ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR-
UND MEERESFORSCHUNG

EXPEDITION PROGRAMME PS107

Polarstern

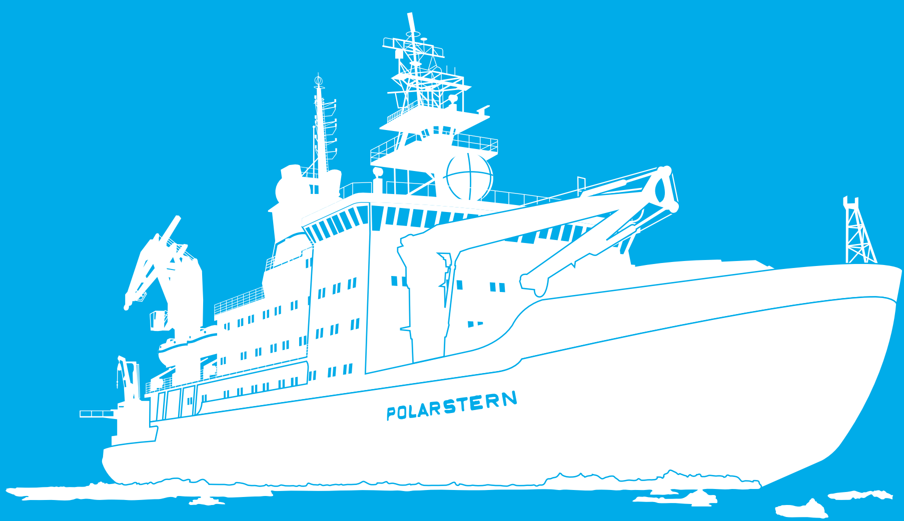
PS107

Tromsø – Tromsø

23 July 2017 - 19 August 2017

Coordinator: Rainer Knust

Chief Scientist: Ingo Schewe



Bremerhaven, Juni 2017

Alfred-Wegener-Institut
Helmholtz-Zentrum
für Polar- und Meeresforschung
Am Handelshafen 12
D-27570 Bremerhaven

Telefon: ++49 471 4831- 0
Telefax: ++49 471 4831 – 1149
E-Mail: info@awi.de
Website: http://www.awi.de

Email Coordinator: rainer.knust@awi.de
Email Chief Scientist: ingo.schewe@awi.de

PS107

(ARK-XXXI/2)

23 July 2017 - 19 August 2017

Tromsø - Tromsø

Chief scientist
Ingo Schewe

Coordinator
Rainer Knust

Contents

1. ÜBERBLICK UND FAHRTVERLAUF

Ingo Schewe (AWI)

Die *Polarstern* Expedition PS107 in die Arktis (Tromsø – Tromsø) wird am 23. Juli 2017 beginnen und vorwiegend in Arbeitsgebiete in der zentralen und östlichen Framstraße, führen.

Sie wird vornehmlich Beiträge zu verschiedenen nationalen und internationalen Forschungs- und Infrastrukturprojekten (INTAROS, FRAM, SIOS, OceanSITES) sowie dem Forschungsprogramm PACES II (Polar Regions and Coasts in the changing Earth System) des Alfred-Wegener-Instituts Helmholtz-Zentrum für Polar- und Meeresforschung (AWI) leisten. Im Arbeitspaket WP4 (Arctic sea ice and its interaction with ocean and ecosystems) des PACES-II Programms werden die mit dem Rückgang des Meereises verbundenen Ökosystemverschiebungen im Pelagial und im tiefen Ozean ermittelt und quantifiziert, und Rückkopplungsprozesse auf zeitliche und räumliche Prozesse untersucht. Unser Beitrag zum PACES-II Arbeitspaket WP6 (Large scale variability and change in polar benthic biota and ecosystem functions) beinhaltet die Identifizierung räumlicher und zeitlicher Entwicklungen in der Funktion ausgewählter Benthos-Gemeinschaften sowie den Aufbau eines umfassenden Repositoriums für Beobachtungsdaten. Die Arbeiten stellen einen weiteren Beitrag zur Sicherstellung der Langzeitbeobachtungen am LTER Observatorium HAUSGARTEN dar, in denen der Einfluß von Umweltveränderungen auf ein arktisches Tiefseeökosystem dokumentiert wird. Diese Arbeiten werden in enger Zusammenarbeit der HGF-MPG Brückengruppe für Tiefsee-Ökologie und -Technologie, der PEBCAO-Gruppe (Phytoplankton Ecology and Biogeochemistry in the Changing Arctic Ocean) des AWI und der Helmholtz-Hochschul-Nachwuchsgruppe SEAPUMP (Seasonal and regional food web interactions with the biological pump) durchgeführt.

Die Expedition soll darüber hinaus genutzt werden, um weitere Installationen im Rahmen der HGF Infrastrukturmaßnahme FRAM (Frontiers in Arctic marine Monitoring) vorzunehmen. Das FRAM Ocean Observing System wird kontinuierliche Untersuchungen von der Meeresoberfläche bis in die Tiefsee ermöglichen und zeitnah Daten zur Erdsystem-Dynamik sowie zu Klima- und Ökosystem-Veränderungen liefern. Daten des Observatoriums werden zu einem besseren Verständnis der Veränderungen in der Ozeanzirkulation, den Wasser–masseneigenschaften und des Meereisrückgangs sowie deren Auswirkungen auf das arktische, marine Ökosystem beitragen. FRAM führt Sensoren in Observationsplattformen zusammen, die sowohl die Registrierung von Ozeanvariablen, als auch physiko-chemischer und biologischer Prozesse im Ozean erlauben. Experimentelle und ereignisgesteuerte Systeme ergänzen diese Beobachtungsplattformen. Produkte der Infrastruktur umfassen hochaufgelöste Langzeitdaten sowie Basisdaten für Modelle und die Fernerkundung. Die Expedition PS107 wird am 19. August 2017 in Tromsø enden.

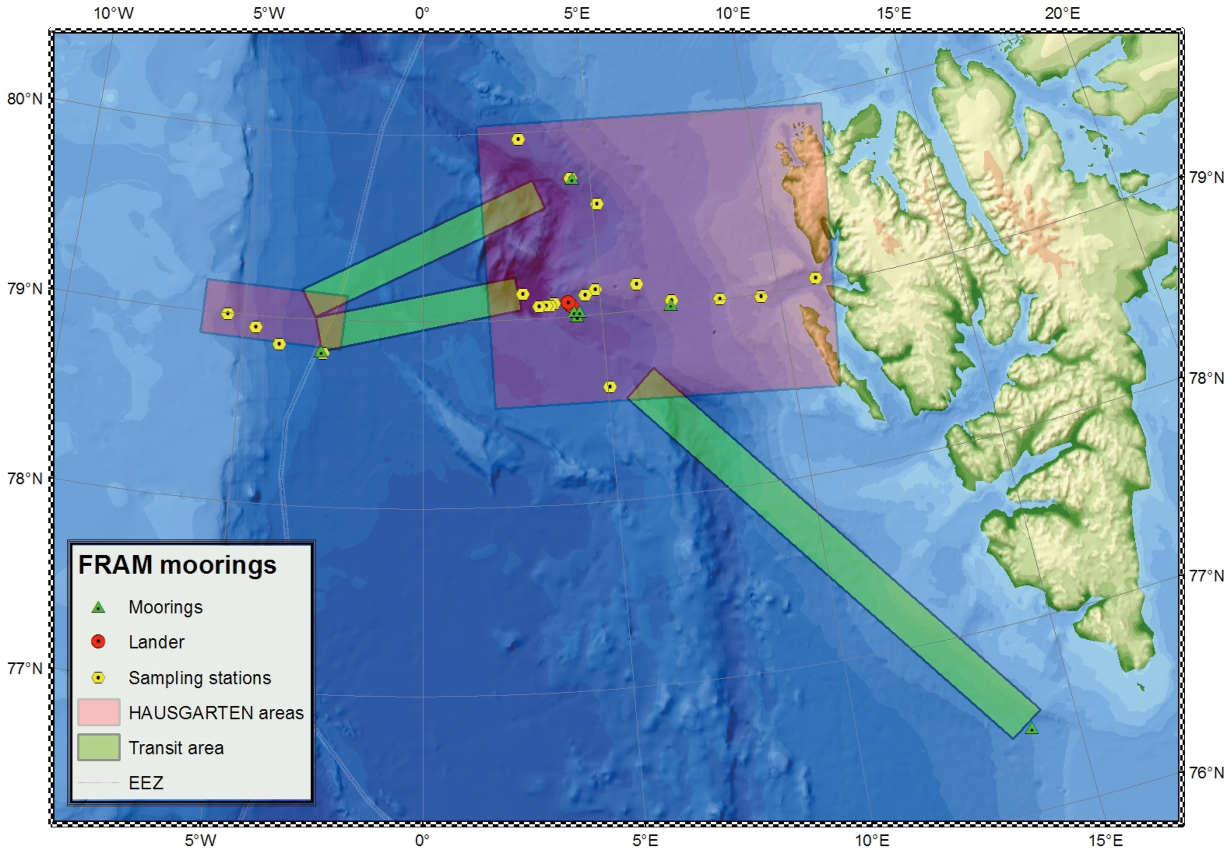


Abb. 1: Untersuchungsgebiete der Polarstern-Expedition PS107
Fig. 1: Areas of investigations during Polarstern expedition PS107

SUMMARY AND ITINERARY

The *Polarstern* expedition PS107 to the Arctic (Tromsø – Tromsø) will start on 23 July 2017 and lead particularly to study areas in the central and eastern Fram Strait.

It will contribute to various large national and international research and infrastructure projects (e.g. INTAROS, FRAM, SIOS, OceanSITES) as well as to the research programme PACES-II (Polar Regions and Coasts in the changing Earth System) of the Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung (AWI). Investigations within Work Package 4 (Arctic sea ice and its interaction with ocean and ecosystems) of the PACES-II programme, aim at assessing and quantifying ecosystem changes from surface waters to the deep ocean in response to the retreating sea ice, and at exploring the most important (feedback) processes determining temporal and spatial variability. Contributions to the PACES-II Work Package 6 (Large scale variability and change in polar benthic biota and ecosystem functions) include the identification of spatial patterns and temporal trends in relevant benthic community functions, and the development of a comprehensive science community reference collection of observational data. Work carried out within WPs 4 and 6 will support the time-series studies at the LTER (Long-Term Ecological Research) observatory HAUSGARTEN, where we will document Global Change induced environmental variations on a polar deep-water ecosystem. This work is carried out in close co-operation between the HGF-MPG Joint Research Group on Deep-Sea Ecology and Technology, the PEBCAO Group (Phytoplankton Ecology and Biogeochemistry in the Changing Arctic Ocean) at AWI and the Helmholtz Young Investigators Group SEAPUMP (Seasonal and regional food web interactions with the biological pump), representing a joint effort between the AWI, the MARUM - Center for Marine Environmental Sciences, and the University of Bremen.

The expedition will also be used to accomplish installations for the HGF infrastructure project FRAM (Frontiers in Arctic marine Monitoring). The FRAM Ocean Observing System aims at permanent presence at sea, from surface to depth, for the provision of near real-time data on Earth system dynamics, climate variability and ecosystem change. It serves national and international tasks towards a better understanding of the effects of change in ocean circulation, water mass properties and sea-ice retreat on Arctic marine ecosystems and their main functions and services. FRAM implements existing and next-generation sensors and observatory platforms, allowing synchronous observation of relevant ocean variables as well as the study of physical, chemical and biological processes in the ocean. Experimental and event-triggered platforms complement the observational platforms. Products of the infrastructure are continuous long-term data with appropriate resolution in space and time, as well as ground-truthing information for ocean models and remote sensing.

The cruise will end on 19 August 2017 in Tromsø (Norway).

2. MEASUREMENTS OF ATMOSPHERIC WATER VAPOR, AEROSOL AND THIN CLOUDS USING FT SPECTROSCOPY IN THE INFRARED

P. Richter (Uni Bremen),
M. Palm, J. Notholt, C. Weinzierl, R. Basu (Uni Bremen, not on board)

Objectives

We will use mobile FTIR spectrometers onboard the *Polarstern* cruise PS 107 in the Arctic to study the geographical and temporal distribution of H_2O, HDO, thin clouds and aerosol in the Arctic (Fig. 2.1). Together with the same suite of measurements at the AWIPEV research base in Ny-Ålesund, Spitsbergen the measurements will allow us to assess the representativity of the supersite in Ny -Ålesund for the Arctic.

a) Measurements of columnar H_2O and HDO

Solar absorption spectroscopy in the infrared can be used to determine the distribution of many infrared trace gases in the atmosphere. In particular it is possible to measure the isotopic composition H_2O in the troposphere. The isotopic ratio of H_2O and HDO can be used to study the history of the air parcels sampled.

b) Measurements of properties of aerosol layers and thin clouds

Emission spectroscopy in the infrared can be used to study the composition of aerosols and properties of thin clouds. Since the self-emission of the the atmosphere is measured, those measurements are independent of an external light source like moon or sun.

