EXPEDITIONSPROGRAMM NR. 89

FS POLARSTERN

ARK-XXVII/1
ARK-XXVII/2
ARK-XXVII/3

Koordination
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DEUTSCHER FORSCHUNGSZENTREN E.V. (HGF)

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EXPEDITION PROGRAMME NO. 89

RV POLARSTERN

ARK-XXVII/1
14 June 2012 - 15 July 2012
Bremerhaven - Longyearbyen

ARK-XXVII/2
15 July 2012 - 30 July 2012
Longyearbyen - Tromsø

ARK-XXVII/3
2 August 2012 - 7 October 2012
Tromsø - Bremerhaven

Coordination
Dr. E. Fahrbach
Dr. R. Knust

Chief Scientists

ARK-XXVII/1	Agnieszka Beszczynska-Möller
ARK-XXVII/2	Thomas Soltwedel
ARK-XXVII/3	Antje Boetius

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ARK-XXVII/1

14 June 2012 - 15 July 2012
Bremerhaven - Longyearbyen

Chief scientist

Agnieszka Beszczynska-Möller

Coordination
Eberhard Fahrbach
Rainer Knust

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1. ÜBERBLICK UND FAHRTVERLAUF

Agnieszka Beszczynska-Möller (AWI)

Der erste Fahrabschnitt der 27. *Polarstern*-Expedition in die Arktis beginnt am 14. Juni 2012. Das Schiff wird von Bremerhaven auslaufen, um Untersuchungen in der Framstraße durchzuführen (Abb. 1). Die Arbeiten werden im Rahmen von mehreren Projekten entlang eines Schnittes bei 78°50'N über die gesamte Framstraße zwischen dem Kontinentalabhang westlich von Spitzbergen und dem ostgrönländischen Schelf erfolgen. Die Reise wird am 15. Juli 2012 in Longyearbyen enden.

Die in das EU-Projekt ACOBAR (Acoustic Technology for Observing the Interior of the Arctic Ocean) eingebetteten ozeanographischen Arbeiten haben zum Ziel, Änderungen des Wassermassen- und Wärmeaustauschs zwischen dem Nordpolarmeer und dem nördlichen Atlantik und die Zirkulation in der Framstraße zu quantifizieren. Dafür werden Temperatur, Salzgehalt und Sauerstoff an etwa 80 Stationen sowie Meeresströmungen quasi-kontinuierlich in den oberen Schichten des Meeres entlang des Schnitts gemessen. Ozeanographische Verankerungen, die vor einem oder zwei Jahren auf diesem Schnitt ausgelegt wurden, um Temperatur, Salzgehalt, Strömungsgeschwindigkeit und Strömungsrichtung kontinuierlich zu registrieren, werden aufgenommen und mit neuen Geräten wieder ausgelegt. Damit wird die mittlerweile 15 Jahre dauernde Langzeitmessung fortgesetzt. Um die Verankerungsmessungen mit hochauflösenden hydrographischen Schnitten ergänzen, wird ein Seaglider für drei Monate in der Framstraße ausgelegt. Zur Navigation des Seagliders unter dem Eis werden außerdem 8 akustische RAFOS-Schallquellen in der westlichen Framstraße verankert.

Für biologische Untersuchungen werden an den CTD-Stationen zusätzlich Netzfänge ausgeführt und Sedimentproben genommen. Klimabedingte Veränderungen der Plankton-Zusammensetzung in der Framstraße werden durch die AWI-Arbeitsgruppe PEBCAO (Phytoplankton Ecology and Biogeochemistry in the Changing Ocean) untersucht. Die Arbeiten der pelagischen Mikrobiogeochemie befassen sich mit der Untersuchung des Umsatzes organischer Substanz und von Zersetzungsprozessen, um ein besseres Verständnis der biogeochemischen und mikrobiologischen Rückkoppelungsprozesse im Ozean der Zukunft zu erlangen. Entlang des Temperaturgradienten von Bremerhaven nach Spitzbergen werden Wasserproben genommen, um aus Phytoplankton DNA und RNA zu isolieren und zu sequenzieren. Die Verteilung von Amphipoden in der Framstraße wird im Rahmen des BMBF-Projekts „Arktische pelagische Amphipoden" untersucht.

Zur Untersuchung des natürlichen und anthropogen Kohlenstoffhaushalts verschiedener Wassermassen, der Eigenschaften der unterschiedlichen Strömungen und um Veränderungen in der Ventilation zu quantifizieren, werden Verteilungen der Konzentration von DIC, Sauerstoff, Nährstoffen und den Spurenstoffen CFC-12 (Fluorchlorkohlenwasserstoff-12) und SF6 (Schwefelhexafluorid) entlang des Schnitts gemessen. Die Verteilung stabiler Sauerstoffisotope ($\delta^{18}O$), radiogener Neodymium-Isotope (Nd) und Seltener Erden (REE) wird gemessen, um die Wassermassenverteilung in der Framstraße zu charakterisieren. Wasserproben zur Bestimmung von gelöstem schwarzen Kohlenstoff (DBC), gelöstem organischen Kohlenstoff (DOC) und farbigem gelöstem organischen Material (CDOM) werden genommen und analysiert, um zu bestimmen wie viel DBC von den Flüssen in den Arktischen Ozean und damit schließlich in den Atlantischen Ozean eingebracht wird. Um die Ozean-Atmosphären-Flüsse von CO_2, CH_4, N_2O und CO in der Framstraße zu quantifizieren, wird einen Equilibrator an das en-Route-Pumpensystem der *Polarstern* angeschlossen. Ein Membran-Inlet-Massenspektrometer wird genutzt, um kontinuierlich das Verhältnis von gelöstem Sauerstoff zu Argon (O_2/Ar) zu messen und daraus biologische Sauerstoffflüsse zu berechnen.

Zur Erfassung der Veränderungen des grönländischen Eisschilds, die durch die Deformation der Erdoberfläche indirekt sichtbar werden, werden im Rahmen der geodätischen Arbeiten in Nordost-Grönland mit den Hubschraubern GPS-Sensoren ausgebracht.

Während des gesamten Fahrtabschnitts erfolgen Beobachtungen von Seevögeln und mariner Säugetiere. Ziel der Langzeituntersuchung ist, die *in-situ*-Verteilung dieser Tiere in Abhängigkeit von der Verteilung der ozeanischen Wassermassen, Frontalzonen und dem Packeis sowie der Eiskante zu quantifizieren.

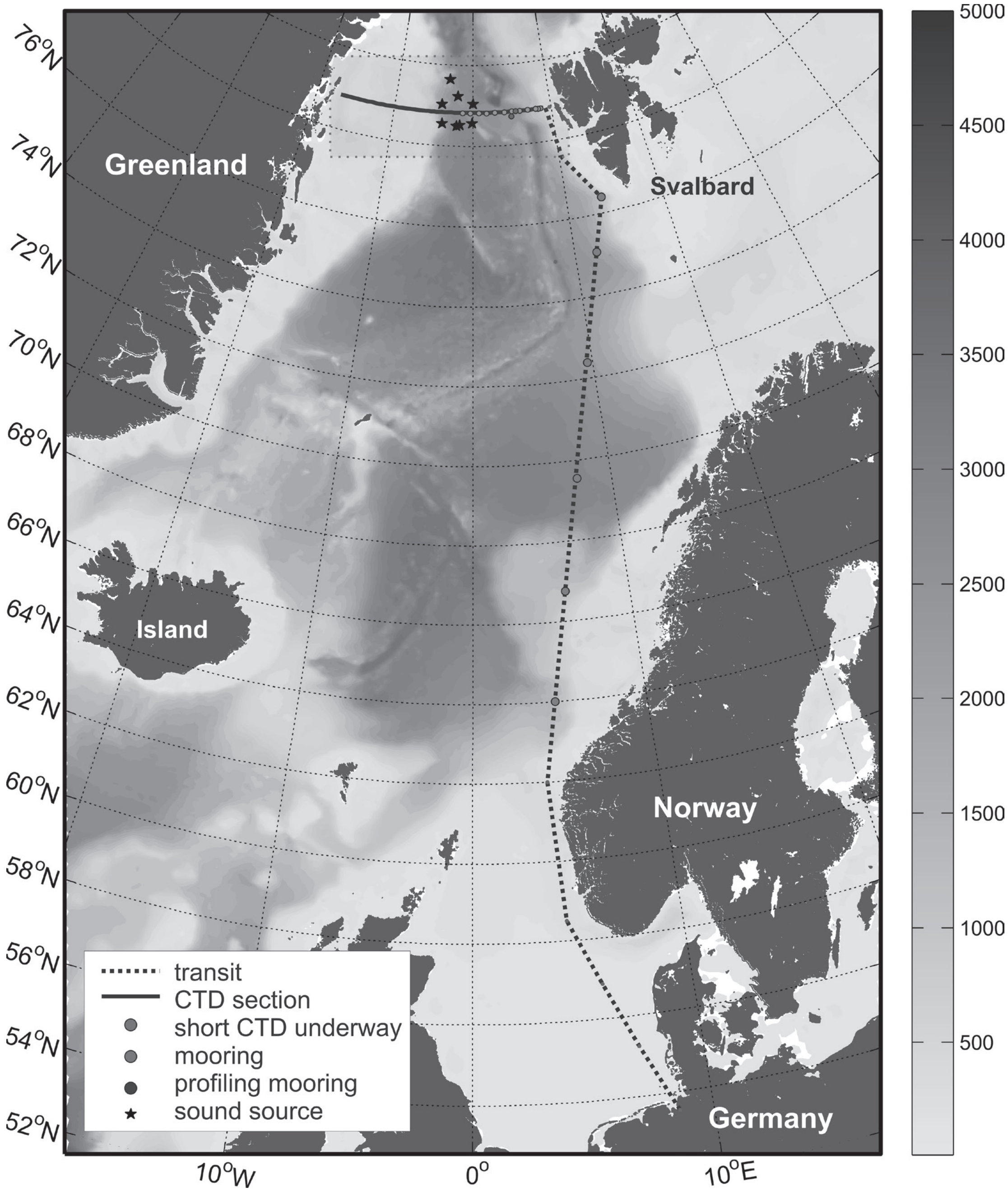

Abb. 1: Geplante Fahrtroute der Polarstern-Expedition ARK-XXVII/1
Fig. 1: Planned cruise track during the Polarstern Expedition ARK-XXVII/1

SUMMARY AND ITINERARY

The first leg of the 27th *Polarstern* expedition to the Arctic will start on 14 June 2012. The ship will leave from Bremerhaven to conduct research in the northern part of Fram Strait. The field work will serve different projects and concentrate along a section across the entire Fram Strait from the continental slope west of Svalbard to the east Greenland shelf along 78°50'N. The cruise will end on 15 July 2011 in Longyearbyen (Svalbard).

The oceanographic measurements in the frame of the EU project ACOBAR (Acoustic Technology for Observing the Interior of the Arctic Ocean) aim on the estimation of oceanic volume and heat fluxes though Fram Strait between the northern North Atlantic and the Arctic Ocean with special emphasis on inter-annual and decadal variability. Hydrographic measurements (temperature, salinity and oxygen) will be conducted on ca. 80 stations along the section and ocean currents in the upper layer will be measured both on stations and underway. The moored array, deployed in 2010 and in 2011 for continuous, year-round measurements of temperature, salinity and currents will be recovered and redeployed with new instrumentation. Measurements at the moored array will provide an extension of the existing 15-year long time series of unbroken observations in Fram Strait. To complement the continuous in time but spatially relatively sparse observations by moorings, the high resolution hydrographic sections will be measured by a Seaglider, deployed during ARK-XXVII/1 for a 3-month long mission in Fram Strait. Eight RAFOS sound sources will be deployed in the western, ice-covered part of Fram Strait for under-ice acoustic navigation of the glider.

Hydrographic measurements at selected stations will be combined with net sampling, trawls and sediment coring for the biogeochemical studies. Climate-induced changes of plankton communities in Fram Strait will be studied by the AWI research group PEBCAO (Phytoplankton Ecology and Biogeochemistry in the Changing Ocean). The pelagic microbiogeochemical processes in the Arctic Ocean will be examined with a special focus on the turnover of organic matter during production and decomposition processes to achieve better understanding of the biogeochemical and microbiological feedback processes in the future ocean. Water samples will be taken along the temperature gradient from Bremerhaven to Spitsbergen in order to isolate and sequence from these samples DNA and RNA from phytoplankton. The amphipod composition will be investigated under the BMBF project 'Arctic pelagic Amphipoda'.

To provide information about the natural and anthropogenic carbon budget of the water masses, characteristics of ocean currents, and to quantify changes in ventilation, the concentration of DIC, oxygen, nutrients and the transient tracers CFC-12 (Chlorofluorocarbon -12) and SF6 (Sulfur hexafluoride) will be measured along the Fram Strait section. The stable oxygen isotope analysis ($\delta^{18}O$), radiogenic neodymium (Nd) isotopes and of rare earth element (REE) patterns will be used for the assessment of water mass signatures in Fram Strait. Water samples for DBC (dissolved black carbon), DOC (dissolved organic carbon) and CDOM (colored dissolved organic matter) will be collected and analysed to determine how much of the riverine DBC entering the Arctic Ocean is subsequently exported to the Atlantic Ocean. To quantify air-sea exchange fluxes of CO_2, CH_4, N_2O and CO in Fram Strait, a glass-bed equilibrator will be connected to the underway sampling system of *Polarstern*. A membrane-inlet mass spectrometer will be used to continuously measure dissolved oxygen-to-argon (O_2/Ar) ratios and these will be used to calculate biological oxygen fluxes.

To study changes of the Greenland ice sheet, visible indirectly at deformations of the surface of the Earth, geodetic work will be carried out in the north-eastern Greenland to deploy GPS sensors with helicopters.

During the entire cruise leg continuous observations and counting of seabirds and marine mammals will be performed. This long-term study is aimed to quantify *at-sea* distribution of these animals in respect to spatial variability of oceanic water masses, frontal zones as well as the concentration of pack ice and the location of sea ice edge.

2. VARIABILITY OF OCEANIC FLUXES THROUGH FRAM STRAIT

A. Beszczynska-Möller, A. Wisotzki, O. Strothmann, M. Monsees, J. Walter, K. Castro-Morales, F. Greil, L. Caesar, J. Kölling, S. Menze, D. Grimm, M. Stärz (AWI)

Background and objectives

Our aim is to investigate the variability of the oceanic fluxes through Fram Strait. This work contributes to long-term studies addressing the response of the various Arctic subsystems to the rigorous climatic changes of the last decades.

The spread of warmth to high latitudes in the Atlantic is part of the global thermohaline circulation. From the North Atlantic warm and saline water flows to the Arctic Ocean where it is modified by cooling, freezing and melting and where huge amounts of river runoff is added. Shallow fresh waters, ice and saline deep waters return to the North Atlantic. The outflow from the Arctic Ocean to the Nordic Seas and further to the Atlantic Ocean is part of the driving of the thermohaline circulation cell. Atlantic water enters the Arctic Ocean either through the shallow Barents Sea or through Fram Strait which represents the only deep connection between the Arctic Ocean and the Nordic Seas. Just as the freshwater transport from the Arctic Ocean is of major influence on convection in the Nordic Seas and further south, the transport of warm and saline Atlantic water affects the water mass characteristics in the Arctic Ocean which has consequences for the internal circulation and possibly influences also ice and atmosphere.

The complicated topographic structure of the Fram Strait leads to a splitting of the West Spitsbergen Current carrying Atlantic Water northward into at least three branches. One current branch follows the shelf edge and enters the Arctic Ocean north of Svalbard. This part has to cross the Yermak Plateau which poses a sill for the flow with a depth of approximately 700 m. A second branch flows northward along the north-western slope of the Yermak Plateau and the third one recirculates immediately in Fram Strait at about 79°N. Evidently, the size and strength of the different branches largely determine the input of oceanic heat to the inner Arctic Ocean. The East Greenland Current, carrying water from the Arctic Ocean southwards has a concentrated core above the continental slope.

The aim of the oceanographic work is to quantify the inter-annual to decadal variation of volume, heat and salt fluxes through Fram Strait. Since 1997 an array of moorings has been maintained to measure currents, temperature and salinity. The year-round measurements are combined with hydrographic sections taken during summer cruises. Until 2005 the observations were done in the framework of the European Union projects ‘VEINS’ (Variability of Exchanges in Northern Seas, 1997-2000) and ‘ASOF-N’ (Arctic-Subarctic Ocean Fluxes, 2002-2005) with a support from the national funding. Since 2006 the work had been carried out as a part of `DAMOCLES’ EU Integrated Project until 2009 when the new EU project ‘ACOBAR’ (Acoustic Technology for Observing the Interior of the Arctic Ocean) started, which embraces also oceanographic measurements in Fram Strait.

Work at sea

An array of 18 moorings covers the entire deep part of Fram Strait along 78°50'N from the eastern to the western shelf edge. 12 moorings in the eastern and central part of the strait are maintained by AWI, while 6 moorings in the western part are operated by the Norwegian Polar Institute.

In 2011 the eastern part of the array was exchanged during the summer *Polarstern* cruise ARK-XXVI/1. During ARK-XXVII/1 in summer 2012 the complete array of 12 AWI moorings in the eastern and central part of Fram Strait will be exchanged and two bottom moorings with PIES will be recovered. Eight of the AWI moorings were equipped with upward-looking ADCPs (Acoustic Doppler Current Profilers) to test the new configuration of the moored array to be adopted under the HAFOS (Hybrid Arctic/Antarctic Float Observing System) project. In future, the HAFOS moored array will consist of gliders covering the upper 300 m layer and shorter moorings with ADCPs at the top. In the current configuration, each subsurface mooring carries 3 to 8 instruments (current meters from Aanderaa, acoustic Doppler current profilers (ADCP) from RDI and temperature and salinity sensors from Seabird), distributed at the nominal levels: 50 m (subsurface layer), 250 m (Atlantic water layer), 750 m (lower boundary of the Atlantic water), 1500 m (deep water) and 5 m above bottom (near-bottom layer). The horizontal distances between moorings are smaller at the upper slope (moorings F1 to F3) and increase towards the deep part of the strait (ca. 20 km). During the deployment in summer 2012 three moorings in the eastern Fram Strait will be equipped with the low-frequency modems to test underwater acoustic data transfer. Two additional moorings will be also deployed, aiming in testing the profiling winches with TS profiler equipped with Iridium modem for data transfer. The profilers will cover the upper water column up to the surface. These moorings will be located next to the moorings F5-F6 at the offshore boundary of the West Spitsbergen Current. The additional moorings with profiling winches and modems will be recovered during autumn cruise of KV *Svalbard* in 2012 for evaluation of the acoustic data transmission.

Hydrographic stations with a CTD system SBE 9/11+ in the combination with a SBE 32 Carousel Water Sampler (Seabird) and an *in-situ* oxygen sensor and ship-borne ADCP measurements will be conducted along the mooring line to supply temperature, salinity and velocity measurements with the higher spatial resolution than given by moorings. The salinity of water samples will be analysed on board with the Optimare Precision Salinometer. In the eastern and central part of Fram Strait the CTD stations will be measured in between mooring work and after completing mooring operations, the hydrographic section will be continued farther westward, according to the available ship time.

A Seaglider, an autonomous buoyancy driven profiling vehicle equipped with pressure, temperature, conductivity, oxygen sensors as well as with RAFOS hardware will be deployed in the eastern Fram Strait during ARK-XXVII/1. This will be the fifth summer mission of the AWI glider, after successful deployments in summers 2008-2011. The glider operations occur in close cooperation with Craig Lee from APL at the University of Washington in Seattle. The Seaglider will be operated from the pilot station in Bremerhaven during ca. 3-month long mission, aimed in profiling the upper 1000 m layer along sections in the open water part of Fram Strait (mostly to provide repeated snapshots of the high resolution hydrographic conditions along the mooring line). For the purpose of development and testing of the underwater acoustic navigation system, the Seaglider will receive and register RAFOS transmissions, provided by RAFOS sound sources moored in Fram Strait. During ARK-XXVII/1 eight RAFOS sound sources will be deployed in the western and central part of the strait in the ice covered area for testing the acoustic propagation of RAFOS signals under ice. The set of RAFOS sources will consist of six RAFOS sources from develogic GmbH and two Webb sources, the latter two have to be redeployed. The results of this operation are a crucial knowledge required for future under-ice missions of acoustically navigated gliders. The Seaglider deployed in summer

2012 will also receive RAFOS signals transmitted by two tomography moorings, deployed in Fram Strait in the frame of the ACOBAR project (the third tomography mooring failed to provide RAFOS signals). Depending on the performance of the RAFOS based acoustic navigation of the glider, a short under ice mission is planned during its summer deployment.

Data and samples

CTD data collected during ARK-XXVII/1 will be delivered after the post-cruise calibration to the PANGAEA data base and to the appropriate national data banks. The data recorded by the moored instrumentation will be post processed after the cruise at AWI and submitted to the PANGAEA data base within one year. The glider data collected during the summer mission are recorded at AWI in near-real time. The preliminary processing is done during the mission while the final post processing of the glider data takes place after the completion of the mission. The processed glider data will be delivered to the PANGAEA data base within one year after the mission, provided that the necessary data formats and upload procedures will be worked out in the data base.

