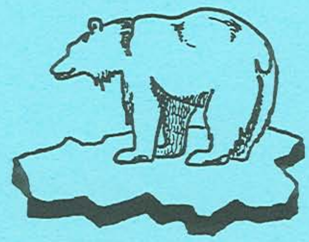
FS „Polarstern"
Expeditionsprogramm Nr. 27



Arktis IX/2 und 3

1993

Nordostwasser-Polynja-Expedition

Northeast Water Polynya

Alfred-Wegener-Institut für Polar- und Meeresforschung
Bremerhaven

März 1993

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Koordinator: E. Rachor

Fahrtleiter/Chief Scientists

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Bremerhaven

März 1993

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Fahrtabschnitte/Legs ARK IX/2 und 3

ARK IX/2: Bremerhaven-Tromsø, vom 16. Mai - 24. Juni 1993
Fahrtleiter/Chief Scientist: Gerhard Kattner

ARK IX/3: Tromsø-Tromsø, vom 25. Juni - 4. August 1993
Fahrtleiter/Chief Scientist: Hans-Jürgen Hirche

Zusammenfassung

Während der neunten Expedition der "Polarstern" in die Arktis im Sommer 1993 wird auf dem 2. und 3. Fahrtabschnitt die Nordostwasser-Polynja vor Grönland untersucht. Diese Untersuchungen finden im Rahmen des Internationalen Arktischen Polynja Programms (IAPP) unter der Schirmherrschaft des Arctic Ocean Sciences Board (AOSB) statt. Die Entstehung und das Ökosystem der Polynja sollen intensiv untersucht werden. Physikalische, biologische, chemische und geologische Programme sind während der fast dreimonatigen Untersuchungsphase geplant, um einen möglichst vollständigen Datensatz aus diesem Gebiet zu erhalten. Dazu kommen Beobachtungen der Eisbedeckung, Eisbeschaffenheit und Eisdrift.

Der 2. Fahrtabschnitt wird am 16. Mai in Bremerhaven beginnen und zunächst nach Tromsø führen. Während dieser Anreise wird das neue Navigationssystem sowie die Hydrosweep-Anlage der "Polarstern" getestet. In Tromsø werden dann die für das Testen des Navigationssystems zuständigen Personen das Schiff verlassen und weitere Wissenschaftler zusteigen. Am 21. Mai wird die "Polarstern" Tromsø in Richtung Nordost-Grönland verlassen. Je nach Eisbedeckung wird sie dann in wenigen Tagen das Untersuchungsgebiet erreicht haben. Hier ist geplant, die wissenschaftlichen Arbeiten an verschiedenen Stationen durchzuführen, wobei sich die Ausdehnung des Stationsnetzes wiederum nach der Eisbedeckung richten muß.

Am 24. Juni wird die "Polarstern" wieder in Tromsø sein. Hier muß das Schiff bunkern, und ein Austausch von Wissenschaftlern und Besatzung ist vorgesehen. Am nächsten Tag, dem 25. Juni, beginnt mit Auslaufen Tromsø der 3. Fahrtabschnitt. Es wird direkt wieder das Polynja-Gebiet angelaufen, um die Untersuchungen möglichst kontinuierlich fortsetzen zu können. Ende Juli wird der amerikanische Eisbrecher "Polar Sea" in der Polynja erwartet, auf dem sich dann weitere 33 Wissenschaftler an den Untersuchungen beteiligen werden. Ein gemeinsames Programm ist für die letzte Woche vorgesehen, in der die "Polarstern" in diesem

Gebiet ist. Der 3. Fahrtabschnitt wird dann am 4. August wiederum in Tromsø enden.

Parallel zu den Arbeiten auf See finden biologische, archäologische und glaziologische Untersuchungen auf Nordost-Grönland statt im Rahmen des NEWLAND Programms, das in das IAPP integriert ist.

Summary

During the 9th expedition (legs 2 and 3) of RV "Polarstern" to the Arctic the Northeast Water Polynya (NEW) off Greenland will be investigated. This study will be conducted within the framework of the International Arctic Polynya Programme (IAPP) under the umbrella of the Arctic Ocean Sciences Board (AOSB). The generation mechanisms of the polynya and its ecosystem will be studied in detail. Physical, biological, chemical and geological programmes are planned for almost three months to obtain a complete data set from this area. Observations of ice coverage, ice conditions and drift will complete this study.

On May 16th, the 2nd leg will start in Bremerhaven and will first be interrupted in Tromsø. During this part of the cruise a new navigation system and the hydrosweep system of the "Polarstern" will be tested. In Tromsø there will be an exchange of the testing personel and scientists. On May 21st, "Polarstern" will depart from Tromsø and proceed towards the NEW. Depending on the ice conditions we shall arrive in the polynya after a few days. The scientific station work will cover the whole polynya area depending again on the ice cover.

