EXPEDITION PROGRAMME No. 87

RV POLARSTERN

ARK-XXVI/1

15 June 2011 - 13 July 2011
Bremerhaven - Longyearbyen

ARK-XXVI/2

13 July 2011 - 3 August 2011
Longyearbyen - Tromsø

ARK-XXVI/3

5 August 2011 - 7 October 2011
Tromsø - Bremerhaven

Coordinator
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ARK-XXVI/1

15 June 2011 - 13 July 2011

Bremerhaven - Longyearbyen
Fram Strait

Chief Scientist
Agnieszka Beszczynska-Möller

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1. ÜBERBLICK UND FAHRTVERLAUF

A. Beszczynska-Möller, Alfred-Wegener-Institut

Der erste Fahrtabschnitt der 26. *Polarstern* Expedition in die Arktis wird am 15. Juni beginnen. Das Schiff wird von Bremerhaven auslaufen, um Untersuchungen in der Framstraße durchzuführen (Abb. 1). Während der Reise werden verschiedene Projekte entlang eines Schnittes über die gesamte Framstraße zwischen dem Kontinentalhang westlich von Spitzbergen und dem ostgrönländischen Schelf bearbeitet werden. Die Reise wird am 13. Juli 2011 in Longyearbyen (Spitzbergen) 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 der Zirkulation in der Framstraße zu quantifizieren. Dafür werden Temperatur, Salzgehalt, Sauerstoff an etwa 80 Stationen sowie Meeresströmungen in den oberen Schichten entlang eines Schnitts bei 78°50'N gemessen. Ozeanographische Verankerungen, die vor einem Jahr 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 14 Jahre dauernde Langzeitmessung fortgesetzt. Um die Verankerungsmessungen mit den hochauflösenden hydrographischen Schnitten zu ergänzen, wird ein Seaglider für eine drei Monate dauernde Mission in der Framstraße ausgelegt. Zur Navigation des Seagliders unter dem Eis werden außerdem vier akustische RAFOS-Schallquellen in der westlichen Framstraße verankert.

Für die biologischen Arbeiten werden an den CTD-Stationen zusätzlich Netzfänge ausgeführt und Sedimentproben genommen. Klimabedingte Veränderungen der Planktonzusammensetzung werden durch die PEBCAO-Arbeitsgruppe (Phytoplankton Ecology and Biogeochemistry in the Changing Ocean) untersucht. Die pelagische Mikrobiogeochemie im Polarmeer wird mit Schwerpunkt auf den Umsatz organischer Substanz und auf Zersetzungsprozesse untersucht, um ein besseres Verständnis der biogeochemischen und mikrobiologischen Rückkoppelungsprozesse im zukünftigen Ozean zu erlangen. Eine Kalibrierungsstudie für paläoozeanographische Rekonstruktionen wird durchgeführt, um den Zusammenhang zwischen der Variabilität der ozeanischen thermohalinen Struktur und der Zusammensetzung der Kalkschalen planktischer und benthischer Foraminiferen (winziger Meeresorganismen) besser zu erkennen.

Während des gesamten Fahrtabschnitts werden Beobachtungen von Seevögeln und marinen Säugetieren durchgeführt. Ziel der Langzeituntersuchung ist, die *in-situ* Verteilung der Seevögel und mariner Säugetiere in Zusammenhang mit der Verteilung der ozeanischen Wassermassen, Frontalzonen sowie mit dem Packeis und der Eiskante zu quantifizieren.

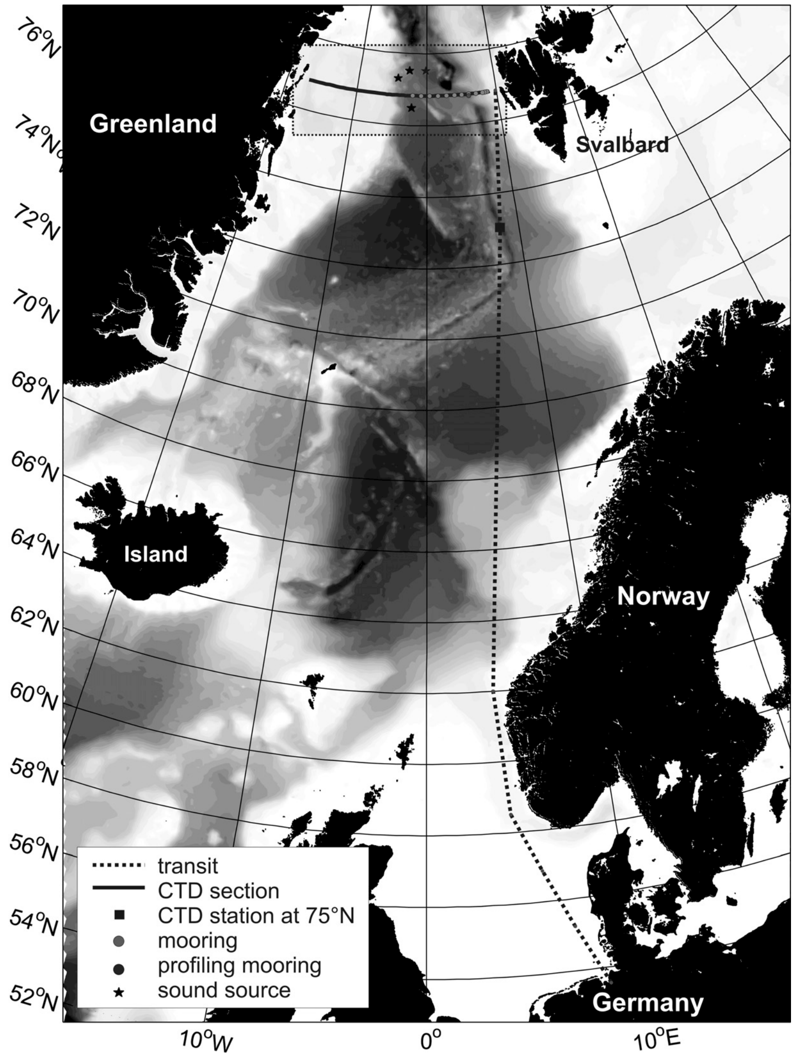

Abb. 1: Geplante Fahrtroute der Polarstern-Expedition ARK-XXVI/1
Fig. 1: Planned cruise track during the Polarstern Expedition ARK-XXVI/1

ITINERARY AND SUMMARY

The first leg of the 26th *Polarstern* expedition to the Arctic will start on 15 June 2011. The ship will depart from Bremerhaven to conduct research in the northern part of Fram Strait. The field work will serve different projects and concentrate along the long section across the entire Fram Strait from the shelf edge west of Svalbard to the east Greenland shelf. The cruise is scheduled to end in Longyearbyen (Svalbard) on 13 July 2011.

The oceanographic measurements in the frame of the EU project ACOBAR (Acoustic Technology for Observing the Interior of the Arctic Ocean) are aimed at 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 at about 80 stations at the section along 78°50'N, and ocean currents in the upper layer will be measured both on stations and underway. The moored array, deployed in 2010 for continuous, year-round measuremets of temperature, salinity and currents will be recovered and redeployed with new instrumentation. Measurements at the moored array will provide an extention of the existing 14-year long time series of unbroken observations in Fram Strait. To complement the continuous but spatially relatively sparse observations by moorings, the high resolution hydrographic sections will be measured by Seaglider, deployed during the ARK-XXVI/1 cruise leg for a 3-months long mission in Fram Strait. Four 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 research group PEBCAO (Phytoplankton Ecology and Biogeochemistry in the Changing Ocean). The pelagic microbiogeochemistry in the Arctic Ocean will be examined with a special focus on the turnover of organic matter during production and decomposition processes to achieve a better understanding of the biogeochemical and microbiological feedback processes in the future ocean. The calibration study for the paleo-oceanographic reconstructions will be conducted to study the correlation between recent variability of the ocean thermohaline structure and the composition of shells of planktonic and benthic foraminifera (calcareous microorganisms).

During the entire cruise leg the continuous observations and counting of seabirds and marine mammals will be performed. This long-term study is aimed to quantify *at sea* distribution of seabirds and marine mammals 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, O. Strothmann, M. Monsees, S. Rettig, J. Walter,
U. Menzel, A. Monczak, G. Allen, X. Xu, X. Wang, C. Wekerle, V. Haid (AWI)

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 provides the initial 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 on ice and in the 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 interannual 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. The present EU project 'ACOBAR' (Acoustic Technology for Observing the Interior of the Arctic Ocean) started in 2009 and 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 2010 the whole array was exchanged during the summer *Polarstern* cruise. Additionally two bottom moorings with PIES (Pressure Inverted Echo Sounders) were deployed in September 2010 from KV Svalbard. During ARK-XXVI/1 cruise eight AWI moorings in the eastern and central part of Fram Strait will be exchanged and PIES will be recovered. These seven 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 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) for a sufficient vertical resolution distributed at nominal levels: 50 m (subsurface layer), 250 m (Atlantic water layer), 750 m (lower boundary of the Atlantic water), 1,500 m (deep water) and 5 m above bottom (near-bottom layer). 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). Two moorings in the eastern Fram Strait will be equipped with the low-frequency modems to test underwater acoustic data transfer. Depending on their performance, the modems will be recovered during autumn cruise of KV *Svalbard* for evaluation of the acoustic data transmission or will stay in water until the 2012 *Polarstern* summer cruise. An additional mooring will be also deployed, aimed in testing the profiling winch with TS profiler with Iridium modem for data transfer, which will cover the upper water column up to the surface. This mooring will be located next to the mooring F6 at the offshore boundary of the West Spitsbergen Current.

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 with the higher spatial resolution than given by moorings. Water samples will be analysed for salinity with an Autosal 8400A salinometer (Guildline). 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-XXVI/1. This will be the fourth summer mission of the AWI glider, after three successful deployments in summers 2008 - 2010. The Seaglider will be operated from the pilot station in Bremerhaven during an about 3-months long mission, aimed in profiling the upper 1,000 m layer along sections in the open water part of Fram Strait (mostly to provide repeated snapshots of the high resolution hydrography 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-XXVI/1 four RAFOS sound sources (three RAFOS sources from URI and one prototype from develogic GmbH) 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. This is a crucial knowledge required for future under-ice missions of acoustically navigated gliders. The Seaglider deployed in summer 2011 will also receive RAFOS signals transmitted by three tomography moorings, deployed in Fram Strait in the frame of the ACOBAR project.

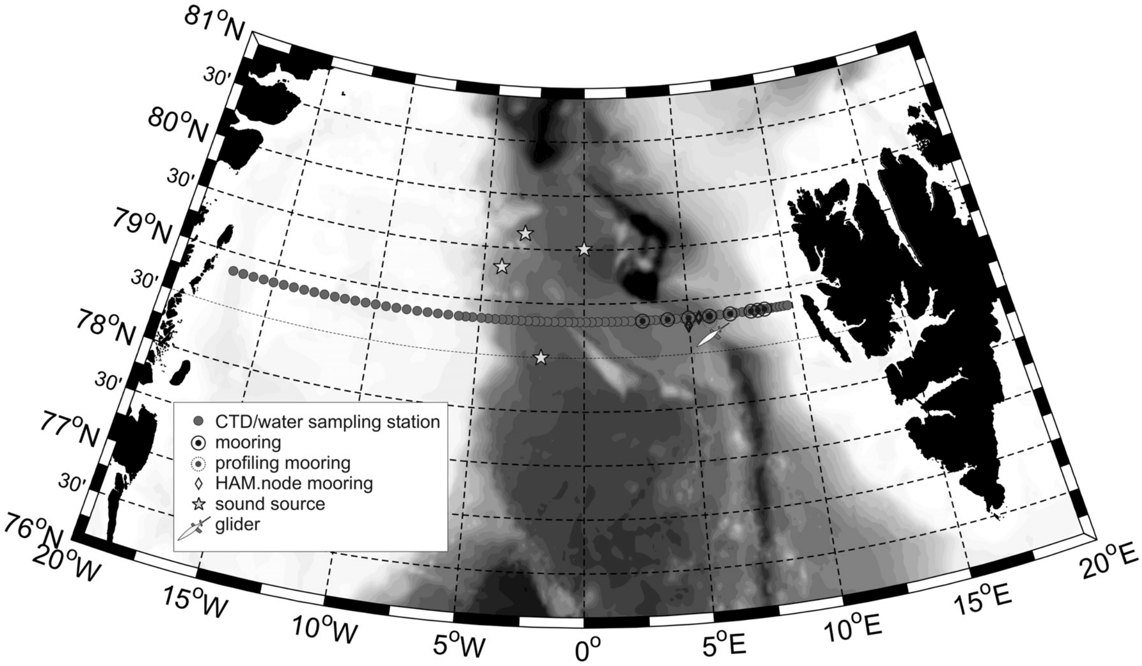

Fig. 2.1: Positions of moorings and CTD stations in Fram Strait

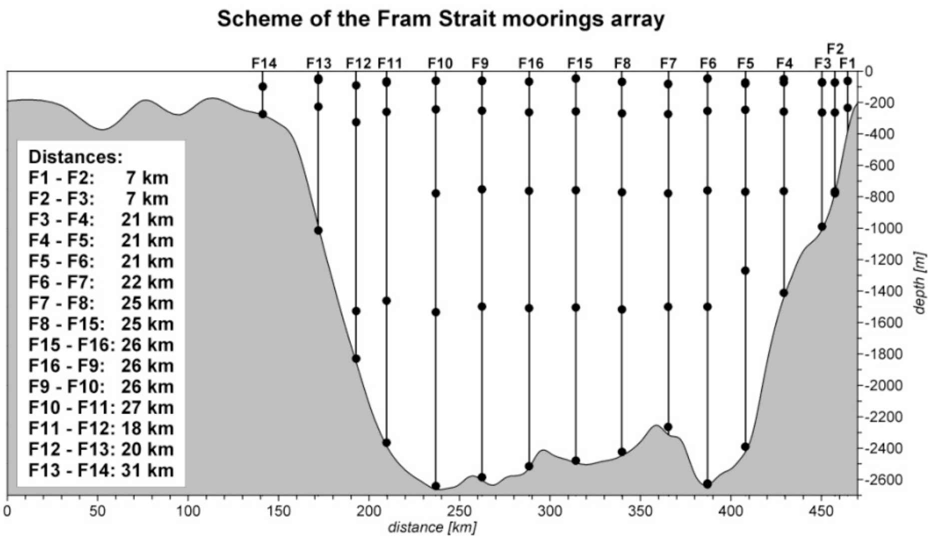

Fig. 2.2: Scheme of instrumentation at the Fram Strait moored array (moorings F1 to F8 will be exchanged during ARK-XXVI/1)

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

S. Gäbler-Schwarz, J. Piontek, M. Sperling (AWI), L. Federwisch (AWI Glocar, PI Anja Engel), Kristin Hardge, Maria Winkler, Karolin Thomisch (AWI, PIs Eva-Maria Nöthig, Barbara Niehoff; Ilka Peeken, AWI & MARUM Bremen; H. Auel, Uni Bremen)

State of the art & objectives

The Arctic Ocean has gained increasing attention over the past years because of the drastic decrease in sea ice and 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 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 will gain more importance in mediating element- and matter- as well as export fluxes in the Arctic pelagic system. One of them, Phaeocystis pouchetii, having an intermediate position regarding size can play a key role in the cycle of sulphur and carbon. However, little is known about the diversity distribution, occurrence and physiology of this species 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.