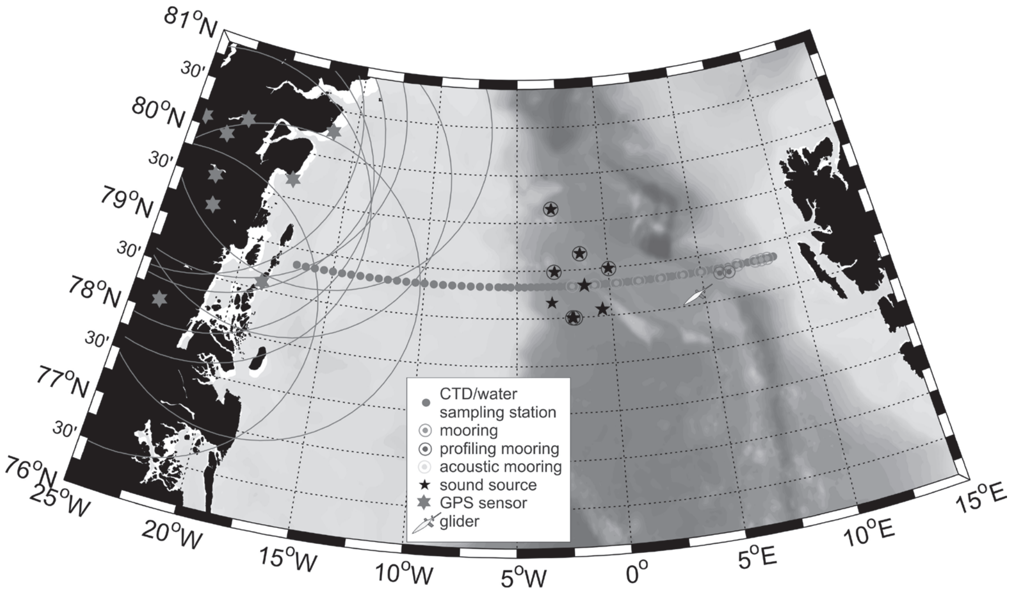

Fig. 2.1: Positions of moorings and CTD stations in Fram Strait

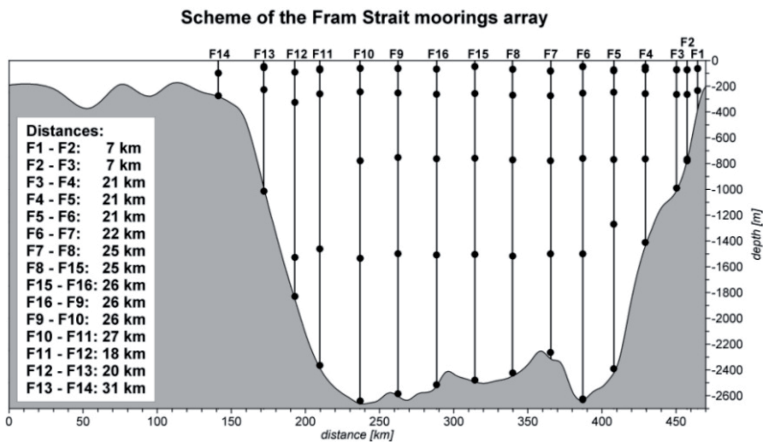

Fig. 2.2: Scheme of instrumentation at the Fram Strait moored array (moorings between F1 and F10 will be exchanged during ARK-XXVII/1)

3. PLANKTON ECOLOGY AND BIOGEOCHEMISTRY IN THE CHANGING ARCTIC OCEAN (PEBCAO)

B. Niehoff, S. Gäbler-Schwarz, K. Kohls, N. Hildebrandt, I. Petersen, M. Winkler, A. Wolanin (AWI), not on board: E.-M. Nöthig, K. Metfies; Ilka Peeken, (AWI & MARUM Bremen)

Objectives

The Arctic Ocean has gained increasing attention over the past years because of the drastic decrease in sea ice and its temperature increase which is about twice as fast as the global mean rate. In addition, changes in surface ocean chemical equilibrium and elemental cycling are occurring due to ocean acidification. These physical and chemical changes of the environment will eventually bear enormous consequences for the pelagic system and for the net carbon balance of Arctic ecosystems. Our aim is to contribute to a better understanding of the direction and strength of biological feedback processes in the future Arctic Ocean by detection and tracking of large-scale environmental changes.

Climatically induced changes will also impact species selection in pelagic ecosystems. A shift in species composition is expected in all size classes of the phytoplankton, however, smallest algae may thrive the phytoplankton in the future Arctic Ocean. Besides diatoms, other much smaller algae and possibly also cyanobacteria, will gain more importance in mediating element- and matter- as well as export fluxes in the Arctic pelagic system. Changes on lower trophic levels will lead to another followed-up generation within the grazer communities having an additional effect on organic matter fluxes.

The marine algae, *Phaeocystis pouchetii*, having an intermediate position regarding size, can play a key role in the carbon and sulphur cycle. However, little is known about its diversity, distribution, occurrence and physiology in Arctic pelagic regions. A shift in species composition is also expected in the zooplankton communities due to the warmer Atlantic water prevailing in the Fram Strait since the last 10 years. These different communities may alter the transport and modification of organic matter flux.

Molecular methods are well suited to provide refined information on the composition and biogeographical differences of Arctic phytoplankton communities, including the smallest fractions (e.g. cyanobacteria). The characterization of phytoplankton communities with molecular methods is independent of cell-size and distinct morphological features. The assessment of the biodiversity and biogeography of Arctic phytoplankton will be based on the analysis of ribosomal genes, taking advantage of latest 454-pyrosequencing technology, Automated Ribosomal Intragenic Sequence Analysis (ARISA) or ribosomal probe based methods.

During ARK-XXVII/1 the following topics are covered:

- Monitoring plankton species and biomass distribution as well as biogeochemical parameters along the Fram Strait transect
- Investigations on selected phyto- and zooplankton and related biogeochemical parameters
- Investigations on nanoplankton with focus on key species *Phaeocystis pouchetii.*

Work at sea

We intend to sample Arctic seawater by CTD/rosette sampler along the oceanographic transect (78°50'N) at about 5-8 depths.

Measurements of CTD samples

Biogeochemical parameters:

- chlorophyll a
- HPLC pigments,
- CDOM (coloured dissolved organic matter)
- particulate organic carbon (POC)
- particulate organic nitrogen (PON)
- particulate biogenic silica (PbSi).
- Biological parameters from CTD casts:
- phytoplankton & protozooplankton abundance
- sampling for genetic analyses & clonal cultures
- sampling for moelcularbiological approches
- flow cytometer.

Biological parameters with net hauls (Multinet, Bongo net):

- sampling of live phytoplankton and zooplankton in the field
- mesozooplankton composition and depth distribution will be determined by means of multinet hauls.
- Bongo net hauls will be taken to collect organisms:
  - for biochemical analyses (carbon, nitrogen, protein and lipid content, fatty acid composition);
  - for enzyme activity analyses (citrate synthase, digestive enzymes).

Culture work

We also intend to sample Arctic seawater by CTD/rosette sampler and hand-net hauls along the 78°50' N transect to catch phytoplankton for isolation for later performing clonal cultures, genetic analyses will be carried out with the isolates.

Experimental work

We will study the response of dominant Arctic copepods to elevated CO_2 concentrations by means of incubation experiments. Particularly we will focus on grazing, egestion and egg production rates, which will all be measured on board ship. In addition, we will deep freeze individuals over the course of the experiment to determine changes in body mass and enzyme activities. This will elucidate whether and on which level high CO_2 concentrations affect performance of copepods.

Sample storage and analyses

All samples will be preserved or frozen at 20°C and partly at – 80° C for further analyses, or haltered in the cooling culture lab container for clonal culturing and physiological experiments in the home laboratory at AWI.

Data and samples

Almost all sample processing will be carried out in the home laboratory at AWI. It usually takes one to three years depending on the parameter as well as analyzing methods such as chemical measurements or tedious swimmer picking in trap material and species enumerations and identifications, respectively. As soon as the data sets are available they can be used by other cruise participants after request. When the data will be published they will be submitted to PANGAEA and are open for external use.

4. SEA OF CHANGE – EUKARYOTIK PHYTOPLANKTON DIVERSITY AND ACTIVITY IN THE POLAR OCEAN

Katrin Schmidt, Mariam Rizkallah, not on board: Klaus Valentin, Thomas Mock, Gerhard Dieckmann (AWI)

Objectives

We currently observe a warming of the oceans with unforeseen consequences on phytoplankton diversity and activity. Our current data of five metatranscriptomes from different ocean temperature samples suggest that warming will significantly change phytoplankton composition and gene expression with a shift from diatoms towards dinoflagellates and from protein metabolism towards carbohydrate metabolism, respectively, with warming. In order to broaden this database we were awarded a grant from Joint Genome Institute (JGI) to sequence additional 16 metagenomes and metatranscriptomes from phytoplankton of different water temperature. We therefore will take water samples along a temperature gradient from Bremerhaven to Spitsbergen. From these samples DNA and RNA shall be isolated and sequenced by JGI. Sampling will be done for phytoplankton and used for DNA/RNA isolation as well as chlorophyll a and pigments. We will later attempt to correlate biodiversity and gene expression data to abiotic factors, mainly to temperature.

Work at sea

Water samples will be collected in Niskin bottles mounted on a rosette sampler at discrete depths throughout the water column on several stations along transects. In addition we will record supplementary station parameters such as temperature, salinity and flouroscence maxium. We will preserve or freeze samples to be returned to the home laboratory for further analyses.

Data and samples

The data of all measured physical parameters will be deposited in PANGEA with no limitations for access. All sequence data will submitted to Genbank and made available for the public after the DFG and JGI projects, respectively, are terminated, or published in scientific journals.

5. ARCTIC PELAGIC AMPHIPODA

N. Knüppel, G. Lax (AWI), not on board: A. Kraft, E. M. Nöthig (AWI),

Objectives

Pelagic Amphipoda are key components in marine ecosystems. They are the link between herbivores and higher trophic levels. However, their role in the polar ecosystems, especially in ice-covered Arctic seas, is still poorly understood. Current knowledge is exclusively based on seasonally limited material collected mostly during summer observations. Data, especially on their year round distribution in Arctic waters and nutritional value for marine sea-birds and mammals are scarce. Nowadays, the amphipods in the Arctic are faced with a drastically changing environment including increasing ocean temperatures and acidification as well as a rapidly declining sea ice cover. As the sea ice disappears, we expect that typical large cold water amphipods, such as the Arctic specialist *Themisto libellula*, will be replaced by smaller and more temperature tolerant Atlantic generalists. Therefore, the BMBF-funded 'Arctic pelagic Amphipoda' project will investigate the following aspects:

1) The biological performance of the true pelagic amphipods *Themisto* and *Cyclocaris* in the context their geographical migration and association to respective water masses.

2) The ecological impact of pelagic amphipods on polar food webs under the aspect of changing temperature and sea ice properties.

Work at sea

During ARK-XXVII/1 we plan to investigate the amphipod composition with the use of a large multinet (HYDRO-BIOS type Maxi with an aperture of 0.5 m² and nine 1,000 µ net bags). The net sampling will include vertical hauls from 2,000 m to the surface. The net will be hoisted at 0.8-1 m/s with stops at 1,500 m, 1,000 m, 800 m, 600 m, 400 m, 200 m, 100 m and 50 m in order to analyze the occurrence of pelagic amphipods at the different depth horizons. In total, amphipods will be sampled at least at with 10 vertical hauls along the 78'50°N transect. The samples will transported to the cooling container, sorted, identified to species level, if possible, and measured. Afterwards, the collected amphipods will be preserved or frozen at -80 °C for further analyses in the home laboratory at the AWI.

Data and samples

The samples will transported to the cooling container, sorted, identified to species level, if possible, and measured. Afterwards, the collected amphipods will be preserved or frozen at -80 °C for further analyses in the home laboratory at the AWI.

6. TRANSIENT TRACERS DYNAMICS, CARBON DIOXIDE AND DISSOLVED OXYGEN IN FRAM STRAIT

Tim Stöven, Boie Bogner, Hanna Schade (GEOMAR), Chris Schrammar (AWI)
not on board: Toste Tanhua (GEOMAR), Mario Hoppema (AWI)

Rationale

The CO_2 uptake by the ocean is an important process in terms of climate change and interactions. The deep water formations in the northern North Atlantic and the Arctic Ocean are major transformation processes of upper and surface water layers into the deep water. These upper layers are characterized by high concentrations of anthropogenic carbon (Cant) and are therefore an important sink of Cant into the deep ocean. The Fram Strait connects the northern North Atlantic (i.e. the Nordic Seas) with the Arctic Ocean. Several north- and southward currents flow through the Fram Strait and we will investigate the concentration structure of DIC, oxygen, nutrients and the transient tracers CFC-12 (Chlorofluorocarbon – 12) and SF6 (Sulfur hexafluoride) along 78°50' N. These parameters should provide information about the natural and anthropogenic carbon budget of the water masses and physical characteristics of the different currents.

Furthermore, transient tracers are powerful tools in oceanographic studies. Ventilation and transport processes as well as the characteristics of mixing rates (the share of advection and diffusion) of water masses can be described by transient tracers. CFC-12 and SF6 is a common tracer couple due to its property to describe mixing of young and recently ventilated and also older less ventilated water masses.

Objectives

Specific objectives of the proposed research include:

- Determine the physical and chemical characteristics (CO_2, oxygen, nutrients, transient tracers) of the major north- and southward currents
- Investigate spatial and temporal variability of ocean interior content of carbonate species, nutrients and oxygen; i.e. we will compare our data to historic data in the region
- Quantify changes in ventilation in the Fram Strait from transient tracer measurements, these and historic ones
- Calculate the concentration and transport of anthropogenic carbon through Fram Strait
- Quantify the transport of SF6 originating from a deliberate tracer release experiment conducted in 1996 in the central Greenland Sea, recent data indicate a significant amount of the tracer in the Greenland Sea gyre also today.

Work at sea

Samples will be taken from all bottom casts of the rosette water sampler with a discrete depth profile through the whole water column. The transient tracers CFC-12 and SF6 will be measured on board with two purge and trap gas chromatographic systems equipped with electron capture detectors. Dissolved Inorganic Carbon and Total Alkalinity (DIC/TA) samples will be poisoned with

$HgCl_2$ and stored in glass bottles. The nutrients will be sampled with plastic bottles and stored at -20°C after freezing at -80°C: DIC/TA and nutrients (phosphate, nitrate, nitrite, silicate) will be measured onshore at the GEOMAR in Kiel. The nutrient sampling and measuring will be achieved in cooperation with Dorothea Bauch and Martin Frank at GEOMAR. Oxygen will be determined with a Titronic titration system based on the Winkler method on the ship.

Data and Samples

The data of all measured parameters including the raw data, calibrations and further calculations will be administrated by the data management system of GEOMAR. The access authorization to the database will be controlled by the project leaders. The final data set will be submitted to CDIAC after at the most three years after the cruise.

7. GPS OBSERVATIONS IN NORTH-EAST GREENLAND TO DETERMINE VERTICAL AND HORIZONTAL DEFORMATIONS OF THE EARTH'S CRUST

R. Rosenau, K. Krawutschke, not on board: M. Scheinert (TU Dresden)

Objectives

In Greenland, there still exists the only continental ice sheet outside Antarctica. It plays an important role for the global climate. Despite it contains only 10 % of the global freshwater storage in comparison to the Antarctic ice sheet, due to its location at high- and subpolar latitudes it reacts in a very sensitive way to changes in the environmental and climate conditions. Therefore, the Greenland ice sheet has been subject to intensive geophysical and glaciological investigations for almost one century.

Changes of the ice sheet are visible indirectly at deformations of the surface of the Earth. Ice mass changes can be regarded as changing surface loads, which cause – due to the rheological properties of the upper layers of the Earth – long-term visco-elastic and immediate elastic reactions. Hence, in the observable vertical deformation of the Earth's crust we can find the integral effect of all ice-mass changes during glacial history and in present times.

North-East Greenland is characterized by a high variability of the ice edge with regard to its location and mass change as well as of a visco-elastic signal due to glacial history, which – according to model predictions – reaches maximum values for entire Greenland. Additionally, deformations of tectonic origin cannot be excluded, which will be tested by analysing the horizontal components.

Satellite-based positioning by means of GPS allows a precise geodetic determination of coordinates and, with repeated observations, the determination of precise changes for the horizontal as well as for the vertical components with an accuracy in the sub-centimeter level. In order to ensure a high accuracy of repeated measurements, a stable base for the GPS marker has to be chosen. Therefore, the stations are to be set-up at ice-free bedrock locations.

This project can be regarded as a continuing contribution to the internationally coordinated projects, initiated by the IPY 2007/08 project POLENET (Polar Earth Observatory Network) and to be continued by the SCAR program SERCE (Solid Earth Response and Cryosphere Evolution). Linked to this international coordination we closely cooperate with Danish and other international partners (cf. project partners).

Planned activities

The geodetic work to be carried out during this *Polarstern* cruise is a continuation of a project started 2008 during the cruises ARK-XXIII/1+2 (2008) and ARK-XXIV/3 (2009). During these expeditions, 22 locations at bedrock were surveyed, where GPS stations were successfully set up and most of them observed for the first time. The geodetic network configuration realized in this way includes a west-east component (stations at the ice edge and at the coast), and covers a north-south extension from about 74°N to 81.5°N. Due to the logistic conditions of the planned cruise, we will occupy up to 10 stations between 78°N and 81°N again in order to carry out a first re-observation by geodetic GPS positioning. All locations will be reached by helicopter. The GPS equipment will be set up and remain at each location to observe permanently for 3 to 6 days at least.

From the analysis of the repeated GPS observations we will come up with deformations respectively rates, which serve as an independent source of information for the validation and improvement of models on the glacial history and on the recent ice mass balance of North-East Greenland. While testing the significance of horizontal deformations, we will contribute to an improved analysis of the tectonic regime in the working area.

Table 1: List of GPS stations installed and observed in 2008, 2009 and to be re-observed during ARK-XXVII/1

ID	Longitude	Latitude	Geographical Region
ROME	-19.0617	81.0718	Kronprins Christian Land CN
CENT	-21.7236	80.1913	Centrumsø (Kronprins Christian Land CS)
HOLM	-16.4315	80.2730	Holm Land SE
CRIW	-24.3136	80.0925	Kronprins Christian Land SW
BLAF	-22.6494	79.5329	Kronprins Christian Land S
MUSK	-22.7228	79.9795	Skallingen (Kronprins Christian Land SW)
HOVG	-18.2306	79.7002	Hovgaard Ø
LAMW	-22.3061	79.2265	Lambert Land W
BILD	-23.5033	78.1164	Bildsøe Nunatakker
FRAN	-18.6273	78.5784	Franske Øer

SW South-West
SE South-East
CS Centre-South
etc.

Data

All measured GPS data will be archived at the Institut für Planetare Geodäsie. For this purpose we will use a database which is maintained in the framework of SCAR (SCAR GIANT - Geodetic Infrastructure in Antarctica). As long-term data format the RINEX format will be used.

8. WATER MASS SIGNATURES ($\delta^{18}O$, ND AND RARE EARTH ELEMENTS)

Moritz Zieringer, Jutta Heinze (GEOMAR), not on board: Dorothea Bauch,
Martin Frank (GEOMAR)

Objectives

The overall purpose of the project is to provide an assessment of water mass signatures based on stable oxygen isotope analysis ($\delta^{18}O$), radiogenic neodymium (Nd) isotopes (expressed as eNd) and of rare earth element (REE) patterns. Sampling in Fram Strait allows to capture water masses entering and exiting the Arctic Ocean through Fram Strait. Based on hydrological data and stable oxygen isotope analysis ($\delta^{18}O$) the influence of shelf-derived freshwaters and contributions of waters containing a brine signal originating from sea-ice formation can be quantified. Together with nutrient data (NO_x, PO_4 and O_2) also the Atlantic and Pacific-derived components can be quantified within the halocline. This information will be supported by dissolved Nd-isotope and rare earth element (REE) signatures, which can be used to identify the source regions of the water masses and their degree of mixing. The current database available for comparison indicates that there are strong interannual as well as interdecadal variations in the distribution of Siberian and Alaskan freshwater, as well as of the contribution of Pacific waters to the Arctic Ocean halocline. At greater depth the variability of Atlantic inflow and Arctic outflow will be investigated with the same proxy tracers. A quantitative evaluation of the freshwater exchange through Fram Strait will help to further understand the impact of the variations in Arctic Ocean hydrographic conditions and Arctic and global climate change.

Background information

With the significant reduction seen in summer sea-ice cover considerable changes in the sea-ice regimes of the Arctic shelves and the shelf-derived Arctic Ocean halocline are expected. Melt water and huge amounts of river water are released on the Arctic Ocean shelf areas in summer, while sea-ice and brine waters are produced during winter. Stable oxygen isotope ratios ($^{18}O/^{16}O$; usually expressed as $\delta^{18}O$ values, which is the ‰ deviation relative to a sea-water standard, SMOW) in conjunction with hydrological data are an excellent tool to investigate the contribution of the different water masses from the Arctic shelf regions (Bauch et al., 1995; Ekwurzel et al., 2001). Arctic rivers are strongly depleted in heavy oxygen isotopes (^{18}O) relative to marine waters. Sea-ice processes on the other hand also strongly influence the salinity of the water, but have little influence on the $\delta^{18}O$ value of the water column. Therefore $\delta^{18}O$ analysis gives important quantitative information about freshwater sources, such as river water, sea-ice meltwater or sea-ice formation. A further quantification of Atlantic and Pacific-derived waters within the marine fraction can be made based on nutrient concentrations (Ekwurzel et al., 2001; Jones et al., 1998, 2008; Yamamoto-Kawai et al., 2008; Bauch et al., 2011).

