad conditions will be studied.

2. Little is known on the reproductive biology of mesopelagic copepods. In incubation experiments the gonad development, egg production mode, egg production rate and egg development will be studied and the role of lipids in energy storage. At the same time, egg development time will be measured and, if possible, naupliar development will be followed.

3. While large calanoid copepods contribute most to zooplankton biomass, small species are numerically important. Their role in the food web of the Arctic is poorly understood. Grazing experiments and measurements of respiration and excretion will be conducted with *Oithona spec.* and *Oncaea spec.* Similar experiments will be conducted in the Mediterranean to study adaptation mechanisms in small copepods.

Stable isotopes (N and C) together with lipid markers will be used to study the trophic relationships in the pelagic system. Special emphasis will be on gelatinous plankton like chaetognaths, appendicularians, ctenophores and medusae.

Work at sea
In order to collect larger zooplankton organisms and to study their abundance and distribution, a RMT net will be trawled, ice conditions permitting.

In addition to the measurements described above, a new optical system to image zooplankton will be tested. A high resolution digital camera will record the freshly collected samples. Later they will be analysed using an automatic image analysis system.

5.2 BIODIVERSITY OF POLAR DEEP-SEA EUKARYOTIC MICROBIOTA – MOLECULAR VERSUS MORPHOLOGICAL APPROACH

Béatrice Lecroq (UG)

Background and objectives.
Over the past few years, cultivation-independent identification of microbial organisms by PCR amplification and sequencing of ribosomal RNA genes revealed a huge diversity of microbiota in environmental samples. Many new species and higher-level lineages have been discovered. However, the microbial diversity in the polar deep-sea benthos is still largely unexplored.

The main objective of this project is to examine the diversity of microbial eukaryotes (protists) in deep-sea Arctic sediments by using environmental DNA approach.

The project will focus on two important groups of marine protists: Foraminifera and Cercozoa. Both groups belong to the recently established supergroup of Rhizaria (Nikolaev et al., 2004). Our previous studies of polar Foraminifera revealed exceptionally high morphological and molecular diversity of some monothalamous (single-chambered) morphospecies, particularly abundant in high-latitude settings (Gooday et al., 1996, Pawlowski et al., 2002, Pawlowski et al., 2005). On the other hand, we found very weak genetic differentiation between some common Arctic and Antarctic deep-sea calcareous species (Pawlowski et al., in press).

Using material collected during this cruise, we aim to
(1) obtain rDNA sequence data for broad taxon sampling of Arctic Foraminifera and Cercozoa;
(2) establish their phylogenetic relationships with Antarctic and other deep-sea species; and
(3) describe new species based on their morphological and genetic characteristics.

Work at sea
We intend to identify Foraminifera and Cercozoa from different water depths and seafloor habitats using surface sediment samples obtained by multicorer or box corer. The sediment samples will be sieved and part of them will be frozen in liquid nitrogen for environmental DNA study. The rest of the samples will be examined immediately for the presence of living foraminifera, which will be picked under a binocular microscope and fixed for further molecular and morphological study. The environmental DNA diversity will be examined using

foraminiferal and rhizarian specific primers and protocols described in Pawlowski (2000) and Lecroq et al. (in prep.).

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Pawlowski, J., Fahrni, J.F., Guiard, J., Konlan, K., Hardecker, J., Habura, A., Bowser, S.S. (2005) Allogromiid foraminifera and gromiids from under the Ross Ice Shelf: morphological and molecular diversity. Polar Biology 28:514-522

Pawlowski J., Fahrni J., Lecroq B., Longet D., Cornelius N., Excoffier L., Cedhagen T., Gooday A.J. Bipolar gene flow in deep-sea foraminifera. Molecular Ecology (in press)

6. MARINE GEOLOGY

Norbert Lensch (AWI), Robert Spielhagen (IFM-GEOMAR), Valery Rusakov (SIO), Peter Semyonov (VNIIO)

General

The overall goals of the marine geological research programme are i) high-resolution studies of paleoenvironmental changes in the northern Kara Sea, its continental margin, and in the adjacent eastern Arctic Ocean, (ii) high-resolution studies of the history of water masses and ice coverage in the Late Quaternary eastern and central Arctic Ocean, and (iii) to obtain sediments deposited in the pre-Quaternary Arctic Ocean.

Background and previous work

Arctic river runoff is of vital importance for the Arctic low saline surface water outflow and the formation of the Arctic sea ice cover, both a prerequisite for the maintenance of strong oceanographic contrasts in the Nordic Seas and the deepwater renewal, which runs the thermohaline convection (THC), as well as for the sediment and chemical budgets of the Arctic Ocean. Climatic models have shown that the deepwater renewal is sensitive to changes in freshwater runoff, but little is known about the freshwater runoff variability from the Arctic in the past. While there is some evidence for Holocene variability from earlier studies in the southern Kara Sea (SIRRO Project), knowledge for changes in the deglaciation, the Weichselian, and the last interglacial ("Eemian") are scarce. It is still unknown whether the river runoff across the Kara Sea shelf was blocked by the northern

Eurasian ice sheet during part of the last glacial maximum (LGM). A damming must have led to a rapid decrease of river runoff, the subsequent formation of an ice-dammed lake, and the discharge of huge amounts of freshwater during the deglacial break-up of ice. For earlier glacial episodes, the exact glacial limits of ice sheets on the Kara Sea are also elusive. The position of the ice front and its variability must have exerted enormous influence on the sediment export to the Arctic Eurasian Basin (debis flows, turbidites etc.).