Based on the awareness that global change has increasingly changed marine ecosystems, we also intend to examine the ‘present day’ situation of pelagic microbiogeochemistry 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). Our overarching goal is to contribute to a better understanding of the direction and strength of biogeochemical and microbiological feedback processes in the future ocean.

During ARK-XXVI/1 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 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 (~79°N) to determine the impact of microbial processes on the aggregation and sedimentation of organic matter as part of the work of the PEBCAO group. We sample water at about 5 - 8 depths.

Measurements of CTD samples biogeochemical parameters:

- chlorophyll a &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 exopolymer particles (TEP);
- particulate biogenic silica (PbSi).

Measurements of biological parameters from CTD casts:

- phytoplankton & protozooplankton abundance;
- bacterial cell numbers;
- bacterial biomass production and extracellular enzyme activity;
- sampling for genetic analyses & clonal cultures;
- flow cytometer.

Measurements of biological parameters with net hauls (Multinet, Bongo net):

- sampling of live phytoplankton and zooplankton from the field;
- mesozooplankton composition and depth distribution will be determined by means of multi net 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 79°N transect to catch phytoplankton for isolation for later performing clonal cultures, genetic analyses will be carried out with the isolates.

Experimental work
Furthermore, effects of changing seawater temperature and pH on the bacterial utilization of different organic matter sources will be investigated by on-board incubation experiments. Rates of bacterial activity that are potentially sensitive to upcoming warming and seawater acidification may affect the turnover of organic matter in the future Arctic Ocean.

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.

4. ARCTIC PELAGIC AMPHIPODA

A. Kraft, N. Knüppel (AWI)
Not on board: U. Bathmann, 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-XXVI/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 mircon net bags). The net sampling will include vertical hauls from 2,000 m to the surface and horizontal tows in an equal water horizon at the sampling site if possible. 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. This aims at the quantitative collection of amphipods in the respective water horizons. The frequency of vertical and horizontal hauls in the Greenland Sea and along the 78'50°N transect will depend on overall program in these regions. Expected are 2 - 5 vertical hauls and 2 horizontal tows on the transect, as well as 4 vertical hauls and 3 horizontal tows in the Greenland Sea.

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.

5. CALIBRATION STUDY WITH RECENT FORAMINIFERA FOR PALEOCEANOGRAPHIC RECONSTRUCTIONS

T. Pados, M. Telesinski (IFM-GEOMAR)

Objectives

Isotopic and geochemical analyses and abundances of fossil foraminifera are common tools for paleoceanographic reconstructions. Oxygen isotopic ($\delta^{18}O$) records of sediment cores provide information about variation in sea surface temperatures and salinities in the past, while carbon isotopic ($\delta^{13}C$) records refer to e.g., paleoproductivity and stratification. However, for a correct interpretation of the fossil data it is important to improve our understanding of the correlation between recent oceanic variability and the composition of shells of living calcareous microorganisms. The aim of the studies to be performed during ARK-XXVI/1 is to investigate how *in-situ* conditions like salinity, temperature, and stable isotopic ratios of the ambient water are reflected in the tests of living foraminifera. Furthermore, the species distribution will be investigated to determine changes related to the variability of water temperature and salinity, water mass structure, and ice coverage. For a precise correlation of proxies used for paleoceanographic reconstructions and the water properties to be obtained from CTD measurements, plankton tows, water samples, and sediment surface samples will be collected from identical positions. Analysed proxies comprise the faunal distribution, the oxygen and carbon isotopic composition and the Mg/Ca ratio of the calcareous shells of planktic and benthic foraminifera.

The Holocene has been long described as a period of relatively stable oceanographic and climatic conditions, especially compared to the highly variable Pleistocene. However, more studies show significant environmental fluctuations also within the present interglacial. Their spatial and temporal distribution is however not known well enough. The Nordic Seas are an important location to study the paleoceanographical variability during the last 10,000 years. In this region, a crucial area is the Fram Strait as it is the main and narrow way for the exchange of both surface and the deep waters between the Nordic Seas (and therefore the entire North Atlantic) and the Arctic Ocean. Even minor changes in the currents strength, the water masses, the sea ice cover etc. are amplified in this area and therefore should be easier to observe in the sediment record. The main focus of the study during ARK-XXVI/1 are the oxygen and carbon isotopes from planktic and benthic foraminifera and the planktic foraminiferal species distribution, as they yield diverse information on multiple environmental parameters, such as temperature, salinity, current strength, sea ice cover, bioproductivity etc.

Work at sea

Plankton samples will be collected by multinet casts along the planned transect, at approximately 15 stations across the Fram Strait. The nets of 63 µm mesh size will towed vertically on regular depth intervals (usually 500 - 300 m, 300 - 200 m, 200 - 100 m, 100 - 50 m, 50 - 0 m). Temperature and salinity of the water column will be measured by CTD. Water samples for stable isotope analyses will be taken from the rosette sampler, directly after arriving on the deck to minimize the exchange of contained CO_2 with the atmosphere. Special emphasis of water sampling will be laid on the interval covered by multinet sampling and on bottom-near waters. Water samples will be poisoned to stop biochemical reactions, which may alter the carbon isotopic composition of CO_2. All samples will be stored cool (4°C) and analyzed at IFM-GEOMAR in Kiel.

Sediment surface samples will be obtained from multicorer deployments performed for paleoenvironmental studies. It is planned also planned to retrieve 15 to 20 cores using a multicorer, preferably across the entire width of the Fram Strait, to obtain possibly the most complete image of the spatial variability. Locations with relatively high sedimentation rates will be chosen, for the sake of the highest possible temporal resolution. All cores will be sampled every centimeter and studied in terms of the oxygen and carbon isotopes from planktic and benthic foraminifera as well as the planktic foraminiferal species distribution and possibly other proxies. The work is a part of a broader project, concerning the entire Nordic Seas area. Apart from cores retrieved during this cruise, material from former expeditions in this region will be used. The project belongs to the CASE ITN Programme and therefore the collected material might also be used by other participants in their studies. The retrieved material will be stored at IFM-GEOMAR in Kiel, at the temperature of 4°C. One set of surface sediment samples will be frozen for the biomarkers studies (at AWI).

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

C. R. Joiris, D. Verbelen, G. Driessens, D. Monticelli, G. Nijs (PolE)

Objectives

The aim of this sudy is to quantify the at-sea distribution of seabirds and marine mammals, in order to refine their links with the main oceanological structure: water masses and pack ice, fronts and ice edge.

In the frame of a long-term study by the same team - and thus the same methodology - started in 1974 (Joiris, 1976), the aim is also to try and identify changes in population numbers and/ or in geographical distribution. Such evolutions are to be interpreted in the frame of global changes and decreasing Arctic pack ice coverage, even if important year-to-year changes cannot directly be attributed to this long-term trend. The main large scale changes to be studied in detail are: on the one hand, the difficulty for breeding seabirds to travel to the ice edge for feeding (e.g. little auk), the distance between colony and feeding ground becoming too large in case of low ice coverage (Joiris, 2007; Joiris and Falck, 2010). On the other hand, the recent increase of large whales in the Greenland Sea (bowhead, blue, humpback), apparently coming from the much larger Pacific stocks, apparently became possible because the NW and/ or NE Passages were made accessible due to low ice conditions (Joiris in prep.).

Special attention will also be payed to medium scale concentrations (large feeding grounds for seabirds and cetaceans: Joiris, submitted), as well as small scale local ones (fronts and eddies: Joiris and Falck, 2010). These very high concentrations must correspond to very high densities of their prey: zooplankon, nekton, small fish: this is why special zooplankton sampling will be organised in such areas, in collaboration with E. Nöthig (AWI).

Work at sea

Transect (strip) counts without width limitation from the bridge on a continuous basis, visibility conditions allowing (interruptions due to night darkness and/ or heavy fog conditions). Comparison with data collected from the crownest will be organised as well. Observations of cetaceans will be added to the MAPS data set in real time.

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7. BETEILIGTE INSTITUTE / PARTICIPATING INSTITUTES

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HeliService	Heli Service International GmbH Am Luneort 15 27572 Bremerhaven Germany
IFM-GEOMAR	Leibniz-Institut für Meereswissenschaften an der Christian-Albrechts Universität zu Kiel Wischhofstr. 1-3 24148 Kiel Germany
PolE	Laboratory for Polar Ecology Rue du Fodia 18 B-1367 Ramillies, Belgium

8. FAHRTTEILNEHMER / PARTICIPANTS

Name	Vorname/ First Name	Institut/ Institute	Beruf/ Profession
Allen	GongXun	AWI	PhD Student/Oceanography
Beszczynska-Möller	Agnieszka	AWI	Oceanographer, Chief Scientist
Büchner	Jürgen	HeliService Intl.	Pilot
Buldt	Klaus	DWD	Technician
Driessens	Gerald	PolE	Biologist
Federwisch	Luisa	AWI	Student/Biology
Gäbler-Schwarz	Steffi	AWI	Biologist
Gall	Fabian	HeliService Intl.	Mechanic
Gong (Mr.)	Xun	AWI	Student
Haid	Verena	AWI	PhD Student/Oceanography
Hardge	Kristin	AWI	Student/Biology
Heckmann	Markus	HeliService Intl.	Pilot
Joiris	Claude R.	PolE	Biologist
Knüppel	Nadine	AWI	Technician/Biology
Kraft	Angelina	AWI	Biologist
Menzel	Uta	AWI	Student/Oceanography
Miller	Max	DWD	Meteorologist
Monczak	Agnieszka	AWI	Student/Oceanography
Monsees	Matthias	AWI	Technician/Oceanography
Monticelli	David	PolE	Biologist
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Pados	Theodora	IFM-GEOMAR	PhD Student/Paleoceanography
Piontek	Judith	AWI	Environmental scientist
Rettig	Stefanie	AWI	Engineer/Oceanography
Sperling	Martin	AWI	PhD Student/Biology
Strothmann	Olaf	AWI	Technician/Oceanography
Telesinski	Maciej	IFM-GEOMAR	PhD Student/Paleoceanography
Thomisch	Karolin	AWI	Student/Biology
Vaupel	Lars	HeliService Intl.	Pilot
Verbelen	Dominique	PolE	Biologist
Walter	Jörg	AWI	Technician/Oceanography
Wang	Xuezhu	AWI	PhD Student/Oceanography
Wekerle	Claudia	AWI	PhD Student/Oceanography
Winkler	Maria	AWI	Student/Biology
Xu	Xu	AWI	PhD Student/Oceanography

9. SCHIFFSBESATZUNG / SHIP'S CREW

No.	Name	Rank
01.	Pahl, Uwe	Master
02.	Spielke, Steffen	1.Offc.
03.	Ziemann, Olaf	Ch.Eng.
04.	Hering, Igor	2.Offc.
05.	Peine, Lutz	2.Offc.
06.	Lauber, Felix	2.Offc.
07.	Grägel, Eberhard	Doctor
08.	Koch, Georg	R.Offc.
09.	Kotnik, Herbert	2.Eng.
10.	Schnürch, Helmut	2.Eng.
11.	Westphal, Henning	2.Eng.
12.	Holtz, Hartmut	Elec.Tech.
13.	Fröb, Martin	Electron.
14.	Stronzek, David	Electron.
15.	Winter, Andreas	Electron.
16.	Feiertag, Thomas	Electron.
17.	Clasen, Burkhard	Boatsw.
18.	Neisner,Winfried	Carpenter
19.	NN	A.B.
20.	Schultz, Ottomar	A.B.
21.	Burzan, G.-Ekkehard	A.B.
22.	Schröder, Norbert	A.B.
23.	Moser, Siegfried	A.B.
24.	Hartwig-L., Andreas	A.B.
25.	Kretzschmar, Uwe	A.B.
26.	NN	A.B.
27.	Schröter, Rene	A.B.
28.	Beth, Detlef	Storekeep.
29.	Kliem, Peter	Mot-man
30.	Fritz, Günter	Mot-man
31.	Krösche, Eckard	Mot-man
32.	Dinse, Horst	Mot-man
33.	Watzel, Bernhard	Mot-man
34.	Fischer, Matthias	Cook
35.	Tupy,Mario	Cooksmate
36.	Völske, Thomas	Cooksmate
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38.	Hennig, Christina	Stwdss/KS
39.	Gaude, Hans-Jürgen	2.Steward
40.	Hischke, Peggy	2.Stwdess
41.	Wartenberg, Irina	2.Stwdess
42.	Hu, Guo Yong	2.Steward
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44.	Ruan, Hui Guang	Laundrym.