Coupled dissolved signatures of radiogenic neodymium (Nd) isotopes (expressed as εNd) and of rare earth element (REE) patterns are powerful geochemical tracers of water masses introduced into seawater through weathering of the rocks in the source areas of the water masses [cf. Frank, 2002]. Source rock composition and age of the continental crust are geographically variable and characteristic for particular groups and ages of rocks providing a geochemical “finger-print”. The global average residence time of Nd in seawater is about 400-1000 years (Arsouze et al., 2009). Thus typical isotopic signatures of water masses can be preserved and transported over large distances. While changes in weathering inputs from land (rivers, exchange with shelf sediments) influence the surface water signatures, changes of the Nd isotope signatures in the open ocean are only controlled by mixing of water masses with different signatures, which can also be extracted from sediments and have been used for reconstruction of past water mass mixing and ocean circulation in the Arctic Ocean (e.g. Haley et al., 2008).

Work at sea

We plan to take water samples for stable oxygen isotope analysis ($\delta^{18}O$) in parallel to CTD measurements and hydrological sampling (samples will be frozen and transported to Kiel for analysis; sampling and analysis will be conducted in cooperation with CFC-group Toste Tanhua/Tim Stöven). It is planned to sample water for Nd-isotopes and REE signature (10-20l) at about 10 stations and about 10 depth levels from CTD-rosette.

Sampling is planned within the halocline and the intermediate waters down to a depth of about 1000 m. Sampling within the deep and bottom waters is also planned for a selection of stations. Sampling should be conducted across Fram Strait and as far as possible onto the Greenland shelf in order to access slope processes and contributions exiting the Arctic Ocean halocline in the East Greenland Current and over the Greenland shelf.

Sampling plan

Water sampling for $\delta^{18}O$ analysis (100 ml) from CTD-rosette is planned throughout the water column at all available stations and depth levels (but no multiple casts). The planned sampling depths are at about : 0 m, 5 m, 10 m, 20 m, 30 m, 50 m, 75 m, 100 m, 150 m, 200 m, 300 m, 400 m, 500 m, 600 m, 700 m, 800 m, 900 m, 1,000 m. At selected stations further sampling down to the sea floor at additional depth: 1,250 m 1,500 m 1750 m 2,000 m, 2,250 m, 2,500 m, 2,600 m, bottom depth.

Sampling of water for Nd-isotopes and REE signature (10-20 l) from CTD-rosette is planned at about 10 Stations within each water mass (about 100 samples in total). Planned sampling depths for Nd-isotopes are at about: 10 m, 50 m, 100 m, 200 m, 350 m, 500 m, 1,000 m, 1,500 m, 2,000 m, bottom depth (with a sample about 50 m above ground and if possible an additional sample about 5 m above ground).

Data and samples

Samples will be transported to Kiel. Analysis for stable oxygen isotope composition will be conducted at the Leibniz Laboratory at Kiel University, Kiel, Germany and at the Stable Isotope Facility at CEOAS at Oregon State University, Oregon, USA within 1 year. Water for Nd-isotopes and REE signature (10-20l) from CTD-rosette will be analyzed at GEOMAR within 1 year. Samples for PO_4/NO_3 and silicate will be frozen and transported to Kiel for analysis within 2 month.

Data will be stored at the PANGAEA data repository and will be made public after publication at PANGAEA Data Repository.

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9. FLUXES OF DISSOLVED BLACK CARBON THROUGH THE ARCTIC OCEAN

A. Stubbins (Skidaway IO)

State of research

Dissolved organic matter

Dissolved organic matter (DOM) plays a major role in key biogeochemical processes, providing sustenance at the base of microbial foodwebs and mediating fluxes of carbon (C) from vegetation and soils, to rivers, the oceans, and eventually the atmospheric CO_2 pool. The DOM pool in the oceans represents one of the largest global C pools (~700 Pg C), storing approximately the same amount of C as is found in all living organisms on Earth. Due to its great size, even minor changes in the dynamics of the DOM pool or its components can impact the global ecosystem, particularly ocean C-storage and atmospheric CO_2. The DOM pool is of further interest as an information rich set of tracers, diverse in source, reactivity and history. These molecules carry the signatures of their source and subsequent journey through the environment to their point of analysis. This work focuses upon one component signature within the DOM pool: dissolved black carbon.

Dissolved black carbon

In the context of this work, dissolved black carbon (DBC) refers specifically to dissolved polycyclic aromatics. As far as is known, DBC can only be formed thermogenically making it a specific tracer for thermally altered DOM. Heating of organic matter results in a number of reactions, including condensation reactions which yield polycyclic aromatics (PCAs; alternatively referred to as polycyclic aromatic hydrocarbons (PAHs) and condensed aromatics, in the literature). It is the biphenol carboxylic acid oxidation products of these condensed aromatics which will be identified and quantified as DBC in the planned work. Dissolved black carbon was recently found to occur throughout all studied ocean water masses at concentrations between 600 and

810 nanomols of carbon per L (nM-C) or ~2% of total dissolved organic carbon (DOC). This makes DBC one of the most prevalent of organic molecular classes quantified in the global ocean.

Inputs of terrestrial black carbon to the Arctic Ocean

We quantified dissolved black carbon in the largest six Arctic Rivers, the Kolyma, Lena, Ob, Mackenzie, Yenisey and Yukon. Using these data, together with discharge data for Arctic Rivers, total annual export of terrestrial dissolved black carbon to the Arctic Ocean from the Kolyma, Lena, Ob, Mackenzie, Yenisey and Yukon was calculated to be 0.8 Tg-BC yr^{-1}. This flux equates to 3-4% of the total riverine export of DOC to the Arctic Ocean (18-26 Tg-DOC yr^{-1}). It is estimated that DBC makes up 2% of DOC in the global ocean. Assuming an oceanic DOC pool of 700 Pg-C, the oceanic DBC pool would be 14 Pg-BC. That being the case, Arctic River inputs could replenish the standing stock of oceanic DBC in ~17,000 years (14 Pg-BC / 0.8 Tg-BC yr^{-1}), which is the approximate age of high molecular weight DBC in oceanic waters (18,000 years). Therefore, DBC inputs by Arctic Rivers are sufficient to account for the radiocarbon based turnover of DBC in the global ocean.

Objectives

Determine how much of the riverine DBC entering the Arctic Ocean is subsequently exported to the Atlantic Ocean in order to better constrain the global DBC cycle and to allow a 1st order estimate of the degradation of terrestrial DBC that occurs in the Arctic Ocean.

Participation in RV *Polarstern* cruise ARK-XXVII/1 will provide for the collection of samples from the East Greenland Current and West Spitsbergen Current as they pass through the Fram Strait for DBC analyses.

DBC will be related to DOM optical properties to produce proxies for the estimation of DBC in other waters.

Work at sea

1 to 4 L samples for dissolved black carbon: Sampling of 1-4 L of seawater from CTD casts focused on the West Spitsbergen and East Greenland Currents. Dependent upon weather conditions and ice cover, between 50 and 100 of these larger volume samples would be collected from stations determined with the cruise chief scientist. Samples will be filtered and extracted on board using simple, gravity driven equipment. No pumps or mechanical equipment will be required.

The following samples will be collected:

- 100 mL samples for DOC and CDOM: Sampling of ~100 mL of water from all CTDs casts with this volume of water to spare. Samples will be acidified on board for DOC and frozen for CDOM analyses.
- 1-4 L from select CTD casts already planned in the West Spitsbergen and East Greenland Currents
- 100 mL from other CTD casts that are already planned

Data and samples

Responsible data manager and point of contact: Aron Stubbins. aron.stubbins@skio.usg.edu. Tel:+1(912)598-2320.

Types of data: Data and metadata for this project will be generated at SkIO and the Max Planck Institute Marine Geochemistry Group, Oldenburg, Germany. Data will consist primarily of DBC, CDOM, DOC, and high resolution Fourier transform ion cyclotron mass spectrometry data. These data will be accompanied by detailed metadata. The total number of data files will be ~1000.

Data and metadata formats, standards, and organization

a. Formats. Data and metadata will be delivered to ACADIS in Excel or ASCII format in order to allow ready access to the data by all interested parties.

b. Metadata. Metadata will be at the file level, as well as at the collection level. The ACADIS metadata authoring tool will aid in developing the metadata profile at the collection level. Where appropriate, standard vocabularies, keywords, or other conventions will be integrated with the help of ACADIS.

c. Organization. Stubbins will plan fieldwork, conduct analyses and curate the data.

d. Data quality. Data will be collated by PI Stubbins and organized in Microsoft Excel spreadsheets. While the individual labs that generate the various data streams will be responsible for maintaining records of data quality (standard curves, measures of analytical error, etc.), the collated data will also be screened for anomalies. Where possible, re-analyses of archived samples will be completed to check anomalous values. Possible outliers included in the data will be flagged to alert subsequent data users.

Data access and sharing: The data and metadata generated will be made public and submitted to ACADIS no more than one year after the above quality checks. There are no exceptional arrangements needed to provide appropriate ethical restriction to data access and use.

Data Reuse: Data will be described in accordance with ACADIS standards (which are being developed). The investigators will work closely with ACADIS curators to ensure accurate and complete documentation in accordance with the ACADIS designated level of service.

Data Preservation: Upon collection data will be stored on a local hard drive and the Skidaway Institute of Oceanography's virtual drive which is backed up daily and at the University System of Georgia's online repository. ACADIS will endeavor to archive the data according to the ISO-standard Open Archives Information System Reference Model, and will ensure that the data end up in a relevant long-term archive. Project investigators will work closely with ACADIS curators to provide all information necessary for data preservation in accordance with the ACADIS designated level of service.

10. HIGHER TROPHIC LEVELS: DISTRIBUTION AT SEA OF SEABIRDS AND MARINE MAMMALS

Jeremy Demey, Diederik D'Hert, Raphaël Lebrun, not on board Claude R Joiris (PolE)

Background and objectives

The main aim of our long-term study of the higher trophic levels - cetaceans, pinnipeds and seabirds – is to confirm and develop the links with the main factors influencing their distribution at sea: water masses and fronts, pack ice and ice edge, eddies, especially in polar ecosystems. Within these very « poor » ecosystems with low biodiversity (e.g. low number of species), some hot spots deserve special attention:

- very local, extremely high concentrations of little auks (Krabbentaucher) and harp seals at the narrow front between Polar and Arctic Water masses. It is mostly situated at the ice edge, but can also be found at other positions of the area, including deep eddies;
- local very high concentrations of large cetaceans (whales), on the one hand in the south-eastern part of the Greenland Sea (Denmark Strait): hundreds of humpback whales and on the other in the northeastern part of Greenland Sea and Fram Strait, off western Spitsbergen, both close to the continental slope: mainly hundreds of fin whales, as well as blue and humpback whales, and a few bowheads. The last becoming the obvious priorities of legs 1 & 2 of this expedition.

These high concentrations correspond to a drastic increase of populations from 2005, mainly from 2007 on. This huge increase by a factor 20 cannot be explained by a growth of local « stocks »: our interpretation is that populations were previously separated by ice conditions, the Atlantic ones being at extremely low levels after over-exploitation by whaling while the Pacific ones were at clearly higher levels. When Arctic pack ice coverage strongly decreased in 2005 (then the year with lowest coverage), the Western and Eastern Passages opened, and might have allowed exchanges between whale stocks resulting in such an increase in Atlantic populations. The most striking example concerns the bowhead, with 1 observation only during more than 5,000 counts on board RV *Polarstern* from 1988 to 2003, but 1 to 8 observations during each expedition after 2007 in the same area (a few hundred counts each). A similar increase was detected for blue, fin and humpback whales.

Possible effects of decreasing ice coverage are also to be considered:

- polar bear is often cited as a threatened species, due to decreasing pack ice coverage. This does not seem to be the case in the Greenland Sea and Fram Strait : the population seems stable in numbers and health based on the numbers of cubs. The really threatened populations are actually the marginal ones, suffering much more of decreasing ice coverage (e.g. Hudson Bay, where studies were conducted).
- in contrast, seabirds might be much more affected. The example of the most numerous species, little auks can be cited: in order to bring food (polar zooplankton), they must travel between colony and feeding ground (basically ice edge: see higher) on a daily basis. If due to lower ice coverage, the distance becomes larger than 100 km - 150 km maximum, they might become unable to breed successfully.

Work at sea

Birds and mammals will be recorded by transect counts from the bridge, without width limitation. Animals are detected with naked eye, observations being confirmed and detailed with binocular and/ or telescope. Each count lasts 30 minutes - an adaptation to poor ecosystems – with a 90° angle in front of *Polarstern*. Counting will be continuous during all displacements of the ship, visibility conditions allowing. Complementary counts will be realized when possible from the crow's nest and helicopter flights following the same route, in order to allow comparison between data obtained from different observation platforms.

Data

Data will be stored in the PolE data set, and made available to the public as summary: joiriscr@gmail.com, and will soon be published in international scientific publications. Data will be available in the PANGAEA data set, one month after the end of the expedition. Publication usually follows within the year.

11. AIR-SEA EXCHANGE OF GREENHOUSE GASES IN RELATION TO BIOLOGICAL NET AND GROSS OXYGEN PRODUCTION IN THE ARCTIC

Natalie J. Wager (UEA), not onboard: Jan Kaiser, Dorothee C. E. Bakker, Gareth A. Lee (UEA)

Background

The Arctic is subject to amplified effects of global warming in comparison to other parts of the world. Sea ice retreat may leave the Arctic vulnerable to physical and biological changes, including the release and uptake of climatically active gases. Changes in sea surface temperature and salinity influence the solubility of gases. Also, the reduced sea-ice cover allows for faster air-sea gas exchange in the Arctic Ocean. Such changes highlight the vulnerability of this sensitive ecosystem to the effects of climate change.

Carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) are the three most important anthropogenic greenhouse gases, with atmospheric lifetimes of decades to centuries. Carbon monoxide (CO) is not a greenhouse gas itself, but since it is the most important sink for atmospheric hydroxyl radicals (OH), it strongly affects other atmospheric trace gases, including CH_4. To enable an accurate assessment of future impacts on the world climate, it is essential to quantify the natural sources and sinks of these climatically active gases. There are currently large uncertainties in their oceanic global budgets as well as the biogeochemical processes driving production and uptake, particularly in the Arctic.

This project aims to find links between biological production rates and trace gas exchange fluxes. The CO_2, N_2O, CH_4 and CO saturations will be determined using a shipboard equilibrator coupled to highly stable and precise optical cavity ring-down spectrometers. Production rates will be derived from online oxygen-argon (O_2/Ar) ratio measurements by membrane inlet mass spectrometry (MIMS) and discrete offline analyses of oxygen isotope ratios in dissolved O_2 ($^{17}O/^{16}O$, $^{18}O/^{16}O$). Except for the isotope ratios, all measurements can be done in a largely automated fashion using water from the ship's underway sampling system. The O_2/Ar and isotope ratios and trace gas saturations will be combined with air-sea gas exchange parameterisations to derive net biological and gross photosynthetic O_2 as well as trace gas fluxes. We expect areas of CO_2 drawdown to correspond to net sources of O_2. In contrast, the link between N_2O, CH_4 and CO fluxes and O_2 fluxes is less obvious because their production is tied to biological processes below the mixed layer. The temporal and spatial extent of any correlation needs to be investigated. A further goal of our research are instrument performance comparisons, e.g. between membrane inlet and equilibrator inlet mass spectrometry for O_2/Ar ratios.

Objectives

- To quantify air-sea exchange fluxes of CO_2, CH_4, N_2O and CO in Fram Strait, Norwegian Sea and Greenland Sea
- To derive estimates of mixed layer net community production
- To derive estimates of photosynthetic gross production
- To establish empirical relationships between trace gas fluxes and productivity estimates
- To compare the p(CO_2) measurements by AWI's shipborne GO-LICOR instrument with UEA's ICOS analyser
- To compare O_2/Ar measurements using membrane inlet mass spectrometry (MIMS), equilibrator inlet mass spectrometry (EIMS) and discrete samples.

Work at sea

A glass-bed equilibrator will be connected to the underway sampling system of *Polarstern*. The headspace will be sampled continuously by a daisy-chain of two Los Gatos ICOS analysers, one for combined CO_2/CH_4/H_2O measurements, the other for combined N_2O/CO/H_2O measurements. The analysers provide dry mixing ratios of CO_2, CH_4, N_2O and CO. Measurements will be continuous, only interrupted by daily calibrations with three standard gas mixtures, running 20 min each, and regular analyses of clean air (5 min every hour). The results will be combined with ship-based wind-speed measurements and suitable wind speed-gas exchange parameterisations to calculate air-sea gas exchange fluxes.

A membrane-inlet mass spectrometer will be used to continuously measure dissolved oxygen-to-argon (O_2/Ar) ratios, these will be used to calculate biological oxygen fluxes (Kaiser et al., 2005). Discrete water samples will also be collected from the pumped surface seawater supply and analysed for the triple oxygen isotope composition of dissolved O_2. These samples will also be used to provide calibration data for the O_2/Ar measurements obtained by MIMS. The ^{17}O isotope excess in the dissolved O_2 can be used to estimate the contribution of atmospheric and photosynthetic O_2 in the mixed layer. This, in turn, is used to calculate gross productivity using wind speed-gas exchange parameterisations (Kaiser, 2011).

Depth profiles of O_2/Ar ratios will be analysed at selected CTD stations to allow a correction to be made for vertical entrainment of thermocline waters, which may otherwise bias net community production estimates. In the Arctic, mixed layer depths are often shallower than the euphotic zone. We will therefore also use the vertical profiles and repeat observation during east-to-west and west-to east transects of Fram Strait to account for production below the mixed layer and disequilibrium fluxes.

Continuous underway measurements of CO_2, CH_4, N_2O and CO and O_2/Ar ratios, along with sampling at six short underway CTD stations will occur on the route from Bremerhaven to Fram Strait. Within Fram Strait the continuous underway measurements will be continued with sampling at twenty-four short underway CTD stations.

Data and samples

Data will be quality-controlled and flagged according to international metadata and data standardisation initiatives, such as the Ocean Data Standards Pilot Project (ODS, http://www.oceandatastandards.org), the NERC Data Grid programme (http://ndg.nerc.ac.uk) and the SeaDataNet programme (http://www.seadatanet.org). Quality-controlled data collected during the proposed research activities will be submitted for archiving to the British Oceanographic Data Centre (BODC, http://www.bodc.ac.uk) and the British Atmospheric Data Centre (BADC, http://badc.nerc.ac.uk). The $\delta(^{17}O)$ and $\delta(^{18}O)$ isotope delta values and the O_2/Ar ratios that are to be measured by isotope ratio mass spectrometry will be analysed after the cruise in the Stable Isotope Lab of the School of Environmental Sciences at the University of East Anglia. The CO_2 data will also be entered into the Surface Ocean CO_2 Atlas SOCAT (http://www.socat.info), which is led by Co-I Dorothee Bakker. To protect the intellectual property of the PhD student who will be gathering data the data will not be released publicly until the end of the PhD thesis project (about October 2015).

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12. FAHRTTEILNEHMER/PARTICIPANTS

Name	Vorname/First name	Institut/Institute	Beruf/Profession
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Buldt	Klaus	DWD	Technician
Caesar	Levke	AWI/Student	Student
Castro-Morales	Karel	AWI	Oceanographer
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Gäbler-Schwarz	Steffi	AWI	Biologist
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Greil	Florian	AWI	Physicist
Grimm	Dennis	AWI/Student	Student
Heckmann	Hans	HeliService	Pilot
Heinze	Jutta	GEOMAR	Technician
Hempelt	Juliane	DWD	Technician
Hildebrandt	Nicole	AWI	PhD student
Knüppel	Nadine	AWI	Technician
Kohls	Katharina	AWI	Biologist
Kölling	Jannes	AWI/Student	Student/OZE
Krawutschke	Katharina	TU Dresden	Geodesist
Lax	Gordon	AWI/Student	Student
Lebrun	Raphaël	PolE	Ecologisst
Menze	Sebastian	AWI/Student	Student
Möllendorf	Carsten	HeliService	Mechanic
Monsees	Matthias	AWI	Technician
Niehoff	Barbara	AWI	Biologist
Petersen	Imke	AWI/Student	Student
Rentsch	Harald	DWD	Meteorologist
Rizkallah	Imke	AWI/Student	Student
Rosenau	Ralf	TU Dresden	Geodesist
Schade	Hanna	GEOMAR	Student
Schmidt	Katrin	AWI	PhD student
Schramm	Stefanie	Media	Journalist

Schrammar	Chris	GEOMAR	Student
Stärz	Michael	AWI	PhD student
Stöven	Tim	GEOMAR	PhD student
Strothmann	Olaf	AWI	Technician
Stubbins	Aron	Skidaway IO	Biogeochemist
Wager	Natalie	UEA UK	PhD Student
Walter	Jörg	AWI	Technician
Winkler	Maria	AWI	Student
Wisotzki	Andreas	AWI	Oceanographer
Wolanin	Aleksandra	AWI/Student	PhD student
Zieringer	Moritz	GEOMAR	PhD student

13. BETEILIGTE INSTITUTE/PARTICIPATING INSTITUTES

Institut/Institute	Addresse/Address
AWI	Alfred-Wegener-Institut für Polar- und Meeresforschung in der Helmholtz-Gemeinschaft Postfach 120161 27515 Bremerhaven Germany
DWD	Deutscher Wetterdienst Geschäftsbereich Wettervorhersage Seeschifffahrtsberatung Bernhard Nocht Str. 76 20359 Hamburg Germany
HeliService	HeliService international GmbH Am Luneort 15 D-27572 Bremerhaven/Germany
IFM-GEOMAR	GEOMAR | Helmholtz-Zentrum für Ozeanforschung Kiel Düsternbrooker Weg 20 24109 Kiel Germany
PolE	Laboratory for Polar Ecology Rue du Fodia 18 B-1367 Ramillies/ Belgium
Skidaway IO	Skidaway Institute of Oceanography 10 Ocean Science Circle Savannah, GA-31411/USA
TU Dresden	Technische Universität Dresden Institut für Planetare Geodäsie 01062 Dresden/ Germany
UEA	University of East Anglia School of Environmental Sciences Norwich, NR4 7TJ United Kingdom

14. SCHIFFSBESATZUNG / SHIP'S CREW

Name	Rank
Schwarze, Stefan	Master
Grundmann, Uwe	1. Offc.
Farysch, Bernd	Ch. Eng.
Fallei, Holger	2. Offc.
Lesch, Florian	2. Offc.
Rackete, Carola	2. Offc.
Pohl, Claus	Doctor
Hecht, Andreas	R.Offc.
Sümnicht, Stefan	2. Eng.
Minzlaff, Hans-Ulrich	2. Eng.
Holst, Wolfgang	3. Eng.
Scholz, Manfred	Elec. Tech.
Dimmler, Werner	Electron.
Hebold, Catharina	Electron.
Nasis, Ilias	Electron.
Himmel, Frank	Electron.
Voy, Bernd	Boatsw.
Reise, Lutz	Carpenter
Scheel, Sebastian	A.B.
Brickmann, Peter	A.B.
Winkler, Michael	A.B.
Hagemann, Manfred	A.B.
Schmidt, Uwe	A.B.
Guse, Hartmut	A.B.
Wende, Uwe	A.B.
Bäcker, Andreas	A.B.
Preußner, Jörg	Storek.
Teichert, Uwe	Mot-man
Schütt, Norbert	Mot-man
Elsner, Klaus	Mot-man
Plehn, Markus	Mot-man
Pinske, Lutz	Mot-man
Müller-Homburg, Ralf-Dieter	Cook
Silinski, Frank	Cooksmate
Martens, Michael	Cooksmate
Czyborra, Bärbel	1. Stwdess
Wöckener, Martina	Stwdss/KS
Gaude, Hans-Jürgen	2. Steward
Silinski, Carmen	2.Stwdess
NN	2.Steward
Möller, Wolfgang	2.Steward
Sun, Yong Shen	2.Steward
Yu, Kwok Yuen	Laundrym.
NN	Appr.
NN	Appr.