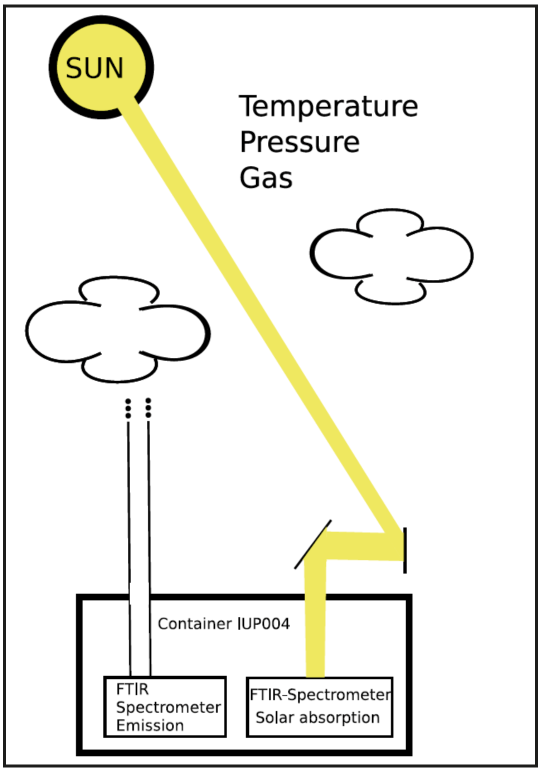


Fig. 2.1: Setup oft he FTIR measuring system during the expedition PS107. Two FTIR spectrometers are mounted within the container IUP004. One is used to detect atmospheric emissions by thermic infrared measurements. The second spectrometer is used for atmospheric absorption measurements by using a sun-tracer which is focusing the sunlight

Work on board *Polarstern*

Prior the departure from Bremerhaven a container containing two mobile FTIR instruments will be installed onboard *Polarstern*. The measurements will be performed continuously during the cruse whenever weather conditions permit.

1. FTIR Spectrometer Bruker IFS 66. This instrument will be used to measure down welling radiation in solar absorption mode. It requires clear sight to the sun during operation.
2. FTIR spectrometer Bruker IFS 28. It will be used to measure radiation emitted from the atmosphere. These measurements can also be performed during slightly cloudy conditions

Expected results

1. Low resolution profiles of H2O and HDO and their ratio will be derived from the solar absorption measurements. A trajectory model will be used to track the path of the air parcels sensed.
2. mean radius, and chemical composition of particles contained in clouds or aerosol layers.

Data management

All data processing and quality control will be carried out in the IUP, University of Bremen.

As soon as the data are available they will be accessible to other cruise participants and research partners on request. Depending on the finalization of academic theses and publications, data will be submitted to PANGAEA within 1-2 years.

3. BIOLOGICAL-PHYSICAL COUPLING AT THE SEA-ICE EDGE

W-J. von Appen, M. Falla, C. Wekerle, V. Schourup-Kristensen (AWI)

Objectives

The 4D survey will determine how processes associated with submesoscale fronts resupply nutrients to the euphotic layer. In Fram Strait, due to the shallow mixed layer, primary production will likely be enhanced where vertical upward nutrient transports into the euphotic layer occur. A towed undulating profiler (topAWI) is capable of properly measuring physical and biological parameters at submesoscale resolving horizontal resolution. It can be towed at speeds of 2–10 knots with a measurement range of 2–400 m and can be operated horizontally offset from the ship, outside of the ship's wake. The design of the process study (as illustrated in Fig. 3.1) has been guided by the results from a single transect across a meltwater front (Wulff et al., 2016) and studies at lower latitudes (Omand et al., 2015; Klymak et al., 2016).

The process study in Fram Strait will be located at a meltwater front. The recent sea surface temperature and ocean color product from the Sentinel 3A satellite provides images with a 300 m horizontal, i.e. submesoscale resolving, resolution in cloud free conditions. Through cooperation with Tilman Dinter (AWI) and Astrid Bracher (AWI), this data product will be available in near-real-time for survey planning at sea and afterwards to assess the regional representativeness of the measurements. Submesoscale fields rapidly evolve with e-folding instability growth rates of ~1/day in the high latitudes. Thus it is expected that a submesoscale front will evolve to adjusted or spun-down state within 4 days. The process study will start with an initial topAWI survey that aims to build a 3D description of the parameters controlling primary production. As the submesoscale fields within that surveyed volume of the ocean evolve, as many as possible consecutive surveys will study it over a period of 4 days.

Prior to the initial survey, 1–2 CTD casts will be taken in the area to calculate the depth of the mixed layer, the depth of the euphotic layer, and the depth of the Ekman layer. Submesoscale biological-physical coupling may take place between the surface and the deepest of these depths. In order to account for possible horizontal changes, the depth h to which the survey will measure will be ≈1.5 times the deepest of the CTD determined depths. In Fram Strait, that is likely going to be ≈50 m. The CTD casts will also be used to calculate the mixed layer Rossby radius R_{ML}. Based on the results of Wulff et al. (2016), it is likely going to be 1.5 km in Fram Strait. For illustrative purposes, the presumed Fram Strait values are used below, but it should be noted that the actual scales of the surveys will be adjusted to conform with the locally determined values of h and R_{ML}.

The survey will be laid out in a pattern as shown in Fig. 3.1. In order to be submesoscale resolving, the horizontal resolution should not exceed $R_{ML}/6$, i.e. 250 m. With a surveying depth of 50 m, we will employ a saw-tooth pattern of 250 m horizontal by 50 m vertical. In order to contain several frontal meanders or mixed layer eddies, which are roughly R_{ML} large, the whole survey area (Fig. 3.1) will cover an area of 6 by 6 R_{ML}, i.e. 10 km by 10 km. The horizontal spacing between adjacent sections will be 1 km, which is less than R_{ML} and thus allows for an appropriate estimation of the along-frontal gradients. This pattern (Fig. 3.1) results in a total section length of 120 km. At a towing speed of 7 knots, the survey will take 10 hours. Since the inertial period $2\pi/f \approx 12$ hours in Fram Strait, such a survey will be very close to synoptic, i.e. the physical state of the system will not have changed significantly during the time needed for the survey.

Before and after the initial survey, we will try to take *in-situ* water column samples with a CTD and multi-net for the biological and biogeochemical calibration of the measurements obtained by topAWI. This is important since the conversion from the raw voltage measurements of the instruments to the biologically relevant parameters such as biomass density depends on the species present.

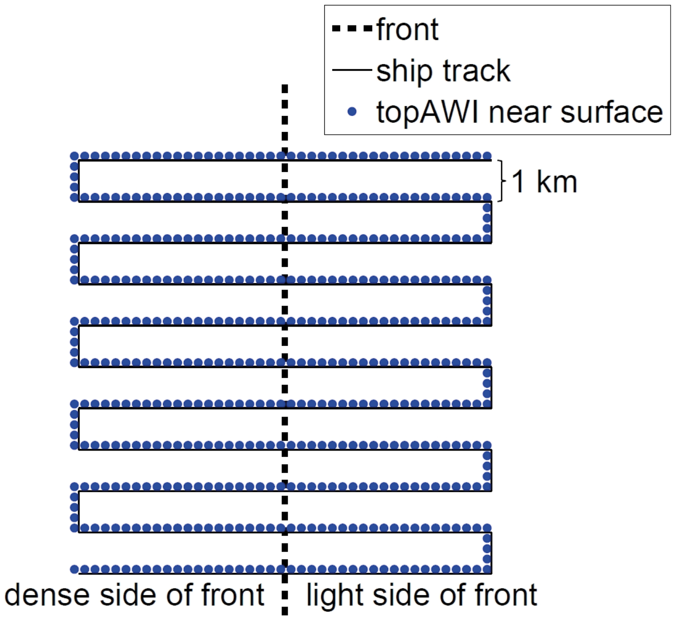


Fig 3.1: Top-down view of the planned submesoscale process study. The ship track starting in the top right is shown with respect to the front (black dashed line). topAWI will be towed 100 m horizontally offset from the ship and surface every 250 m.

The 2D section will establish the degree to which primary production is enhanced by submesoscale physical gradients through acquiring long-distance sections. The interaction of physical and biogeochemical parameters (eddy advection, Strass, 1992) and of biogeochemical parameters among each other (eddy reaction, Martin et al., 2015) on scales of the mesoscale and submesoscale appear to be important globally (Lévy et al., 2012). However, those estimates are almost entirely based on numerical models and Martin et al. (2015) call for more observational data in different parts of the world to assess whether and by how much they enhance primary production. This can be done with statistical correlation of the physical and biogeochemical parameters for which long-distance sections are an ideal data source.

We will try to acquire several long-distance sections with topAWI, with each section exceeding 10 R_{ML}; some sections may include sections with strong submesoscale gradients and others weak gradients. We will use transits of *Polarstern* between working areas targeted by other scientists on the cruise. The maximum length of an individual section will be 100 km. The vertical sampling range will be from near the surface down to 50 m or to 1.5 times the base of the mixed layer, whichever is deeper. The horizontal resolution will ideally be R_{ML} /6 in order to be submesoscale resolving in the along-track direction. We will keep the vertical sampling range and the horizontal resolution constant throughout each section in order to avoid analysis complications associated with non-uniform sampling. Roughly every 100 km, we will try to take a CTD and a multi-net cast for *in-situ* calibration of the sensors on topAWI. This is due to the fact that the phyto- and zooplankton species composition will likely change over such spatial distances. During each of the sections, we will record environmental parameters such as sea-ice concentration and significant wave height, as well as wind speed and direction. These parameters as well as stratification and the sampled water masses, define possibly different regimes of biological-physical interaction in the polar oceans.

Parameter	Sensor on topAWI
Distance to sea-ice	up and down looking altimeters
Location	iXBlue transponder
Temperature	SeaBird 911+ CTD with Dual TC Duct
Salinity	SeaBird 911+ CTD with Dual TC Duct
Oxygen concentration	SeaBird Oxygen sensors
Photosynthetically active radiation	Satlantic cosine PAR sensor
Species specific optics	TriOS Ramses Hyperspectral Radiometer
Transmission, absorption	WETLabs ACS in-situ transmissiometer and absorptionmeter
Transmission	WETLabs C-star Transmissiometer
Chlorophyll concentration	WETLabs Eco Fluorometer
Spectrally resolved absoroption	ac-s In-Situ Spectrophotometer
Velocity	150kHz RDI ADCP on *Polarstern*
Velocity, ~10cm scale turbulence	5-beam RDI ADCP 1200/600 kHz
Zooplankton concentration	2-F zooplankton echosounder EK80
Zooplankton concentration	Simrad EK60 on *Polarstern*

Table 3.1: Sensors integrated on the towed undulating profiler (topAWI)

Work at sea

AWI has purchased a towed undulating profiler ("topAWI") capable of measuring various biological, chemical, and physical parameters in the water column (see Table 3.1 for a full list). This complex system was used by AWI for the first time in February 2017 (*Heincke* HE477). On PS107, the system will be used on *Polarstern* for the first time. Acquiring experience in handling the system and ensuring that the mounted instruments reliably provide good data is the major goal on PS107 before the system can start routine operational mode. The locations of the testing will be chosen such that, if things go well, data are collected either in a 4D survey of a small region or in a 2D section along a long distance.

Data management

All the raw data collected by topAWI will be stored in the data publisher *Pangaea*. After it will have been processed at AWI, the processed data will also be made available through *Pangaea*.

References

Klymak, J. M., and Coauthors, 2016: Submesoscale streamers exchange water on the north wall of the Gulf Stream. Geophysical Research Letters, 43 (3), 1226–1233.

Lévy, M., R. Ferrari, P. J. Franks, A. P. Martin, and P. Rivière, 2012: Bringing physics to life at the submesoscale. Geophysical Research Letters, 39 (14).

Martin, A. P., M. Lévy, S. Gennip, S. Pardo, M. Srokosz, J. Allen, S. C. Painter, and R. Pidcock, 2015: An observational assessment of the influence of mesoscale and submesoscale heterogeneity on ocean biogeochemical reactions. Global Biogeochemical Cycles, 29 (9), 1421–1438.

Omand, M. M., E. A. D'Asaro, C. M. Lee, M. J. Perry, N. Briggs, I. Cetinic, and A. Mahadevan, 2015: Eddy-driven subduction exports particulate organic carbon from the spring bloom. Science, 348 (6231), 222–225.

Strass, V. H., 1992: Chlorophyll patchiness caused by mesoscale upwelling at fronts. Deep Sea Research Part A. Oceanographic Research Papers, 39 (1), 75–96.