ARK-XXVI/ 2

13 July 2011 - 3 August 2011

Longyearbyen – Tromsø

Chief Scientist
Michael Klages

CONTENTS

1. ÜBERBLICK UND FAHRTVERLAUF

Michael Klages
Alfred-Wegener-Institut

Die Ausfahrt des Forschungsschiffs *Polarstern* im Sommer 2011 soll genutzt werden, um einerseits Beprobungen und *in-situ* Experimente für die EU-Projekte HERMIONE, HYPOX, ESONET bzw. sein Folgeprogramm EMSO durchzuführen und andererseits Beiträge zu dem Anfang 2009 begonnenen Forschungsprogramm PACES (Polar Regions and Coasts in the changing Earth System) des AWI zu liefern. In PACES werden Beiträge zu dem Topic "The changing Arctic and Antarctic" und hierbei speziell zu dem Arbeitspaket 3 "Sea ice – atmosphere – ocean – ecosystem interactions in a bi-polar perspective" und dem Arbeitspaket 6 "Ocean warming and acidification: organisms and their changing role in marine ecosystems" erbracht. Unsere Arbeiten sind in Arbeitspaket 3 durch Forschungsaktivitäten während der beantragten *Polarstern*-Expedition bezüglich veränderter Meereisbedeckung und dessen Einfluss auf marine Ökosysteme und Nahrungsnetze eingebunden. Die Beiträge zu Arbeitspaket 6 basieren auf Untersuchungen zur funktionalen Rolle ausgewählter Schlüsselarten unter den klimatischen Bedingungen einer polaren Region und den daraus resultierenden Umgebungs- bzw. Lebensbedingungen. Ein Teil unserer Arbeiten wird sich darauf konzentrieren, wie ausgewählte Arten im Pelagial und am Meeresboden auf fortschreitende Erwärmung auf funktionaler Ebene (molekular bis ökosystemar) reagieren. Aufbauend auf vorliegenden Erkenntnissen sollen die geplanten Arbeiten dazu beitragen, einerseits den physiologischen und ökologischen Hintergrund artspezifischer Belastungsgrenzen aufzuzeigen, andererseits auch die Kapazität von ausgewählten Organismen hinsichtlich Eingewöhnung und Anpassung auf Veränderungen zu erarbeiten. Schließlich stellen die geplanten Arbeiten einen weiteren Beitrag zur Sicherstellung der Langzeitbeobachtung am HAUSGARTEN - Tiefseeobservatorium dar (Fig. 1), in denen wir den Einfluss von klimatisch induzierten Veränderungen auf ein arktisches Tiefseeökosystem dokumentieren, so dass HAUSGARTEN als nördlichster Knoten in einem Netzwerk von zehn europäischen Observatorien innerhalb von ESONET bzw. EMSO ausgewählt wurde.

Für die Durchführung des Expeditionsprogrammes wird das unbemannte ROV (Remotely Operated Vehicle) "KIEL 6000" des IFM-GEOMAR aus Kiel an Bord sein.

Mit diesem Unterwasserfahrzeug sollen gezielt Proben gewonnen werden. Ein erster Tauchgang ist bei etwa 400 m Wassertiefe westlich von Prinz Karlvorland geplant. Hier wurden kürzlich zahlreiche Gasfahnen mit Hilfe eines Fischereiecholotes registriert. Ein weiterer Tauchgang ist am Vestnesa-Rücken geplant bis dann weitere Tauchgänge im Bereich des HAUSGARTEN stattfinden werden. Neben einem Standardprobennahme-programm (Aufnehmen und Ausbringen von Verankerungen, Freifall-Landern) wird "KIEL 6000" genutzt, um unter natürlichen Umgebungsgedingungen in der Tiefsee verschiedene Experimente durchzuführen, aber auch um gezielt Sediment- und andere Proben aufzunehmen. Der Fahrtabschnitt PS ARK-XXVI/2 wird am 3. August 2011 im Hafen von Tromsø enden.

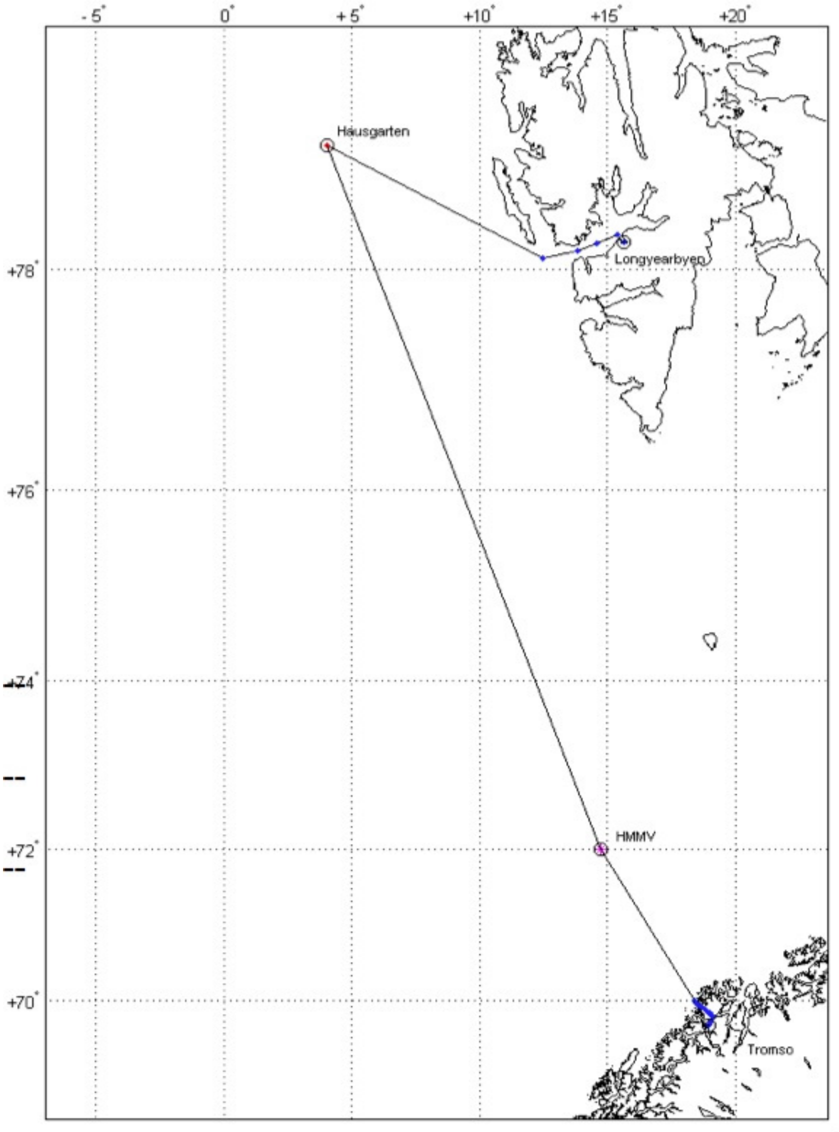

Abb. 1: Geplanter Fahrtverlauf der "Polarstern"-Expedition ARK-XXVI/2 ausgehend von Longyearbyen über das Untersuchungsgebiet HAUSGARTEN nach Tromsø

Fig. 1: Planned cruise track of "Polarstern" from Longyearbyen into the working area HAUSGARTEN to Tromsø during ARK-XXVI/2

ITINERARY AND SUMMARY

The work to be carried out during the *Polarstern* expedition into the Arctic in summer 2011 will be both, first another milestone for the EU projects HERMIONE, HYPOX, ESONET and his successor EMSO, and second a contribution to the PACES (Polar Regions and Coasts in the changing Earth System) research programme of the Alfred Wegener Institute started in 2009. As a contribution to the topic “The changing Arctic and Antarctic” we will perform research activities to workpackage 3 “Sea ice – atmosphere – ocean – ecosystem interactions in a bi-polar perspective“ and workpackage 6 “Ocean warming and acidification: organisms and their changing role in marine ecosystems”. Our proposed work is embedded in WP 3 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 and modelling. Our contribution to WP 6 originates from our studies on the functional specialization of selected polar marine species, from algae to mammals, on polar climate regimes and associated living conditions. These activities qualify and quantify the responses of model organisms to ongoing warming trends at key functional levels, from molecular to ecosystem. Building on recent progress, they also characterize the physiological and ecological background of species-specific sensitivities as well as the capacity of organisms and ecosystems to acclimate or adapt to change. Finally, the proposed research programme contributes to the time-series studies at the deep-sea long-term observatory HAUSGARTEN where we investigate the impacts of Climate Change on an Arctic marine deep-sea ecosystem through field studies, observations and models since 1999, which qualifies this station for ESONET and EMSO.

The work plan is based on the use of the unmanned Remotely Operated Vehicle (ROV) "KIEL 6000” of the IFM-GEOMAR in Kiel. Among a standard sampling programme including exchange of moorings and free falling landers, here the ROV will be used for various *in-situ* experiments. We plan to have one short dive at locations around 400 m water depth west of Prins Karlsvorland where many methane seeps have been recorded recently with fishery echosounders. Further dives are planned at the Vestnesa ridge and finally at the central experimental site of HAUSGARTEN. The cruise ARK-XXVI/2 will end at the port of Tromsø on 3 August 2011.

2. IMPACT OF CLIMATE CHANGE ON ARCTIC MARINE ECOSYSTEMS

T. Soltwedel, E. Bauerfeind, U. Hoge, C. Lalande, S. Lehmenhecker, K. Lochte, N. Lochthofen, K. Meyer, A. Pappert, B. Sablotny, I. Schewe, P. Vosteen, F. Wenzhöfer, T. Wulff (AWI), S. Albrecht, F. Tardeck (FIELAX), V. Asendorf, J. Felden, A. Nordhausen (MPI), O. Pfannkuche (IFM-GEOMAR), K. Shurn (BluefinRobotics)

KIEL 6000 ROV Team (IFM-GEOMAR) : M. Pieper, H. Huusmann, P. Cuno, A. Meier, G. Engemann, W. Queisser, I. Suck

Objectives

The marine Arctic has played an essential role in the history of our planet over the past 130 million years and contributes considerably to the present functioning of the Earth and its life.

The past decades have seen remarkable changes in key variables, including a decrease in sea-ice extent and thickness, changes in water temperature and salinity and associated shifts in nutrient distributions. Since Arctic organisms are highly adapted to extreme environmental conditions with strong seasonal forcing, the accelerating rate of recent climate change challenges the resilience of arctic life. The stability of a number of arctic populations and ecosystems is probably not strong enough to withstand the sum of these factors which might lead to a collapse of subsystems.

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

HAUSGARTEN observatory in the eastern Fram Strait includes 17 permanent sampling sites along a depth transect (1,000 - 5,500 m water depth) and along a latitudinal transect following the 2,500 m isobath crossing the central HAUSGARTEN station (Fig. 2.1). Multidisciplinary research activities at HAUSGARTEN cover almost all compartments of the marine ecosystem from the pelagic zone to the benthic realm. 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 assessing large-scale distribution patterns of mega/epifaunal organisms as well as their temporal development. To determine the factors controlling deep-sea biodiversity, various biological short- and long-term experiments are carried out at the deep seafloor using a Remotely Operated Vehicle (ROV).

Within the framework of an international project KONGHAU ("Impact of climate change on Arctic marine community structures and food webs"), co-financed by the EU Integrated Project HERMES ("Hotspot Ecosystem Research on the Margins of European Seas") and the Norwegian oil company Statoil/Hydro, we will retrieve additional sediment samples on the continental shelf of Svalbard and inside the Kongsfjord (Fig. 2.1). KONGHAU combines data collected over the past 10 years from time-series work at Kongsfjord and HAUSGARTEN.

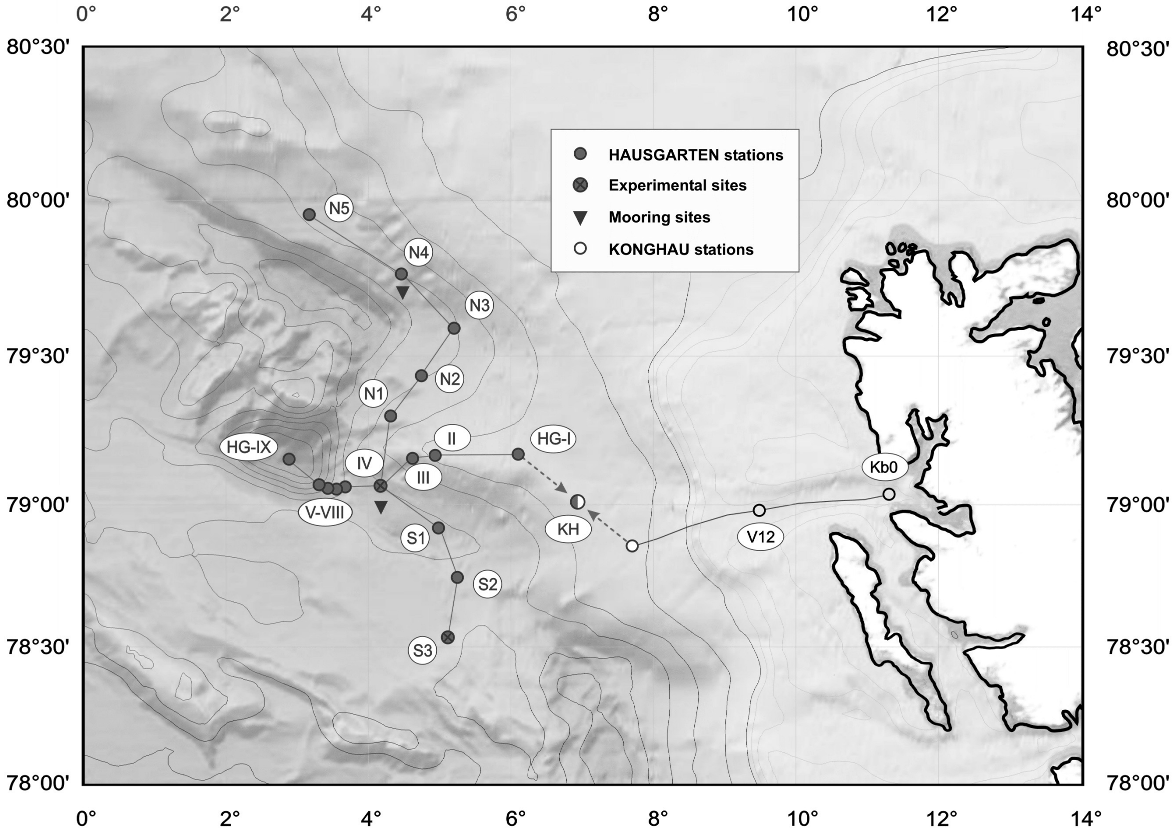

Fig. 2.1: The deep-sea long-term observatory HAUSGARTEN and sampling stations of the Kongsfjorden time-series study in eastern Fram Strait