ARK-XXVII/2

15 July 2012 - 30 July 2012
Longyearbyen - Tromsø

Deep-Sea Observatory HAUSGARTEN

Chief Scientist
Thomas Soltwedel

Coordination
Eberhard Fahrbach
Rainer Knust

Contents

1. ÜBERBLICK UND FAHRTVERLAUF

Thomas Soltwedel (AWI)

Der zweite Fahrtabschnitt der 27. *Polarstern* Expedition in die Arktis wird am 15. Juli 2012 beginnen. Das Schiff wird von Longyearbyen (Spitzbergen) auslaufen, um Untersuchungen in der östlichen Framstraße durchzuführen (Abb. 1). Die Arbeiten werden verschiedene Projekte am Spitzbergen-Kontinentalhang (Tiefsee-Observatorium HAUSGARTEN) und auf dem Schelf entlang eines kurzen Transekts zum Kongsfjord unterstützen. Die Reise wird am 30. Juli 2012 in Tromsø (Norwegen) enden.

Die im Bereich des HAUSGARTENs geplanten Probennahmen und *in-situ* Experimente liefern wichtige Beiträge zu den ESFRI (European Strategy Forum on Research Infrastructures) Roadmap Projekten SIOS (Svalbard Integrated Arctic Earth Observing System) und ICOS (Integrated Carbon Observation System) sowie dem Anfang 2009 begonnenen Forschungsprogramm PACES (Polar regions and coasts in the changing Earth system) des AWI. In PACES werden Beiträge zum Topic „The changing Arctic and Antarctic", speziell zum Themenbereich ‚'Sea ice - atmosphere - ocean - ecosystem interactions in a bi-polar perspective" erbracht. Die geplanten Arbeiten stellen einen weiteren Beitrag zur Sicherstellung der Langzeitbeobachtung am HAUSGARTEN dar, in denen der Einfluss von klimatisch induzierten Veränderungen auf ein arktisches Tiefseeökosystem dokumentiert wird.

Die im Rahmen des durch die EU und die norwegische Öl-Gesellschaft Statoil/Hydro finanzierten KONGHAU-Projekts (Impact of climate change on Arctic marine community structures and food webs) begonnenen Langzeituntersuchungen, werden durch weitere Probennahmen auf dem Spitzbergen-Schelf und im Bereich des Kongsfjords fortgesetzt.

Klimabedingte Veränderungen der Phyto- und Zooplankton-Zusammensetzung in der Framstraße werden durch die am AWI etablierte Arbeitsgruppe PEBCAO (Phytoplankton Ecology and Biogeochemistry in the Changing Arctic Ocean) untersucht.

Während des zweiten Fahrtabschnitts werden die Beobachtungen von Seevögeln und marinen Säugetieren aus dem vorhergehenden Abschnitt fortgesetzt.

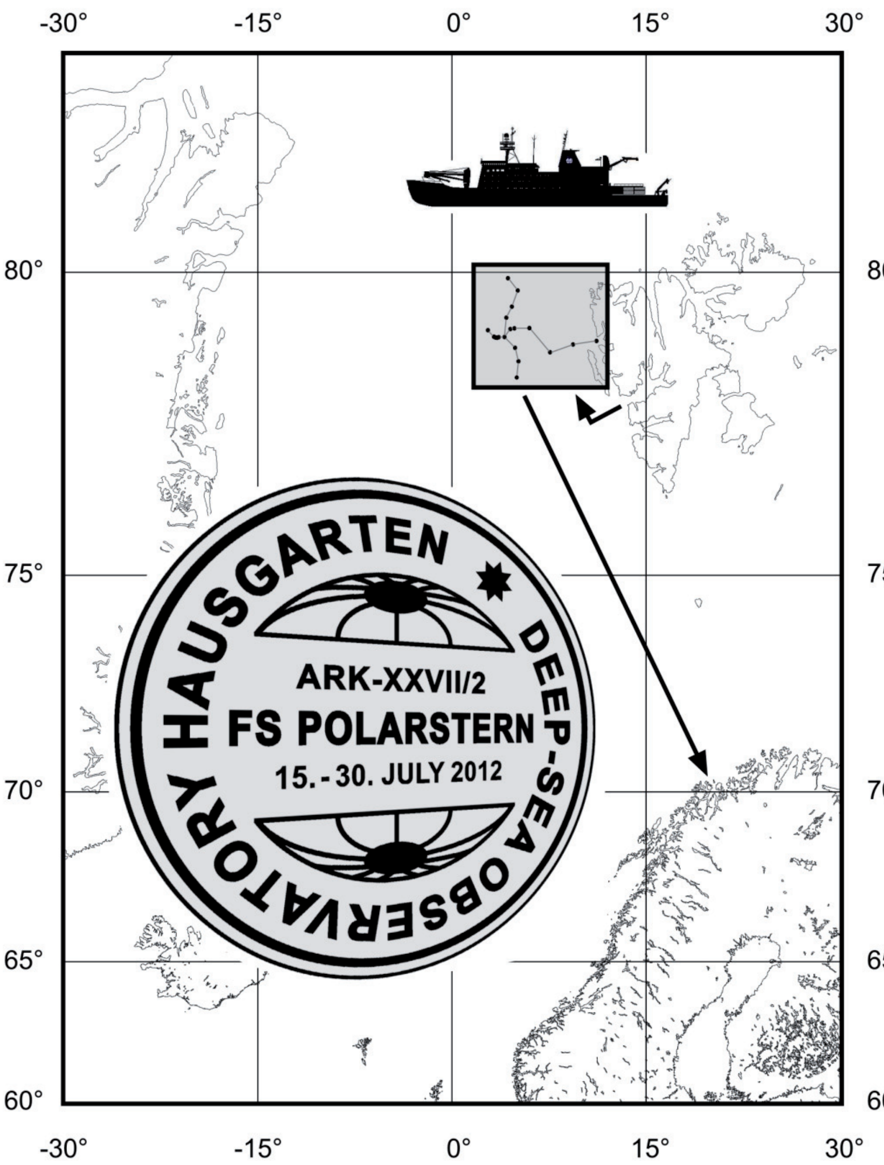

Abb. 1: Geplante Fahrtroute der Polarstern-Expedition ARK-XXVII/2

Fig. 1: Planned cruise track during Polarstern expedition ARK-XXVII/2

SUMMARY AND ITINERARY

The second leg of the 27th *Polarstern* expedition to the Arctic will start on 15 July 2012. The ship will depart from Longyearbyen (Svalbard) to conduct research in the eastern parts of Fram Strait (Fig. 1). The work will serve various projects and concentrate on the continental margin off Svalbard (Deep-Sea Observatory HAUSGARTEN) and a short transect on the shelf towards Kongfjorden. The cruise will end on 31 July 2012 in Tromsø (Norway).

The work planned for the HAUSGARTEN area will contribute to the ESFRI (European Strategy Forum on Research Infrastructures) Roadmap projects SIOS (Svalbard Integrated Arctic Earth Observing System) and ICOS (Integrated Carbon Observation System) as well as to the AWI research programme PACES (Polar Regions and Coasts in the changing Earth System), which started at the beginning of 2009. The work is embedded in various research activities through studies on changing Arctic sea ice conditions and their impact on ecosystems and food webs. These changes will be addressed through a dedicated combination of long-term observations, experimental work, and modelling. The research contributes to the time-series studies at HAUSGARTEN, where we investigate the impacts of Climate Change on an Arctic marine deep-sea ecosystem through field studies and models since 1999.

Research activities started within the framework of the former KONGHAU project (Impact of climate change on Arctic marine community structures and food webs), co-financed by the EU and the Norwegian oil company Statoil/Hydro, will be continued by taking additional samples on the continental shelf off Svalbard and inside Kongsfjorden.

Climate-induced changes of phyto- and zooplankton communities in Fram Strait will be investigated by the AWI research group PEBCAO (Phytoplankton Ecology and Biogeochemistry in the Changing Arctic Ocean).

During ARK-XXVII/2, the observation and counting of sea birds and marine mammals from the previous leg will be continued.

2. IMPACT OF CLIMATE CHANGE ON ARCTIC MARINE ECOSYSTEMS

I. Schewe, E. Bauerfeind, M. Bergmann, L. Caesar, J. Dannheim, J. Hagemann, C. Hasemann, U. Hoge, M. Klages, J. Kölling, A. Ledrich, S. Lehmenhecker, N. Lochthofen, K. Meyer, A. Pappert, B. Sablotny, M. Seifert, A.-K. Siegmund, K. Wätjen, T. Wulff (AWI); N. Budaeva, V. Mokievsky, A. Vedenin (IORAS)

Objectives and scientific programme

Over the past 130 million years, the marine Arctic has played an essential role in the history of our planet, contributing 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 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 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 Observatory HAUSGARTEN, which constitutes the first, and until now only open-ocean long-term station in a polar region.

The HAUSGARTEN observatory in the eastern Fram Strait includes 20 permanent sampling sites along a depth transect (1,000 – 5,500 m) and along a latitudinal transect following the 2,500 m isobath crossing the central HAUSGARTEN station (Fig. 2.1). 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, biological long-term experiments are carried out. Multidisciplinary research activities at HAUSGARTEN cover almost all compartments of the marine ecosystem from the pelagic zone to the benthic realm.

The concentration of carbon dioxide and other trace gases related to the greenhouse effect such as methane and nitrous oxide in the atmosphere is increasing because global biogeochemical cycles are being substantially disrupted by human activity. The climate changes caused by this increase represent a major challenge to mankind. Climate policy measures have been introduced which attempt to reduce greenhouse gas emissions. Whether these actions are successful will depend on the continuous supply of new data and findings that cover biogeochemical processes and their interaction with climate.

Long-term and internationally comparable measurements are a key factor in improving our knowledge of the complex interactions between Climate on the one hand and biosphere, hydrosphere and atmosphere on the other. HAUSGARTEN has been proposed as one of the two marine observatory sites within the German contribution to the European research infrastructure “Integrated Carbon Observation System” (ICOS). Since the beginning of 2012 the national implementation plan is being funded by the BMBF. During ARK-XXVII/2 first deployments of sensor packages with winch operated and mobile platforms are planned as AWI contributions to this project.

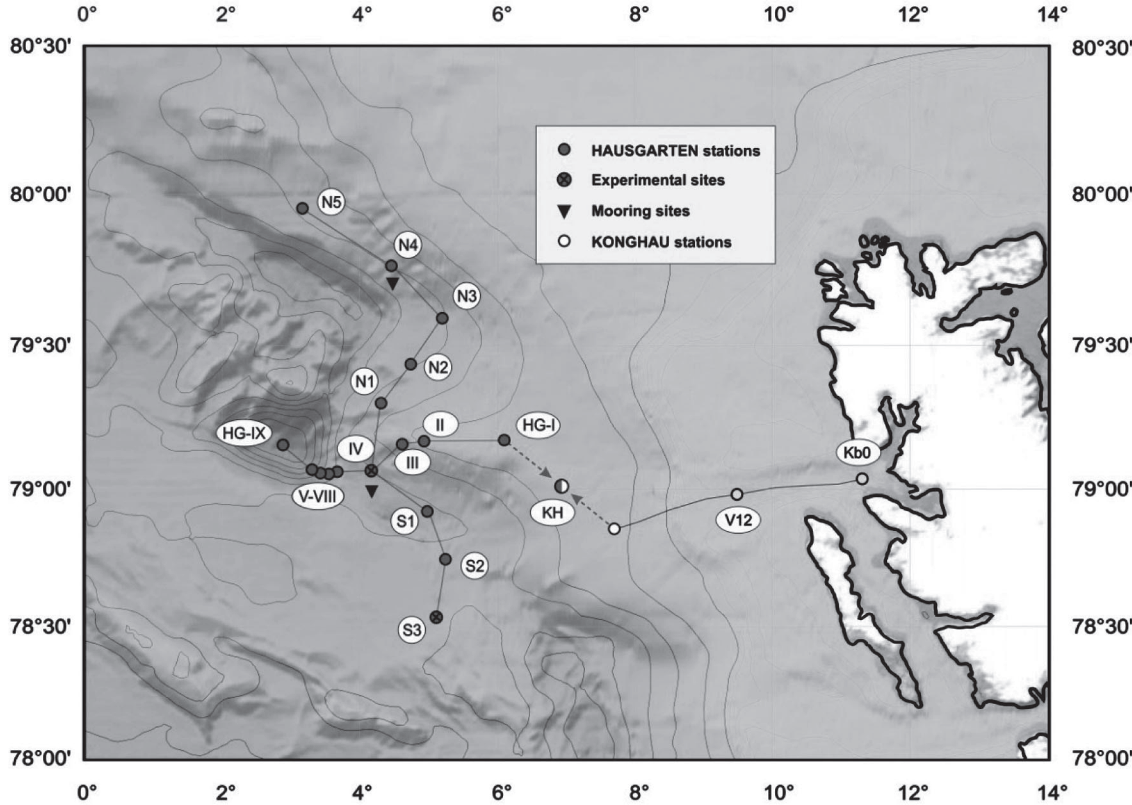

Fig. 2.1: The Deep-Sea Observatory HAUSGARTEN and sampling stations of the Kongsfjorden Time-Series Study (KONGHAU) in the eastern Fram Strait

Work at sea

Hydrographic data will be assessed using a cabled CTD/Rosette sampler system and an Autonomous Underwater Vehicle (AUV). Vertical profiles with a pCO_2-sensor and CTD will be carried out during Multiple Corer (MUC) casts. In order to use ship-time as efficient as possible we intent to attach the sensors to the MUC frame.

Since 2008, the Alfred Wegener Institute pursues the goal of transforming the institute's AUV (Fig. 2.2) into a high precision measuring instrument for biological and chemical processes in polar waters. This process is not finished yet and thus the sensors and vehicle operation guidelines were further developed in 2011/2012.

In addition to that, large efforts were made to integrate the vehicle data into the greater context of the polar environment – resulting in the development of new methods and instruments to record relevant environmental data during a dive. These new methods and instruments face first polar service during the upcoming expedition.

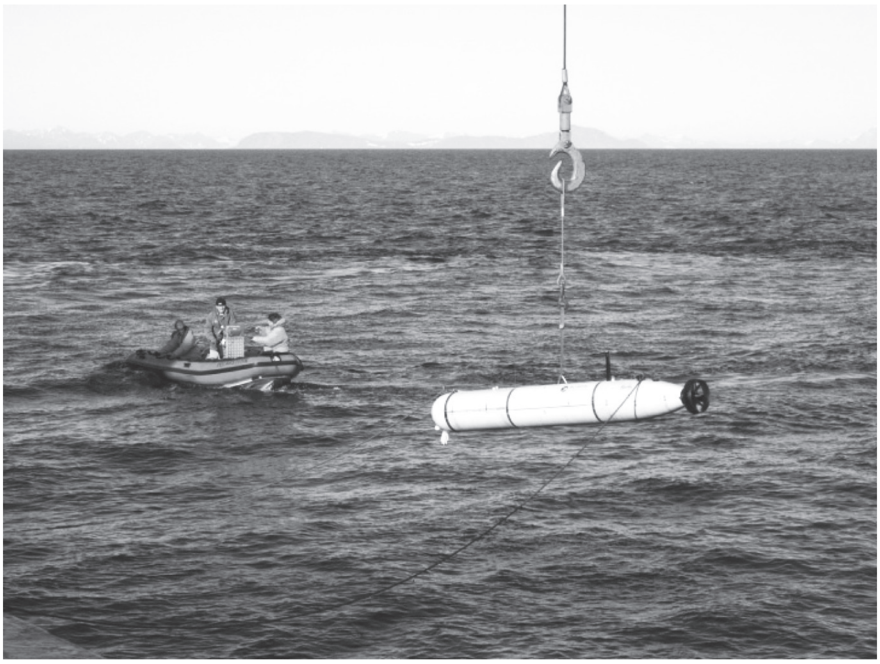

Fig. 2.2: Deployment of the Autonomous Underwater Vehicle (AUV)

As in previous years the payload of the AUV will consist of the vehicle's water sample collector and a sensor package. However, in comparison to 2011, the AUV will carry an extended sensor package, giving the vehicle the ability to acquire 10 independent parameters *in-situ*. Furthermore, during a single dive, 22 water samples with a total volume of 4.8 litres can be collected and subsequently be analyzed on board or preserved for later analyses.

As primary production in the Arctic Ocean is the main subject of AUV based research, the vehicle's working depth will be primarily limited to the euphotic zone. Consequently, mission planning includes dives close to the surface with a maximum depth of 500 m. However, these dives will lead the vehicle several kilometres away from *Polarstern* so that the reliability of the vehicle is of extreme importance.

During ARK-XXVII/2, the AUV mission planning also includes at least one under-ice dive below the Arctic sea ice. This type of mission is extremely complex and tough to accomplish. Based on experiences made in 2010 and 2011 the ice drift turned out to be a crucial aspect for the safety of the vehicle during these missions. For this reason a flying machine (Hexacopter) was developed in the AWI Deep-Sea Department. The Hexacopter is remotely controlled and carries a GPS receiver and a data transmitter. It will land on the ice and continuously submit its position to *Polarstern* via radio communication. This procedure will facilitate to measure the drift of the ice, and to plan the AUV dive accordingly.

Long-term measurements of the vertical particle flux at HAUSGARTEN are conducted since the year 2000. By means of these measurements we are able to quantify the export of organic matter from the sea surface to the deep sea, and trace changes in these fluxes over time. The organic material which is produced in the upper water layers or which is introduced from land is the main food source for deep-sea organisms. Measurements of organic matter fluxes are conducted by bottom tethered moorings carrying sediment traps at a ~200 m, approx. 1,000 m below sea-surface, and about 180 m above the seafloor. Besides sediment traps the moorings are also equipped with Aanderaa current meters (RCM 11) and self-recording CTD's (Seabird MicroCats). During ARK-XXVII/2, we will exchange moorings and instruments that were deployed at ~2,500 m water depth at the central HAUSGARTEN site (79°00'N/04°20'E), and at a position in the northern HAUSGARTEN area (79°46'N/04°30'E). Another sediment trap, integrated in a free-falling system (bottom-lander), supporting a current meter and optical oxygen sensors (optodes) at 2.5 m above ground, will be replaced. At all stations where moorings are operating, we will conduct CTD casts from the surface close to the seafloor. Water samples will be taken for the analyses of chlorophyll *a*, particulate organic carbon and nitrogen (POC/N), total particulate matter (seston), calcium carbonate ($CaCO_3$), and stable isotopes ($\delta^{15}N/\delta^{13}C$) in the particulate matter. This work as well as the sampling at the other HAUSGARTEN stations will be conducted in close cooperation with the PEBCAO group. For further details regarding the work in the water column see the contribution of the PEBCAO group (Chapter 3).

Virtually undisturbed sediment samples will be taken using a video-guided Multiple Corer (MUC; Fig. 2.3). Various biogenic compounds from these sediments will be analysed to estimate benthic activities (e.g. bacterial exo-enzymatic activity) and the total biomass of the smallest sediment-inhabiting organisms. In comparison with long-term data, results will help to describe ecosystem changes in the benthal of the Arctic Ocean. Sediments retrieved by the MUC will also be analysed for the quantitative and qualitative assessment of the small benthic biota.