Wulff, T., E. Bauerfeind, and W.-J. von Appen, 2016: Physical and ecological processes at a moving ice edge in the Fram Strait as observed with an AUV. Deep Sea Research, 115, 253–264, doi:10.1016/j.dsr.2016.07.001.

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

K. Metfies, N. Hildebrandt, N. Knüppel , Y. Liu, S. Murawski, S. Töller, S. Wiegmann (AWI),
R. Flerus, J. Grosse (GEOMAR)
A. Bracher, E.-M. Nöthig, I. Peeken, B. Niehoff (AWI, not on board)
A. Engel (GEOMAR, not on board)

Objectives and scientific programme

The Arctic Ocean has gained increasing attention over the past years because of the drastic decrease in sea ice and increase in temperature, which is about twice as fast as the global mean rate. In addition, the chemical equilibrium and the elemental cycling in the surface ocean will alter due to ocean acidification. These environmental changes will have consequences for the biogeochemistry and ecology of the Arctic pelagic system. The effects of changes in the environmental conditions on the polar plankton community can only be detected through long-term observation of the species and processes. Our studies on plankton ecology have started in 1991 and sampling has been intensified since 2009 in the Fram Strait at ~79°N. Since then our studies are based on combining a broad set of analysed parameters. This includes e.g. classical bulk measurements and microscopy, optical measurements, satellite observations, molecular genetic approaches, or cutting edge methods for zooplankton observations to study plankton ecology in a holistic approach. Over the past eight years we have compiled complementary information on annual variability in plankton composition, primary production, bacterial activity or zooplankton composition. Since 2014 the PEBCAO group is a member of the FRAM (Frontiers in Arctic Monitoring) Ocean Observatorium Team providing ground truth information for water column monitoring of plankton ecological, biogeochemical parameters and microbial (prokaryotic and eukaryotic) biodiversity. We are also involved in the development of automatic platforms and sampling technology for long-term observation in the Arctic Ocean with main focus on the AWI HAUSGRTEN situated in the Fram Strait.

Climate induced changes will impact the biodiversity in pelagic ecosystems with concomitant changes in carbon cycling and sequestering. At the base of the food web, we expect small algae to gain more importance in mediating element and matter turnover as well as matter and energy fluxes in future Arctic pelagic systems. In order to examine changes, including the smallest fractions, molecular methods are applied to complement traditional microscopy.

The characterization of the communities with molecular methods is independent of cell-size and distinct morphological features. The assessment of the biodiversity and biogeography of Arctic phytoplankton will be based on the analysis of ribosomal genes with next generation sequencing technology, Automated Ribosomal Intragenic Sequence Analysis (ARISA), and quantitative PCR. Zooplankton organisms are affected by the changes at the base of the food web and, this may alter the transport and modification of organic matter. Also, the zooplankton community composition may shift due to the warmer Atlantic water in the Fram Strait. Most of our knowledge on zooplankton species composition and distribution has been derived from traditional multiple net samplers, which allow to sample depth intervals of several hundred meters. Newly developed optical methods, such as the zooplankton recorder LOKI (light frame on-sight key species investigations), now continuously take pictures from the organisms floating in the water column from 1,000 m depth to the surface. Linked to each picture, hydrographical parameters are being recorded, e.g. salinity, temperature, oxygen concentration and fluorescence. This allows to exactly identifying distribution patterns in relation to environmental conditions.

Global change increasingly affects also pelagic microbial biogeochemistry in the Arctic Ocean. Thus we will continue to monitor concentrations of organic carbon and nitrogen as well as of specific compounds like gel particles, amino acids and carbohydrates. The analysis of dissolved organic compounds will be combined with those of particles. The particulate fraction can be divided into phytoplankton and bacteria, both with different functions in marine food webs. The composition of carbohydrates and amino acids of phytoplankton biomass reflects the relative availability of inorganic nutrients and determines the particles' food quality for zooplankton. Additionally, phytoplankton releases dissolved compounds, which in turn fuel growth of heterotrophic bacteria and remineralization processes. By linking compound dynamics and bacteria, phyto- and zooplankton community structure we will gain further inside into the flow of carbon through Arctic food webs. Our overarching goal is to improve the mechanistic understanding of biogeochemical and microbiological feedback processes in the Arctic Ocean and to assess the potential for changes in the near future.

Ocean colour remote sensing allows for estimating the overall phytoplankton biomass (indicated by chlorophyll-a concentration (chl-a)) and of distinctive major groups and coloured dissolved organic matter (CDOM) at greater spatial and temporal scales. However, at high latitudes ocean colour satellite data have sparse coverage due to the presence of sea ice, clouds and low sun elevation. We use the PEBCAO *in-situ* data as input and for validation of satellite ocean colour algorithms. We will run continuously in the surface water a WET labs AC-S hyperspectral transmissiometer and absorption meter, but also during stations hyperspectral radiometers and an additional AC-S in the water profile, in order to develop the analysis of optical data to obtain continuous information on phytoplankton overall biomass, composition, size structure and CDOM loading, These continuously measured optical data require frequent validation with measurements by direct biological or chemical analysis of water samples. We will take from the surface water regularly (every 3 hours) and at 6 water depths during CTD stations water samples for pigment composition (HPLC) and absorption of particles, phytoplankton and CDOM. The received bio-optical and biochemical data will also serve for validation of similar measurements obtained with the AUV and other autonomous platforms (an AC-S mounted to the topAWI-system) during the cruise. With that as much as possible collocated data to Sentinel-3 (launched in February 2016) ocean color sensor OLCI data shall be acquired for validation and if launched until then also with data from the TROPOMI sensor on-board Sentinel-5 Precursor. (The group of A. Bracher is part of the Sentine-3 Validation Team). This research will give a fundamental contribution for further development of hyper- and multispectral ocean colour satellite retrievals focusing on fluorescence and absorption signals.

In summary during PS 107 the following topics are covered:

- Monitoring plankton species composition and biomass distribution
- Monitoring biogeochemical parameters
- Investigations on selected phyto- and zooplankton and related biogeochemical parameters
- Composition of organic matter in a changing Arctic Ocean
- Investigation on the amount and composition of CDOM and its interplay with phytoplankton
- Characterization of the underwater light field and its interplay with optical constituents, such as phytoplankton and CDOM

Work at sea

Biogeochemical & biological parameters from rosette samples, including the automated filtration system for marine microbes AUTOFIM

We will sample Arctic seawater by CTD/rosette sampler at the main HAUSGARTEN/ FRAM stations at about 3-10 depths (details see below).

In addition to this we will collect particles close to the surface (~ 10 m) with the automated filtration system for marine microbes AUTOFIM (Fig. 4.1) that is coupled to the ships pump system. Using AUTOFIM we will collect seawater after regular intervals (~ 1° longitude / latitude) starting as soon as possible after *Polarstern* has left Svalbard and in parallel to the sampling via CTD. AUTOFIM allows filtration of a sampling volume up to 5 litres. In total 12 filters can be taken and stored in a sealed sample archive. Prior to the storage a preservative can be applied to the filters to prevent degradation of the sample material, that can be used for molecular or biochemical analyses.

Water samples for CDOM absorption analysis are filtered through 0.2 µm filters and analyzed onboard with a 2.5-m path length liquid waveguide capillary cell system (LWCC, WPI). Particulate and phytoplankton absorption coefficients are determined with the quantitative filter techniques using sample filtered onto glass-fiber filters QFT-ICAM and measuring them in a portable QFT integrating cavity setup Röttgers et al. (2016).

Measurements for alkalinity will also be performed on board.

All other samples will be partly filtered and preserved or frozen at - 20°C and partly at - 80° C for further analyses. At the home laboratory at AWI we will determine the following parameters to describe the biogeochemistry and the abundance and biomass distribution of protists:

- Chlorophyll a concentration (total and fractionated)
- HPLC pigments
- Dissolved organic carbon (DOC)
- Particulate organic carbon (POC)
- Total dissolved nitrogen (TDN)
- Particulate organic nitrogen (PON)
- Particulate biogenic silica (PbSi)
- Particulate organic phosphorus (POP)
- Transparent exopolymer particles (TEP)
- Coomassie-stainable particles (CSP)
- Particulate and dissolved combined carbohydrates and amino acids
- Phytoplankton, protozooplankton and bacterial abundance

- Molecular based information (Next Generation Sequencing, quantitative PCR) on community structure, diversity and distributional patterns of protists
- Information on the quality of automated sampling and sample preservation using AUTOFIM

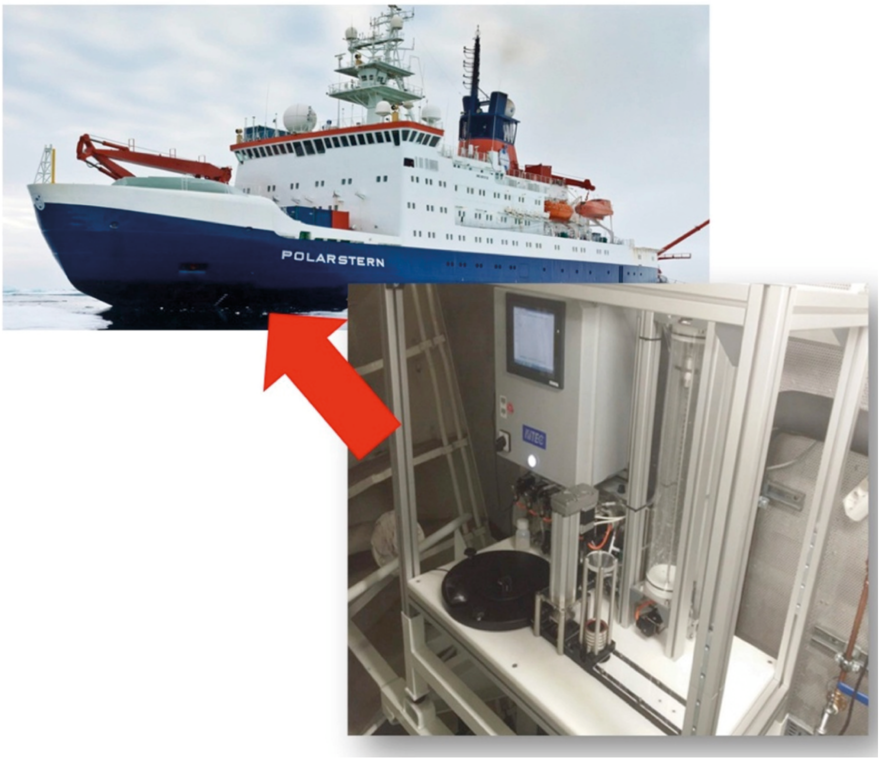


Fig. 4.1: The fully automated filtration module AUTOFIM is installed on RV Polarstern in the "Bugstrahlruderraum" close to the inflow of the ships-pump system. AUTOFIM is suited to collect samples with a maximum volume of 5 Liters. Filtration can be triggered on demand or after fixed intervals.

Zooplankton sampling

Mesozooplankton composition and depth distribution will be determined by means of vertical Multi net tows from 1,500m depth to the surface. In addition, optical surveys with the LOKI (light on-sight key species investigations, Fig. 4.2) will be conducted to determine the small-scale distribution of zooplankton in the water column. Bongo net hauls will be taken to collect organisms for biochemical analyses (carbon, nitrogen, protein and lipid content, fatty acid composition).