Work at sea

Hydrographic data will be assessed using a CTD - Rosette Water Sampler and an Autonomous Underwater Vehicle (AUV) equipped with a CTD, a water sampling system, and a fluorescence sensor. Water samples will be analysed for bio-optical parameters for the validation of satellite data. Organic matter produced in the upper water layers or introduced from land is the main food source for deep-sea organisms. To characterise and quantify organic matter fluxes to the seafloor, we use moorings carrying large sediment traps at approx. 100 m below sea-surface and about 180 m above the seafloor. Two moorings deployed in summer 2010 at approx. 2,500 m water depth at the northernmost and the central HAUSGARTEN site (HG-IV) will be recovered and newly installed for another year of sampling. A free-falling device (bottom-lander) at HG-IV supporting a current meter, optical oxygen sensors (optodes), and a smaller sediment trap at 2.5 m above ground will be replaced. At all stations where moorings are operating we will conduct CTD casts from the surface to close to the seafloor. Water samples will be taken for the analyses of Chl a, POC/N, seston, carbonate and stable isotopes ($\delta^{15}N/\delta^{13}C$) in the particulate matter. This work as well as sampling at the other stations at the HAUSGARTEN will be conducted in cooperation with the PEBCAO group. Details see contribution of the PEBCAO group

The benthic carbon remineralization will mainly be studied along a latitudinal transect (HAUSGARTEN stations S3, HG-IV, and N3; Fig. 2.1) following the measurements in 2010 to investigate the inter-annual variability related to different export fluxes. The benthic O_2 uptake is a commonly used measure for the total benthic mineralization rate. We plan to measure benthic oxygen consumption rates at different spatial and temporal scales. Two bottom-landers will be equipped with different instruments to investigate the oxygen penetration and distribution as well as the oxygen uptake of the arctic sediments by means of

(1) a microprofiler for high-resolution pore water profiles (e.g. O_2, pH, temperature, resistivity),
(2) a benthic chamber to measure the total oxygen consumption and nutrient exchange of the sediment, and
(3) an eddy correlation device for non-invasive oxygen consumption measurements.

To determine the inner-annual variability in benthic oxygen consumption rates, a long-term O_2 microprofiler will be deployed capable to perform 52 sets of pore water profiles over 12 months. Another goal is to follow the benthic response to diatom- and coccolithophorid-dominated sedimentation pulses by simulated phytodetritus pulses in *in-situ* enrichment experiments using a bottom-lander integrated benthic mesocosms at the HAUSGARTEN central station. $^{13}C/^{15}N$ labelled phytodetritus of different phytoplankton composition will be injected into the mesocosms; the benthic reaction will be investigated after several days of incubation. The overall benthic reaction is followed by measurement of sediment community oxygen consumption to calculate carbon turnover rates.

Virtually undisturbed sediment samples are taken using a video-guided multiple corer (MUC). Various biogenic compounds from these sediments are analysed to estimate activities (e.g. bacterial exoenzymatic activity) and the total biomass of the smallest sediment-inhabiting organisms. In comparison with time series data, new 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.

The ROV "KIEL 6000" (IfM-GEOMAR, Kiel) will be used to install and sample different experiments to study causes and effects of physical, chemical and biological gradients at the deep seafloor, and to survey large-scale distribution patterns of epi/megafauna organisms along a defined transect. By means of push-corers handled by the ROV, we will retrieve sediment samples inside and outside a flume (8 m in length and 50 x 50 cm in cross section) installed in 2003 at the southernmost HAUSGARTEN site, to study effects of increased near-bottom currents on solute exchanges at the sediment-water interface and the reaction of the associated small biota. The ROV will also be used to retrieve sediments from surface sediments covered by 4 m² cages with solid lids, preventing the sedimentation of particulate organic matter, i.e. the main food/energy source for benthic organisms. These cages were deployed in summer 2008 and will be repeatedly sampled over the next years to assess the reaction of the small biota to decreasing food availability. Small inert fluorescing microspheres, so-called luminophores, will be spread by the ROV on a defined area at the deep seafloor to start an experiment assessing bioturbation rates by larger benthic organisms at the central HAUSGARTEN site. The ROV will also be used to install and re-deploy autonomous instrument (e.g. microprofiler, incubation chambers) for short-term measurements during the expedition.

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

J. Piontek, M. Sperling, L. Federwisch, K. Hardge, M. Winkler, N. Hildebrandt (AWI), B. Rajasakaren (JUB)

Objectives

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 bear 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 of phytoplankton ecology, carried out since several years as sub-programme of the analysis of the regularly deployment of sediment traps in the Arctic at AWI HAUSGARTEN, were very sporadic. As the Arctic Ocean experiences rapid environmental changes, we intend to extend our sampling programme by conducting molecular investigations on pico- and nanoplankton, with focus on key species like *Phaeocystis pouchetii*, copepods & 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 assessment of plankton, including the smallest fractions, and to cut down the effort and the costs required carrying out observations in the Arctic marine environment, molecular methods are well suited to serve as a basis for the development of innovative smart observation methods and strategies to survey the biodiversity within the Arctic phytoplankton. They provide the possibility to facilitate the investigation of physiology, ecology, and distribution of species at the base of the marine food web, especially of those that are size limited or missing distinct morphological features. Molecular methods, based on the analysis of the rRNA gene will be used for the assessment of biodiversity, e.g. the development of molecular probes used for the surveillance of organisms in combination with a wide variety of hybridization based methods, such as RNA-based nucleic acid biosensors or DNA-microarrays (PHYLOCHIPS). Nucleic acid biosensors and PHYLOCHIPS are chip based formats that allow a parallel identification and quantification of multiple taxa in a single experiment. The identification is based on solid phase hybridization of molecular probes, immobilized to the surface of the sensor chips to the rRNA or rDNA of the target species.

In the zooplankton, copepod & amphipod species can eventually 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 obained in the swimmer fraction within the sediment-trap-monitoring-programme at AWI HAUSGARTEN.

Based on the awareness that global change has increasingly changed marine ecosystems, we also intend to examine the ‘present day’ situation of pelagic microbiogeochemistry 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). Our overarching goal is to contribute to a better understanding of the direction and strength of biogeochemical and microbiological feedback processes in the future ocean.

Work at sea
During ARK-XXVI/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.

We intend to sample arctic seawater by CTD/rosette sampler at the HAUSGARTEN transect (~79°N) to determine the impact of microbial processes on the aggregation and sedimentation of organic matter as part of the work of the PEBCAO group. We sample water at about 5 - 8 different water depths.

Measurements of CTD samples

a) biogeochemical parameters
chlorophyll a &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 exopolymer particles (TEP), particulate biogenic silica (PbSi)

b) biological parameters from CTD casts
-phytoplankton & protozooplankton abundance
-bacterial cell numbers, bacterial biomass production and extracellular enzyme activity
-sampling for genetic analyses & clonal cultures
-flow cytometer

c) biological parameters with net hauls (handnet, Multinet, Bongo net)
-sampling of live phytoplankton and zooplankton from the field
-mesozooplankton composition and depth distribution will be determined by means of multi net 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 79°N transect to catch phytoplankton for isolation for later performing clonal cultures, genetic analyses will be carried out with the isolates.

Experimental work
Furthermore, effects of changing seawater temperature and pH on the bacterial utilization of different organic matter sources will be investigated by *on-board* incubation experiments. Rates of bacterial activity that are potentially sensitive to upcoming warming and seawater acidification may affect the turnover of organic matter in the future Arctic Ocean.

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.

4. ARCTIC PELAGIC AMPHIPODS

A. Kraft, N. Knüppel (AWI)

Objectives
Climate change in the Arctic Ocean is evident. One observation includes the influx of warmer Atlantic water masses into the central Arctic Ocean. This phenomenon, also called 'Atlantification', will most likely have severe consequences for the ecology within all trophic levels. This overall perspective leads to several objectives concerning respective members of the Arctic pelagic food web. One of them are pelagic amphipods connecting herbivorous production with end members like birds, fishes and whales of the food web. Although frequently observed, relatively little is known about the relevance of amphipods within polar food webs, especially on their seasonal distribution, nutritional values and on their impact on organic matter cycling. Within this BMBF-funded project, the following questions regarding pelagic amphipods will be addressed:

1.) What are the species composition patterns of Arctic pelagic Amphipoda in the HAUSGARTEN & Fram Strait area and how do they relate to changes of the environment?

Thereby, the results from plankton net samples taken during the cruise ARK-XXVI/1+2 will be compared to the amphipod samples from moored sediment traps in order to understand what consequences a change in the population structure and life cycles of pelagic amphipods appear due to 'a warmer - more Atlantic world'.

2.) Determine differences in nutritional ecology (lipid biomarkers & gut content) of the dominating pelagic Amphipoda *Themisto libellula*, *T. abyssorum*, *T. compressa* and *Cyclocaris guilelmi.*

To address this objective we test the following hypothesis: *Themisto libellula*, *T. abyssorum*, *T. compressa* and *Cyclocaris guilelmi* have different feeding and overwintering strategies leading to differences in gut content and lipid content compositions. Hence, investigations on lipid biomarkers & gut contents will be carried out in order to understand differences of the utilization of food and on the nutritional value for higher trophic levels.

Work at sea

The net sampling will include vertical hauls from 2,000 m to the surface and horizontal tows in an equal water horizon at the sampling site if possible. Thereby, a large multinet (HYDRO-BIOS type Maxi with an aperture of 0.5 m² and nine 1,000 µm net bags) 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. Furthermore, horizontal tows (0 - 2,000 m depth) are planned in the HAUSGARTEN during the steaming between the following stations: HG-I to HG-II, HG-IV to S1, S2 to S3, N3 to N4 and HG-VII to HG-IX. The estimated towing speed will be 1.5 knots. This aims at the quantitative collection of amphipods in the respective water horizons which are needed for gut content and lipid analysis. Additional sampling sites are planned along 79°N. The work will be carried out in close cooperation with the Deep-Sea Ecology Group, AWI and the sediment-trap-monitoring programme at HAUSGARTEN.

The analysis of the selected samples will include an investigation of composition patterns by the determination to a species level focused on morphological characteristics on board, the analysis of age structures by length-frequency distributions and the comparison of abundance data. Furthermore, selected individuals from different water layers (0 - 2,000 m depth) in the eastern Fram Strait will be frozen (-80°C) and analyzed for their gut content and their lipid composition at the AWI home laboratory.

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

R.-M. Lafontaine, R. Beudels (PolE)

Objectives

The aim of this study is to quantify the at-sea distribution of seabirds and marine mammals, in order to refine their links with the main oceanological structure: water masses and pack ice, fronts and ice edge.

In the frame of a long-term study by the same team - and thus the same methodology - started in 1974 (Joiris, 1976), the aim is also to try and identify changes in population numbers and/or in geographical distribution. Such evolutions are to be interpreted in the frame of global changes and decreasing Arctic pack ice coverage, even if important year-to-year changes cannot directly be attributed to this long-term trend. The main large scale changes to be studied in detail are: on the one hand, the difficulty for breeding seabirds to travel to the ice edge for feeding *(*e.g. little auk), the distance between colony and feeding ground becoming too large in case of low ice coverage (Joiris, 2007; Joiris and Falck, 2010). On the other hand, the recent increase of large whales into the Greenland Sea (bowhead, blue, humpback), apparently coming from the much larger Pacific stocks, apparently became possible because the NW and/ or NE Passages were made accessible due to low ice conditions (Joiris in prep.).

Special attention will also be payed to medium scale concentrations (large feeding grounds for seabirds and cetaceans (Joiris, submitted), as well as small scale local ones (fronts and eddies: Joiris and Falck, 2010). These very high concentrations must correspond to very high densities of their prey: zooplankon, nekton, small fish: this is why special zooplankton sampling will be organised in such areas, in collaboration with E. Nöthig (AWI).

Work at sea
Transect (strip) counts without width limitation from the bridge on a continuous basis, visibility conditions allowing (interruptions due to night darkness and/ or heavy fog conditions). Comparison with data collected from the crownest will be organised as well. Observations of cetaceans will be added to the MAPS data set in real time.

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6. CULTURE EXPERIMENTS ON THE $\delta^{13}C$ VALUES RECORDED IN TESTS OF BENTHIC FORAMINIFERA FROM INTERMEDIATE TO DEEP-WATER SITES AT THE WESTERN CONTINENTAL SLOPE OF SPITSBERGEN

J. Wollenburg, R. Petereit, M. Sühs (AWI)

Objectives
Whether the $\delta^{13}C$ signal from benthic foraminifers is a valid tool for identifying potential sources of submarine methane release to the atmosphere is heavily discussed and is verified by our project. During the last years we have successfully carried out methane-related cultivation experiments on benthic foraminifera faunas from the methane emanating Hakon Mosby mud volcano under *in-situ* (high-pressure conditions using a newly developed autoclave system.

Work at sea
During this years' expedition we will retrieve normal marine Arctic deep-sea sediments for comparative methane-related cultivation experiments under high (*in-situ*) pressure conditions. Five autoclaves were built and will be operated during this years cruise, ROV "KIEL 6000" of IFM-GEOMAR Kiel will take three of the autoclaves (one or two per dive) to the seafloor, fill it with a push core, close it, and take it back onboard with the seafloor bottom pressure (125 - 128 bar). During the subsequent months the unique action of these autoclaves will enable us to carry out experiments on deep-sea benthic foraminifera and their associated fauna and flora under *in-situ* pressure. Additional push cores (alternatively multiple core liners) will be transferred in two additional autoclaves that will be reset to seafloor pressure by means of high-pressure pumps. Additional sediment cores will be transferred in pressure-free mesocosms, treated in the same way than the autoclaves. The experimental results obtained approximately 6 months after the expedition, will be compared to similar successful experiments from 2007 - 2010.