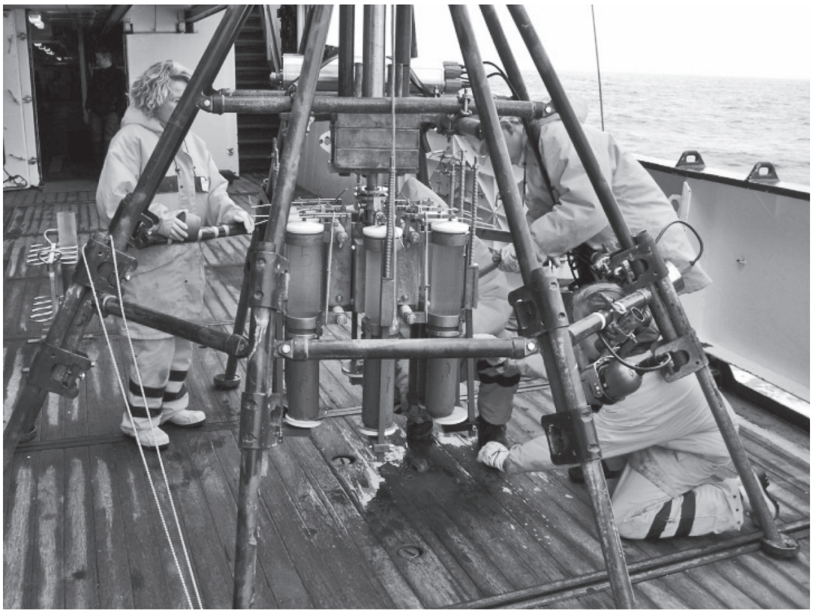

Fig. 2.3: Sediment sampling using a video-guided Multiple Corer (MUC)

In order to continue the time-series work on the bacterial communities at HAUSGARTEN, its structure will be investigated and correlated with environmental parameters. MUC samples from all 20 stations will be frozen for DNA/RNA analyses as well as fixed with formalin for bacterial cell counts and fluorescence *in-situ* hybridisation.

The study of spatial variations in the structure of macrofauna communities along the HAUSGARTEN latitudinal transect will allow estimating the variability of major community parameters in a high-productive high-latitude area. The comparison of previously obtained data from the same area and similar studies conducted in tropical, temperate, and permanently ice-covered areas will help understanding spatial changes in deep-sea macrobenthic communities in general. We plan to retrieve nine box-corer samples along the latitudinal transect (ca. 125 km along the 2,500 m isobaths; stations N1-5, HG-IV, S1-3; see Fig. 2.1). The repetition of additional stations sampled by N. Budaeva in 2003 (78º55.00’N, 05º00.25’E and 78º56.00’N, 04º59.60’E, respectively) will provide a unique opportunity to evaluate changes in deep-sea macrofauna communities under conditions of global warming over a nine-year time period. All samples will be collected with USNEL box corer. Each sample will divided into a number of subsamples (Fig. 2.4). Each subsample will be washed through a 500 µm sieve to allow comparisons with previous studies. Knowledge gained on spatial variations in macrofauna community structure at different spatial scales along the latitudinal transect will help to detect and separate effects of the climate change from spatial heterogeneity in the distribution of deep-sea macrofauna.

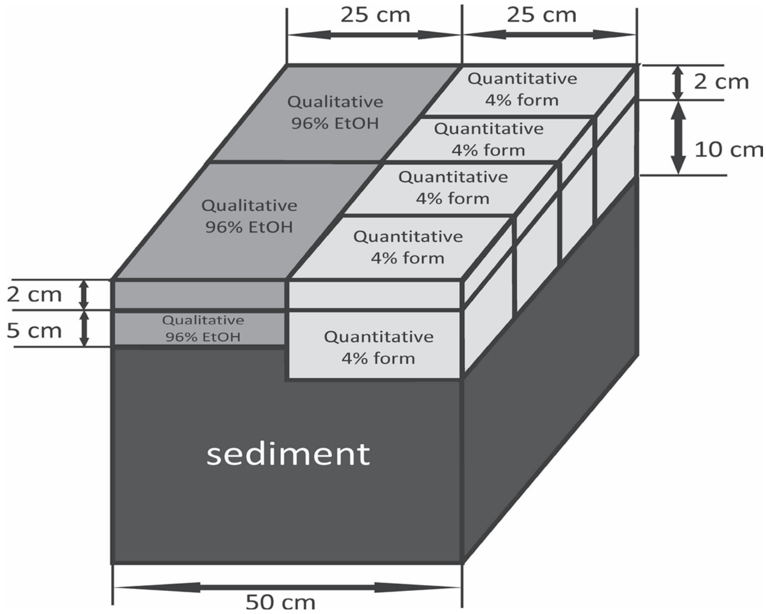

Fig. 2.4: Subsampling scheme for the box corer samples: quantitative samples will be used to estimate species composition, richness, diversity, evenness, density, and biomass; qualitative samples will be collected for the identification of the benthic fauna using molecular techniques

Through the continuous redistribution of organic matter, oxygen and other nutrients in surficial sediments by remineralisation, bioturbation and burial of sunken matter, benthic biota play an important role in the global carbon cycle. Epibenthic megafauna inhabit the sediment-water interface and are defined as the group of organisms ≥1 cm. They contribute considerably to benthic respiration and have a strong effect on the physical and biogeochemical micro-scale environment. Megafaunal organisms create pits, mounds and traces that enhance habitat heterogeneity and thus diversity of smaller sediment-inhabiting biota in otherwise apparently homogenous environments. Erect biota enhances the 3-dimensional habitat complexity and provides shelter from predation. Megafaunal predators control the population dynamics of their prey and therefore shape benthic food webs and community structure. Sunken organic matter that is not converted into benthic biomass and forwarded along food chains might be actively transported from the water column-sediment interface into the sediment by bioturbation. Organic matter is then degraded/recycled into nutrients and CO_2. Mega- and macrofaunal species thus actively influence biogeochemical processes at the sediment–water interface. An understanding of megafaunal dynamics is therefore vital to our understanding of the fate of carbon at the deep seafloor, Earth’s greatest carbon repository.

During ARK-XXVII/2, we will continue studying inter-annual dynamics of megafaunal organisms using our towed photo/video system OFOS (Ocean Floor Observation System; Fig. 2.5). The OFOS will be towed along established tracks at HAUSGARTEN stations of the latitudinal transect (N3, N5, HG-IV, S3), at HG I, and at a large depression ("Senke") on the Vestnesa slope close to HG-II. The new footage will extend our image time series that started in 2002.

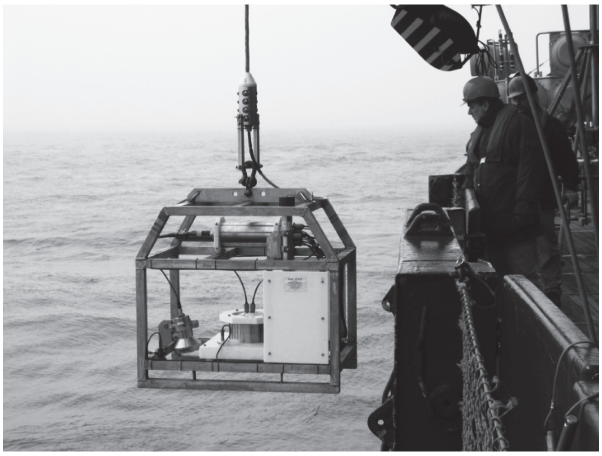

Fig. 2.5: Deployment of the Ocean Floor Observation System (OFOS)

Many megafaunal organisms cannot be identified from images alone. To collect physical specimens for ground-truthing, we will use an Agassiz trawl at selected HAUSGARTEN stations along the latitudinal transect (N3, HG-IV, S3), and at HG-I. The biota caught will be measured and weighed to determine the mega/epifaunal population structure, which allows for benthic production modelling. Furthermore, we will take tissue samples for bulk stable isotope analyses to determine the trophic position of megafaunal species and characterize the food web. Comparison with previous results will enable us to assess trophic changes. For the first time, we will also take samples for the analysis of fatty acids and the ice diatom biomarker IP25 to determine the importance of ice algae to the deep-sea megafauna during an era of shrinking sea ice. Sediment samples from a Multiple Corer (MUC) and filtered water samples (POM) from the CTD/Rosette will also be taken for these analyses. The tissues of fish (*Lycodes frigidus*) caught by traps fitted to a bottom-lander will be sampled for the same analyses. Comparison with previous samples will allow us to assess changes at higher trophic levels.

An experiment will be conducted to assess potential bioturbation over time. To determine the depth of sediment reworking by mega- and macrofaunal species, luminophores will be added to freshly collected sediment cores from HG-I and incubated for 2-3 months.

Data and samples

Sample processing will be carried out at AWI, IORAS and UGOT. Data acquisition from the several types of investigation will be differently time-consuming. The time periods from post processing to data provision will vary from one year maximum for sensor data, to several years for organism related datasets. Until then preliminary data will be available to the cruise participants and external users after request to the senior scientist. The finally processed data will be submitted to the PANGAEA data library. The unrestricted availability from PANGAEA will depend on the required time and effort for acquisition of individual datasets and its status of scientific publication.

3. PLANKTON ECOLOGY AND BIOGEOCHEMISTRY IN THE CHANGING ARCTIC OCEAN (PEBCAO)

K. Metfies, S. Endres, M. Hildebrandt, N. Hildebrandt, C. Mages,S. Murawski, I. Petersen, J. Roa, M. Winkler (AWI)

Objectives and scientific programme

The Arctic Ocean has gained increasing attention over the past years because of the drastic decrease in sea ice cover and extent as well as a temperature increase about twice as fast as the global mean rate. In addition, changes in surface ocean chemical equilibrium and elemental cycling are occurring due to ocean acidification. These physical and chemical changes of the environment will eventually have enormous consequences for the pelagic system and for the net carbon balance of Arctic ecosystems. In order to understand and track these expected changes, long-term investigations in the Arctic Ocean are needed to contribute to a better understanding of the direction and strength of biological feedback processes in the future Arctic. Investigations on phytoplankton ecology, carried out since several years as sub-program of the analysis of the regularly deployment of sediment traps in the Arctic at HAUSGARTEN, were very sporadic. Because the Arctic Ocean experiences rapid environmental changes, we extend our sampling program by conducting molecular investigations on pico- and nanoplankton, with focus on key species like *Phaeocystis pouchetii*, copepods and amphipods, and on changes in the composition of organic matter.

Climatically induced changes will impact species selection in pelagic ecosystems. A shift in biomass and in species composition is expected in all size classes of the phytoplankton, however, smallest algae may thrive the phytoplankton in the future Arctic Ocean. Besides diatoms, other smaller planktonic algae will gain more importance in mediating element- and matter- as well as export fluxes. One of them, *Phaeocystis pouchetii*, having an intermediate position regarding size can play a key role in the cycle of sulphur and carbon. Little is known about the diversity distribution, occurrence and physiology of this species in Arctic pelagic regions.

In order to enable the assessment of phytoplankton, including the smallest fractions in the Arctic marine environment, molecular methods are well suited to provide refined information on the composition and bio-geographical differences of arctic phytoplankton communities. The characterization of phytoplankton communities with molecular methods is independent of cell-size and distinct morphological features. The assessment of the biodiversity and biogeography of Arctic phytoplankton will be based on the analysis of ribosomal genes, taking advantage of the latest 454-pyrosequencing technology, Automated Ribosomal Intragenic Sequence Analysis (ARISA), or ribosomal probe-based methods.

In the zooplankton, copepod and amphipod species may serve as indicators for warming water masses in the Fram Strait. Sampling for detailed species analyses of the dominating groups will reveal additional insight to results already obtained in the swimmer fraction within the sediment-trap monitoring program at HAUSGARTEN.

Based on the awareness, that global change has increasingly affected marine ecosystems, we also intend to examine the ‘present day’ situation of pelagic micro-biogeochemistry in the Arctic Ocean, with emphasis on the turnover of organic matter during production and decomposition processes. The data shall serve as a database for a better evaluation of the relevance of changes that are determined in perturbation experiments, such as the Svalbard CO_2 mesocosm study 2010 (EPOCA).

During ARK-XXVII/2, the following topics are covered:

- Production, fate and composition of organic matter in a changing Arctic Ocean
- Investigations on selected phyto- and zooplankton and related biogeochemical parameters
- Investigations on pico- and nanoplankton.

Work at sea

We intend to sample Arctic seawater by a CTD/rosette sampler along the bathymetric HAUSGARTEN transects (~79°N) to determine the impact of microbial processes on the aggregation and sedimentation of organic matter. Water samples will be taken at 5-8 depths.

Field work

a) Biogeochemical parameters from CTD casts:

Chlorophyll *a* and HPLC pigments, ground-truth data for satellite imaging work, dissolved and particulate organic carbon (DOC & POC), dissolved and particulate organic nitrogen (DON & PON), dissolved and total polysaccharides (DCHO & CHO), dissolved and total amino acids (DAA & AA), transparent exo-polymer particles (TEP), particulate biogenic silica (PbSi), total alkalinity.

b) Biological parameters from CTD casts:

Phytoplankton and protozooplankton abundance, bacterial cell numbers, extracellular enzyme activity, sampling for genetic analyses and clonal cultures, flow cytometer.

c) Biological parameters from net hauls (Hand-net, Multi-net, Bongo net):

The sampling of phytoplankton and zooplankton will be conducted by means of different plankton nets (Fig. 3.1). The mesozooplankton composition and depth distribution will be determined; organisms will be collected for biochemical analyses (i.e. carbon, nitrogen, protein and lipid content, and fatty acid composition) and for enzyme activity analyses (i.e. citrate synthase and digestive enzymes).

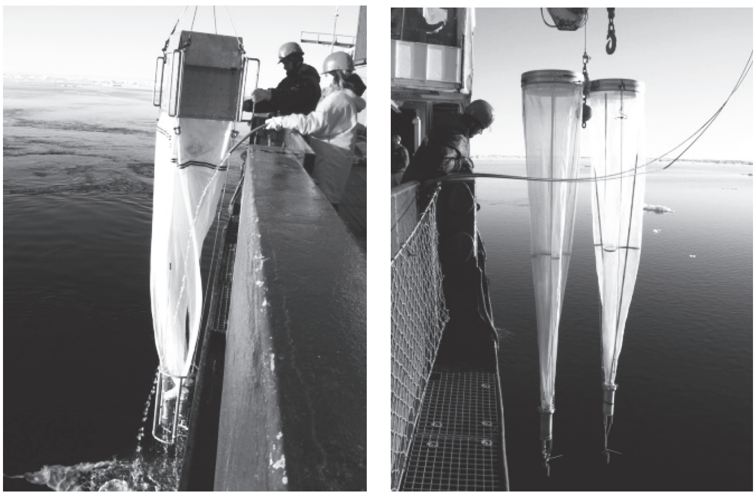

Fig. 3.1: Deployment of the Multi-net (left) and the Bongo-net (right)

Culture work

We intend to sample Arctic seawater by the CTD/Rosette water sampler, and to conduct further plankton hand-net hauls along the 79°N transect. The phytoplankton will be isolated for performing clonal cultures, and later genetic analyses of the isolates.

Experimental work

We will study the response of dominant Arctic copepods to elevated CO_2 concentrations by means of incubation experiments. Particularly, we will focus on the grazing, ingestion, and egg production rates, which will all be measured onboard. In addition, we will deep-freeze individuals over the course of the experiment to determine changes in body mass and enzyme activities. This will elucidate whether and at which level high CO_2 concentrations affect performance of copepods.

Sample storage and analyses

All samples will be preserved or frozen at -20°C and partly at -80°C for further analyses, or haltered in the cooling culture lab container for clonal culturing and physiological experiments at the home laboratory.

Data and samples

Almost all sample processing will be carried out in the home laboratory at AWI. It usually takes one to three years depending on the parameter as well as analyzing methods such as chemical measurements or tedious swimmer picking in trap material and species enumerations and identifications, respectively. As soon as the data sets are available they can be used by other cruise participants on request. When the data will be published they will be submitted to PANGAEA and are open for external use.

4. HIGHER TROPHIC LEVELS: AT-SEA DISTRIBUTION OF SEABIRDS AND MARINE MAMMALS

D. Sévrin, D. D.Hert, Q. Goffette (PolE)

Objectives and scientific programme

The main aim of our long-term study on the higher trophic levels of the Arctic Ocean (i.e. cetaceans, pinnipeds, and seabirds) is to confirm and develop the links with the main factors influencing their distribution at sea, i.e. the sea ice and ice edge, water masses, fronts and eddies. Within these systems with low biodiversity (e.g. low number of species), some hot spots deserve special attention:

- Extremely high concentrations of little auks (“Krabbentaucher”) and harp seals at the narrow front between Polar and Arctic Water masses. These hot spots are mostly situated at the ice edge, but can also be found at other sites in the area, including deep eddies.
- Very high concentrations of large cetaceans (humpback whales) in the south-eastern part of the Greenland Sea (Denmark Strait) and in the north-eastern part of Greenland Sea and Fram Strait (fin whales as well as blue and humpback whales, and a few bowheads). The latter becoming the obvious observational priority of legs 1 and 2 of ARK-XXVII.

The high concentrations of whales correspond to a drastic increase of populations from 2005, and especially from 2007 on. The huge increase by a factor 20 cannot be explained by a growth of local stocks. Our interpretation is that the cetacean populations were previously separated by the prevailing ice conditions. While Pacific whale populations occurred at clearly higher levels, Atlantic populations came along at extremely low levels after over-exploitation by whaling. When the Arctic sea ice coverage strongly decreased in 2005, the Western and Eastern Passages opened, and might have allowed exchanges between whale stocks in both areas, resulting in a strong increase in Atlantic populations. The most striking example concerns the bowhead, with only one observation during more than 5,000 counts on board *RV Polarstern* from 1988 to 2003, but 1 to 8 observations during each expedition after 2007 in the same area. A lesser, but still significant increase was detected for blue, fin and humpback whales.

Effects of the decreasing ice coverage are also considered for other higher trophic levels:

- The Polar bear is often cited as a threatened species, due to decreasing pack ice coverage. This does not seem to be the case in the Greenland Sea and Fram Strait: the population seems stable in numbers and health based on the data registered by our observations. The really threatened populations are actually the marginal ones, suffering much more of decreasing ice coverage (e.g. Hudson Bay).
- Seabirds might be much more affected by the decreasing sea ice. One example is the little auks, the most numerous species in the area. In order to bring food (polar zooplankton) they must travel between their colony on Svalbard and their feeding grounds close to the ice edge on a daily basis. If, due to the sea-ice retreat, distances between the sites become larger than 100-150 km maximum, the little auk might become unable to breed successfully.

Work at sea

Birds and mammals will be recorded by transect counts from the ship's bridge, without width limitation. Animals are detected with naked eye, observations being confirmed and detailed with binocular and/or telescope. As an adaptation to the generally poor ecosystem, each count lasts 30 minutes with a 90° angle in front of *RV Polarstern*. If visibility conditions generally allow, counting will be continuous during all displacements of the ship. When possible, complementary counts will be accomplished from the ship's "crow's nest". Frequent helicopter flights following the ship's route complete our observations during ARK-XXVII/2 and allow comparisons between the data obtained from different observation platforms.

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Lesch, Florian	2. Offc.
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Pohl, Claus	Doctor
Hecht, Andreas	R.Offc.
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ARK-XXVII/3

2 August 2012 – 7 October 2012
Tromsø - Bremerhaven

Chief Scientist
Antje Boetius

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Contents

1. ÜBERBLICK UND FAHRTVERLAUF

Antje Boetius - HGF MPG Gruppe für Tiefseeökologie und -Technologie
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Die Expedition ARK-XXVII/3 „IceArc“ (Sea ice - ocean - seafloor interactions in the changingArctic) hat zum Ziel die Biologie, Chemie und Physik des Meereises zu erkunden und die Auswirkungen seines Rückgangs auf das gesamte Ozeansystem bis in die Tiefsee zu erforschen. Es ist zu vermuten, dass das Schwinden des Meereises und die zunehmende Erwärmung des Arktischen Ozeans nicht nur seine Hydrographie verändert, sondern auch in vielfältiger Weise auf biogeochemische und biologische Prozesse wirkt. Die Rolle des mehrjährigen Meereises für die Nährstoffverteilung, Produktivität und Zusammensetzung der pelagischen und benthischen Lebensgemeinschaften, sowie für den Export von Stoffen in die Atmosphäre und die Tiefsee zu untersuchen, ist daher eines der Hauptziele der Expedition „IceArc“. Mittels interdisziplinärer Prozessstudien soll dazu die Wechselwirkung zwischen Hydrographie, Eisphysik, Biogeochemie und Biodiversität des arktischen Systems vom Meereis bis zum Tiefseeboden erforscht werden. Unter Berücksichtigung der kurz- und langfristigen regionalen Entwicklung der Eisbedeckung werden vergleichende Untersuchungen in verschiedenen Arbeitsgebieten ohne Eisbedeckung, in der Eisrandzone und mit mehrjähriger Eisbedeckung in der zentralen Arktis durchgeführt. Zudem werden kurz- und langfristige Verankerungen und Eis-Observatorien ausgetauscht, die ganzjährig die Dicke des Meereises, die Zirkulation des Atlantikwassers und die damit verknüpften Partikelflüsse messen. Die zu erwartenden Ergebnisse dieser Expedition sind eine wichtige Grundlage, um die Auswirkungen von Änderungen in der Meereisbedeckung auf den Arktischen Ozean und seine Ökosysteme zu quantifizieren.