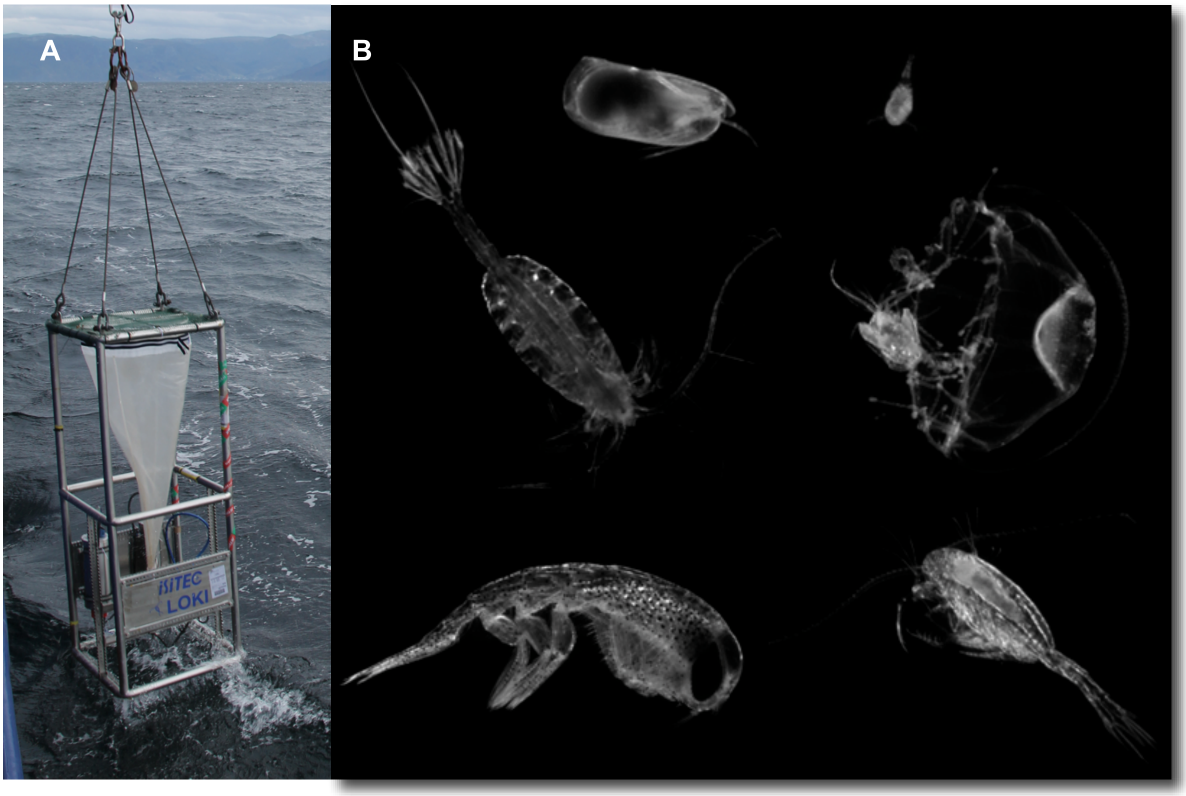


Fig. 4.2: The LOKI system during deployment (A) and a compilation of photographs taken by LOKI (B); in clockwise direction: an ostracod (Boroecia sp.), a small cyclopoid copepod (Oncaea sp.), a jelly fish (Botrynema ellinorae), a large calanoid copepod (Metridia longa), a hyperiid amphipod (Themisto libellula) and a large calanoid copepod (Paraeuchaeta sp.) (Pictures, N. Hildebrandt, AWI).

Continuous optical measurements

Continuous inherent optical properties (IOPs) with a hyperspectral spectrophotometer: For the continuous underway surface sampling an *in-situ*–spectrophotometer (AC-S; WET labs) will be operated in flow-through mode to obtain total and particulate matter attenuation and absorption of surface water. The instrument is mounted to a seawater supply taking surface ocean water (Fig. 4.3). A flow-control with a time-programmed filter is mounted to the AC-S to allow alternating measurements of the total and the CDOM inherent optical properties of the sea water. Flow-control and debubbler-system ensure water flow through the instrument with no air bubbles.

A second AC-S instrument is mounted on a steel frame together with a depth sensors and a set of hyperspectral radiometers (Ramses sensors from TRIOS, Fig. 4.3) and operated during CTD stations. The frame is lowered down to maximal 120 m with a continuous speed of 0.1 m/s or during daylight with additionally stops at 2, 4, 6, 8, 10, 12.5, 15, 20, 25 and 30 m to allow a better collection of radiometric data (see later).

The Apparent Optical Properties of water (AOPs) (mostly light attenuation through the water column) will be estimated based on downwelling and upwelling irradiance measurements in the surface water profile (down to the 0.1% light depth) from the radiometers calibrated for the incident sunlight with measurements of a radiometer on deck. The AC-S will measure the inherent optical properties (IOPs: total attenuation, scattering and absorption) in the water profile.

Another AC-S instrument will be operated on the topAWI system (see chapter 3 in this expedition booklet). The measurements of the AC-S run continuously at surface and in the water column during stations will be inter-compared to the AC-S run on the topAWI system to ensure quality control for the topAWI-AC-S system.

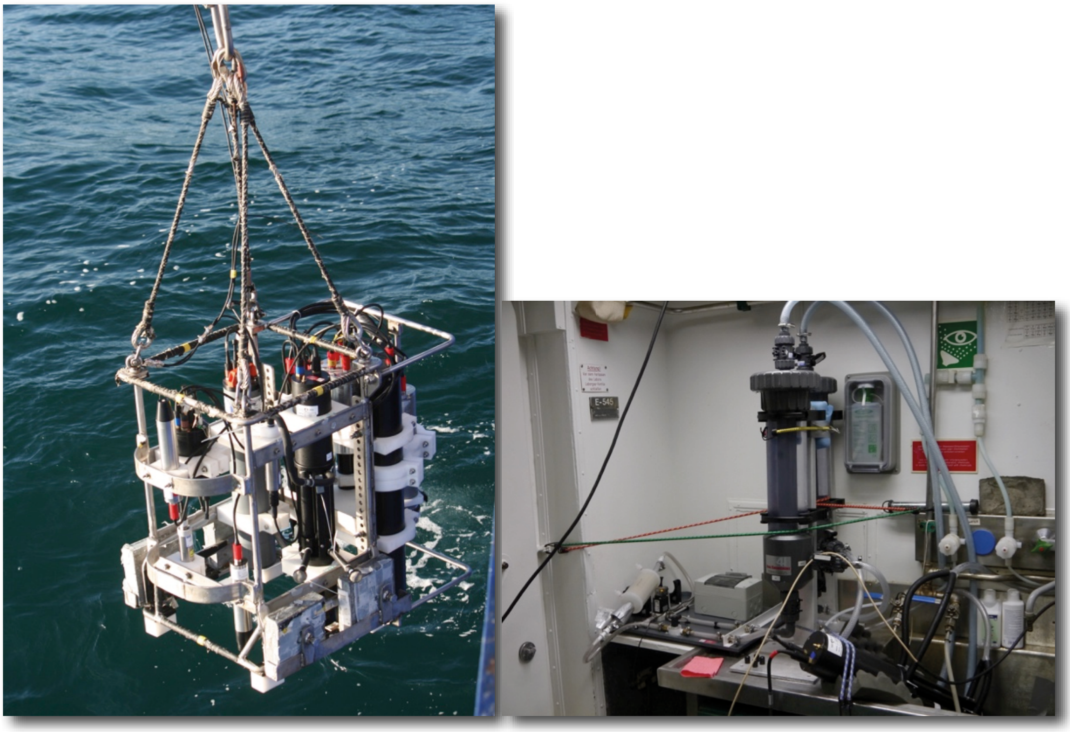


Fig. 4.3: Left: Underwater light field measurements (during FRAM expedition PS 99) with TRIOS RAMSES radiometers detecting the hyperspectral up- and downwelling radiation and WETLABS AC-s (including data logger and battery) measuring extinction and absorption within the surface water profile. (In addition on the right also a SUNA nitrate sensor is mounted on the frame). The data are used via using semi-analytical techniques to determine the concentration of optical constituents, such as chl-a conc., CDOM absorption and particle backscattering, but also for validating satellite ocean colour retrievals.

Right: Continuous measurements of the extinction and absorption of light in Arctic surface waters using a WETLABS AC-s mounted to the RV Polarstern surface sea water pump system. From those measurements directly the absorption and scattering of particles and CDOM is determined for the whole spectrum in the visible resolved with about 3 nm resolution. This data then can be decomposed various specific algorithms to determine the particle size distribution and the various phytoplankton pigment composition.

Data management and samples

During our cruises, we sample a large variety of interconnected parameters. Many of the samples (i.e. pigment analyses, particulate matter in the water column, etc.) will be analysed at AWI and at GEOMAR within about a year after the cruise. We plan that the full data set will be available at latest about two years after the cruise. Most of species samples and samples which will not be analysed immediately, will be stored at the AWI at least for another 10 years and will be available for other colleagues. Data will be made available to the public via PANGAEA after publishing (depending on how many comparisons will be made, long-term study 2 to 5 years after the cruise). ACs data are foreseen to be uploaded at the FRAM data portal as raw data immediately after the cruise and as calibrated data set after careful executing quality controls and calibrations with discrete water sample measurements.

References

Röttgers, R. Doxaran, D. and C. Dupouy (2016) Quantitative filter technique measurements of spectral light absorption by aquatic particles using a portable integrating cavity absorption meter (QFT-ICAM), Opt. Express 24, A1-A20.

5. SENSITIVITY OF ARCTIC ZOOPLANKTON TO TEMPERATURE CHANGE: FROM ECOPHYSIOLOGICAL EFFECTS TO COMMUNITY RESPONSE

H. Auel, C. Havermans, E. Köhler (Uni Bremen), R. Zelm (MARUM), M. Scheel (UAlg)

Background and objectives

In the Arctic marginal seas, such as Fram Strait, closely related, congeneric species of polar vs. boreal-Atlantic origin occur sympatrically. It is expected that the polar representatives will be replaced by boreal-Atlantic congeners in the course of global climate change and warming. In order to better understand the dynamics and potential effects of this shift in species composition, species-specific sensitivities of polar vs. boreal-Atlantic species to temperature increase will be determined experimentally. Respiration measurements will be conducted onboard at different ambient temperatures. Differences in gene activity and gene regulation between polar and Atlantic species at different ambient temperatures will be studied in collaboration with the University of the Algarve. In addition, long-term changes in zooplankton species composition over the last 20 years shall be studied by comparing the current situation with comparative data from 1997 and 2006.

The Arctic Ocean and adjacent ice-covered seas are the areas most rapidly and strongly affected by global warming over the coming decades. Climate models predict a rise in air temperature in the Arctic by 3 to 6°C over the coming 50 years. The temperature increase will be similar throughout the year, but with stronger effects during the summer season, when it will result in a longer and more intense melting period of the sea ice. Within one or two human generations, we will continue to witness principal changes in the extent, thickness and seasonal coverage of sea ice, strongly affecting not only ice-associated biota, but also pelagic communities beneath the ice.

Physical oceanographic studies in Arctic Fram Strait revealed an increasing Atlantic inflow via the West Spitsbergen Current in recent years, although it is not yet clear whether this is a temporary event or the start of a permanent regime shift.

Zooplankton are particularly suitable as indicators of environmental change due to their rapid response (generally short life-cycles), direct coupling to physical forcing (relatively passive drifters) and the fact that they are not subject to targeted harvesting, which could bias or obscure other environmental impacts. In the North Atlantic, a northward shift of several hundred kilometers of the distribution ranges of many zooplankton species has been observed with more southerly species replacing northerly relatives at higher latitudes.

Climate change induced impacts on species composition also occur in Arctic marine ecosystems. Repetitive analyses of zooplankton community structure demonstrate substantial changes in species composition and biodiversity between the 1990s and 2006, both in Fram Strait and in Svalbard fjord systems. Boreal-Atlantic species have shifted in distribution further north and now dominate plankton communities in Fram Strait. For instance, in the AWI Hausgarten sediment trap time series from 2000 to 2012, the boreal-Atlantic amphipod *Themisto compressa* only occurred from 2004 onwards. Until 2010 only older individuals were present indicating that reproduction still did not take place in the Fram Strait region. However, in 2011 the presence of ovigerous females and recently hatched juveniles provided first evidence of reproductive success of this southern invader at high-Arctic latitudes.

Such changes in species composition will have a strong impact on secondary production of Arctic seas, pelagic-benthic coupling processes and sedimentation rates, in particular as most of the boreal-Atlantic species are smaller and have a lower lipid content than their polar relatives. However, different components of polar food webs will react differently to climate change and increasing Atlantic inflow. Based on model calculations, a mismatch in the timing of the phytoplankton bloom and the seasonal ascent of the dominant copepod *Calanus hyperboreus* from its hibernation depth could disrupt pelagic food chains and lead to a system dominated by microzooplankton that would not support higher trophic levels and fisheries. In contrast, other studies predict an increased zooplankton production and a better food supply for pelagic fish in conjunction with warmer sea surface temperatures. Thus, present predictions are still highly controversial and the effects of an increasing Atlantic inflow on pelagic biodiversity and productivity represent key questions for future ecological research in the Arctic. Further studies on the physiological and ecological response of key species to ocean warming and an increasing Atlantic inflow will enable us to assess and forecast potential impacts of global change on marine pelagic ecosystems in Arctic seas.

Fram Strait represents the ideal location to study temperature-induced effects on Arctic zooplankton as it is characterized by opposing ocean currents, which provide substantially different hydrographic regimes and zooplankton communities in close proximity. On the eastern side of Fram Strait, the West Spitsbergen Current transports relatively warm and saline water from the North Atlantic northward into the Arctic Ocean, whereas on the western side, the East Greenland Current transports cold polar water and sea ice derived from the Transpolar Drift southward into the Atlantic Ocean. Thus, short steaming distances of only 250 to 300 nm across Fram Strait allow access to different hydrographic domains from Atlantic to polar waters with the associated respective plankton communities.