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Wollenburg	Jutta	AWI	Biologist
Wuff	Thorben	AWI	Engineer

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No.	Name	Rank
01.	Pahl, Uwe	Master
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05.	Peine, Lutz	2.Offc.
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07.	Grägel, Eberhard	Doctor
08.	Koch, Georg	R.Offc.
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10.	Schnürch, Helmut	2.Eng.
11.	Westphal, Henning	2.Eng.
12.	Holtz, Hartmut	Elec.Tech.
13.	Fröb, Martin	Electron.
14.	Stronzek, David	Electron.
15.	Winter, Andreas	Electron.
16.	Feiertag, Thomas	Electron.
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18.	Neisner,Winfried	Carpenter
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29.	Kliem, Peter	Mot-man
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31.	Krösche, Eckard	Mot-man
32.	Dinse, Horst	Mot-man
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44.	Ruan, Hui Guang	Laundrym.

ARK-XXVI/3

5 August 2011 – 7 October 2011
Tromsø - Bremerhaven

Chief Scientist
Ursula Schauer

CONTENTS

1. ÜBERBLICK UND FAHRTVERLAUF

Ursula Schauer
Alfred-Wegener-Institut

Die Expedition ARK-XXVI/3 "TransArc“ (Trans-Arctic survey of the Arctic Ocean in transition) dient der Erfassung der physikalischen, biologischen und chemischen Veränderungen im Arktischen Ozean. Während der Rückgang der Eisausdehnung vom Satelliten aus beobachtet werden kann, müssen alle weiteren Veränderungen, wie die der Dicke und Beschaffenheit des Meereises, der Wassermasseneigenschaften und ihrer Zirkulation sowie veränderte chemische und biologische Größen auf wiederholten Schiffsexpeditionen gemessen werden. Die Reduzierung des Meereises und die Änderungen in der Ozean-zirkulation und im Wärme- und Süßwasserhaushalt sind eng verknüpft mit Änderungen im Gasaustausch sowie mit biogeochemischen Stoffumsätzen und Prozessen im Ökosystem im Eis und in der gesamten Wassersäule. Während TransArc werden diese Zusammenhänge durch Beprobung aller Parameter an gemeinsamen Stationen entlang von Gradienten von den Eurasischen Schelfmeeren bis ins Kanadische Becken und vom offenen Ozean bis ins Packeis untersucht. Vier Jahre nach dem Internationalen Polarjahr IPY 2007/2008 wird mit TransArc die erste Wiederholungsaufnahme des komplexen Systems durchgeführt. Ergänzt werden die Aufnahmen durch geologische und mikrobiologische Probennahme von Sediment an dem schwer zugänglichen Alpha-Mendelejew-Rücken, bzw. am Gakkelrücken.

ARK-XXVI/3 beginnt am 5. August 2011 in Tromsø. *Polarstern* wird die Barentssee passieren und nördlich von Franz-Josef-Land wird das Arbeitsprogramm mit der Bergung einer Verankerung des internationalen Programms NABOS (Nansen and Amundsen Basins Observational System) beginnen. Von dort geht es nach Norden auf einem Schnitt mit hydrographisch/biogeochemischen und biologischen Stationen, Eisstationen und Netzfängen in engem Abstand. Ergänzt werden die Stationen durch Arbeiten vom Hubschrauber aus. Der Schnitt erstreckt sich von der Schelfkante der Barentssee über das Nansenbecken, das Amundsenbecken und den Lomonossowrücken hinweg bis zum Alpha-Mendelejew-Rücken, soweit es die Eissituation erlaubt. Hier wird die Beprobung mehrjährigen Packeises ihren Schwerpunkt haben. Am Alpha-Mendelejew-Rücken liegt auch der Fokus des geologischen Programms. Je nach Eissituation werden auf dem Schnitt diverse Eisbojen ausgebracht, die einen Beitrag zum IABP (International Arctic Buoy Program) liefern.

Vom Alpha-Mendelejew-Rücken aus geht es nach Süden ins Mendelejewbecken, um den pazifisch beeinflussten Bereich zu erfassen. Von dort führt ein Schnitt zurück in den eurasischen Sektor Richtung Laptewsee. Auf beiden Flanken des Gakkelrückens werden je zwei Verankerungen mit ozeanographischen Instrumenten und biologischen Probennehmern ausgesetzt, die im Sommer 2012 auf der Polarsternexpedition ICEARC aufgenommen werden sollen. Beim Queren des Gakkelrückens werden Gebiete mit Hydrothermalquellen beprobt. Im Nansenbecken werden weitere Eisbojen ausgesetzt und am Kontinentalhang werden zwei weitere NABOS-Verankerungen aufgenommen. Der Schnitt wird mit dem Stationsprogramm bis ca. 75°N in die Laptewsee fortgesetzt. Von dort aus wird die Rückreise durch die Nordostpassage angetreten. Am 7. Oktober 2011 wird die Expedition in Bremerhaven enden.

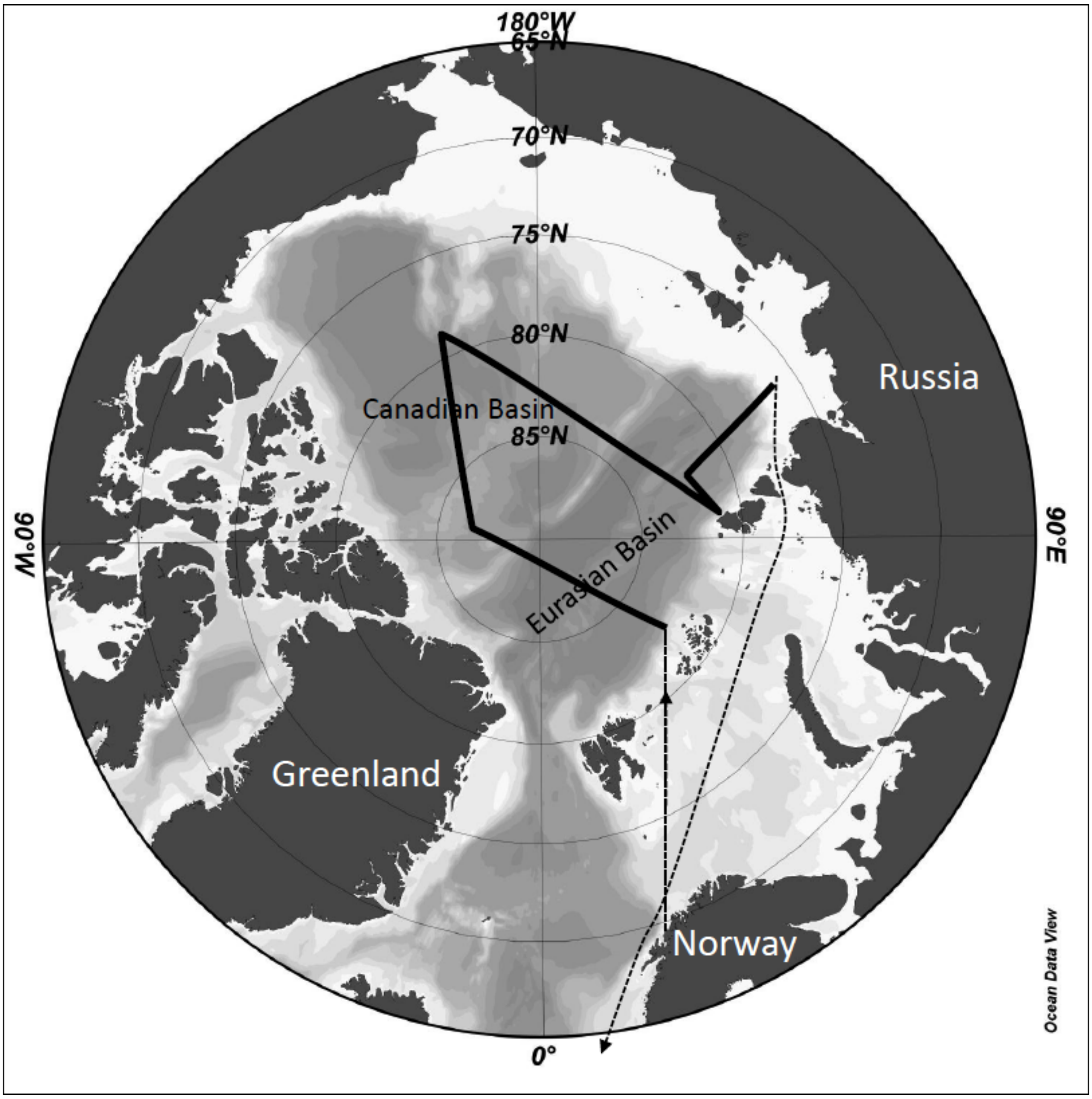

Abb. 1: Schnitte mit Stationsarbeiten (dicke Linie) und An/Abfahrtroute (gestrichelte Linie) während ARK-XXVI/3. Die Reise beginnt am 5. August 2011 in Tromsö und endet am 7. Oktober 2011 in Bremerhaven. Der genaue Verlauf der Reise ist abhängig von der Eissituation und der Forschungsgenehmigung für die russische Wirtschaftszone.

Fig. 1: Cruise track for research (thick line) and steaming (stippled line) of ARK-XXVI/3. The cruise starts at August 5, 2011 in Tromsö and ends October 7, 2011 in Bremerhaven. The exact cruise track depends on the ice situation and on the clearance for the Russian exclusive economic zone.

SUMMARY AND ITINERARY

The expedition "TransArc“ (Trans-Arctic survey of the Arctic Ocean in transition) will survey the current state of the system Arctic Ocean which is necessary to assess its changes. While the retreat of the sea ice can partly be seen through satellite observations all other changes such as the thickness and properties of sea ice, water mass properties and circulation have to be measured through repeated ship expeditions. The reduction of sea ice and the variability of ocean circulation and its heat and fresh water budgets are tightly linked with changes in the gas exchange as well as with biogeochemical and ecosystem processes in the sea ice and in the entire water column. During TransArc these interrelations will be studied through joint stations along gradients from the Eurasian shelf seas into the Canadian Basin and from the pack ice into the open water. TransArc will be the first trans-Arctic repeat survey of the complex system after the extensive field work during the International Polar Year 2007/08. The programme is complemented by geological and biological sampling of the sea floor at the Alpha-Mendeleyev Ridge and the Gakkel Ridge respectively.

ARK-XXVI/3 will start in Tromsø on August 5, 2011. *Polarstern* will steam through the Barents Sea and the work will begin with the recovery of a mooring of the international programme NABOS (Nansen and Amundsen Basins Observational System). We will continue working along a northward section which consists of hydrographic/biogeochemical and biological stations, ice stations and net hauls. The stations will be completed by helicopter-borne work. The section extends from the Barents Sea across the Nansen and Amundsen Basins and the Lomonosov Ridge up to the Alpha-Mendeleev Ridge where we expect to meet and sample heavy pack ice. The Alpha-Mendeleyev Ridge is also the focus of the geological work. Depending on the overall ice situation, various ice buoys will be deployed that will contribute to the IABP (International Arctic Buoy Program).

Leaving this northernmost position we will run a section southward into the Mendeleev Basin to capture the Pacific derived waters. The next section will head back to the Eurasian sector towards the Laptev Sea. On both sides of the Gakkel Ridge we will deploy pairs of moorings with oceanographic and biological instrumentation. These moorings will be recovered in summer 2012 during the *Polarstern* cruise ICEARC. When crossing the Gakkel Ridge, vent areas will be sampled. In the Nansen Basin, further ice buoys will be deployed. At the Laptev Sea continental slope two more NABOS moorings will be recovered. The section will be continued into the shallow Laptev Sea. From there we will get back along the Northern Sea Route and return to Bremerhaven where *Polarstern* will arrive at 7 October 2011.

2. SEA ICE PHYSICS

S. Hendricks, N. Marcel, M. Hoppema, P. Hunkeler, C. Katlein, NN (AWI)

Objectives

Satellite observations reveal a reduction of Arctic summer sea ice extent in the order of 8 % per decade. 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, our goal 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 from 2.5 m in 1991 to 0.9 m in 2007 in the Transpolar Drift region. While the individual ice thickness surveys reveal a snapshot of the Arctic sea ice thickness 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.

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. 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.

Work at Sea

Helicopter surveys will be carried out along the cruise track approximately every second day in ice covered region. During this 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

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 transmissivity of sea ice with under-ice transects of an remote operated vehicle (ROV)
- Deployment of drifting ice-mass balance buoys (IMB's)

The general sea ice conditions will be quantified by hourly visual observations from the bridge and recorded in a standardized protocol. Besides the deployment of ice mass balance buoys, we want to contribute to the International Arctic Buoy Programm (IABP) with several meteorological ice drifters in areas with limited coverage of drifting buoys.

3. PHYSICAL OCEANOGRAPHY

B. Rabe, U. Schauer, H. Sumata, A. Wisotzki (AWI), S. Pisarev (SIO), B. Rudels (FIMR), I. Waddington (IARC), O. Zenk (Optimare)

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.

Inflow of water from the Atlantic and the Pacific have been warmer throughout the past decades. Arctic-wide surveys, particularly during the International Polar Year 2007/08, showed that in the same time the Arctic Ocean waters became warmer. This indicates that - if at all - only a fraction of the additional heat has been released to the surface. 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 contribute the different fresh water sources such as Siberian river runoff, Pacific water inflow and ice melt.

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. Nutrient concentrations measured by the biogeochemistry group will also permit to distinguish Pacific-derived waters.

As during the International Polar Year (IPY 2007/08) this cruise will again cover much of the Arctic Ocean basins. 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 and deployment of seafloor-mounted moorings and the deployment of ice-tethered platforms.

Profiles of ocean temperature, salinity and oxygen will be measured and samples for home-lab $\delta^{18}O$ analysis 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 sensors calibration.

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 XCTDs (eXpendable CTD) system and a newly designed 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 two hours.

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:

- Two POPS (Polar Ocean Profiling System) are 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.
- One ITAC (Ice-tethered Acoustic Current profiler) consisting of a Teledyne RDI ADCP (150 kHz, Quartermaster) will be deployed, measuring velocity in the upper 320 m at frequencies between several minutes to two hours.