In the last two decades a number of sediment cores has been investigated which gave valuable information on the history of the Late Quaternary Arctic Ocean, its water masses, and its ice coverage. Most of these cores stem from the eastern Arctic Ocean (15°W 75°E) and the Lomonosov Ridge relatively close to the Pole. Information from the Siberian sector of the eastern Arctic Ocean is still rather scarce. Even less information exists on the pre-Quaternary history of the Arctic Ocean. Apart from sediments obtained during one IODP drilling on the Lomonosov Ridge in 2004 the number of samples older than 2 million years is very low and large gaps of knowledge exist for the development of the Arctic Ocean from an ice-free to an ice-covered state.

Objectives

To improve our knowledge of the history of the Arctic Ocean the marine geological working group will obtain long sediment cores in combination with high-resolution acoustic mapping. The sedimentary records should cover both the long-term history (last 200 ky) and the postglacial history (in high resolution). The high-resolution studies should include studies of the post-glacial/Holocene short-term (decadal-centennialmillenial) variability in siliciclastic and biogenic/organic-carbon fluxes and its relationship to natural environmental/climate change. Sedimentological, geochemical, and micropaleontological proxies will be used to reconstruct environmental changes such as river discharge, sea ice cover, and oceanographic circulation pattern. These high-resolution sedimentary records, going back beyond the timescale of direct discharge measurements and anthropogenic influence, will improve our understanding of natural Arctic climate variability. Studies will include multidisciplinary investigations of surface sediments (recent situation) as well as (high-sedimentation-rate-) sediment cores.

Work at sea

Sampling will be performed on three transects across the northern Kara Sea continental margin, the adjacent Nansen Basin, and towards Gakkel Ridge. Coring positions will be selected carefully using detailed bathymetric mapping and sub-bottom profiling systems (i.e., Hydrosweep and Parasound, respectively). Long large-volume sediment cores (square-barrel Kastenlot cores, 30 x 30 x 1200 cm) will be obtained in conjunction with large-volume cores of the surficial sediments (box corer, 50 x 50 x 50 cm) and multicores. The same equipment will be used at single suitable sites on the Gakkel, Lomonosov, and Alpha-Mendeleyev ridges where undisturbed sequences can be identified from sub-bottom profiles. To possibly obtain pre-Quaternary deposits from suitable sites on the Alpha-Mendeleyev Ridge (e.g., from steep slopes) gravity corers will be used. All sediment cores will be stored cool on board and transported to the AWI core depository in Bremerhaven from where they will be made available for investigations.

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9. SCHIFFSBESATZUNG / SHIP'S CREW

Name of Ship: RV *POLARSTERN*
Nationality: GERMAN
Tromsø - Bremerhaven 28 July 2007 - 10 October 2007

No.	Name	Rank
1.	Schwarze Stefan	Master
2.	Spielke, Steffen	1.Offc.
3.	Farysch, Bernd	Ch.Eng.
4.	Fallei, Holger	2.Offc.
5.	Wunderlich, Thomas	2.Offc.
6.	Kaufmann, Tino	2.Offc.
7.	Schuchardt	Doctor
8.	Hecht, Andreas	R.Offc.
9.	Minzlaff, Hans-Ulrich	2.Eng.
10.	Schäfer, Marc	2.Eng.
11.	Sümnicht, Stefan	3.Eng.
12.	Scholz, Manfred	Elec.Tech.
13.	Nasis, Ilias	Electron.
14.	Verhoeven, Roger	Electron.
15.	Muhle, Helmut	Electron.
16.	Himmel, Frank	Electron.
17.	Loidl, Reiner	Boatsw.
18.	Reise, Lutz	Carpenter
19.	Rhau, Lars-Peter	A.B.
20.	Stutz, Heinz-Werner	A.B.
21.	Winkler, Michael	A.B.
22.	Reichert, Jörg	A.B.
23.	Hagemann, Manfred	A.B.
24.	Schmidt, Uwe	A.B.
25.	Bäcker, Andreas	A.B.
26.	Wende, Uwe	A.B.
27.	Preußner, Jörg	Storekeep.
28.	Ipsen, Michael	Mot-man
29.	Voy, Bernd	Mot-man
30.	Elsner, Klaus	Mot-man
31.	Hartmann, Ernst-Uwe	Mot-man
32.	Pinske, Lutz	Mot-man
33.	Müller-Homburg, Ralf-Dieter	Cook
34.	Silinski, Frank	Cooksmate
35.	Martens, Michael	Cooksmate
36.	Jürgens, Monika	1.Stwdess
37.	Wöckener, Martina	Stwdss/KS
38.	Czyborra, Bärbel	2.Steward
39.	Silinski, Carmen	2.Stwdess
40.	Gaude, Hans-Jürgen	2.Stwdess
41.	Möller, Wolfgang	2.Steward
42.	Huang, Wu-Mei	2.Steward
43.	Yu,Chung Leung	Laundrym.