The most interesting aspect for studies on the temperature sensitivity of zooplankton in Fram Strait is the fact that both plankton communities, the boreal-Atlantic and the polar, are dominated by closely related sister species from the same genera. Among the biomass-rich herbivorous copepods, *Calanus hyperboreus* and *Calanus glacialis* are most abundant under Arctic and polar conditions, whereas *Calanus finmarchicus* dominates biomass in the Atlantic domain of the West Spitsbergen Current. Similarly on the carnivorous trophic level, pairs of congeners prevail either under polar or under boreal-Atlantic conditions, such as the copepods *Paraeuchaeta glacialis* (polar) vs. *Paraeuchaeta norvegica* (boreal-Atlantic) or the hyperiid amphipods *Themisto libellula* (polar) vs. *Themisto abyssorum* and *Themisto compressa* (both boreal-Atlantic). Among the euphausiid shrimps (krill), *Thysanoessa inermis* prevails in polar regions, whereas *Thysanoessa longicaudata* is dominant under boreal-Atlantic conditions.

In most cases, the polar sister species is substantially larger and contains more lipids than the boreal-Atlantic congener. This has profound consequences for marine food chains in the Arctic. Often the larger, more lipid-rich polar species are the preferred prey. For instance, little auks (*Alle alle*), which are the most abundant seabirds in the marginal ice zone of Fram Strait, almost exclusively feed on the polar *T. libellula* and *C. hyperboreus*. Although very abundant in the West Spitsbergen Current, *C. finmarchicus* is too small or not adequate as food item for little auks. Therefore, changes in the zooplankton species composition will propagate throughout the food web and result in altered trophic pathways.

In order to establish at which temperature thresholds changes in zooplankton species composition from polar to boreal-Atlantic species will occur and what consequences they will have, the temperature sensitivity of Artic key zooplankton species will be studied.

The project will address and test the following four hypotheses and issues:

- Boreal-Atlantic zooplankton species will have a higher tolerance with regard to increasing ambient temperatures than their polar sister species. Species-specific tolerance thresholds for dominant pelagic species with regard to increasing water temperatures will be established.
- Polar and boreal-Atlantic zooplankton species differ in gene activity and gene regulation. Some of these differences are triggered by ambient temperature. For that purpose, comparative gene expression responses and transcriptional regulation of polar vs. boreal-Atlantic key zooplankton species will be established under varying thermal regimes. These data will be integrated with physiological responses to temperature to gain insight into phenotypic differentiation in Arctic and boreal-Atlantic species that may be crucial for adaptation under climate change scenarios.
- Zooplankton species composition in Fram Strait has already been subject to long-term changes over the past 20 years.
- Polar and boreal-Atlantic zooplankton differ in lipid content and, hence, nutritional value for predators.

Work at sea

Mesozooplankton will be sampled by stratified vertical hauls down to 2,000 m with opening and closing nets (Hydro-Bios MultiNet, 200 µm mesh size). In order to combine deep sampling with a higher vertical resolution of the upper water layers, two successive hauls will be conducted at each station to 2,000 m depth and to 200 m depth, respectively. Macrozooplankton such as amphipods and krill will be collected by double oblique tows with a Bongo net (500 µm mesh size). Specimens of the target species will be sorted immediately after the catch in a temperature-controlled lab container and used for respiration experiments onboard or genetic and biochemical analyses in the home labs. The remains of the samples will be preserved for later quantitative analysis of species composition and abundance.

Sampling will concentrate on two transects across Fram Strait between approx. 78°N and 80°N in order to cover the different hydrographic regimes.

To establish species-specific temperature sensitivities, respiration measurements will be conducted onboard with polar and boreal-Atlantic zooplankton species at different ambient temperatures (*in-situ*, +2°C, +4°C, +6°C, and +8°C). Their respiration rates and behaviour will be recorded by high resolution optode respirometry throughout the incubation at different temperatures. The physiological response of polar vs. boreal-Atlantic key species to increasing temperatures will be compared and species-specific tolerance thresholds with regard to temperature will be determined. These results will help to understand at which temperature thresholds shifts in species composition from polar to boreal-Atlantic congeners are to be expected and how far distribution ranges will change. Are boreal-Atlantic “invaders” better adapted to increasing temperatures than polar congeners and, if so, how will this affect future species composition and trophic interactions under scenarios of global climate change?

Additional samples will be collected, incubated at different temperature regimes and preserved in RNA later for transcriptomic analyses. Studies will focus on the same species and temperature treatments as the respiration measurements to foster an integrated interpretation of physiological and genetic results. The objective is to identify genetic differences – in gene activity and/or gene regulation – that could explain phenotypic (i.e. physiological) differentiation between polar and boreal-Atlantic species that may be crucial for adaptation under climate change scenarios. For that purpose, total RNA will be extracted from specimens and used for RNAseq. Generation of de novo transcriptome assemblies, transcriptome analysis, and subsequent bioinformatic analysis (functional annotation, gene expression) will be performed at the University of the Algarve.

Individuals of polar and boreal-Atlantic zooplankton species will be collected and deep-frozen at -80°C onboard for determination of dry mass and lipid content at Bremen University. A quantitative assessment of the different caloric and nutritional value of polar vs. boreal-Atlantic zooplankton will help to better understand the effects of shifts in zooplankton species composition on higher trophic levels such as fish and seabirds and for the structure and secondary production of Arctic marine ecosystems in general.

Data management and samples

Data and samples to be collected during the cruise will be analysed by the cruise participants and collaborating scientists. They will form an integral part of two Ph.D. theses. The results will be published within two to three years after the cruise. Geo-referenced data sets such as plankton abundance or biomass, will be archived and made publicly accessible via the PANGAEA database, jointly operated by MARUM and AWI. DNA sequence data to be obtained from molecular genetic analyses will be archived and published in GenBank. Quantitative plankton samples preserved in formaldehyde or ethanol will be stored at BreMarE, Bremen University.

6. PELAGIC FOOD WEB INTERACTIONS WITH THE BIOLOGICAL PUMP

M. H. Iversen (AWI), C. Konrad, M. Kriegl (MARUM)

Rationale

Anthropogenic activities have increased atmospheric carbon dioxide (CO2) levels to above 400 ppm, higher than at any point during the past 2 to 5 million years. Small sinking particles in the ocean are paramount for the control of carbon dioxide removal from the atmosphere and into the ocean. This is because the formation of sinking aggregates from photosynthetic plankton moves carbon from the surface to the deep ocean, which allows for further uptake of atmospheric carbon dioxide by the ocean. In this way, the oceans have the capacity to sequester large amounts of atmospheric CO2 by exporting biologically fixed carbon to the deep ocean. The sinking aggregates also feed life below the ocean’s surface sustaining the biomass of deep sea fish and other organisms and determine sediment formation on the seafloor. However, most of the organic matter produced by photosynthetic plants in the surface ocean is eaten by small animals or degraded by bacteria before it sinks deeper than 100 meters. This means that the carbon dioxide is only removed from the atmosphere for a few weeks before it is outgassed from the ocean again. The particles need to sink below 1,000 meter depth to be removed from the atmosphere for more than 1,000 years and only those particles reaching the seafloor will have their organic matter stored for millennia. Unfortunately we know very little about processes that remove and transform the particles as they sink through the water column and, hence, the sequestration of atmospheric carbon dioxide in the world's oceans is only poorly understood. Only by understanding those processes can we make any hopes of bringing the carbon that we have released via fossil fuel burning back into the ocean-floor. Since the end of the 19th century we humans have added more carbon dioxide to the atmosphere than accumulated there in a 5,000-year period when the last Ice Age came to an end. Back then, the ice shields covering North America and parts of Eurasia (combined continental landmass of Europe and Asia) melted and caused a 130 meter sea level rise.

Objectives and scientific programme

Our main objective during the cruise is to study the controlling mechanisms for attenuation and export of organic carbon flux through the water column. This will be done by detailed investigations of particle dynamics in relations to plankton community structure and aggregate composition. We will do this by looking at both large and small scale, i.e. on a whole water perspective using *in-situ* optics and drifting traps on short time-scale or by using our BioOptical Platform for long-term patterns in aggregate size-distribution and abundance. The small scale study will be done on individual aggregates collected in from different depths through the water column.

Work at sea

We will perform deployments and recoveries of drifting trap arrays and use a combination of different optical, biological, and physical sensors to capture particle processes through the water column. This will be done at the long-term monitoring stations in the AWI HAUSGARTEN. These studies will be accompanied by laboratory experiments to investigate specific mechanisms responsible for *in-situ* carbon turnover within marine settling aggregates. These studies will be done on *in-situ* collected material (using the marine snow catcher) to measure rates for zooplankton flux feeding and microbial degradation. Each drifting sediment trap consists of three trap arrays (e.g. 100, 200, 400 m depths) each with four collection cylinders. At every trap depth, one of the collection cylinders are filled with a special gel to preserve fragile marine snow aggregates sinking into the cylinders. The deployment times will be over a day-night cycle. In addition to the sediment traps, there will be an infra-red camera system on the drifting array which will capture the zooplankton activity and make it possible observe the influence from zooplankton migration and flux feeding on the biological pump.

Concomitant investigations of the water column are planned. These investigations include deployments of the profiling *in-situ* particle camera, the ship's rosette-CTD, the ships acoustic system SIMRAD and PARASOUND, and multi-nets and LOKI for zooplankton distributions (in collaboration with Babara Niehoff, AWI). The vertically changing particle concentrations and size distribution determined with the *in-situ* optical systems can be used to derive high resolution carbon fluxes and remineralisation rates in various depth ranges. These high resolution carbon fluxes will enable determinations of bacterial degradation rates and, in combination with the quantification of zooplankton from vertical hauls with the multi-net, consumption rates of aggregates due to zooplankton flux feeding. Water samples from the rosette sampler and sinking aggregates collected with the Marine Snow Catcher are used to study the formation, physical characteristics, organic carbon remineralisation and size-specific sinking rates of marine snow and fecal pellets. We will also recover our prototype of the BioOptical Platform and deploy an updated version of the BOP system to follow the settling of particles and changes in particle types and sizes throughout a whole year.

Data and samples

We expect to be able to quantify the role from microbes and zooplankton and carbon flux attenuation, as well as quantify the export fluxes through the upper mesopelagic zone.

7. FREE-LIVING AND PARTICLE-ASSOCIATED BACTERIAL AND ARCHAEAL COMMUNITIES IN FRAM STRAIT

E. Fadeev, M. H. Iversen, T. Hargesheimer (AWI), C. Bienhold (MPI-MM, not on board)
Ian Salter (AWI, not on board)

Objectives and scientific programme

Long-term studies at the LTER HAUSGARTEN observatory in the past two decades have revealed changes in pelagic microbial communities, *e.g.* shifts in the phytoplankton community from diatom-dominated towards *Phaeocystis*-dominated communities (Soltwedel et al., 2015). But no baseline has been established yet for bacterial and archaeal communities, in order to assess temporal changes in their structure and function as a result of changing environmental conditions. In the framework of the FRAM project, a Molecular Microbial Observatory is currently established. Within this framework, samples will be obtained using various platforms to study the composition and function of bacterial and archaeal communities of different water masses in the Fram Strait (Soltwedel et al., 2013). The work will be coordinated with and linked to the sampling of eukaryotic microbial communities (Chapter 4).

Sinking particulate organic matter (POM) plays a major role in linking pelagic and benthic ecosystems (De La Rocha and Passow, 2007). Sinking particles get quickly colonized by microbial communities and degraded on their way through the water column, eventually reaching the seafloor. Characterizing colonization patterns and the composition and function of bacteria and archaea on sinking particles will thus help to better understand organic matter export in different regions of Fram Strait. Our main objective during the expedition will be to better understand the effect of “seed” free-living microbial communities from different water masses, on the colonization and degradation patterns of POM. An experimental set-up will be complemented by analyses of environmental samples (*e.g.* marine snow catcher and sediment traps).

Work at sea

Water samples for bacterial and archaeal community structure analyses will be obtained using 12L Niskin bottles housed on a rosette equipped with SBE conductivity–temperature–depth (CTD) sensors or using Large Volume Water Transfer Systems (WTS-LV), which allow collecting samples *in-situ* onto 142mm membrane filters. The sampling stations and depths will be coordinated with the sampling of eukaryotic microbial communities (Chapter 4). Triplicates from each sample will be filtered using peristaltic pumps through a Sterivex filter (0.22 μm pore size, Millipore).

The particle incubation experiment will be conducted in freshly sampled water from distinct water masses, targeting the surface North Atlantic waters (AW) in the eastern part of the Strait and the surface Polar waters (PSW) in the western part. The water will be collected at 50 m using a CTD, in order to target microbial communities below the DCM, which are adapted to fresh sinking POM. In parallel to the water collection using niskin bottles, the same water masses will be sampled using marine snow catchers (Chapter 6). Using rotating tanks, we will incubate magnetic chitin particles in the different water samples and conduct time series sampling for cell counts, nucleic acid extraction, enzymatic activity, and nutrients concentrations.