Sea-floor mounted moorings in will be deployed and recovered:

- Three moorings will be recovered which were deployed two to three years ago at the continental slope of the Barents, Kara and Laptev seas within the Nansen and Amundsen Basins Observational System (NABOS) project.
- Two pairs of moorings from AWI will be deployed near the Gakkel Ridge. Each pair 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 will register sea ice presence and thickness. In addition, biological parameters, such as sediment deposition, will be sampled in sediment traps.

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).

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

4. BIOLOGY OF SEA ICE

I. Peeken (AWI/MARUM), M. Fernandez Mendez (AWI/MPI), K. Hänselmann (AWI/University Hamburg)

Objectives

Sea ice provides a habitat for marine life. Organisms inhabiting the ice need to tolerate extreme environmental conditions due to rapid changes in light, salinity, temperature and nutrients. 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 reducing 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.

The loss of sea ice might be favourable for the phytoplankton primary production by increasing the 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 bottom 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 and EPS and POC will enable us determine shifts in this pools due to environmental change and to access the role of sea ice biota for the vertical flux.

CDOM and DOC are considered to be precursors for volatile organic compounds particular under the influence of UV-light. Since previous studies have shown that volatile organic compounds (VOCs) are concentrated in the ice covered region, the combined approach of estimating the algae biomass and production together with CDOM and DOC will allow distinguishing the various processes affecting the release of VOCs in the ice covered regions.

Work at sea

Various sea ice types from MYI to first year ice will be investigated, both in the Atlantic and the Pacific sector of the Central Arctic. Regular sea ice sampling involves the collection of melted ice-core sections, under-ice water and ice pond water if available. 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). Bacteria biomass will be estimated by flow cytomery. Also biogenic silicate, particulate organic carbon and nitrogen (POC, PON) and the isotopic composition of POC and PON ($\delta^{13}C_{POC}$ and $\delta^{15}N_{PON}$) will be determined. Salinity, temperature and nutrients will be directly measured on board in collaboration with the physical and geochemical team. Samples will be stored and measured at the AWI for determination of other variables. These measurements will be combined with PI curves of primary production of the various habitats.

Together with the physical ice team a remotely operated vehicle will be used for flow-wide under-ice irradiance measurements. Point measurements will be carried out in drill holes for a validation of the hyperspectral estimates of ice-algae concentrations with particulate absorption, and CDOM and pigment (HPLC) will be measured from this ice cores.

5. BIOGEOCHEMISTRY

G. Dieckmann, E. Damm, E. Helmke, L. Wischnewski, L. Wagenknecht, K. Ludwichowski, C. Burau (AWI)

The aim of this work (in collaboration with other groups) is to characterise the biogeochemical properties of summer sea ice and the underlying water column in order to understand the involved processes. Currently, one of the main limitations of our sea ice studies is the paucity of data that do not allow to resolve temporal variability and/or evolution. TransArc gives us the rare opportunity to characterise sea ice processes on the turn from summer to autumn.

Topics to be covered are the formation of climate relevant trace gases (methane and DMS) in seawater and sea ice in the Atlantic- and Pacific-dominated Arctic Ocean, the role of Calcium carbonate precipitation in the Arctic carbon cycle, microbiology and chemical Oceanography.

Objectives

Methane and DMS

Methanogens form methane via various pathways commonly classified with respect to the type of carbon precursor utilized, e.g. the methylothrophic pathway indicates the intact conversion of a methyl group to methane. Although the contribution of methylated substrates is potentially large in the near-surface ocean, methylothrophic methanogenis is considered to be a principal pathway from which methane is readily formed by microbial activity. However, direct evidence of the role of methylated substrates in aerobic seawater and sea ice is still lacking.

DMSP is an abundant methylated substrate in the surface ocean and large amounts are produced annually by marine phytoplankton and sea ice algae. DMSP turnover plays a significant role in carbon and sulphur cycling in the surface ocean. DMSP degradation occurs via a demethylation pathway and a cleavage pathway. Cleavage of DMSP can be carried out by bacteria or by phytoplankton, and leads to formation of DMS (dimethylsulfide).

DMS partly escapes to the atmosphere where it is oxidized to sulphuric acid and methanesulfonic acid. These sulphur-containing aerosols serve as cloud condensation nuclei altering the global radiation budget. Thus DMS may exert a cooling effect on earth's climate. However, bacteria oxidize a large amount of the DMS before it can be released to the atmosphere. Anaerobic metabolism of DMS results in the production of methane. Hence, the DMSP catabolism may also have a warming effect on the earth's climate due to the formation of the greenhouse gas methane.

On this expedition we expect to expand our knowledge about the recently described marine methane cycle. The aim of the investigations is to estimate the balance between the production/consumption pathways and the resultant isotopic fractionation in the water column and sea ice during the transition from summer to autumn. Furthermore we intend to study the flux of excess methane (related to background concentrations) from sea ice and ocean to air.

Calcium carbonate precipitation
The interaction between the marine and the atmospheric carbon cycle is a critical factor in understanding climate change. The polar oceans play an important role in mediating the Earth's climate by providing an appreciable part of the global carbon sink in their surface waters. So far, little attention has been paid the consequences of carbonate formation and its subsequent dissolution which are complex and may have a strong bearing on the carbon cycle and sequestration in polar oceans. For example, it has been estimated that 720,000,000 t of carbon may be removed from surface to deep polar waters as a consequence of carbonate mineral formation in sea ice. Until recently, these estimates have remained subjective and speculative, because neither carbonate minerals nor their mineral form had been described, while the effects of physical-chemical properties on their precipitation and dissolution in sea ice was unknown.

We plan to look for and quantify ikaite crystals in sea ice and to study the conditions leading to their precipitation.

Chemical Oceanography
The nutrient distribution is closely connected with the physical and planktological distribution. Phytoplankton is dependent on available nutrients, and nutrients are good indicators of the phytoplankton development in open waters but also in marginal ice zones and below the ice (ice algae development). Nutrients are also well suited as tracers for the identification of water masses. Strong gradients exist between the Eurasian and Canadian Basins, and the influence of the large riverine discharge into the Laptev Sea will be determined. In addition, samples for the determination of dissolved organic matter (DOM) will be collected. Dissolved organic carbon (DOC) and nitrogen (DON) will be measured to follow the outflow of organic-rich material from the Siberian rivers. The distribution and transport of the nutrients and DOM will be followed from the Laptev Sea through the central Arctic Ocean to the Fram Strait region. We expect to follow the outflow of water masses transporting nutrients and terrestrial

organic matter from the huge Siberian river via the Transpolar Drift towards the Fram Strait. Detailed DOM characteristics, analyzed by ultrahigh resolution mass spectrometry later in the home lab, will provide chemical indicators for DOM sources and modification processes during the transport from the rivers to the open ocean. The programme is closely connected with studies in the Lena Delta.

Microbiology
Diversity, structure, activity (sec. production) and function of bacterial communities in surface waters as well as in different representative sea ice habitats will be studied. Special emphasis will be laid on sea ice melt pools which are expected to increase due to Global Warming and change in chemical composition due to thinning of sea ice. Currently, melt pools are characterized by ultraoligotrophic conditions and by an untypical bacteria flora of beta- Proteobacteria and Actinobacteria. In contrast, sea ice is populated by alpha- and gamma-Proteobacteria as well as Bacteroidetes. Further, sea ice bacteria of the different phyla are characterized by the secretion of copious amounts of mucous (EPS). The function of EPS within the ice is still unknown but EPS is also a starting material for Transparent Exopolymer Particles (TEP) and marine snow particles that may transport fixed carbon from the surface to the ultraoligotrophic deep sea of the Arctic Ocean. Amount and chemical composition of EPS in sea ice and different water depths will be followed up.

Methane as relevant climatic gas is also in the focus of our project: “Ecology and diversity of foraminifera and bacteria communities at venting sites on the Gakkel ridge and in the Eastern Siberian with particular consideration of submarine methane sources” (together with the geological group). In various vent to seepage sites in the high northern latitudes we found spectacular and very different faunas and bacterial communities. This study shall be broadened. Community structure and physiological potential of the bacterial and foraminiferal communities in water (plumes) and sediment samples at venting sites will be studied in comparison to vent-unaffected sites to get an idea about impact and importance of vent associated microbial communities in the Arctic Ocean and about biogeochemical processes at the end member of the middle oceanic ridge system.

Work at Sea
Water samples will be collected from the rosette system. Brine samples will be collected from Sack holes in sea ice and samples will be obtained from meltponds. Methane and DMS will be measured on board, using gas chromatographs equipped with a flame ionization detector (FID) and a pulsed flame photometric detector (PFPD), respectively. Furthermore, DMSP particular and dissolved will be analysed in seawater, ice and sediments. Gas samples will be stored for analyses of the $\delta^{13}C_{CH4}$ values in the home laboratory.

Sea ice will be sampled by taking cores with a standard corer. Sea ice cores will be sectioned and melted at 4°C, and the samples will be checked for crystals under a stereo microscope. Alternatively they will be filtered and the collected crystals stored in Ethanol at -20°C for later analyses in the home laboratory. Archive cores will also be taken and stored at -20°C to be returned to the home laboratory. In addition we will record supplementary sea ice parameters such as temperature, salinity and texture as well as other parameters in brine. We will preserve or freeze samples to be returned to the home laboratory for further analyses.

Water and sediment will be sampled from the Gakkel Ridge and seepage sites. We will start the sampling programme with CTD (YoYo-) casts and look for temperature anomalies. Based on the CTD results we will take water samples and sediment samples will be taken either with the multiple or grab corer. Video guidance is necessary to choose appropriate sampling locations because venting sites are very patchy and small scaled. Young basaltic formations can only be sampled by video guided gears.

Bacterial production will be determined with labeled compounds to get more information about the role of the microbial communities and their impact on formation and degradation of CO_2 and methane. Molecular biological techniques like fluorescence *in-situ* hybridisation (FISH) and denaturing gradient gel electrophoresis (DGGE) will be employed and cloning libraries conducted to describe the structure of the different bacterial communities including those associated with the specific foraminifera fauna. In advance of the preparations for these specific techniques, samples have to be filtered and sediment samples to be diluted and preserved.

From water samples taken with the rosette sampler as well as in brine from sack holes in sea ice, the nutrients - nitrate, nitrite, ammonium, phosphate and silicate will be determined on board with an Autoanalyser-system according to standard methods. DOM samples will be taken for bulk determinations and also extracted from seawater at representative stations using PPL sorbent. DOM sampling will be decided from results of the fluorescence profiles.

6. GEOCHEMISTRY

6.1 CARBONATE SYSTEM

A. Ulfsbo and Y. Ericson (UGot)

Objectives

The objective of this study is to further improve our understanding of the Arctic Ocean carbon system, with an emphasis on carbon fluxes and ocean acidification. More specifically we aim at increasing our understanding of the feedbacks among the physical and biogeochemical components of the Arctic Ocean carbon system, which include the assessment of likely changes in the export of marine produced organic matter to the deep central Arctic Ocean when the sea ice coverage is absent during the productive summer season. A summer sea ice free Arctic Ocean will further result in more brine formation that contributes to deep water formation as a larger winter sea ice production is expected (sea ice production is larger in open water than ice covered), possible in combination with a higher surface water salinity if mixing of the upper water layers increases. Both changes in export production and ventilation of the deep waters impact the sequestration of anthropogenic CO_2. Finally we also aim at assessing the “natural” ocean acidification, i.e. the pH reduction caused by biogeochemical processes in the ocean, in relation to that originating from uptake of anthropogenic CO_2.

Work at sea

This study will be implemented by analysing seawater samples throughout the water column at as many stations that is possible considering the time for analysis. The constituents to be determined on board, within hours of sampling, are pH, Total Dissolved Inorganic Carbon, and Total Alkalinity. In order to perform these analyses we need to collect two 250 mL samples per depth.

6.2 RADIUM AND THORIUM ISOTOPES

M. Rutgers van der Loeff, D. Scholz (AWI), A. Charkin (POI)

Objectives

The particle export from surface water can be determined with the short lived isotope ^{234}Th (half-life 24 days). During ARK-XXII/2 in 2007 we have found that ^{234}Th-based export rates were very low in the central Arctic, but there were indications of enhanced particle fluxes in the area of the Lomonosov Ridge.

We wish to determine the ^{234}Th/^{238}U ratio to determine the scavenging rates in the surface water. This will give us an estimate of POC export, which we can compare with the results of the 2007 expedition and with fluxes we hope to measure with sediment traps.

Four radium isotopes are supplied to the ocean by contact with the continent or (deep-sea)-sediments: ^{223}Ra, (half-life 11.4 d); ^{224}Ra (3.7 d), ^{226}Ra (1620 y) and ^{228}Ra (5.8 y). The distribution of these isotopes in seawater has been shown to be most helpful to evaluate shelf-basin exchange and water residence times. ^{228}Ra is released by sediments and accumulates to high activities over the Arctic shelves. When these waters are transported across the central Arctic Ocean towards Fram Strait, the signal decays with the half-life of 5.8 y. The isotope is therefore used to trace this transport of shelf-influenced waters in the Trans Polar Drift. During this transport, the granddaughter ^{228}Th, which is efficiently removed on the shelves, grows towards equilibrium. The distribution of the ^{228}Th/^{228}Ra ratio is therefore determined by a competition between ingrowth, which depends on time (^{228}Th half-life 1.9 yr) and removal, which depends on particle flux.

It is our aim to use the ^{234}Th/^{238}U data to determine the distribution of scavenging rates. This will be compared with data on suspended load, primarily from transmissometry. These scavenging rates will then be used to interpret the ^{228}Th/^{228}Ra data and determine to what extent they can be used as time marker for shelf waters.

The short-lived radium isotopes ^{224}Ra and ^{223}Ra are used extensively for the study of submarine groundwater discharge. We may see signals of direct release of these isotopes on stations nearest to the coast, but the isotopes will primarily be used as proxies for their longer lived parents ^{228}Th and ^{227}Ac.