ARK-XXVII/3 beginnt am 2. August 2012 in Tromsø. *Polarstern* wird durch norwegische Gewässer in Richtung Norden steuern, Spitzbergen östlich passieren, und dann entlang der Eisrandzone ostwärts fahren bis in die sibirischen Randmeere. Im Eis werden ozeanographische und eisphysikalische Messungen durchgeführt und Proben für biogeochemische und biologische Analysen genommen. An ausgewählten Stationen werden Eis-Observatorien und benthische Freifallgeräte ausgesetzt. Die Biodiversität und Funktion pelagischer und benthischer Gemeinschaften aller Grössenklassen wird erfasst in Zusammenhang mit der Untersuchung der Nährstoffbudgets und der Kohlenstoffflüsse im Eis, an der Meeresoberfläche und in der Tiefsee. Die Stationsarbeiten vom Schiff und Eis aus werden mit Arbeiten vom Hubschrauber ergänzt. Die Lokationen für die Prozessstudien werden in Abhängigkeit von der Eisbedeckung, Nährstoffsituation und Oberflächenproduktivität ausgewählt. Entlang der Route werden zwei im Vorjahr (ARK-XXVI/3) ausgesetzte Meereisverankerungen aufgenommen. Wenn Arbeitszeit und Genehmigung es erlauben, ist es zudem geplant, russische Verankerungen am Laptewsee-Kontinentalhang zu bergen. Von dort geht es dann auf nördlicher Route zurück ins Eis, um auch unter geschlossener Eisdecke ozeanographische und biogeochemische Untersuchungen durchzuführen. Das Schiff kehrt je nach Eissituation entweder östlich oder westlich von Spitzbergen in Richtung Bremerhaven zurück. *Polarstern* wird am 7. Oktober 2012 wieder in Bremerhaven einlaufen.

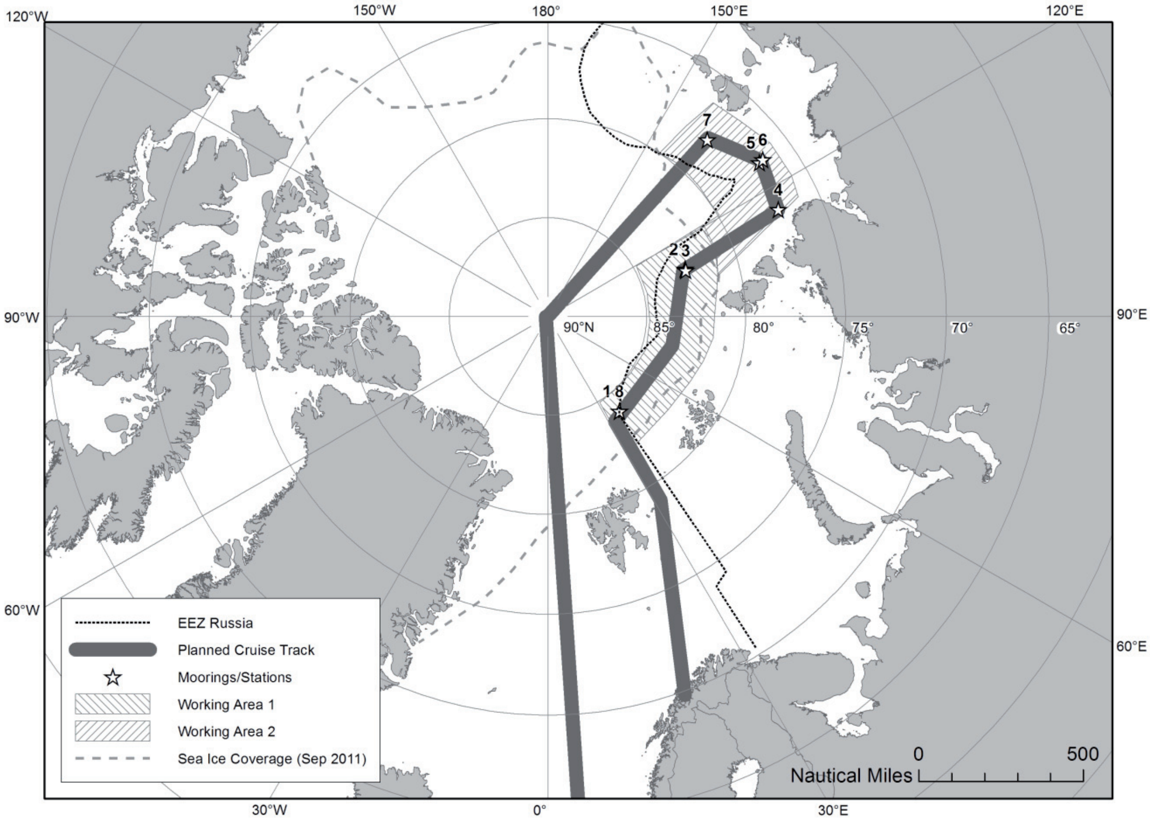

Abb. 1: Geplante Fahrtroute der Expedition ARK-XXVII/3 mit Durchquerung der zentralen Arktis (dicke Linie). Die Reise beginnt am 2. August 2012 in Tromsø und endet am 7. Oktober 2012 in Bremerhaven. Der genaue Verlauf der Reise ist abhängig von der Eissituation zwischen August und Oktober 2012. Die Meereis-Observatorien an Station 1 und 2 werden auf dem Rückweg wieder angefahren (Station 3 und 8). Wenn Arbeitszeit und Genehmigung es erlauben, ist es geplant Verankerungen am Laptewsee-Kontinentalhang zu bergen.

Fig. 1: Planned cruise track of ARK-XXVII/3 crossing the central Arctic (solid thick line). The cruise starts on August 2, 2012 in Tromsø and ends on October 7, 2012 in Bremerhaven. The exact cruise track will depend on ice conditions in August – October 2012. Two sea ice observatories (station 1 and 2) will be recovered at the end of the mission (ice mooring station 3, 8). If working time and permission allow, it is planned to recover moorings at the upper Laptev Sea slope.

SUMMARY AND ITINERARY

The expedition ARK-XXVII/3 “IceArc” (Sea ice - ocean - seafloor interactions in the changing Arctic) will investigate the biology, chemistry and physics of sea ice and the impact of sea ice loss on the entire Arctic Ocean system. The decrease in sea ice cover and increased temperatures are affecting physical properties of the Arctic Ocean, and are also expected to influence geochemical and biological processes. Therefore, the expedition IceArc is dedicated to investigating the role of multiyear sea ice for the distribution of nutrients, productivity and pelagic and benthic communities, as well as for the export of compounds to the atmosphere and the deep sea. Using integrated interdisciplinary process studies, the expedition IceArc will focus on the interactions between hydrography, ice physics, biogeochemistry and biodiversity in the Arctic system, from the sea ice to the deep-sea floor. Sampling sites will be selected based on their different short- and long-term regional development of the ice cover, and comparative studies will be carried out in the central Arctic in different working areas with no sea ice cover, at the ice edge and in multiyear sea ice. In addition, we will combine ice-, ocean- and seafloor moorings to observe sea ice thickness, circulation of Atlantic water and corresponding particle flux throughout the year. The expected results will present an important basis to better understand and quantify the effects of changes in sea ice cover on the Arctic Ocean and its ecosystems.

ARK-XXVII/3 will start on 2 August 2012 in Tromsø. *Polarstern* will head north through Norwegian waters, pass east of Spitsbergen, and then move eastwards along the ice edge into Siberian seas. In the ice, oceanographic and sea ice physics related measurements will be carried out, and samples will be taken for biogeochemical and biological analyses. At selected stations benthic free-falling instruments will be deployed and recovered at the end of near-by sea ice stations, combined with systematic sampling of the hydrography, biogeochemistry and the biodiversity of all size classes from surface to the deep sea. Furthermore, different sea-ice physics, oceanographic and biogeochemical instruments will be operated on and under the ice. Station work will be complemented with helicopter-based surveys. Two moorings of the previous year (ARK-XXVI/3) will be recovered along the route. If working time and permission allow, it is also planned to recover moorings at the upper Laptev Sea continental slope. From there we will follow a Northern route through the ice, for further investigations under full ice-cover. After recovery of our ice-buoys and moorings, *Polarstern* will return to Bremerhaven on 7 October 2012.

2. SEA ICE PHYSICS

S. Hendricks (AWI), M. Nicolaus (AWI), T. Krumpen (AWI), C. Katlein (AWI), B. Lange (U Alberta), M. Schiller (AWI), L. Istomina (University of Bremen), S. Sorensen (UDEL), A. Mahoney (UAF, not on board)

Objectives

Satellite observations reveal a reduction of Arctic summer sea ice extent in the order of 8 % per decade with the lowest ice extents in the period between 2007 and 2011. This reduction is accompanied by a decrease of ice age, leaving a smaller, younger and subsequently thinner ice cover at the end of the annual melting cycle. The critical factor to assess these changes is the sea ice thickness distribution. However, satellite based ice thickness monitoring does not yield reliable results in the summer season due to unfavourable surface conditions such as melt ponds. Therefore, one of our main goals is to estimate the regional sea ice thickness distribution along the cruise track with helicopter surveys using an airborne electromagnetic induction sensor (EM-Bird). Similar experiments from earlier Polarstern cruises revealed a reduction of the level ice thickness in the Transpolar Drift region from 2.5 m in 1991 to 0.9 m in 2007 and 2011 (Haas et al., 2008; Hendricks et al., cruise report ARK-XXVI/3).

An additional source of information regarding the state of the Arctic sea ice cover is visual classification of key sea ice variables by sea ice observers. Efforts have been made in the recent years by the international science community to create a standardized observation protocol for the Arctic. This protocol will be applied for most of the Arctic expeditions from this year on, including this cruise. Though quite subjective, visual observations have the promise of creating a large datasets due to the numbers of vessels in the summer Arctic.

The observed thinning demonstrates a shift from thicker multi-year to thinner first-year sea ice in the central Arctic, which has consequences for various physical and biological processes within the sea ice and the upper ocean layer. For example, thin ponded sea ice transmits a significantly higher portion of the incoming solar radiation than snow covered thick ice. Hence, the optical properties of sea ice determine the amount of light (energy) that is transmitted into the ice and further into the upper ocean, contributing to warming and melting of sea ice. In addition, the amount of solar radiation dominates primary production and other biological processes in and below the ice layer. As part of the interdisciplinary sea-ice program on this cruise, we want to investigate the variability of light availability in and under different types of sea ice along the cruise track by extensive under-ice radiation measurements. These data, together with detailed information of the ice structure and coordinated biological sampling, shall lead to a better understanding of the future evolution of Arctic sea ice.

While the individual ice observations and airborne surveys reveal a snapshot of the Arctic sea ice property distribution, a time series at certain locations can be realized by ice drifting buoys, which continuously record the thickness evolution in the following winter season.

Work at sea

Helicopter surveys will be carried out along the cruise track approximately every second day in ice covered region. During these flights (two hours) the following physical properties of sea ice will be measured:

- sea ice thickness distribution with an airborne electromagnetic (EM) induction sensor (EM-Bird)
- surface roughness using laser altimetry
- general surface condition (melt pond fraction) by nadir-looking aerial imaging.

A remotely operated vehicle (ROV) will be used for under-ice studies on each sea-ice station. Transect lengths will be several hundred meters and allow the description of variability on each floe / in each region.

- Measurements of (spectral) light transmission through snow and sea ice
- Measurements of CTD-data, fluorescence and other water properties to describe the habitat under sea ice and to support the optical data set
- High-resolution video for documentation.

The physical properties of different sea ice types will be assessed during regular ice stations. During each ice station we will

- estimate the vertical micro-structure of sea ice by ice coring. The ice cores will be analyzed during the cruise in a freezer laboratory container on *Polarstern*.
- create a high resolution ice thickness data set with ground-based EM and ice drilling. The results serve as a validation dataset for the larger-scale airborne ice thickness estimates.

In addition to this standard ice-station programme we will perform additional measurements on extended ice stations at selected sites:

- Measurements of spectral albedo to complete the radiation energy budget together with the transmissivity measurements
- Deployment of drifting ice-mass balance buoys (IMB's)
- Deployment of drifting snow-depth buoys.

A time series of sea-ice mass balance and optical properties of sea ice shall be accomplished with autonomous stations (radiometers, weather station, sea-ice and snow mass and energy balance) on the long-term ice station. The instrumentation will be retrieved at the end of the cruise.

Continuous observations of the sea ice conditions shall be made while the ship is moving with

- hourly observations of sea ice condition by trained observers from the bridge
- continuous recording of the sea ice surface with a sideward-looking 3D sea ice camera.

Besides the deployment of ice mass balance buoys, we want to contribute to the International Arctic Buoy Program (IABP) with several meteorological ice drifters in areas with limited coverage of drifting buoys. We plan to participate in the validation of the sea ice concentration product of the Advanced Microwave Scanning Radiometer 2 (AMSR2) with melt-pond fraction evaluation from aerial imagery and the estimation of atmosphere aerosol content with a hand-held sun-photometer.

Data and samples

All data from the EM-Bird, the radiation sensors from the optical stations and ROV, aerial photos from the helicopter surveys and sea ice camera require post-processing after the cruise. The data from AWI sensors will be made publically available in the PANGAEA database within one year. Sea ice thickness data from airborne EM will also be entered into the Sea Ice Thickness Climate Data Record. Visual sea ice observation data will be distributed by a standardized database at the International Arctic Research Center, University of Alaska, Fairbanks. Drifting buoy positions and atmospheric parameters can be obtained in near-realtime from the website of the International Arctic Buoy Program. Sea ice cores taken at ice stations will be archived in the cold storage facilities of the Alfred Wegener Institute.

References

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3. PHYSICAL OCEANOGRAPHY

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Objectives

Processes in the Arctic Ocean are linked to regional forcing and also conditions elsewhere. Through the conversion of water masses by cooling, freezing and melting, the outflow to the North Atlantic can influence the Atlantic-wide meridional overturning circulation. Processes within the Arctic Ocean are strongly impacted by the upper ocean stratification, which influences the transfer of heat, freshwater and momentum between the water and the ice and atmosphere. The stratification, in turn, is due to the input of Pacific Water, freshwater from rivers and precipitation as well as freezing and melting.

Inflows of water from the Atlantic and the Pacific have experienced several warm pulses throughout the past decades. Arctic-wide surveys, particularly during the International Polar Year 2007/08 and in 2011 (TransArc), showed that in the same time the temperatures of the Arctic Ocean waters have been changing. Continuing strong upper ocean stratification raises questions about the origin of changes in salinity (freshwater) and temperature at various depths. More recently a considerable accumulation of fresh water has been observed which can be assessed as manifestation of long-term variability. Deep-water properties have also been found to change in recent years relative to observations from the 1990s.

The objective of the oceanographic programme is to determine the present state of regional distribution of water masses and their circulation with respect to the above changes. The questions are: how Atlantic water temperature and salinity anomalies propagate through the Eurasian Basin or spill into the Canadian Basin; how the pathways of Barents Sea and Fram Strait inflow differ or merge; if the deep water warming in the Eurasian Basin continues or if the warming is diluted by mixing over a larger area; how and to which extent the different fresh water sources such as Siberian river runoff, Pacific water inflow and ice melt contribute. Not only the influence on the upper ocean but also the potential of shelf slope convection on deeper water masses remains to be answered.

In combination with temperature, oxygen and salinity measurements the oxygen isotope composition ($\delta^{18}O$) will be used in a mass-balance to determine the contributing water masses such as river water, sea ice meltwater/formation and Atlantic-derived waters (see section on “Oxygen Isotope Water Mass Signatures, $\delta^{18}O$). Nutrient concentrations measured by the biogeochemistry group will also permit to distinguish Pacific-derived waters.

As during the TransArc (2011) this cruise will again cover much of the Arctic Ocean basins, but with a stronger focus on the Eurasian basin and the ice edge at the end of summer, the region north of the Eurasian continental slope. The ship-borne measurements will be extended temporally and spatially by autonomous systems mounted on the sea-floor and underneath moving ice floes.

Work at sea

The oceanographic work will consist of CTD (Conductivity Temperature Depth)/rosette sampler and Acoustic Doppler Current Profiler (ADCP) sections, the recovery of seafloor-mounted moorings and the deployment of ice-tethered platforms; possibly the recovery of the latter.

Profiles of ocean temperature and salinity will be measured and samples for home-lab $\delta^{18}O$ analysis (see section on "Oxygen Isotope Water Mass Signatures, $\delta^{18}O$) will be taken along all sections. The casts will be carried out with a CTD / rosette system with Seabird components (SBE9+ and SBE32) with double temperature and conductivity sensors. Water samples will also be taken occasionally for salinity and oxygen sensor calibrations.

To increase the spatial resolution of the sections and to extend them into regions with heavy ice we will go to suitable ice flows by helicopter and conduct CTD casts there with an autonomous XCTD (eXpendable CTD) system and a mobile "Heli-"CTD unit. The XCTD equipment can measure temperature and conductivity (i.e. salinity) from the sea surface to 1,100 m depth in only five minutes. The "Heli-"CTD unit consists of a ballasted Seacat CTD (SBE19 Plus; internally recording) mounted on an ultra-light line and allows profiling down to the seafloor, which takes about three hours for a 4000 m cast. The use of a ship-based underway profiling CTD-System is currently under consideration.

Along the transects, the velocity field of the upper 200 m will be measured with a ship-borne 150-kHz broadband ADCP.

In order to extend the measurements of ocean temperature, salinity and velocity in time and space, ice-tethered platforms with various instrumentation will be deployed:

- One POPS (Polar Ocean Profiling System) is equipped with Seabird SBE41CP CTDs, that will measure profiles of temperature and salinity once per day between the surface and 800 m water depth. In addition, these systems sample air temperature and pressure every hour.
- Four ITP (Ice-tethered Profiler) are similar to the POPS but obtain profiles twice or three times per day. Three of these systems also measure dissolved oxygen and one system also measures bio-optical parameters throughout the CTD profiles.

Sea-floor mounted moorings will be recovered:

- Up to five moorings will be recovered near the continental slope on the Laptev Sea shelf within the Russian-German collaborative project "Eurasische Schelfmeere im Umbruch - Ozeanische Fronten und Polynjasysteme in der Laptev-See" funded by the German Science Ministry (BMBF) and the Russian Federation. These moorings have been obtaining velocity profiles using ADCP and point measurements of pressure, temperature and salinity.
- Two sets of moorings from AWI will be recovered near the Gakkel Ridge. Each set consists of one full depth CTD profiler mooring and another mooring with ADCPs and various instruments obtaining point measurements of temperature, salinity, pressure and velocity at different depths. Upward looking sonars have been registering sea ice presence and thickness. In addition, biological parameters, such as sediment deposition, have been sampled in sediment traps. Furthermore, one near-surface CTD-profiler is moored on the Amundsen-basin side of the Gakkel Ridge.

The ice-tethered platforms contribute to the "International Arctic Buoy Program" (IABP) and the "International Arctic Ocean Observing System" (IAOOS) as well as to the "Arctic Observing Network" (AON). They are a component of the Hybrid Arctic Float Observing System (HAFOS).

The oceanographic work is supported by contributions from the BMBF-funded Project "North-Atlantic II", by the Woods Hole Oceanographic Institution (WHOI), the US National Science Foundation (NSF) and the Japan Agency for Marine-Earth Science and Technology (JAMSTEC).

Data

Data from ship CTD casts will require post cruise calibration and processing. This will take up to one year. Until then preliminary data will be available to the cruise participants and external users after request to Benjamin.Rabe@awi.de or Ursula.Schauer@awi.de. As soon as data processing is complete the finally processed data will be submitted to PANGAEA. The unrestricted availability from PANGAEA will depend on the progress of scientific analyses within the AWI Observational Oceanography group. Data from the mobile CTD unit will be handled in the same way as ship CTD casts. Data from ITP will be available in real time and after completion of the mission of the respective system under http://www.whoi.edu/itp. Data from POPS will be made available in a similar manner as the ship CTD casts, pending processing, which is still under development. Data from the vessel mounted ADCP and, if used, LADCP, will be available on request from Benjamin.Rabe@awi.de or Ursula.Schauer@awi.de, as handling of these data in public databases is currently under development. Processing of these data may take up to one year. CTD casts from the XCTD system may be requested from Takashi Kikuchi (JAMSTEC; takashik@jamstec.go.jp), pending processing and ongoing scientific analyses at JAMSTEC. Data from the moored observatories: mooring observations in the Laptev Sea are subject to restrictions within the corresponding project (contact Markus.Janout@awi.de or Jens.Hoehlemann@awi.de); mooring observations near the Gakkel Ridge are subject to processing and on-going scientific analyses, as these moorings were deployed for the first time, involving different scientific groups at AWI (contact: Benjamin.Rabe@awi.de, Ursula.Schauer@awi.de, Eva-Maria.Noethig@awi.de). CTD casts from the underway profiling CTD system, if used, are subject to the same restrictions as the Laptev Sea mooring observations. For $\delta^{18}O$ samples see section on “Oxygen Isotope Water Mass Signatures, $\delta^{18}O$.

3.1 Oxygen isotope water mass signatures ($\delta^{18}O$)

D. Bauch (GEOMAR, not on board), B. Rabe (AWI)

Objectives

The overall purpose of the project is to provide an assessment of water mass signatures based on stable oxygen isotope analysis ($\delta^{18}O$). Based on hydrological data and stable oxygen isotope analysis ($\delta^{18}O$) the influence of shelf-derived freshwaters and contributions of waters containing a brine signal originating from sea-ice formation can be quantified. Together with nutrient data (NOx, PO_4 and O_2) also the Atlantic and Pacific-derived components can be quantified within the halocline. The current database available for comparison indicates strong interannual as well as interdecadal variations in the distribution of Siberian and Alaskan fresh-water, as well as of the contribution of Pacific waters to the Arctic Ocean halocline. At greater depth the signature of different deep-water components will be investigated.