Data management

Post-cruise data archival will be mainly hosted by the information system PANGAEA at the World Data Centre for Marine Environmental Sciences (WDC-MARE), which is operated on a long-term base by the Alfred-Wegener-Institute Helmholtz-Zentrum für Polar- und Meeresforschung (AWI), Bremerhaven and the Zentrum für Marine Umweltwissenschaften (MARUM), Bremen. Scientific data retrieved from observations, measurements and home-based data analyses will be submitted to PANGAEA either upon publication or with password protection as soon as the data is available and quality-assessed. This includes also biological data, for most of which parameters are already defined in PANGAEA. Molecular data will be deposited in public repositories such as NCBI and ENA. Microbiological samples will be stored deep frozen or fixed at the Max Planck Institute for Marine Microbiology (MPIMM) in Bremen. Two of the three replicates from each sample will be used for the long term biological archive of the Molecular Observatory at the Alfred-Wegener-Institute Helmholtz-Zentrum für Polar- und Meeresforschung (AWI), Bremerhaven.

References

De La Rocha, C. L., and Passow, U. (2007). Factors influencing the sinking of POC and the efficiency of the biological carbon pump. Deep Sea Res. Part II Top. Stud. Oceanogr. 54, 639–658. doi:10.1016/j.dsr2.2007.01.004.

Soltwedel, T., Bauerfeind, E., Bergmann, M., Bracher, A., Budaeva, N., Busch, K., et al. (2015). Natural variability or anthropogenically-induced variation? Insights from 15 years of multidisciplinary observations at the arctic marine LTER site HAUSGARTEN. Ecol. Indic., 1–14. doi:10.1016/j.ecolind.2015.10.001.

Soltwedel, T., Schauer, U., Boebel, O., Nöthig, M., Bracher, A., Metfies, K., et al. (2013). FRAM - FRontiers in Arctic marine Monitoring Visions for Permanent Observations in a Gateway to the Arctic Ocean.

8. FRAM POLLUTION OBSERVATORY: ASSESSMENTS OF ANTHROPOGENIC LITTER AND MICROPLASTIC IN DIFFERENT ECOSYSTEM COMPARTMENTS

M. Tekman (AWI), A. Lusher (UiO)
M. Bergmann, L. Gutow, G. Gerdts (AWI, not on board)

Objectives and scientific programme

Marine litter has long been on the political and public agenda as it has been recognised as a rising pollution problem affecting all oceans and coastal areas of the world (Bergmann et al., 2015a). There is currently a discrepancy of several orders of magnitude between estimates of global inputs of plastic litter and figures derived from field measurements highlighting again the question ‘Where is all the plastic?’(Thompson et al., 2004). Degradation of larger litter items into smaller particles termed ‘microplastics’ may be one reason for this discrepancy. Another possibility is that certain ecosystem compartments have not been considered so far. For example, 50 % of the polymers from municipal waste have a density higher then seawater and sink directly to the seafloor, which has been proposed as a sink of marine litter.

Indeed, analysis of seafloor photographs taken at the central station of the HAUSGARTEN observatory indicated that litter doubled between 2002 and 2011 and reached densities similar to those reported from a canyon near the Portuguese capital Lisbon (Bergmann and Klages, 2012). More recent work has shown that litter has continued to increase and has spread further to the North of HAUSGARTEN (N3)(Tekman et al., 2016). Litter was also observed floating at the sea surface in the Fram Strait and Barents Sea (Bergmann et al., 2015b). Recent reports also indicate high concentrations of microplastics in Arctic sea ice (Obbard et al., 2014) and in surface waters south of Svalbard (Lusher et al., 2015), corroborating the presence of a projected sixth garbage patch (van Sebille et al., 2012). Despite the fact that many polymers have a density similar to seawater and may drift in the water column, little is known about the presence of microplastic in the pelagic realm. So, this might be another sink of litter or microplastic.

Fig 8.1: Litter recorded during PS93/ARK XXIX OFOS dives at HAUSGARTEN stations

Work at sea

1. OFOS transects conducted during PS 107 (N3, HG IV, S3, HG I, HG IX) will enable us to assess if marine litter continues to increase on the seafloor. The new footage will extend our image time series that started in 2002.
2. *In-situ* pumps will be used to sample microplastics from large volumes of water in different environmental settings and from different depth strata during deep CTD casts: Kb0/V12 (coastal, 50, 250m), HG IV (WS current 50, 250, 1000, 2,500 m), HG IX (depression, 50, 250, 1,000, 5,500 m), EG IV (EG current, 50, 250, 1,000, 2,500 m), N5 (ice covered, 50, 250, 1,000, 2,500m).
3. Sediments from the same stations will be sampled to assess microplastic contamination of the seafloor (multiple corer).
4. Microplastic contamination of the sea surface will be assessed by deployments of a neuston catamaran at selected stations
5. If possible, snow samples will be gathered during helicopter flights to ice floes to assess atmospheric fallout as a pathway of microplastic to the north.

6. Observer surveys will be done from the working deck to assess litter densities at the sea surface when the ship is in transit.
7. Passive polyethylene samplers will be recovered from the long-term lander to assess the potential of plastic as vectors of persistent organic pollutants adsorbing to their surface to the deep seafloor (Sun et al., 2016) and to assess ambient concentrations of persistent organic pollutants in deep Arctic sediments.
8.

Data management

The image data will be uploaded to PANGAEA and BIIGLE. After completion of analyses and publication, the results will be uploaded to PANGAEA and be fed into the marine litter portal LITTERBASE.

References

Bergmann, M., Gutow, L., Klages, M., 2015a. Marine Anthropogenic Litter. Springer, Berlin.

Bergmann, M., Klages, M., 2012. Increase of litter at the Arctic deep-sea observatory HAUSGARTEN. Marine Pollution Bulletin 64, 2734–2741.

Bergmann, M., Sandhop, N., Schewe, I., D'Hert, D., 2015b. Observations of floating anthropogenic litter in the Barents Sea and Fram Strait, Arctic. Polar Biology.

Lusher, A.L., Tirelli, V., O'Connor, I., Officer, R., 2015. Microplastics in Arctic polar waters: the first reported values of particles in surface and sub-surface samples. Scientific Reports 5, 14947.

Obbard, R.W., Sadri, S., Wong, Y.Q., Khitun, A.A., Baker, I., Thompson, R.C., 2014. Global warming releases microplastic legacy frozen in Arctic Sea ice. Earth's Future 2 (6), 2014EF000240.

Sun, C., Soltwedel, T., Bauerfeind, E., Adelman, D.A., Lohmann, R., 2016. Depth Profiles of Persistent Organic Pollutants in the North and Tropical Atlantic Ocean. Environ Sci Technol 50 (12), 6172-6179.

Tekman, M.B., Krumpen, T., Bergmann, M., 2016. Marine litter on deep Arctic seafloor continues to increase and spreads to the North at the HAUSGARTEN observatory. Deep Sea Research Part I: Oceanographic Research Papers.

Thompson, R.C., Olsen, Y., Mitchell, R.P., Davis, A., Rowland, S.J., John, A.W.G., McGonigle, D., Russell, A.E., 2004. Lost at Sea: Where Is All the Plastic? Science 304 (5672), 838.

van Sebille, E., England, M.H., Froyland, G., 2012. Origin, dynamics and evolution of ocean garbage....patches from observed surface drifters. Environmental Research Letters 7 (4), 044040.

9. HAUSGARTEN: IMPACT OF CLIMATE CHANGE ON ARCTIC MARINE ECOSYSTEMS

I. Schewe, E. Fadeev, J. Hagemann, T. Hargesheimer, U. Hoge, B. Lemcke, N. Lochthoven, J. Ludszuweit, B. Sablotny, I. Salter, M. Tekman (AWI), M. Seifert (Uni Bremen), K. Deja, M. Mazurkiewicz (IOPAN), J. Bäger, R. Stiens (MPI-MM)

Objectives and scientific programme

Polar Regions play a central role for the global climate, as the ice albedo has a crucial influence on the Earth's heat balance. While always in fluctuation, the global climate is presently experiencing a period of rapid change, with a warming trend amplified in the Arctic region. Results of large-scale simulations of the future Earth's climate by several global climate models predict a further increase in temperatures, also leading to further reduction in ice cover. Moreover, there has been a significant thinning of the sea ice by approx. 50 % since the late 1950s. In its recent report, the Intergovernmental Panel on Climate Change (IPCC) predicted that the Arctic Ocean could become ice free at the end of this century, while others argue that this scenario might even take place much earlier, with a forecast as early as end of Arctic summer 2040.

The shift from a white cold ocean to a darker, warmer ocean will have severe impacts on the polar marine ecosystem. Thinner ice may permit better growth of ice algae, but more rapid spring melting may reduce their growing season. The timing and location of pelagic primary production will generally alter. Whether sea ice retreat generally leads to an increase in primary productivity is under debate, but biogeochemical models predict no or even negative changes in productivity and export flux. Altered algal abundance and composition will affect zooplankton community structure and subsequently the flux of particulate organic matter to the seafloor, where the quantity and quality of this matter will impact benthic communities. Changes in the predominance of certain trophic pathways will have cascading effects propagating through the entire marine community. Generally, Arctic marine organisms will be compromised by temperature regimes approaching the limits of their thermal capacity. As a consequence, warmer waters in the Arctic will allow a northward expansion of sub-arctic and boreal species. Besides water temperature increase, expanding ocean acidification will pose another threat to pelagic and benthic life in the Arctic Ocean.

To detect and track the impact of large-scale environmental changes in the transition zone between the northern North Atlantic and the central Arctic Ocean, and to determine experimentally the factors controlling deep-sea biodiversity, the Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung (AWI) established the LTER (Long-Term Ecological Research) observatory HAUSGARTEN. Since 2014, this observatory has successively extended within the frame of the HGF financed infrastructure project FRAM (Frontiers in Arctic marine Monitoring) and covers currently 21 permanent sampling sites on the West-Spitsbergen and East-Greenland slope at water depths between 250 and 5,500 m.

During the *Polarstern* expedition PS107 (Tromsø - Tromsø), multidisciplinary research activities will be conducted at all HAUSGARTEN stations (Fig. 9.1). The research programme will 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, has taken place since the observatory was established back in 1999.

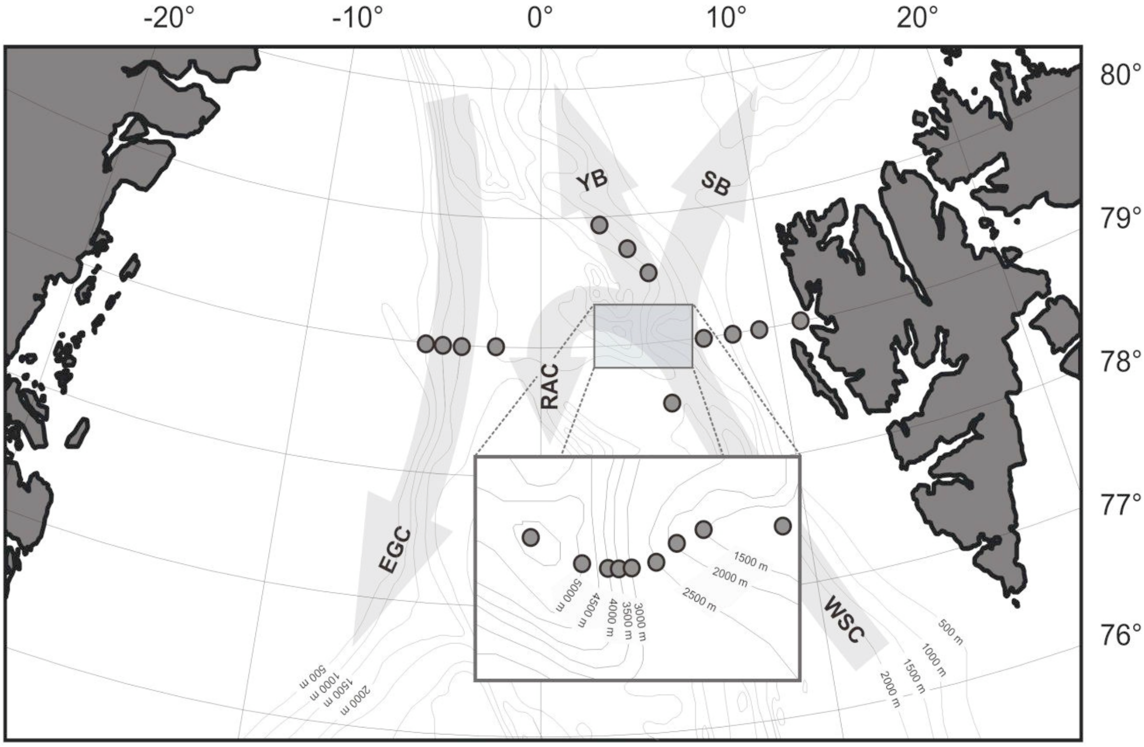


Fig. 5.1: Permanent sampling sites of the LTER Observatory HAUSGARTEN in Fram Strait

Work at sea

Vertical flux of particulate organic matter

Hydrographic data and upper ocean properties will be assessed using a cabled CTD-rosette water sampler

Measurements of the vertical flux of particulate matter at HAUSGARTEN have been conducted since the establishment of the observatory. By means of these measurements we are able to quantify the export of organic matter from the sea surface to the deep sea, and trace changes in these fluxes over time. The organic material which is produced in the upper water layers or introduced from land is the main food source for deep-sea organisms. Measurements of organic matter fluxes are conducted by bottom-tethered moorings carrying sediment traps at a ~200 m and ~1,000 m below sea-surface, and about 180 m above the seafloor (Fig. 9.2). In addition to moored sediment traps new autonomous infrastructure will be deployed on the HAUSGARTEN moorings to track seasonal changes in the dissolved and particulate constituents of the upper water column. These include McLane RAS 500 water samplers that are programmed to collect and preserve water samples (~0.5 L) with approximately weekly resolution, and particle samplers that filter and preserve ~10 L water samplers with approximately bi-weekly resolution. Besides sediment traps the moorings are equipped with Aanderaa currentmeters (RCM8, RCM11), self-recording CTD's (Seabird MicroCATs), and a suite of biogeochemical sensors (full details below). During the *Polarstern* expedition PS107, we will recover moorings and instruments that were deployed at ~2,500 m water depth during the *Polarstern* expedition PS99.2 in 2016.