Work at sea

^{234}Th and POC samples will be collected and processed during this cruise. For depth profiles of ^{234}Th an aliquot of 4-L of seawater will be collected at 0, 25, 50, 75, 100, 150, 200 m. In order to determine the POC/^{234}Th ratio on sinking particles, large sinking particles will be collected at a depth of ca 100 m by deployment of *in-situ* pumps. Nitex screens with particulate matter are ultrasonicated and the suspension is filtered through a 25 mm Ag or precombusted QMA filter. The particulate and the total ^{234}Th samples will be counted onboard using RISO beta counters mounted in the geochemistry container.

For radium isotopes, large volume surface water samples will be collected using the *Polarstern*'s seawater intake, filtered through a 1 µm cartridge filter. The filtrate is transferred to 150 - 300 L tanks. Each sample is pumped at <1 L/min using a peristaltic pump through MnO_2-impregnated acrylic fiber to scavenge radium isotopes. Fibers are dried using compressed air, and short-lived ^{223}Ra and ^{224}Ra measured at sea using RADECC detectors. The longer-lived isotopes will be measured on the fibers by leaching, coprecipitation of

Radium on $BaSO_4$ and gamma counting ^{228}Ra and ^{226}Ra in the shore-based lab. For occasional deeper (i.e. below surface) sampling, large-volume samples require multiple (2-3) Rosette (regular or 30-L) casts, and filling barrels or, if time allows, the deployment of *in-situ* pumps.

6.3 TRACING TERRESTRIAL CARBON ACROSS THE ARCTIC SHELF AND SLOPE

A. Charkin (POI), M. Rutgers van der Loeff (AWI)

Objectives

1) To sample suspended particulate material (SPM) and bottom sediment for in lab measurements of major, trace, and rare earth elements (REE) geochemistry, organic carbon (OC) and isotopic ($\delta^{13}C$) composition on the Arctic shelf,
2) to obtain new data of OC, SPM and REE from the outer continental shelf and continental slope and compare these with data obtained in previous expeditions of the Laboratory of Arctic Investigations of the Pacific Oceanological Institute (POI) of the Far Eastern Branch of the Russian Academy of Sciences (FEB RAS) (1999-2009) from the inner and mid continental Arctic shelf,
3) to trace terrestrial carbon across the Arctic shelf and slope.

Work at Sea

The SPM for the geochemistry of rare earth elements will be obtained by filtration through membrane filters with pore diameter of 0.47 µm. The filtered water volume will vary between 1 and 2 L depending on sediment load. 50 to 100-g samples of bottom sediment will be collected for OC, isotopic ($\delta^{13}C$) composition and REE geochemistry. The particulate OC composition will be analyzed on samples (0.5 and 1 L) filtered onto borosilicate glass fiber filters (GF/F; Whatman Inc. with approximate pore diameters of 0.7 µm). Elementary (OC) and isotopic ($\delta^{13}C$) composition of bottom sediment will be determined by Carlo Erba elemental analyzers and a Finnigan MAT Delta Plus mass spectrometer, respectively, at the International Arctic Research Center, University of Alaska, Fairbanks (USA) or with similar instruments at Stockholm University (Sweden). REE elements will be analyzed in the Vernadskiy Institute of Geochemistry and Analytical Chemistry, Moscow (Russia).

6.4 ATMOSPHERIC DEPOSITION OF TRACE ELEMENTS TO THE ARCTIC OCEAN

B. Galfond (RSMAS)

Objectives

This study aims at improving the assessment of atmospheric input of chemical species into the Arctic Ocean. Applying a novel indirect method, we will use measurements of ^7Be in the surface waters, snow/ice cover and in the lower atmosphere, coupled with trace element measurements in aerosols, to provide estimates of the atmospheric input of relevant trace elements into the Arctic Ocean. The ability to readily derive ^7Be flux from the ocean/ice inventory provides the means to link the chemical concentration data of precipitation and aerosols to flux. Here a novel approach utilizing the ^7Be inventory of the water column (and ice) and the ^{7}Be concentration of aerosols will be used which will provide estimates of the atmospheric deposition of trace elements. This method could ultimately be applied to seasonal study in the Arctic as the partitioning would be expected to vary throughout the year. This is turn would give insight into how trace element deposition will change as sea ice conditions in the Arctic evolve in the future.

^{7}Be is a cosmic ray produced radioisotope that becomes associated with particles in the troposphere and subsequently deposited to the surface ocean. Because of its relatively short half-life (53.3 days) it is reasonable to equate the inventory of ^{7}Be decay in the upper ocean and snow, to the flux of ^{7}Be from the atmosphere. This provides a key linkage between the atmospheric concentration of chemical species and their deposition to the ocean. Such species include many of interest to the GEOTRACES programme such as Hg, Al, Mn, Fe, Cu, Zn, and Cd. The atmospheric flux of these important trace elements (TEs) can then be estimated from multiplying the ^{7}Be atmospheric flux (determined by its ocean or snow/ice inventory) by the TE/^{7}Be ratios in aerosols and wet deposition.

This work involves cooperation of Dr. David Kadko, Dr. William Landing and Dr. Lars-Eric Heimbürger.

Work at sea

- Samples (~ 400 L) from the seawater intake will be taken for ^{7}Be analysis.
- At ice stations we will measure ^{7}Be in the sea ice, snow, in the water directly below the sea ice, and depth profiles in and below the mixed layer.
- Atmospheric sampling using Tisch 5170-VBL high-volume total suspended particle (TSP) aerosol sampler for ^{7}Be and trace elements, as well as sampling of snow/rain.

6.5 NET COMMUNITY PRODUCTIVITY USING DISSOLVED O_2/AR/^{222}RN

N. Cassar (DU), M. Rutgers van der Loeff, D. Scholz (AWI)

Objectives

Estimate net community productivity in the Arctic Ocean using dissolved O_2/Ar measurements, and constrain the biogeochemical controls on carbon fluxes. Oxygen in the mixed layer is influenced by biology, and by physical processes such as bubble injection, temperature and pressure changes. Because argon (Ar) has similar solubility properties as oxygen, the oxygen derived from physical processes can be estimated from the argon concentration relative to its saturation ($[Ar]_{sat}$). The oxygen derived from biology is equal to the total oxygen minus the oxygen derived from physical processes.

^{222}Rn will be used as an independent measure of air-sea exchange. ^{222}Rn is produced in the water column from ^{226}Ra dissolved in seawater. Exchange with the atmosphere creates a depletion in surface waters that can be used as quantification of air-sea exchange. This will give us an additional tool to convert the oxygen over- or undersaturation derived from O_2/Ar ratios into oxygen fluxes and thus into net community productivity (NCP).

Work at sea

High-resolution continuous O_2/Ar measurements are made by equilibrator inlet mass spectrometry. A continuous supply of seawater (3 - 5 liters per min) enters an equilibrator containing discs of hollow fiber arrays. The gas phase is then carried to the mass spectrometer which is mounted right next to the sink with seawater tap.

With the large volume Rosette sampler (MultiWaterSampler MWS, 6 x 30L) we will collect profiles of water samples across the surface layer. ^{222}Rn will be determined: ^{222}Rn is stripped with He, trapped on cooled charcoal traps, transferred to scintillation cells and counted for alpha activity. After purging, the samples will be passed over MnO_2 fiber to collect Radium for quantification of parent ^{226}Ra activity and for the study of short-lived Radium isotopes.

6.6 IMPACT OF CHANGING CLIMATE ON MERCURY CYCLING

L. Heimbürger (OMP)

Objectives

- Determine the distributions of Hg, including its concentration, chemical speciation, and physical form, and to evaluate the sources, sinks, and internal cycling of these species to characterize more completely the physical, chemical and biological processes regulating their distributions (modified from GEOTRACES objective)
- Attempt to include marine inorganic Hg and MeHg species in an Arctic Hg mass balance model
- Determine the role of sea ice in controlling the exchange of Hg between ocean and atmosphere
- Exploring the role of the Arctic Ocean in the global mercury cycle.

Key questions:

1) What controls MeHg trends and variability in the Arctic Ocean?
2) Is the Arctic a sink for atmospheric Hg contamination?
3) What is the environmental response of the MeHg cycle to climate change and increasing anthropogenic emissions?
4) What are the mechanisms that control the dynamic balance between sources and sinks?
5) What is the net impact of atmospheric mercury depletion events (AMDEs)?
6) What are the causes for the alarming rise of Hg levels in Arctic biota?

Work at sea

1) At hydrographic stations CTD casts will be made with the Seabird 911plus equipped with 24 12L-Niskin bottles. At as many stations as possible we will take full-depth profiles of total Hg, requiring approx 1-L samples. We will select several stations for the analysis of Hg speciation.
2) At ice stations we will measure Hg in the sea ice, snow cover, brine and in the water column directly below the sea ice.
3) Atmospheric Hg sampling using Tisch 5170-VBL high-volume total suspended particle (TSP) aerosol sampler (collaboration with Ben Galfond, David Kadko and William M. Landing) as well as sampling of snow/rain.
4) Analysis on board: reactive mercury HgR, total mercury (HgT) and dissolved gaseous mercury (DGM).
5) Analysis at home lab: MeHg.

6.7 DISSOLVED ORGANIC MATTER

R. M.W. Amon (TAM)

Objectives

Recently, an increase in the hydrological cycle has been suggested potentially leading to increased freshwater discharge in Eurasian rivers. Concern has risen as to how these changes might effect the heat budget of the Arctic Ocean, the fate of soil organic carbon stored in tundra and taiga soils, the global thermohaline circulation, and the general climate in the northern hemisphere. The large discharge of freshwater, its modification on the extended shelf areas and its circulation play an important role for the stratification and thus for vertical exchange in the open Arctic Ocean.

This work aims at investigating how elevated levels of terrestrial DOM and associated fluorescence in upper ocean waters can be used to unravel some of the different sources by using a new method combining high resolution spectrofluorometry and parallel factor analysis. With this new method we will be in a much better position to determine source waters involved in halocline formation which is critical for our understanding of climate change the Arctic Ocean system. Some of the analyses, e.g. the combination of 3-dimensional fluorescence and parallel factor analysis, in combination with new tracers such as nitrogen isotopes in nitrate and carbon isotopes in DIC are novel to Arctic Oceanography and will allow significant new insight.

Work at sea

Fluorescence will be measured with CTD profiles by a fluorescence sensor mounted on the CTD unit to obtain the horizontal and vertical distribution of fluorescence which is caused by certain organic compounds dissolved in seawater. Based on the fluorescence signal water samples (between 1 and 20 l) will be taken at several depth levels. We plan to collect about 120 samples during the cruise. Each sample will be split into subsamples to determine the following parameters: dissolved organic carbon (DOC), dissolved organic nitrogen (DON), optical properties (absorbance and fluorescence), lignin phenols, stable isotopes of hydrogen and oxygen (water), carbon (DOC, DIC), and nitrogen (nitrate). The isotope analyses will be carried out in close cooperation with Dr. Bauch (U. Kiel), and Dr. Dieckmann (AWI). Water samples will be frozen and transported to the home laboratory for further analyses which will take about 1 year to complete.

7. PLANKTON ECOLOGY

A. Boetius (MPI, AWI), E. Kilias, S. Wiegmann (AWI), C. Boissard (CEA)

Objectives

The strong changes seen in the Arctic Ocean and sea ice will have major implications for the entire ecosystem of the Arctic with possible impact on the carbon cycle and emission of volatile organic compounds (VOCs) and aerosols.

This programme aims to continue ecological investigations of phyto- and protozooplankton biomass, species composition, 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. Data obtained during this cruise will allow a comparison with the data sets obtained more than 15 years ago in order to understand the eventually changes due to the rapidly changing Arctic environment. Specific questions will be: Are there regional differences in the seasonal distribution patterns of phyto- and protozooplankton, 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 in vertical particle flux and in the biogeochemistry of surface sediments and microbial ecology of bacteria therein?

In order also to extrapolate the cruise findings on phytoplankton composition and distribution, to a broader temporal and spatial scale satellite data will be used. The field measurements of phytoplankton pigment composition, optical characteristics of phytoplankton and other water constituents, reflectance and underwater light measurements are highly precise input parameters for these satellite retrievals, climatologies, models but also used for the validation of results from the analyses of satellite data and modelling. Data will be collected during this cruise to improve our understanding of the oceans variability in optical properties and to improve/develop remote sensing algorithms for the investigated research area.

Phytoplankton has an influence on trace gazes. In the surface layers of the oceans (euphotic zone) planktonic biomass releases organic compounds into the surrounding seawater. Some species have a significant influence on the photochemistry of the atmosphere, particularly unsaturated hydrocarbons (such as isoprene: 2-methyl-1,3 butadiene, or light alkenes) and carbon monoxide (CO). These have a strong impact on the OH radical and ozone budget as well as on the formation of organic aerosols and thus on CCN number and on cloud lifetime and properties. Up to now observations have been only 10 days long and need to be extended to a longer period and should cover a wider region of the Central Arctic. The data are needed to evaluate feedbacks with the radiation balance and to study the spatial-temporal variability of reactive gases in seawater in relation to the distribution of phytoplankton species and its effect on the aerosol production.

Work at Sea

Phytoplankton ecology, vertical particle flux, and sediment sampling

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, particulate organic carbon & nitrogen, carbonate, biogenic silica. Water will be filtered on precombusted Whatman GF/C glass-fibre filters, polycarbonate and, cellulose acetate filters, respectively, stored deep frozen for later analyses in the home laboratory.

In co-operation with the physical oceanographers, two sediment traps (~200 m & ~150 m above sea floor) will be deployed in two moorings near the Gakkel Ridge, respectively, to collect particles in order to investigate vertical flux pattern of organisms and their remnants, of organic matter and lithogenic material under the almost permanent ice cover from mid September 2011 until end of August 2012 (see chapter 3, physical oceanography). The traps are equipped with 20 sampling jars containing poison. The respective sampling intervals are programmed individually. The traps will be recovered one year later.

Bottom samples from sediment surfaces will be obtained by means of a multicorer on the Laptev Sea slope at stations we have been visited during 1993 and 1995 in order to compare the organic matter and bacterial composition and ecology after almost twenty years of change.