With the significant reduction seen in summer sea-ice cover considerable changes in the sea-ice regimes of the Arctic shelves and the shelf-derived Arctic Ocean halocline are expected. Melt water and huge amounts of river water are released on the Arctic Ocean shelf areas in summer, while sea-ice and brine waters are produced during winter. Stable oxygen isotope ratios ($^{18}O/^{16}O$; usually expressed as $\delta^{18}O$ values, which is the ‰ deviation relative to a sea-water standard, SMOW) in conjunction with hydrological data are an excellent tool to investigate the contribution of the different water masses from the arctic shelf regions (Bauch et al., 1995; Ekwurzel et al., 2001). Arctic rivers are strongly depleted in heavy oxygen isotopes (^{18}O) relative to marine waters. Sea-ice processes on the other hand also strongly influence the salinity of the water, but have little influence on the $\delta^{18}O$ value of the water column. Therefore $\delta^{18}O$ analysis gives important quantitative information about freshwater sources, such as river water, sea-ice meltwater or sea-ice formation. A further quantification of Atlantic and Pacific-derived waters within the marine fraction can be made based on nutrient concentrations (Ekwurzel et al., 2001; Jones et al., 1998, 2008; Yamamoto-Kawai et al., 2008; Bauch et al., 2011).

Work at sea

We plan to take water samples for stable oxygen isotope analysis ($\delta^{18}O$) in parallel to CTD measurements and hydrological sampling conducted by partner groups (AWI oceanography and hydrochemistry groups, chapter 3 and 4). Sampling is planned within the halocline and the intermediate waters down to a depth of about 1000 m. Sampling within the Deep and Bottom waters is also planned for a selection of stations. Water sampling for $\delta^{18}O$ analysis (100 ml) from CTD-rosette throughout the water column will be conducted at all available stations and depth levels (but no multiple casts). Planned sampling depths are at about 0 m, 5 m, 10 m, 20 m, 30 m, 50 m, 75 m, 100 m, 150 m, 200 m, 300 m, 400 m, 500 m, 600 m, 700 m, 800 m, 900 m, 1000 m. At selected stations further sampling down to the sea floor will take place at additional depth: 1250 m 1500 m 1750 m 2000 m, 2250 m, 2500 m, 2600 m, bottom depth.

Data and samples

Samples will be transported to Kiel. Analysis for stable oxygen isotope composition will be conducted at the Leibniz Laboratory at Kiel University, Kiel, Germany and at the Stable Isotope Facility at CEOAS at Oregon State University, Oregon, USA within 1 year. Data will be stored at the Pangaea data repository and will be made public after publication at Pangaea Data Repository.

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4. GEOCHEMISTRY (GEOTRACES)

P. Masque (UAB, not on board), M. Rutgers van der Loeff (AWI, not on board), V. Puigcorbe (UAB/ICTA), M. Roca (UAB/ICTA), D. Scholz (AWI), E. Kirschenmann (AWI), C-E. Thuroczy (NIOZ), M. Le Guitton (NIOZ), K. Bakker (NIOZ), E. Damm (AWI, not on board), V. Schoemann (not on board), P. Laan (not on board), J.T.M de Jong (not on board), L. Gerringa (not on board), H.J.W. de Baar (NIOZ, not on board)

4.1 Detection of methane cycling in sea-ice by measurements of methane concentration, stable carbon isotopes and oxidation rates

E. Kirschenmann (AWI), E. Damm (AWI, not on board)

Objectives

Air - sea ice - ocean interactions in the Polar Regions have a substantial impact on the oceanographic regime, natural biogeochemical cycles and global climate. However, our understanding of the fundamentals of the associated surface chemical, physical, and biological exchange processes that occur at relevant interfaces, particularly those associated with sea ice, is very limited indeed. Changes in brine salinity and salt precipitation/dissolution cycles affect the solubility of gases (minor direct relationships for most gases, but quite dramatic, indirect relationships for carbon and sulphur dioxides) and organic solutes. These relationships dictate the physical controls on mass, gas and energy fluxes operating within the ocean-sea ice-atmosphere system and hence play an important role in chemical exchange across the sea ice interface. We will investigate the physical, chemical, and biologically-mediated mechanisms and exchange processes involving pathways of the climatically relevant trace gas methane in sea ice. The aim of our proposed work is to obtain a detailed characterisation of the physical, biological and chemical environment of sea ice, with an emphasis on sites supporting growing biological assemblages.

Work at Sea

Ice cores will be collected from one-year and multi-year ice, respectively. Ice cores will be transported frozen to the home laboratory. Some of them will be melted immediately on board to collect the gas phase. After sampling, methane will be immediately measured on board ship, using gas chromatographs equipped with a flame ionization detector (FID). Furthermore, gas samples will be collected and stored for analyses of the $\delta^{13}C$ CH_4 values in the home laboratory.

Data

Preliminary data will be available to the cruise participants and external users after request to Ellen Damm. After one year the finally processed data will be submitted to PANGAEA.

4.2 Natural radionuclides

V. Puigcorbe (UAB/ICTA), M. Roca (UAB/ICTA), D. Scholz (AWI), P. Masque (UAB, not on board), M. Rutgers van der Loeff (AWI, not on board)

Objectives

The main objective is to evaluate the effect of varying conditions of sea ice coverage in the Arctic Ocean on the carbon export and remineralisation rates from the upper water column, as well as its final fate in the bottom sediments. We will use a suite of natural radionuclides (^{7}Be, ^{210}Pb, ^{210}Po and ^{234}Th) as tracers, with different sources and half-lives and biogeochemical characteristics. We will evaluate the magnitude of the exchange rates between sea ice, atmosphere and surface waters of those isotopes that are instrumental for the main objective and also as proxies for nutrients, Fe, Mn (studied by the parallel program of the NIOZ trace metal group, chapter 4.3) and/or contaminants in the system. Research to be conducted in different areas, as defined by nutrient regimes and their history in ice cover prior to sampling, will allow evaluating, quantifying and predicting regional effects of sea ice retreat on the Arctic ecosystem. The specific objectives to be attained are:

1. To quantify carbon export and remineralisation rates for different nutrient and ice regimes in the Central Arctic.
2. To constrain the efficiency of sea ice in intercepting and accumulating atmospheric fluxes of chemical species and quantify the role of particulate matter, including sea-ice algae, in their accumulation in sea ice and their fate when melting occurs.
3. To quantify the effect of exchanges between sea-ice and water on the distributions of the isotopes used as tracers of carbon in the water column.
4. To determine mixing and sedimentation rates in bottom sediments to evaluate the organic carbon cycling at different time scales.

Since ^{7}Be can be progressively incorporated directly into sea ice via atmospheric deposition during transit, it is a useful tracer of the ability of the ice to incorporate atmospheric fluxes of other chemical species and/or contaminants. In addition, ^{7}Be also can be used as a tracer to estimate the loading of sediment in sea ice and the annual sediment flux associated with melting of sea ice.

We will evaluate the particulate organic carbon (POC) export using the $^{234}Th/^{238}U$ and $^{210}Po/^{210}Po$ disequilibria. The difference in half-lives of ^{234}Th and ^{210}Po enables the study of export production rates over different time scales (weeks and months, respectively).

We will estimate the sediment burial and bioturbation rates using ^{210}Pb and artificial radionuclides (^{137}Cs) as markers. The information shall be of use for the group that shall assess recent and sub-recent sea-ice distribution as reflected in the sedimentary record using sea-ice diatom specific isoprenoids (C25 HBIs) (R. Stein/AWI, chapter 7).

Work at sea

1. Concentrations and fluxes of radionuclides in precipitation and aerosols

We will install a collector of precipitation in the highest possible position of the R/V *Polarstern* to collect atmospheric precipitation (snow). We will quantify the concentrations and fluxes of ^{7}Be, ^{210}Pb and ^{210}Po in snow. Filtration of aerosols using a high flux pump will be carried out in parallel between precipitation events during the cruise. Filters will be also analysed for ^{7}Be, ^{210}Pb and ^{210}Po concentrations. Together with atmospheric fluxes determined from precipitation samples, the data will be used to estimate residence times of the studied nuclides in the atmosphere.

2. Distribution of radionuclides in sea ice

Samples of snow deposited onto the sea ice will be obtained at all stations and analysed for ^{7}Be, ^{210}Pb and ^{210}Po. Isotopic ratios will be compared to those measured in precipitation samples to constrain the estimates of the average atmospheric fluxes. Several replicates of sea ice cores will be collected at each station. We will collect samples for determining both concentration profiles, slicing the ice cores every 20 cm, and total inventories, analysing the whole core. Samples will be filtered to analyse both the dissolved and particulate fractions, operationally defined at 0.4 µm. Radionuclides to be analysed are ^{7}Be, ^{210}Pb, ^{210}Po and ^{234}Th. We will also analyse sea-ice algae for ^{7}Be, ^{210}Pb, ^{210}Po, ^{234}Th and ^{238}U. Sea-ice sediments will be collected from the surface ice when present at each station and during transits (using the helicopter) and analysed for the contents of ^{7}Be, ^{210}Pb, ^{210}Po and ^{234}Th and other gamma emitters. Granulometry, mineralogy and X-ray diffraction analysis will also be conducted to determine the composition of the samples.

3. Water column

Surface sea water samples, both at sites with presence of ice and in open waters, will be collected at the defined stations and during transits at representative depths of the mixed layer. Samples will be analysed for concentrations of ^{7}Be, ^{210}Pb, ^{210}Pb, ^{234}Th and ^{238}U. Samples can be obtained either using the ship's seawater inlet, Niskin bottles or a submersible pump deployed at the desired depth at ice stations. Samples will be filtered through 0.45 µm membrane filters to determine concentrations in both the particulate and dissolved fractions. The data will be combined with the information derived from the atmospheric and ice work to elucidate the exchanges of each isotope between compartments and to estimate the efficiency of sea ice in intercepting atmospheric fluxes and accumulating these isotopes from the water column. The results are of particular interest not only for the understanding of the cycling of the selected radionuclides, but also to investigate the fate of other elements such as metals (Fe and Mn in particular, in collaboration with NIOZ metal team, chapter 4.3).

Profiles of concentrations of ^{234}Th, ^{238}U, ^{210}Pb and ^{210}Po will be obtained for the upper 200 m of the water column at high resolution (12-15 depths) at each station, using Niskin bottles during CTD casts. The data will be used to build mass balances of the particle-reactive isotopes that allow estimating export from the upper ocean driven by sinking particles. Size-fractionated particles (1 µm and 50 µm) will be collected at several depths at each station using *in-situ* pumps and analysed for both the contents of the particle-reactive isotopes and POC and PON. The ratio of concentrations of these parameters to either ^{210}Po or ^{234}Th in sinking particles is used to estimate their export flux, based on the export rates of the selected radionuclide, which is determined from its deficit with respect to its progenitor in the upper water column. Export from the upper ocean and remineralisation rates below the photic layer are to be obtained as part of the main objectives of the cruise.

We will analyse subsamples from the drifting sediment traps that will be deployed for several days as part of the cruise for POC/^{234}Th and POC/^{210}Po ratios. The fluxes of ^{234}Th, ^{210}Po and ^{210}Pb derived from the sediment traps will then be compared to those estimated from the water column. Estimates of both methods differ in the time-scales for which they are representative (traps for the deployed time, water column data for the integrated time corresponding to the mean life of the selected radionuclide, ranging from weeks to months). Comparison also allows constraining the potential effects of hydrodynamical bias of the traps, which is usually corrected using the water column approach.

Uranium-236 is an anthropogenic radionuclide introduced in the environment by nuclear test explosions and by reprocessing of nuclear wastes. The invasion of this transient tracer into the World Ocean has recently become an issue of much interest. We will collect some full depth profiles in addition to the samples collected during the TransArc expedition in summer 2011. Samples will be analysed by the team of Marcus Christl (ETH, Zürich) with Accelerator Mass Spectrometry.

4. Mixing and sedimentation rates in bottom sediments

^{210}Pb, ^{226}Ra and ^{137}Cs will be analysed in bottom sediment cores collected with the multicorer at each station to determine mixing and sedimentation rates at different time scales. These results provide the basis to estimate accumulation and remineralisation of carbon in the seafloor, one of the main goals of the cruise.

Data

Preliminary data will be available to the cruise participants and external users after request to Pere Masqué or Michiel Rutgers van der Loeff. Finally processed data will be submitted to PANGAEA.

4.3 Nutrient and sea ice trace metal biogeochemistry

C-E. Thuroczy (NIOZ), M. Le Guitton (NIOZ), K. Bakker (NIOZ), V. Schoemann (not on board), P. Laan (not on board), J.T.M de Jong (not on board), L. Gerringa (not on board), H.J.W. de Baar (NIOZ, not on board)

Objectives

A main objective is the investigation of nutrients relevant to primary production in and under the ice. Iron (Fe) is an essential micronutrient. It limits primary productivity in more than 30% of the oceans, including some parts of the Arctic Ocean, and has a crucial impact on the biogeochemical cycles of carbon and other elements with ultimate influence on the Earth climate system. Dissolved and particulate Fe concentration data show that Fe is 10-100 times more concentrated in the sea ice than in underlying seawater (e.g. Aguilar-Islas et al., 2008, Lannuzel et al. 2010) and that sea ice melt can deliver up to 70% of the daily Fe supply to the surface waters. According to budget estimates in Antarctica, accumulated Fe would largely derive from the underlying seawater rather than from atmospheric inputs in Antarctica (Lannuzel et al., 2008). This may hold true for the Arctic as well. The Fe fraction that is accessible for phytoplankton uptake (bioavailability) controls the plankton community and consequently the biological carbon pump. Most of the dissolved Fe (> 90 %) is complexed by strong organic ligands. Ligands tend to increase Fe solubility and retain Fe in the upper ocean. Therefore organic Fe might be controlling Fe bioavailability to the plankton community.

Although poorly studied so far, other trace metals, like Mn, Zn, Co and Cu are required for microorganisms cell metabolism and may be (co-) limiting in high nutrient low chlorophyll areas. Inversely, at high concentrations or present under particular chemical forms, some metals, like Cu and Zn, can become toxic to algal growth. The first profiles of Mn, Cu, Zn, Mo and Cd in pack ice (Lannuzel et al., 2011) suggest that most of these trace metals are not incorporated in the sea ice in the same way as Fe. Further data are needed to confirm these results and assess whether these trace metals could be (co-) limiting or toxic for sea algae and phytoplankton. Contrasted Fe isotopic compositions in particulate matter and the dissolved phase inside sea ice cores appeared to reflect the autotrophic and heterotrophic activities of the microbial communities (de Jong et al., 2007). The use of non-traditional isotopes (e.g. Fe, Zn) is a promising tool to trace the origin and the main processes controlling the biogeochemical cycles of biologically relevant trace metals.

The general objective is to assess the role of sea ice as a source of bioavailable Fe and other bio-essential trace metals (Mn, Zn, Cu, Mo, Cd), their impact on primary productivity and on the biological pump.

We will address the following specific questions:

1) What are the concentrations of Fe and of other bio-essential trace metals in the sea ice? How do they vary spatially and temporally?

2) How much Fe and other bio-essential trace metals can the sea ice supply as compared to other sources of trace metals to the Arctic Ocean?

3) What is the origin of the Fe and other bio-essential trace metals in the sea ice?

4) What will be the impact of global change on Fe and other bio-essential metals bioavailability.

Work at sea

Samples collected of seawater and of the sea-ice environment (interstitial seawater, brines, etc.) will be analyzed for dissolved phosphate, silicate, nitrate and nitrite. Samples with high particle content (e.g. plankton) will be filtered before analysis. The samples will be analyzed on board, typically within 12-24 hours after collection, on a Technicon TrAAcs 800 autoanalyzer in the dedicated nutrients laboratory container (NIOZ). Standards of nutrient mixtures in seawater are prepared every day and analyzed in the series together with the samples for accurate calibration. The sum of nitrate plus nitrite is analyzed upon overall reduction to nitrite, and by difference with analysis of nitrite only, the concentration of nitrate is calculated. Typically in open ocean waters the portion of nitrite is small or non-detectable, the large majority is nitrate. Additional samples for analysis of ammonia will be filtered at 0.2 micron filters and stored frozen for analysis afterwards in the NIOZ home laboratory. Samples of sea ice, snow, brines and underlying water will be collected for metal analyses. In order to avoid contamination from the ship, samples will be collected with clean room outfits as far as possible from the ship. First, samples of snow will be taken with trace metal clean shovels. Ice cores will be collected with a novel Titanium corer. Brines will be sampled at 2 depths (shallow and deep), by drilling sack holes into the ice and allowing gravity-driven brine release into the holes and further collecting them using a peristaltic pump and trace metal clean tubing. Under-ice seawater (0 m, 1 m and 30 m deep) will also be sampled by using the peristaltic pump. Core slicing and melting for trace metals analysis will be done at the home laboratory. The snow, brines and seawater samples will be directly processed and measurements of Fe concentrations will be conducted by Flow Injection Analysis (FIA) onboard the RV *Polarstern* in a container equipped with class-100 clean air laminar flow hoods. Samples of ice, snow, brines and seawater for major nutrients (nitrate, phosphate and silicate) will be analyzed onboard. Other measurements will be done at the home laboratory. Concentrations of other bio-essential trace metals (e.g. Mn, Zn, Cu, Mo, Cd) as well as of other trace metals, used as dissolved Fe source tracers of atmospheric dust, continental margins or remineralization (e.g. Al, Mn, Ba) will be determined by isotopic dilution with a HR-ICPMS (Biller et al., 2012). Organic complexation of Fe will be investigated by voltammetry (CLE-ACSV) measurements of the concentration and conditional stability constant of Fe specific natural organic ligands. The fractionation of natural Fe and Zn isotopes will be measured by Nu Plasma MC-ICP-MS, following methodology recently developed (de Jong et al. 2007, de Jong et al. in prep.).

These data will be related to physical (e.g. texture, temperature, salinity), chemical (e.g. POC, DOC) and biological parameters (e.g. Chla, bacteria enumeration) measured by other participants (see chapter 7). In addition, radionuclides measured by Dr. P. Masqué's team

(UAB, chapter 4.2) will allow further estimation of the sources of Fe in the sea ice.

Data

Preliminary data will be available to the cruise participants on board and external users after request to Véronique Schoemann. After one year the finally processed data will be submitted to PANGAEA.

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5. BIOLOGY OF SEA ICE

I. Peeken (AWI/MARUM), M. Fernandez Mendez (AWI/MPI), C. Uhlig (AWI),
A. Stecher (AWI, University of Konstanz), G. Dieckmann (AWI, not on board),
K. Valentin (AWI, not on board)

Objectives

Sea ice is a seemingly hostile habitat but it is populated by a high number of microbial organisms. Organisms inhabiting the ice need to tolerate extreme environmental conditions due to rapid changes in light, salinity, temperature and nutrients. By applying a number of molecular and phylogenetic approaches we will determine the eukaryotic sea ice algae community and its transcriptional activity within the sea ice. By this, we will be able to not only determine the total ("hidden") biodiversity of the sea ice community but also to reveal the active transcriptional input to the entire sea ice community by constructing a cDNA library. Thus, function and phylogenetic affiliation of ESTs (Expressed Sequence Tags) will be determined and the sea ice biodiversity will be linked with transcriptional activity of major groups. These data are collected for a general comparison with sea ice eukaryotes from the Antarctic.

Although the ice-algae production is generally low compared to the production of the polar ecosystem, sea ice biota are crucial for the development stages of several key species e.g. copepods during seasons of total ice coverage. Hence a reduction of the sea ice cover and thickness would have a major implication for the cryo-benthic and cryo-pelagic coupling and thus for the entire ecosystem of the Arctic Ocean. If the extreme ice mass loss, particularly of multiyear ice (MYI), of the last decades continues it might only be possible to study the unique sea ice ecosystem for a few more years.

Light is considered to be the key environmental factor affecting the growth of the ice algae due to the extreme low light intensities caused by the albedo and the strong attenuation of the ice itself. This low light penetration and the increasing attenuation towards lower wavelength in the ice can be compensated by the algae by shifting the accessory photosynthetic pigments. Thus a reduction of sea ice thickness may result in a higher primary production of sea ice algae in the changing Arctic. However, this increase of biomass might not be relevant to sea ice associated metazoans which rely on the occurrence of MYI for their development stages. Ultimately, many sea ice associated organisms depending on MYI probably face extinction and reduce the biodiversity of the Arctic ecosystem.

In addition to the reduction of MYI recently an increase in the areal coverage of melt ponds connected to the underlying sea water has been observed. It is speculated that these are new evolving habitats in the Arctic ecosystem and their role for the overall carbon cycle of the Arctic ecosystem has yet to be determined. Thus the aim of this cruise is to better characterize the carbon pools and production of these melt ponds. Together with the physical sea ice team (chapter 2) we aim to better monitor the spatial variability of these melt ponds to quantify their role in the overall carbon cycle of the Arctic.

The loss of sea ice might be favourable for phytoplankton primary production due to a longer growth season, but nutrient availability is another factor controlling primary production of the Arctic ecosystem. Although nutrients can accumulate in the brine channels and thus reach high concentrations, the most important nutrient supply for the bottom-ice community comes from the sea water/ice interface. Therefore the nutrient concentrations in the underlying water are essential for the magnitude of primary production of the sea ice algae. Recently it was stated, that not the light but a lack of macronutrients will control the magnitude of the primary production in the Arctic Ocean and sea ice.

To understand the role of sea ice algae in the biogeochemical cycle it is essential to study their spatial variability. The strong absorbance signal of the ice algae community allow the use of remotely operated optical techniques to access ice algae abundance. These data, together with PI-curves for the estimation of primary production, will allow to extrapolate the observations on a broader scale and to distinguish how future changes might affect the algae of the various habitats. The detailed studies of the various carbon pools including primary production, DOC, CDOM and EPS and POC will enable us determine shifts in these pools due to environmental change and to assess the role of sea ice biota for the vertical flux.

The aim of this study is to understand the variability of the sea ice associated biomass and production with respect to the sea ice conditions and nutrient availability to assess the role of sea-ice biota for the cryo-pelagic, cryo-benthic coupling under different environmental scenarios. Special emphasis will be given to understand the role of melt ponds in the carbon cycling of the Arctic Ocean. These data can be used for modelling approaches to assess the role of climate change on the carbon cycle of the Arctic Ocean.