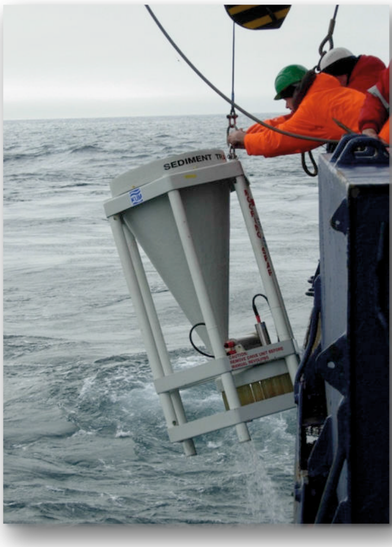


Fig. 9.2: Deployment of a sediment trap to assess particle fluxes to the seafloor

During *Polarstern* expedition PS107 we will re-deploy moorings and instruments at the three main HAUSGARTEN sites in the Western Fram Strait as well as at HG-IV and N4. In addition to these long-term mooring locations two “high-risk moorings” will be exchanged at the newly defined stations F4-S and HG-IV-S that have the objective to place autonomous water column sampling devices shallower in the water column to try and follow the seasonality in biological and chemical parameters in the upper 30 m of the water column. This includes RAS-500 water sampling devices and McLane phytoplankton and particle sampling devices. Numerous biogeochemical sensors are attached to the frames of these autonomous sampling devices and will be exchanged as well.

At the central HAUSGARTEN site, we will deploy a special mooring with an advanced prototype profiling winch system carrying a sensor package. This device has been developed within the BMBF funded project ICOS-D (Integrated Carbon Observation System, Germany) and conducts, in an earlier prototype version deployed in 2016, measurements within the upper 200 m of the water column at regular preprogrammed intervals. At present, the sensor package consists of instruments for measuring carbon dioxide, oxygen, conductivity, temperature, pressure, and chlorophyll fluorescence.

At all stations where moorings are deployed, we will conduct CTD-rosette water sampler casts from the surface close to the seafloor. Water samples will be taken for the analyses of chlorophyll a, particulate organic carbon and nitrogen (POC/N), particulate phosphorous, biogenic particulate silica (bPSi), total particulate matter (seston), calcium carbonate (CaCO3), and the stable isotopes content (δ15N/δ13C) in the particulate matter. This work as well as the sampling at the other HAUSGARTEN stations will be conducted in close cooperation with the PEBCAO group. For further details regarding the work in the water column see Chapter 4.

Investigations of the smallest benthic biota

Virtually undisturbed sediment samples will be taken using a video-guided multicorer (TV-MUC; Fig. 9.3). Various biogenic compounds from these sediments will be analysed to estimate activities (i.e. bacterial exoenzymatic activity) and the total biomass (i.e. particulate proteins, phospholipids) of the smallest sediment-inhabiting organisms. Results will help to describe ecosystem changes in the benthal of the Arctic Ocean. Sediments retrieved by the TV-MUC will also be analysed for the quantitative and qualitative assessment of the small benthic biota (meiofauna).

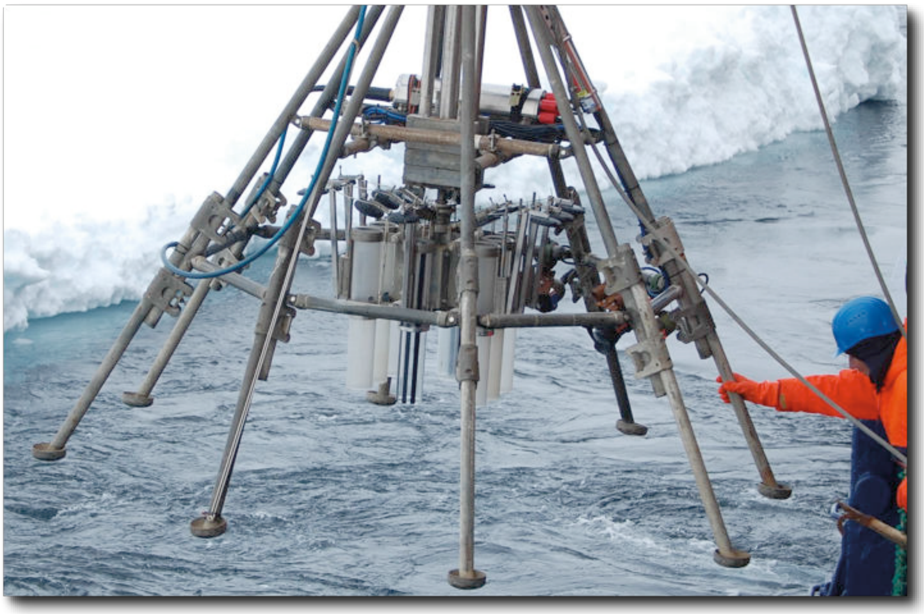


Fig. 9.3: Sediment sampling using a video-guided multicorer (TV-MUC)

Spatial and temporal variations in the structure of macrofaunal benthic communities

Related to climate change, fluctuations in extent of sea ice and ocean currents are now observed in regions of the North Atlantic and southern edges of the Arctic Ocean. In the Fram Strait is localized Marginal Ice Zone, which is especially sensitive to fluctuations of environmental changes caused by climate warming. Recent compilation of 15-year series of investigations conducted in this area showed that between years 2004 and 2008, there was a significant change in hydrological conditions, called Warm Water Anomaly (WWA).

It is already documented that variability of sea ice extent in MIZ has influence on biomass and composition of phytoplankton (Cherkasheva et al. 2014), what has influence on zooplankton and thereafter on the flux of particulate organic matter to the sea floor (Soltwedel et al. 2016). Warm Water Anomaly left a strong footprint in the Arctic marine ecosystem (Soltwedel et al. 2016). Changes in sea ice extent, taxonomic composition of phytoplankton, sedimentation fluxes of particulate organic matter and hence quantity and quality of organic matter reaching to the sea floor was documented after WWA (Soltwedel et al. 2016).

The aim of the study is to determine the influence of changes in environmental regime on deep sea benthic communities in Fram Strait. The object of research will be benthic communities (across meio and macrofauna - their taxonomic composition, biomass, secondary production, respiration and size spectra) in shelf, slope and deep sea sediments.

We hypothesize that increased organic matter sedimentation rate, observed after Warm Water Anomaly determine 1) increase of macro and meiofauna biomass and changes in macrofaunal species composition 2) increase of contributions of larger (macrofaunal) size classes in total benthic standing stocks and functioning.

The hypotheses assume that we can expect that the biomass, respiration, production of the benthic fauna in Arctic sediments will increase in the course of the global warming. That implies greater consumption of sedimentary organic carbon, its faster re-introduction into the metazoan food webs with the consequences for the carbon cycling in this region.

Several environmental variables and meiofauna assemblages have been monitored in Hausgarten area continually since 1999. The meiofauna monitoring was focused on the species composition, diversity and biomass of the dominant group – Nematoda (Hoste et al. 2007, Górska et al. 2014). Macrofaunal materials were collected only sporadically. The assessments of bathymetric gradients in species composition, diversity and total macrofaunal biomass were based on materials collected in 2000 and 2003 and published by Włodarska-Kowalczuk et al. (2004), Węsławski et al. (2003) and Budaeva et al. (2008). In 2010 Górska and Włodarska-Kowalczuk (unpublished study) collected samples of both meio- and macrofauna on 15 stations located along the bathymetric gradient (280-5,000 m) in Hausgarten. Based on these materials they explored the bathymetric gradient in benthic biomass size spectra (Górska and Włodarska-Kowalczuk, manuscript in preparation).

In the framework of the present project it is planned to compare the structure and functioning of benthic communities of Hausgarten habitats before and after WWA. The research material will include samples collected in depth gradient from 300 to 3,000 m in 2000 and 2003 (before WWA), 2010 and 2017 (after WWA). The composition, biomass, size spectra, secondary production, respiration of zoobenthic communities in the bathymetric gradient from shelf, through slope to deep sea will be assessed and compared among sampling years, with the special emphasis on testing for differences between the period before and after WWA.

Moreover, in the present study we would like to address methodological aspect of deep-sea surveys of meiobenthos: the size of sampling core required for the proper estimation of the taxonomic composition in the deep sea sediments.

Work at sea

It is planned to collect samples of meio and macrofauna in 2017 from the same 15 stations as in 2010. At each station samples will be collected from Giant Box Corer (Fig. 9.4): two subsamples for macrozoobenthos (20 cm deep samples of 0.1 m2 surface area, samples sieved on 0.5 mm sieves and fixed with 4 % buffered formalin), three subsamples for meiozoobentos and two for sediment characteristics (5 cm deep samples from small cores of 10 cm2 surface area; meiofauna fixed with 4 % buffered formalin, samples for sediment characteristics frozen in -80ºC). Such a sampling scheme was used to in the previous campaigns.

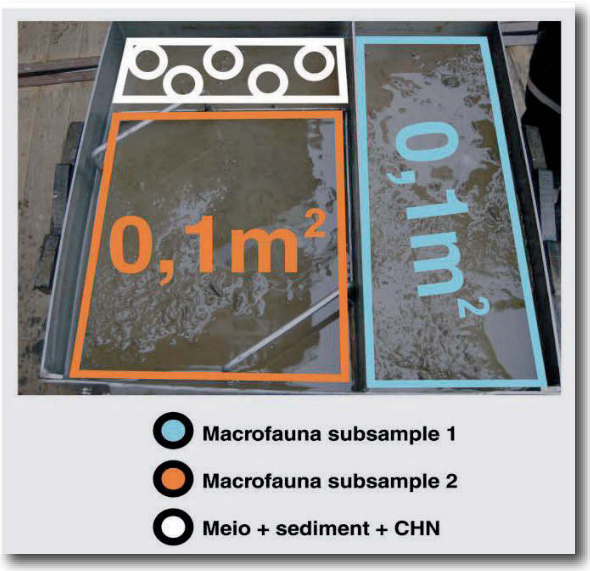


Fig. 9.4: Schematic subsampling of the box corer surface

Samples for methodological studies will be collected at 9 monitoring stations (HG I-HG IX: 1,200-5,500 m) using three different techniques: 1) with use hand core from giant box corer (sampling area 10 cm^2), 2) with use syringe from multiple corer (sampling area 3.14 cm^2) and 3) with use the whole core of multiple corer (sampling area 63.59 cm2).

Sample processing: In laboratory all metazoan organisms will be identified to the possible lowest taxonomic resolution, counted, photographed with camera connected to stereomicroscope and measured with use of digital image analysis in LAS v4.2 software. For the polychaete specimens, which were fragmented during the sample sieving, total length of the specimens will be calculated using equations of the regression between the total length and the width of a selected chaetiger (specific to the family or order; Górska et al., manuscript in preparation). Semi-automated image analysis method will be used for nematode measurements (Mazurkiewicz et al. 2016). Individual biovolumes will be converted to dry weight [μg].

Benthic biomass size spectra will be constructed by plotting the total biomass in each size class against the log2-transformed size of a class. Each individual will be classified into log2 size classes based on its dry weight [μg].