In order to assess plankton, including the smallest fractions which are more common in a warming Arctic Ocean molecular methods will be used as a basis for the development of innovative smart observation methods and strategies to survey the biodiversity of the Arctic phytoplankton especially the pico- and nanoplankton and bacteria. Molecular methods, based on the analysis of the rRNA gene will be used for the assessment of biodiversity in combination with a wide variety of hybridization based methods, such as RNA-based nucleic acid biosensors or DNA-microarrays (PHYLOCHIPS). Sampling will be carried out by filtering sea water polycarbonatefilters of different pore sizes, stored deep frozen for later analyses in the home laboratory.

Satellite ground truth bio-optical measurements and trace gases
For bio-optic measurements and trace gas analysis, water samples will be taken from the surface and from CTD/rosette casts.

The bio-optics samples will be filtered onto GF/F filters for particulate absorption measurements. Absorption of coloured dissolved organic matter (CDOM) will be assessed in 0.2 µm filtrates of the water samples.

Online and *in-situ* optical measurements

- A FastTracka Fast Repetition Rate Fluorimeter (FRRF) will be operated on the small winch to take profile measurements of chlorophyll fluorescence
- Radiometric measurements of the underwater light field and sky radiance will be measured in the water column (0-150 m) at the stations.

Measurements of aerosols & carbon monoxide
In-situ sampling will consist in surface sea water continuously analysed for its content in dissolved organic trace gases, alkenes, isoprene and carbon monoxide. Seawater samples collected from the water pump will be continuously introduced in an equilibration chamber, where dissolved gases will be equilibrated with clean synthetic air, and analysed by gas chromatography (GC). Two instruments will be used: a GC equipped with a PID (photo-ionisation detector) for unsaturated hydrocarbons quantification and a GC equipped with a mercuric oxide detector for CO monitoring. Measurements frequencies are 30 minutes for dissolved hydrocarbons in seawater and 5 minutes for dissolved CO. These data will be corroborated by the sampling of phytoplankton pigments and picoplankton abundance from the pump system (approximately every 6 hours).

'*In-situ*' monitoring of CO mixing ratio in the air will be simultaneously performed on board in order to characterize the air masses and determine the super saturation of the surface seawater with respect to the atmosphere. Samples will be collected in canisters (one or two per day) in order to measure the mixing ratios of light hydrocarbon in surface air.

Measurements of the vertical distribution of organic trace gases in the water column will be performed from the samples collected on station by Niskin bottles. These data will be corroborated by the sampling of phytoplankton pigments and picoplankton abundance from the same CTD-casts in the same depth.

The number of samples analysed per vertical profile as well as the frequency of the vertical profiles studied will be adapted on the plankton biomass variability observed, indicated by fluorescence measurements. A focus will be put on sampling of the euphotic zone and the chlorophyll maxima.

For aerosol measurements it is proposed here to perform a continuous survey of the CCN chemical composition by using automatic aerosol filter sampling every 6h. Local contamination will be detected using an automated real-time analyzer of Black Carbon. Long-range transport of anthropogenic emissions will be monitored using a combination of black carbon measurements & NH_3 (Airrmonia) analyzers.

8. MARINE GEOLOGY

T. Kollaske, N. Lensch, J. Matthiessen, P. Slabon, M. Sühs, H. Zou, (AWI),
A. Meinhardt (ICBM)

The overall goals of the marine-geological research programme are (1) high-resolution studies of changes in paleoclimate, paleoceanic circulation, paleoproductivity, and sea ice distribution in the Central Arctic Ocean and at the adjacent continental margins during the Quaternary, and (2) the long-term history of the Mesozoic and Cenozoic Arctic Ocean and its environmental evolution from a (sub-)tropical to an ice-covered polar ocean. In areas such as the Alpha-Mendeleev Ridge, pre-Quaternary sediments are cropping out close to the seabed, which could even be cored with coring gears aboard *Polarstern* and which would allow to study the Mesozoic/Tertiary history of the (preglacial) Arctic Ocean. Especially, data for the reconstruction of the long-term paleoclimatic history of the Arctic Ocean are sparse and only very short sediment cores taken from drifting ice islands provide information on short time intervals. The new results will be related to those obtained from previous expeditions to the Central Arctic Ocean and the Eurasian continental margin.

The main objectives include:

• *Stratigraphic analyses of sediment sequences*

As basis for all further reconstructions of paleoenvironmental change, a precise chronostratigraphic framework has to be established. This work will include magnetostratigraphy, oxygen and carbon stable isotopes of foraminifera, absolute age dating, biostratigraphy, natural radionuclides (^{10}Be, ^{234}Th), cyclostratigraphy (element cycles, e.g. manganese, physical properties), and correlation to other existing (dated) Arctic Ocean records.

• *Terrigenous sediment supply*

The terrigenous sediment supply to the Arctic Ocean is controlled by river discharge, transport by currents, sea ice and icebergs, gravitative transport processes, and eolian input. Most of these mechanisms also influence biological processes in the water column as well as at the sea floor (eg, surface-water productivity, particle flux through the water column, benthic activity at the sea floor, organic carbon export and burial).

The research will concentrate on the quantification, characterization and variability of terrigenous discharge to the Alpha-Mendeleev Ridge and Lomonosov Ridge. This study will allow estimates of chemical and sedimentary budgets, identifications of major transport processes, and reconstructions of oceanic currents. Of major interest is a detailed sedimentological, geochemical, mineralogical, and micropaleontological study of surface sediments and sediment cores. Methods will include determinations of grain size, clay mineral and heavy mineral composition, and major, minor, and trace (including rare earth elements) elements, as well as organic carbon composition and physical properties. Mapping of sediment echotypes from Parasound profiles will allow an extrapolation of point information from core data into spatial facies pattern.

Analytical techniques include X-ray diffraction (XRD), X-ray fluorescence (XRF), inductivity-coupled plasma mass spectrometry (ICP-MS), and microscopy of coarse fraction. Furthermore, multisensor core logging and XRF-scanning will be applied to obtain continuous records of elemental ratios and physical properties of sediments.

• *Organic-carbon flux and water-mass characteristics: Geochemical and micropaleontological tracers*
One of the major goals is to quantify the flux of organic carbon and to characterize the mechanisms controlling organic carbon deposition and their changes through late Quaternary and Mesozoic/Cenozoic times. A major focus of inorganic geochemical investigations of surface sediments as well as deeper sediment cores is the formation mechanism and geochemical expression of colour cycles ("manganese cycles"). Furthermore, the oxygenation of water masses, surface-water productivity, surface-water temperature, sea ice cover, and terrigenous input are of special interest. Analytical techniques to be used include LECO ($CaCO_3$, TOC, C/N), Rock-Eval pyrolysis, gas chromatography (GC) and gas chromatography/mass spectrometry (GC/MS), XRF, ICP-MS, Mo- and Fe-isotopes and bulk parameters (TC, TIC, TS), and microscopy as well as XRF scanning. The obtained data will be compared with results from previous cruises.

Some important issues are:
- to determine the amount, composition, and maturity of the organic carbon fraction, i.e., (sub-) recent marine and terrigenous organic carbon, reworked fossil material (coals), using organic-geochemical bulk parameters (TOC;C/N, HI values), biomarkers (e.g., *n*-alkanes, sterols, GDGTs, BIT index), maceral assemblages, and stable carbon isotopes of organic matter;
- to quantify the flux of marine and terrigenous organic carbon (accumulation rates), its change through space and time and its relationship to changes in sea ice distribution and paleoclimate;
- to estimate the (paleo-) productivity from various productivity proxies: marine organic-carbon flux, biomarker composition (e.g., n-alkanes, sterols, fatty acids, alkenones, etc.); stable carbon and nitrogen isotopes of organic matter; barium; biogenic opal; diatom and dinoflagellate assemblages;
- to reconstruct sea-surface temperature and sea ice cover from biomarker composition (alkenones, TEX_{86}; HBIs, IP_{25});
- to reconstruct water-mass oxygenation using organic carbon/sulfur and organic carbon/iron/sulfur relationships, redox-sensitive trace elements (e.g., Mo, V, U. Ag, Cd, Zn, Re), and specific biomarkers (isorenieratane); and
- to compare the data with similar data sets from the eastern Central Arctic Ocean and Eurasian continental margin areas.

Micropaleontological proxies
The spatial and temporal distribution of planktonic and benthic foraminifera (calcareous, agglutinated, organic-walled), calcareous nannofossils, ostracods, biosiliceous (diatoms, radiolarians, silicoflagellates) and organic-walled microfossils (dinoflagellate cysts, acritarchs,

chlorophytes) as well as the stable isotope and trace metal composition of planktonic and benthic foraminiferal shells will provide additional information on the variability of the marine environment (surface and deep waters, productivity, sea ice cover) with time.

Work at sea

Coring strategy

Coring will focus on transects across the Lomonsov Ridge and the Alpha-Mendeleev Ridge, using the kastenlot (KAL), gravity corer (SL), piston corer (PC), giant box corer (GKG), and multicorer (MUC). Coring positions have to be selected carefully using detailed bathymetric mapping and sub-bottom profiling systems (Hydrosweep and Parasound). Surface sediments will be sampled to calibrate the various proxies versus modern environmental conditions.

Study of sediment cores

Prior to opening, all sediment will be logged using the Multi-Sensor-Core-Logger (MSCL). Then, cores will be opened and described, sediment slices for X-ray photographs be taken, and color scanning will be carried-out. Smear-slide and coarse-fraction analyses will be done to get information about sediment composition, and X-ray photographs will be studied for amount of ice-rafted debris (IRD). Furthermore, discrete sampling will be done on a selected number of cores for later shore-based studies.

Pore-water programme

Pore waters from fresh cores will be retrieved by rhizon sampling to gain information on the importance of organic matter degradation in Arctic Ocean sediments and the diagenetic mobility of metals like manganese and iron. Pore waters have to be retrieved directly after core recovery to prevent alteration of diagenetic signals. The applied rhizon-technique is a largely non-destructive method and preserves the sediment. Certain parameters (pH, ammonia, alkalinity, nitrite, nitrate, and hydrogen sulfide) alter quickly and therefore have to be determined on board. For later shore-based analyses, subsamples will be acidified for the determination of e.g. sulfate, phosphate, manganese, and iron.

Sampling of sea ice

A sampling of („dirty") sea ice will be carried-out to study the amount and composition of sediments entrained in modern sea ice. Here, selected ice floes will be visited using a helicopter.

9. ZOOPLANKTON

K. Kosobokova (SIO), H. Hirche (AWI), E. Ershova, R. Hopcroft, (IUAF)

Objectives

The inflow of Atlantic water has been shown to have the most profound effect on shaping the quantitative and qualitative zooplankton distribution resulting in a strong regional variability of the zooplankton stock and the pelagic food web structure over the Arctic basins. The fate of advected Atlantic zooplankton populations into the Arctic is determined by their tolerance to Arctic conditions. While many species died off shortly after entering the Arctic Ocean, others continued their development for some time: thus the Arctic Ocean represents a large sink for organic carbon produced in the North Atlantic.

The Arctic biological communities may be particularly sensitive to changes in ice cover and circulation regimes. An increase of advection of Atlantic populations and further warming could favour the survival of the highly productive Atlantic communities which finally could replace the Arctic fauna, resulting in fundamental changes of the pelagic ecosystem structure and productivity. Alternatively, climate change could be non-selective in terms of species, and lead to increased or decreased rates of primary production in the Arctic and thus support more or less zooplankton. Recent studies suggest abundance and biomass of zooplankton is higher than observed several decades ago.

The main objectives of this project are:

1) Elucidate Patterns: Relate composition, abundance and biomass of zooplankton communities to the water masses encountered during the expedition. Determine the relative importance of Atlantic populations to resident fauna.
2) Bar-coding & population genetics: Live samples will be scanned for representatives of the species present in each of the major water masses, and representatives preserved for molecular sequencing. At present ~70 of the 350 known zooplankton species have been successfully sequenced for *Cytochrome Oxidase I*, through Hopcroft's collaborators. Initially these sequences serve to catalogue the species encountered, and establish relationships within, and between, major assemblages of organisms. Secondarily, material can be used to examine if an identifiable subpopulation exists within the panarctic domain. Lastly, the sequences will contribute developing molecular-based identification systems, and provide a means of determining the diet of predatory species through molecular analysis of stomach contents.
3) Egg production experiments: The productivity and viability of both dominant and poorly known copepod species will continue to be examined by way of their egg production rates. Rates will be compared across the sampling region with respect to temperature, local productivity, and the water mass types in which they occur.
4) Zooplankton fauna photo-documentation: We propose to continue our photographic inventory of all zooplankton taxa throughout the entire water column contributing to global catalogues of marine life.

The patterns of distribution and density that emerge from these surveys will illuminate linkages to a variety of spatial and temporal variables, and help resolve the role of deep-water and gelatinous zooplankton in the Arctic Ocean.

Work at sea

Zooplankton samples will be obtained with multinet casts. Casts will be taken in each basin along the sections such that each basin is sampled twice per section. The samples will be used for feeding and egg production experiments on board and for further analysis in the home labs.

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2.	Janik, Michael	1.Offc.
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4.	Fallei, Holger	2. Offc.
5.	Gumtow, Philipp	2.Offc.
6.	NN	2.Offc.
7.	Reinmiedl, Judith	Doctor
8.	Hecht, Andreas	R.Offc.
9.	Sümnicht, Stefan	2.Eng.
10.	Minzlaff, Hans-Ulrich	2.Eng.
11.	Holst, Wolfgang	3. Eng.
12.	Scholz, Manfred	Elec.Tech.
13.	Dimmler, Werner	Electron.
14.	Muhle, Helmut	Electron.
15.	Nasis, Ilias	Electron.
16.	Himmel,Frank	Electron
17.	Loidl, Reiner	Boatsw.
18.	Reise, Lutz	Carpenter
19.	Scheel, Sebastian	A.B.
20.	Brickmann, Peter	A.B.
21.	Winkler, Michael	A.B.
22.	Hagemann, Manfred	A.B.
23.	Schmidt, Uwe	A.B.
24.	Guse, Hartmut	A.B.
25.	Wende, Uwe	A.B.
26.	Schröter, Rene	A.B.
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30.	Voy, Bernd	Mot-man
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32.	Schütt, Norbert	Mot-man
33.	Pinske, Lutz	Mot-man
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