Work at sea

Various sea ice types from MYI to first year ice will be investigated, mainly in the Atlantic and partly in the Pacific sector of the Central Arctic. Regular sea ice sampling involves the collection of melted ice-core sections, under-ice water and melt pond water. In general we aim to collect the following variables: salinity, temperature, nutrients, coloured dissolved organic matter (CDOM), dissolved organic carbon/nitrogen (DOC/DON), exopolymeric substances

(EPS). Additionally, algae biomass and composition will be determined by chlorophyll, marker pigments, molecular markers and cell counts (microscopy and flow cytometer). Also biogenic silicate, particulate organic carbon and nitrogen (POC, PON) and the isotopic composition of POC and PON ($\delta^{13}C_{POC}$ and $\delta^{15}N_{PON}$) as well as specific sea-ice diatom related biomarkers (i.e., the novel sea-ice proxy IP25) will be determined. We further use a diving PAM, a PAR sensor and CTD equipped with a fluorescence probe to investigate the *in-situ* photosynthetic efficiency, light and biomass within the meltponds and the water. These measurements will be combined with primary production measurements of all habitats under constant laboratory conditions. For selected stations additional PI curves and size fractionation of primary production will be conducted. To assess the role of limiting nutrients for the primary production on selected stations bioassay experiments will be performed.

Primary production will be directly measured on board; however these preliminary results need to be finalized against the DIC concentrations which will be measured at the MPI. Salinity, temperature and nutrients will be directly measured on board in collaboration with the physical and geochemical team (Chapter 2 and 4). Together with the physical ice team a remotely operated vehicle will be used for floe-wide under-ice irradiance measurements to determine the spatial variability of the ice algae abundance. For the validation of the hyperspectral measurements, ice core samples will be taken along the ROV-transects for the measurements of particulate absorption, CDOM and marker pigments (HPLC).These data will also be used to calibrate the optical measurements taken during the under-ice surveys of the SUIT (Chapter 6). Flow cytometer measurements of the pico- and nanoplankton from all habitats including the entire water column will be directly counted on board. All other samples will be stored and measured at the AWI for determination of all other variables.

Samples

Except for the microscopic samples, all other variables taken during the cruise will be processed during or after the cruise. Leftovers of the microscopic samples will be stored at the Polar Biological Oceanography at the AWI for approximately 10 years.

Data

Data from Ice work will be collected during and after the cruise. The entire data set will be submitted to PANGAEA within 1-2 years, depending on the progress of a PhD thesis based on the data.

6. PLANKTON ECOLOGY

E.-M. Nöthig (AWI, not on board), C. Lalande (AWI), X. Xiao (AWI), K. Oetjen (AWI), J. Piontek (GEOMAR), L. Galgani (GEOMAR), H. Flores (AWI), C. David (AWI), B. Lange (AWI), M. Van Dorssen (MvD Metaalbewerking/AWI)

Objectives

The Arctic Ocean experiences rapid environmental changes due to increasing temperatures, decreasing sea ice and acidification. These changes will have major implications for the entire pelagic ecosystem with possible impact on the carbon cycle and emission of aerosols. The PEBCAO group (Plankton Ecology and Biogeochemistry in a Changing Arctic Ocean) investigates unicellular plankton organisms including bacteria and zooplankton in the Arctic pelagic system as well as biogeochemical parameters such as dissolved & particulate organic carbon. Our aim is to contribute to a better understanding of the direction and strength of biological feedback processes in the future Arctic Ocean.

The HGF Young Investigators Group *Iceflux* focuses on the importance of carbon assimilated by ice algae for the pelagic food web. A major aim of *Iceflux* is to quantify the trophic carbon flux from sea ice into the under-ice community. During ARK-XXVII/3, the *Iceflux* team aims to investigate the relationship of the under-ice fauna with physical habitat properties, and to collect samples for biomarker studies that help quantifying the importance of sea ice-derived carbon for these organisms.

The PEBCAO program aims to continue ecological investigations of phyto- and protozooplankton species composition and of bacterial communities, biomass, productivity, and related biochemical parameters such as chlorophyll a, particulate organic carbon & nitrogen, carbonate, and biogenic silica carried out in Arctic waters since the nineties in order to understand the eventual changes due to the rapidly changing Arctic environment. Specific questions will be: Are there regional differences in the seasonal distribution patterns of phyto- and zooplankton, and of biogeochemical parameters such as particulate organic carbon & nitrogen, carbonate and biogenic silica in the ice covered Arctic Ocean? 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 and vertical particle flux? What changes can we measure in the water column and in vertical particle flux and what are the consequences of these changes for carbon sequestration?

The objective of marine aerosol sampling is to investigate how organic colloids and gel particles in the sea-surface microlayer and in sea-spray derived organic aerosol vary as a function of biological activity in the surface ocean impacted by climate change. The aim is to explore chemical composition of organic matter within the sea surface microlayer and marine aerosol phase. The project is focused on the hypotheses that amount and composition of nano- and micro-particles in the sea-surface microlayer and in POA (primary organic aerosols) are influenced by biological productivity, as well as that gel particles accumulation on the sea-surface is an important source for POA which will be altered by climate change. As a consequence, also the emission of POA from the ocean will be affected. The study of the sea-surface microlayer and of marine organic aerosol is intended to explore the dynamics occurring at the interface between ocean and atmosphere and the production and export of polymeric organic matter to the aerosol phase: in the Arctic region, where the climate changes faster than in any other place on earth, low-level Arctic clouds play a key role in regulating surface energy fluxes. Their radiative or reflective properties depend on aerosol particles available for condensation that can be formed by aggregates of polymeric organic material from the sea-surface microlayer, as microgels produced by ice algae and phytoplankton in the surface water.

Arctic sea ice ecosystems may thrive significantly on carbon produced by ice-associated microalgae. Species feeding in the ice-water interface layer play a key role in transferring carbon from sea ice into pelagic food webs. To estimate the dependency of pelagic food webs from sea ice derived carbon, the trophic carbon flux from sea ice into the under-ice community must be quantified. This will be achieved by 1) quantitative sampling of the under-ice community and environmental parameters with a Surface and Under-Ice Trawl equipped with a sensor array (SUIT; in collaboration with IMARES, The Netherlands); 2) using molecular and isotopic biomarkers to trace sea ice-derived carbon in pelagic food webs; and 3) applying advanced sea ice-ocean models to project the flux of sea ice derived carbon into the under-ice community in space and time. ANT-XXVII/3 will provide the first bio-environmental dataset for the modeling incentive of *Iceflux*, as well as biological samples for the biomarker approach.

Work at sea

Aerosols

Aerosols measurements will be performed with a stainless steel 5-stage Bernerimpactor provided by Leibniz Institute for Troposphere Research in Leipzig (IFT), and will operate with a flow rate of 75 l/min. The Bernerimpactor will be positioned on the compass platform (Peildeck) as high as possible, and aerosol samples will be collected within a 48 hours sampling time. The Bernerimpactor is provided with five different stages for different size distribution of marine aerosol: 0.05-0.14 µm, 0.14-0.42 µm, 0.42-1.2 µm, 1.2-3.5 µm and 3.5-10 µm intervals. Aerosols are collected on pre-weighted aluminum foils; additionally for the size fractions 0.42-1.2 µm, 1.2-3.5 µm and 3.5-10 µm polycarbonate nucleopore filters of 0.4 µm pore size will be positioned on top of the aluminum foil and image analysis will be conducted for gel particles (TEP and CSP) collected on the polycarbonate membranes. Further chemical analysis of marine aerosols will be performed at IFT in Leipzig for the smaller size fractions. Gel particles in aerosol samples will be compared with sea-surface microlayer samples from meltponds or at sea. Sea-surface microlayer sampling will be performed with the glass plate technique inserting a glass plate of 20 x 50 cm vertically in the surface and wiping through Teflon blades the film that accumulates on the sides of the plate.

Plankton ecology and vertical particle flux

Water will be sampled from the rosette sampling system according to the water mass structure at selected stations for the following parameters: Species abundances - traditional and for molecular biological analysis, chlorophyll *a* and phaeopigments, HPLC pigments, particulate organic carbon & nitrogen (POC/N), carbonate, biogenic silica (bPSi). Water will be filtered on pre-combusted Whatman GF/F glass-fiber filters, polycarbonate and, cellulose acetate filters, respectively, stored deep frozen for later analyses in the home laboratory, or samples will be fixed and stored cool until enumeration.

Bacterial biomass production will be determined by the use of radiolabelled leucine and/or thymidine. Samples of the upper 100 m of the water column including the sea surface microlayer, sea ice and melt ponds will be analyzed. Bacterial abundances will be analyzed by flow cytometry. Analysis of organic matter will be carried out by analysing bulk DOC concentration as well as DOC components like polysaccharides and amino acids from CTD casts and the sea surface microlayer. Furthermore, polysaccharide- and protein-rich gel particles will be quantified and their size-frequency distribution will be analyzed.

In order to enable assessment of phytoplankton, including the smallest fractions in the Arctic marine environment, molecular methods are well suited to provide refined information on the composition and bio-geographical differences of Arctic phytoplankton communities. The characterization of phytoplankton communities with molecular methods is independent of cell-size and distinct morphological features. The assessment of the biodiversity and biogeography of Arctic phytoplankton will be based on the analysis of ribosomal genes, taking advantage of latest 454-pyrosequencing technology, Automated Ribosomal Intergenic Spacer Analysis (ARISA) or ribosomal probe based methods. Sampling will be carried out by filtering seawater on polycarbonate filters of different pore sizes, stored deep frozen for later analyses in the home laboratory.

Mesozooplankton composition and depth distribution will be determined by means of Multinet hauls. In addition, Bongo net hauls will be taken to collect organisms for biochemical analyses. The animals collected in the field will be used for physiological experiments at AWI to elucidate the influence of the zooplankton organisms on the microplankton community and on matter flux.

In co-operation with the physical oceanographers (chapter 3), two sediment traps (~200 m and ~150 m above sea floor) will be retrieved from two moorings near the Gakkel Ridge, respectively. They are deployed to collect particles in order to investigate vertical flux pattern of organisms and their remnants, of organic matter (including specific phytoplankton and sea-ice related biomarkers; in cooperation with K. Fahl/AWI) and lithogenic material under the almost permanent ice cover from mid September 2011 until end of August 2012. The traps were equipped with 20 sampling jars containing poison. The respective sampling intervals were programmed individually. The sampling jars of the traps will be analysed at the AWI home laboratory. In addition, small automatic sediment traps will be deployed at two permanent ice stations for a longer time period and will be recovered close to the end of the cruise on the way back. During routine ice stations it is planned to deploy a short array of two small traps from the ice over a time period of one to three days. All samples will be poisoned and analysed in the AWI home laboratory.

Iceflux

SUIT sampling

A Surface and Under-Ice Trawl (SUIT) will be used to sample the pelagic fauna down to 2 m under the ice. During SUIT tows, data from the physical environment will be recorded, e.g. water temperature, salinity, ice thickness, and multi-spectral light transmission. SUIT deployments are proposed along a transect of gradual transition from open water into the central Arctic multiyear ice field and back. For interpretation of SUIT catches in relation to diel vertical migration of organisms, at least two 24 hours stations, with SUIT hauls every 4 hours at the same location, are envisaged.

Stationary sea ice research

For comparative sampling of physico-chemical and biological properties of the sea ice environment, the Iceflux team cooperates in the following activities:

- Sampling of under-ice habitat properties with an ROV (Peeken, Nicolaus et al.)
- Sedimentation traps (Nöthig, Lalande)
- Ice-coring, including sea ice POC for biomarker analysis, biomass and production estimates, and biogeochemistry (Peeken, Piontek et al.)
- Zooplankton reproduction and grazing (Niehoff et al.)
-

For later biomarker analysis, samples of zooplankton and sea ice biota collected with SUIT, other nets and ice corers will be collected and frozen at -80°C on board.

Data and samples

Almost all sample processing will be carried out in the home laboratory at AWI. It usually takes up to three years depending on the parameter as well as analysis methods (chemical measurements or tedious swimmer picking in trap material and species enumerations and identifications, respectively). As soon as the data are available they will be accessible to other cruise participants and research partners on request. Depending on the finalization of PhD theses and publications, data will be submitted to PANGAEA and SCAR-MarBIN and will be open for external use.

7. BENTHIC BIOGEOCHEMISTRY

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Objectives

Benthic communities at the Arctic deep-sea floor depend on the sedimentation of particulate matter from sea ice and the water column, which is determined by temporal and spatial variations in the vertical export flux from the euphotic zone, and by lateral supply from shelf areas. Most organic matter is recycled in the pelagic realm, but a significant fraction of the organic material ultimately reaches the seafloor, and is either remineralized or retained in the sediment record. One of the central questions about the consequences of the shrinking sea ice cover is to what extent primary production and subsequent export of matter to the seafloor will be affected, and how this will influence the structure and functioning of benthic communities in the Arctic. Using state-of-the-art *in-situ* technologies to measure physical and chemical gradients at the transition between sea ice and water we will gain new insights on ice-associated physical, microbial and biogeochemical processes which shape particle export (collaboration with sea ice and geochemistry groups, chapter 2 and 4).

Benthic oxygen fluxes provide a good integrated measurement of the respiratory metabolic activity in surface sediments (Boetius and Damm 1998, Wenzhöfer and Glud 2002). They can be converted to benthic carbon mineralization rates and thus can be used to evaluate carbon input to the seafloor. Previous studies have shown that *ex-situ* oxygen uptake measurements often overestimate oxygen consumption due to depressurizing and warming. Therefore, we will focus on *in-situ* quantification of oxygen uptake using benthic lander systems, which can be equipped with benthic chambers and microprofilers. Total benthic *in-situ* community respiration under the ice has not been quantified yet, and also sediment trap data are missing due to the logistic and technical difficulties of their recovery. Both of these approaches together with various estimates of primary productivity and export (see chapter 5 and 6) will be applied during ARK-XXVII/3. Furthermore, in order to link long-term variations in sea ice cover to productivity and export flux to the seafloor, detailed information about the extent and variability of paleo sea-ice in relation to other proxies would be very valuable. We will therefore collect sediment samples for the application of a novel biomarker approach (“IP25”), which is based on the determination of sea-ice diatom specific isoprenoids (C25 HBIs) (Belt et al. 2007; Müller et al., 2009; Fahl and Stein, 2012). This will provide information about long-term variations in export of ice-algae from sea ice and may be linked to, for example, estimates of surface-water productivity. The long-term and short-term variations in sea ice and ocean productivity and carbon export are main drivers of the structure and functioning of benthic communities, as indicated by the relationships between biomass and diversity of various benthic taxa and size classes with gradients in organic matter availability in the Arctic (Vanaverbeke et al. 1997, Boetius and Damm 1998, Soltwedel et al. 2009, Bienhold et al. 2012). During ARK-XXVII/3 we will take the opportunity to observe and sample all benthic size classes (megafauna, macrofauna, meiofauna, microbes), in order to compare benthic diversity and functions (e.g. biomass, enzymatic hydrolysis) under different ice situations, including ice-free stations, stations at the ice edge and in the ice.

Major questions addressed within this group during ARK-XXVII/3 will be:

How does primary productivity, export and burial of organic carbon change under a changing sea ice cover? What is the relationship to benthic biomass and diversity across all size classes?

This work is funded by the Helmholtz program PACES, as well as the Leibniz and ERC projects of A. Boetius. J.-P. Balmonte's participation is supported also by NSF.

Work at sea

Microelectrodes (oxygen, temperature, conductivity, pH), as well as an eddy correlation system (for oxygen, heat and salinity fluxes), will be used to measure physico-chemical gradients at the sea ice-water interface, under the ice, as well as in melt ponds. A comparison of carbon and nutrient fluxes in relation to sea ice cover and its effects on benthic community structure and function, will help to better understand and quantify the effects of changes in sea ice cover on the Arctic Ocean and its ecosystems.

The sea ice-water interface eddy correlation work requires various supporting parameters. Sea ice cores will be extracted and analyzed at 5 or 10 cm intervals for primary production, bacterial production, bulk salinity, temperature, O_2, Dissolved inorganic carbon (DIC), Total Alkalinity (TA), and Chl-A (with Sea Ice Biology Group for TBC, chapter 5). Further, a CTD equipped with a PAR sensor and an O_2 optode will be moored directly under the ice to provide light intensity data under the ice as well as reference values for salinity, temperature, and O_2 – all to ground truth the eddy approach and so ascribe gas fluxes to physical or biological processes.

Benthic landers will be deployed to determine *in-situ* oxygen consumption as a measure for organic carbon delivery to the seafloor. These systems will be equipped with three benthic chambers and one microprofiler. Benthic chambers enclose a defined area of sediment including overlying water and are used to measure total exchange rates such as total oxygen uptake between the sediment and the water column. This 3-dimensional measurement includes fauna-mediated oxygen respiration as well as benthic microbial consumption in contrast to the microprofiler, which provides high-resolution horizontal profiles of oxygen distribution in the sediment and can be used to calculate diffusive oxygen uptake (mainly due to microbial respiration and thus mineralization processes).

The video sledge system OFOS (Ocean Floor Observation System, AWI), will be used for online biological observations at the seafloor. For each deployment several hundreds of pictures (released from board) can be stored. OFOS will be used for observations of mega- and macrofauna at the seafloor (collaboration with A. Gebruk, IORAS). Visible organisms, biogenic traces and tracks will be recorded. When possible, megafaunal organisms will be identified to the lowest taxonomic level. The abundance will be estimated as individuals per m^2. In addition, samples of benthic fauna will be taken using the Agassiz trawl, and will be examined and identified to the lowest possible taxonomic level. Selected individuals will be preserved for molecular genetic studies.

Sediment samples will be taken at each station for a range of biological and biogeochemical analyses using a multiple corer (MUC, TV-MUC) and a box corer. Biological analyses of samples on board will include the determination of potential extracellular enzymatic activities, chlorophyll pigment content and geochemical analyses. Sediment samples will be fixed for microbial DNA/RNA extraction, microbial cell counts, meiofauna and macrofauna analyses (collaboration with P. Martinez Arbizu, Senckenberg; T. Brey, AWI; A. Gebruk, IORAS), phospholipid analyses, porosity, the measurement of TOC (total organic carbon), and specific (especially IP25 and phytoplankton) biomarker analyses (with R. Stein, AWI). These analyses will all be performed in the home laboratories. In addition, pore water will be extracted and fixed for the analyses of nutrients, DIC (dissolved inorganic carbon), alkalinity, iron, and DOC (dissolved organic carbon, with T. Dittmar, MPI) in the home laboratory.

Data and samples

Post-cruise data archival will be hosted by the information system PANGAEA at the World Data Center for Marine Environmental Sciences (WDC-MARE), which is operated on a longterm base by the Alfred Wegener Institute for Polar and Marine Research, Bremerhaven (AWI) and the MARUM, Bremen. The ship's station list and all metadata from sampling and observations will be stored in the WDC MARE data base PANGAEA (http://www.pangaea.de), including ship tracks and will be submitted as CSR to the DOD (BSH). Further scientific data retrieved from observations, measurements and home-based data analyses will also be submitted to PANGAEA either upon publication, or with password protection by the individual P.I.s as soon as the data are available and quality-assessed. This includes also biological data, for most of which parameters are already defined in PANGAEA. Molecular data will be deposited in globally accessible databases such as GenBank. For benthic images a photo and video database is under construction at AWI and the research center MARUM (Bremen), which will be accessible to taxonomic specialists. All zoological samples will be stored at U Oldenburg, AWI, and IORAS (Meio-, Macro- and Meiofauna), and all microbiological samples are stored deep frozen or fixed at the MPI in Bremen.

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12. SCHIFFSBESATZUNG / SHIP'S CREW

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Ziemann, Olaf	Ch. Eng.
Lauber, Felix	2. Offc.
Peine, Lutz	2. Offc.
Hering, Igor	2. Offc.
Spilok, Norbert	Doctor
Koch, Georg	R.Offc.
Kotnik, Herbert	2. Eng.
Schnürch, Helmut	2. Eng.
Westphal, Henning	2. Eng.
Brehme, Andreas	Elec. Tech.
Fröb, Martin	Electron.
Muhle, Helmut	Electron.
Winter, Andreas	Electron.
Feiertag, Thomas	Electron.
Clasen, Burkhard	Boatsw.
Neisner, Winfried	Carpenter
Schultz, Ottomar	A.B.
Burzan, G.-Ekkehard	A.B.
Schröder, Norbert	A.B.
Moser, Siegfried	A.B.
Hartwig-L, Andreas	A.B.
Kretschmar, Uwe	A.B.
Kreis, Reinhard	A.B.
Schröter, Rene	A.B.
Beth, Detlef	Storek.
NN	Mot-man
Fritz, Günter	Mot-man
Krösche, Eckard	Mot-man
Dinse, Horst	Mot-man
Watzel, Bernhard	Mot-man
Fischer, Matthias	Cook
Tupy, Mario	Cooksmate
Völske, Thomas	Cooksmate
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Hennig, Christina	Stwdss/KS
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Hirschke, Peggy	2.Stwdess
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Chen, Quan Lun	2.Steward
Ruan, Hui Guang	Laundrym.
NN	Appr.
NN	Appr.

FS POLARSTERN

ARK-XXVII/1	**14.06.2012 - 15.07.2012**	**Bremerhaven - Longyearbyen**
ARK-XXVII/2	**15.07.2012 - 30.07.2012**	**Longyearbyen - Tromsö**
ARK-XXVII/3	**02.08.2012 - 07.10.2012**	**Tromsö - Bremerhaven**