Individual biomass data will be used to calculate annual production and respiration of the studied communities. Production/biomass ratio and annual secondary production as well as mass specific respiration rate and respiration for macrofauna will be estimated using the Artificial Neural Network models as proposed by Brey (2012). Meiofaunal production and respiration will be estimated using equations published by Schwinghamer et al. (1986).

Sediment samples will be analyzed for environmental parameters including chloroplastic pigments, organic carbon content, total nitrogen, isotopic signatures (δ13C), grain size, water content in sediments will be assessed as an indicator of sediment stability.

Fig 9.5: Benthic Megafauna at LTER HAUSGARTEN

Megafaunal dynamics on the seafloor

Through the continuous redistribution of organic matter, oxygen and other nutrients in surficial sediments by remineralisation, bioturbation and burial of sunken matter, benthic biota play an important role in the global carbon cycle. Epibenthic megafauna inhabit the sediment–water interface and are defined as the group of organisms ≥1 cm (Fig. 9.5). They contribute considerably to benthic respiration and have a strong effect on the physical and biogeochemical micro-scale environment. Megafaunal organisms create pits, mounds and traces that enhance habitat heterogeneity and thus diversity of smaller sediment-inhabiting biota in otherwise apparently homogenous environments. Erect biota enhance 3-d habitat complexity and provide shelter from predation. Megafaunal predators control the population dynamics of their prey and therefore shape benthic food webs and community structure.

Sunken organic matter that is not converted into benthic biomass and forwarded along food chains, might be actively transported from the water column-sediment interface into the sediment by bioturbation. Organic matter is then degraded/recycled into nutrients and CO2. Mega- and macrofaunal species thus actively influence biogeochemical processes at the sediment–water interface. An understanding of megafaunal dynamics is therefore vital to our understanding of the fate of carbon at the deep seafloor, Earth's greatest carbon repository.

During PS 107, we will continue to study interannual dynamics of megafaunal organisms using our towed Ocean Floor Observation System (OFOS). The OFOS will be towed along established tracks at HAUSGARTEN stations of the latitudinal transect (N3, HG IV, S3), HG I and the Molloy Hole. The new footage will extend our image time series that started in 2002 (Bergmann et al. 2011; Meyer et al. 2013).

In a new approach, we will study smaller-scale changes on the seafloor over longer time scales. To this end, a new time-lapse camera will be fitted to the benthic long-term lander and tested for a short time period at HG IV. If trials are satisfactory, the camera will be fitted to the long-term lander and deployed to take pictures throughout a whole year.

Proposed work:

- OFOS deployments to assess interannual dynamics of megafauna and litter on the seafloor at selected stations
- Short-term trial deployment of time-lapse camera
- Long-term deployment of time-lapse camera to assess seasonal dynamics of megafauna

Data and samples

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

References

ACIA (2006) Arctic Climate Impact Assessment - Scientific Report. Cambridge University Press, Cambridge

Brey, T. 2012. A multi-parameter artificial neural network model to estimate macrobenthic invertebrate productivity and production. Limnol. Oceanogr. Methods 10: 581–589

Budaeva, N. E., V. O. Mokievsky, T. Soltwedel, and A. V. Gebruk. 2008. Horizontal distribution patterns in Arctic deep-sea macrobenthic communities. Deep Sea Res. Part I Oceanogr. Res. Pap. 55: 1167–1178

Cherkasheva, A., Bracher, A., Melsheimer, C., Köberle, C., Gerdes, R., Nöthig, E. M.,Bauerfeind, E., Boetius, A., 2014. Influence of the physical environment on polarphytoplankton blooms: a case study in the Fram Strait. J. Mar. Syst. 132, 196–207

Górska, B., K. Grzelak, L. Kotwicki, C. Hasemann, I. Schewe, T. Soltwedel, and M. Włodarska-Kowalczuk. 2014. Bathymetric variations in vertical distribution patterns of meiofauna in the surface sediments of the deep Arctic ocean (HAUSGARTEN, Fram strait). Deep Sea Res. Part I Oceanogr. Res. Pap. 91: 36–49

Hoste E, Vanhove S, Schewe I, Soltwedel T, Vanreusel A. 2007. Spatial and temporal variations in deep-sea meiofauna assemblages in the Marginal Ice Zone of the Arctic Ocean. Deep Sea Research I 54:109-129

Mazurkiewicz, M., B. Górska, E. Jankowska, and M. Włodarska-Kowalczuk. 2016. Assessment of nematode biomass in marine sediments: A semi-automated image analysis method. Limnol. Oceanogr. Methods. 14: 816-827

Schwinghamer, P., B. Hargrave, D. Peer, and C. M. Hawkins. 1986. Partitioning of production and respiration among size groups of organisms in an intertidal benthic community. Mar. Ecol. Prog. Ser. 31: 131–142.

Soltwedel, T., E. Bauerfeind, M. Bergmann, and others. 2016. Natural variability or anthropogenically-induced variation? Insights from 15 years of multidisciplinary observations at the arctic marine LTER site HAUSGARTEN. Ecol. Indic. 65: 89–102

Weslawski JM, Wlodarska-Kowalczuk M, Legezynska J (2003) Occurence of soft-bottom macrofauna along the depth gradient in High Arctic, 79 N. Polish Polar Research 24:73-88

Wlodarska-Kowalczuk M, Kendall MA, Weslawski JM, Klages M, Soltwedel T (2004) Depth gradiebts of benthic standing stock and diversity on the continental margin at a high-latitude ice-free site (off Spitsbergen, 79 N). Deep-Sea Res I 51:1903-1914

10. TEILNEHMENDE INSTITUTE / PARTICIPATING INSTITUTIONS

	Address
AWI	Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung Postfach 120161 27515 Bremerhaven Germany
DWD	Deutscher Wetterdienst Geschäftsbereich Wettervorhersage Seeschifffahrtsberatung Bernhard Nocht Str. 76 20359 Hamburg Germany
GEOMAR	GEOMAR Helmholtz Centre for Ocean Research Kiel Wischhofstr. 1-3 24148 Kiel Germany
HeliService	HeliService international GmbH Gorch-Fock-Str. 105 D-26721 Emden Germany
IOPAN	Institute of Oceanology of Polish Academy of Sciences Powstańców Warszawy 55 81-712 Sopot Poland
MARUM	Zentrum für Marine Umweltwissenschaften der Universität Bremen Leobener Straße 28359 Bremen Germany
MPI-MM	Max-Planck-Institut für Marine Mikrobiologie Celsiusstr. 1 28359 Bremen Deutschland
OGS	Istituto Nazionale di Oceanografia e di Geofisica Sperimentale Borgo Grotta Gigante 42/C 34010 Sgonico Italy

	Address
UAlg	Universidade do Algarve Campus da Penha 8005-139 Faro PORTUGAL
Uni Bremen	Universität Bremen Bibliothekstraße 1 28359 Bremen
UiO	The University of Oslo Boks 1072 Blindern NO-0316 OSLO Norway

11. FAHRTTEILNEHMER / CRUISE PARTICIPANTS

Name/ Last name	Vorname/ First name	Institut/ Institute	Beruf/ Profession	Fachbereich/ Discipline
Auel	Holger	Uni Bremen	Scientist	Zooplankton
Bäger	Jana	MPI-MM	Technician	Deep-Sea Ecology
Bensi	Manuel	OGS	Scientist	Oceanography
Deja	Kajetan	IOPAN	Student	Macrofauna
Fadeev	Eduard	AWI	PhD Student	Biogeochem., Nutrients
Falla	Maria	AWI	Engineer	Oceanography, topAWI
Flerus	Ruth	GEOMAR	Technician	Biol. Oceanogr
Grosse	Julia	GEOMAR	Scientist	Biol. Oceanogr
Hagemann	Jonas	AWI	Technician Mooring	biogeochem. sensors
Hargesheimer	Theresa	AWI	Technician	BioGeochem., Nutrients
Havermans	Charlotte	Uni Bremen	Scientist	Zooplankton
Hildebrandt	Nicole	AWI	Scientist	Biol. Oceanogr., Zooplankton
Hoge	Ulrich	AWI	Engineer	OFOS, BioGeochem-Moorings
Iversen	Morten	Uni Bremen	Scientist	Biol. Oceanogr., Drifting Arrays
Knüppel	Nadine	AWI	Technician	Molecular Methods
Köhler	Eva	Uni Bremen	Student	Zooplankton
Konrad	Christian	Uni Bremen	Engineer	Biol. Oceanogr.
Kraus	Florian	Uni Bremen	Student	Deep-Sea Ecology
Kriegl	Michael	Uni Bremen	Student	Biol. Oceanogr
Laso Perez	Rafael	MPI-MM	PhD Student	Biogeochem., Nutrients
Lemcke	Bianka	AWI	FöJ	Deep-Sea Ecology

Name/ Last name	Vorname/ First name	Institut/ Institute	Beruf/ Profession	Fachbereich/ Discipline
Liu	Yangyang	AWI	PhD Student	PHYTOOPTICS
Lochthofen	Normen	AWI	Engineer	Mooring-deployments
Ludszuweit	Janine	AWI	Technician	Mooring-deployments
Lusher	Amy	UiO	Scientist	Litter, Megafauna
Mazurkiewicz	Mikołaj	IOPAN	PhD Student	Macrofauna
Metfies	Katja	AWI	Scientist	Molecular Biology, Protist-diversity
Murawski	Sandra	AWI	Technician	Plankton-Ecology
NN		AWI	Engineer,	Mooring deployments
Richter	Philipp	Uni Bremen	Scientist	Atmosphere
Sablotny	Burkhard	AWI	Engineer	MUC, Lander
Salter	Ian	AWI	Scientist	Biogeochem., Nutrients
Scheel	Maria	Ualg	Student	Zooplankton
Schewe	Ingo	AWI	Cruise Leady	Deep-Sea Ecology
Schorup-Kristensen	Vibe	AWI	Scientist	modelling topAWI
Seifert	Miriam	AWI	Student	Deep-Sea Ecology
Stiens	Rafael	MPI-MM	Technician	Deep-Sea Ecology
Tekman	Mine	AWI	PhD Student	Litter, Megafauna
Töller	Susanne	AWI	Technician	Molecular Biology, Protist diversity
von Appen	Wilken-Jon	AWI	Scientist	Oceanography, topAWI
Wekerle	Claudia	AWI	Scientist	modelling, topAWI
Wiegmann	Sonja	AWI	Technician	PHYTOOPTICS
Zelm	Reinhard	MARUM	Technician	Zooplankton

Name/ Last name	**Vorname/ First name**	**Institut/ Institute**	**Beruf/ Profession**	**Fachbereich/ Discipline**
NN		DWD	Meteorologist	
NN		DWD	Technician	meteorology
NN		HeliService	Pilot	
NN		HeliService	Pilot	
NN		HeliService	Technician	
NN		HeliService	Technician	

12 . SCHIFFSBESATZUNG / SHIP'S CREW

No.	Name	Rank
01.	Schwarze, Stefan	Master
02.	Grundmann,	1.Offc.
03.	Farysch, Bernd	Ch. Eng.
04.	Langhinrichs, Moritz	EO Ladung
05.	Hering, Igor	2.Offc.
06.	Fallei, Holger	2.Offc.
07.	NN	Doctor
08.	Christian, Boris	Comm.Off
09.	Grafe, Jens	2.Eng.
10.	Krinfeld, Oleksandr	2.Eng.
11.	Haack, Michael	2. Eng.
12.	Redmer, Jens	Elec.Tech.
13.	Frank, Gerhard	Electron.
14.	Hüttebräucker, Olaf	Electron.
15.	Nasis, Ilias	Electron.
16.	Himmel,Frank	Electron
17.	Loidl, Reiner	Boatsw.
18.	Reise, Lutz	Carpenter
19.	Hagemann, Manfred	A.B.
20.	Winkler, Michael	A.B.
21.	Scheel, Sebastian	A.B.
22.	Bäcker, Andreas	A.B.
23.	Brück, Sebastian	A.B.
24.	Wende, Uwe	A.B.
25.	Leisner, Karl-Heinz Bert	A.B.
26.	Löscher, Steffen Andreas	A.B.
27.	Preußner, Jörg	Storek.
28.	Teichert, Uwe	Mot-man
29.	Rhau, Lars-Peter	Mot-man
30.	Lamm, Gerd	Mot-man
31.	Schünemann, Mario	Mot-man
32.	Schwarz, Uwe	Mot-man
33.	Redmer, Klaus-Peter	Cook
34.	Silinski, Frank	Cooksmate
35.	Martens, Michael	Cooksmate
36.	Czyborra, Bärbel	1.Stwdess
37.	Wöckener, Martina	Stwdss/KS
38.	Dibenau, Torsten	2.Steward
39.	Silinski, Carmen	2.Stwdess
40.	Duka, Maribel	2.Steward
41.	Arendt, Rene	2.Steward
42.	Sun, Yong Shen	2.Steward
43.	Chen, Dan Sheng	Laundrym.