On June 24th, "Polarstern" will be back in Tromsø. Here an exchange of scientists and crew is possible and the vessel will refuel. On the next day Polarstern will start the 3rd leg which will go back directly to the Polynya to continue the investigations of the 2nd leg. At the end of July the US Coast Guard ice breaker "Polar Sea" with 33 scientists on board is expected in the Polynya region. For the last week a joint programme with both vessels is planned. The 3rd leg will end at Tromsø on August 4th.

Parallel to the seagoing activities, biological, archeological and glaciological investigations are planned ashore off the Northeast Water in Northeast Greenland within the NEWLAND programme which is an integral part of the IAPP-NEW.

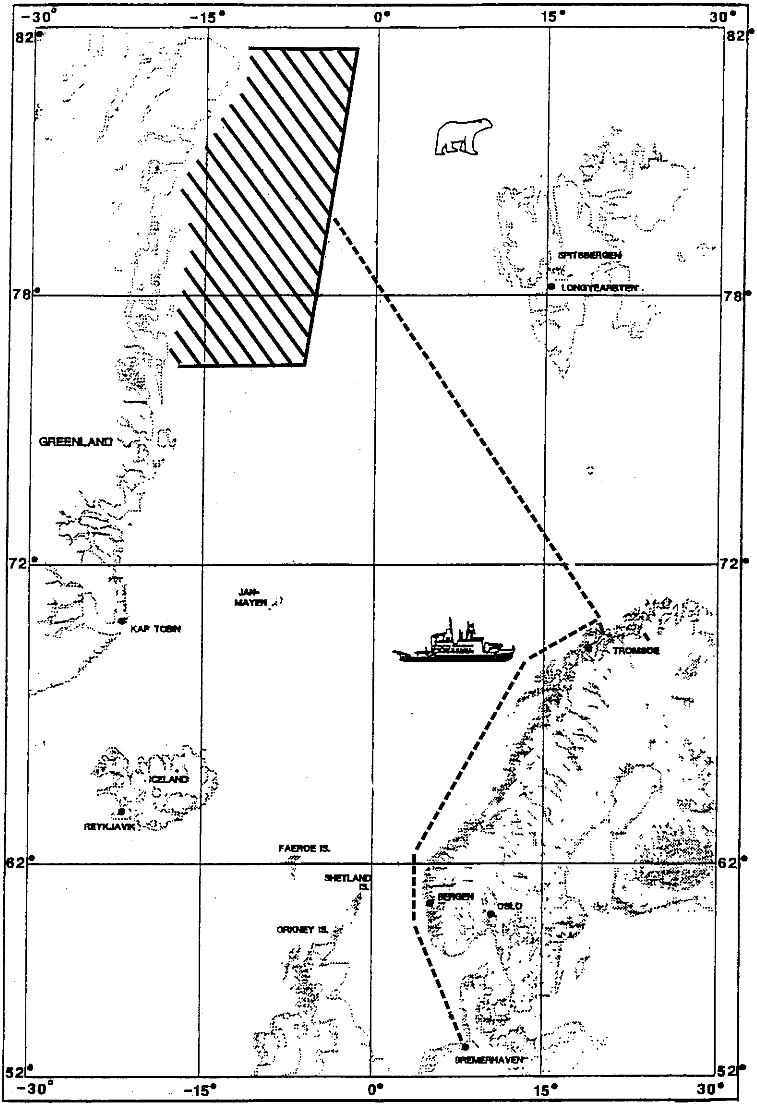

Abb. 1: Fahrtroute und Arbeitsgebiete der Reise ARK IX/2+3

Fig. 1: Planned route and working areas during ARK IX/2+3

1 Introduction

The Northeast Water Polynya Project (NEW) is part of the International Arctic Polynya Programme (IAPP), and its objectives are summarized in the Mission Statement and Core Programme.

1.1 Mission Statement and Core Programme

In 1989, the Arctic Ocean Sciences Board (AOSB) established a major international program devoted to Arctic polynyas. The International Arctic Polynya Programme (IAPP) will address three major topics described below. However, given the different physical and biological characteristics of various polynyas, it may be that these three topics will not receive the same degree of attention in all the polynyas studied under the IAPP.

The three polynya projects will be far more valuable in achieving an understanding of the physical and biological relationships within and between polynyas if they are directly intercomparable. This means that certain measurements must be done in all polynyas and that standard measurement procedures be used. The required core measurements are given below.

1.1.1 Water movements and heat flux

Polynyas and leads constitute at least 3% of the surface area of the Arctic Ocean in winter, but supply about 50% of the heat flux to the atmosphere at that time. Hundreds of watts per square meter are needed, the exact value being mainly dependent on wind velocity and air temperature. If this heat input is locally available from sensible heat in the water, a polynya surrounded by thin ice results; if not, then ice forms so that the required heat input is supplied, at least in part, by the release of latent heat. In the latter case, the ice formed may consolidate into continuous insulating sheet thus reducing the heat input needed. Alternatively, strong currents may remove the ice spicules as they form, releasing them downstream at locations where, in minor currents, they float to the surface and form part of an existing sheet; a polynya plus a locally thickened sea ice sheet results.

Thus polynyas may exist when the required heat flux is available from temperature reduction of the water (a sensible heat polynya), or by spatial redistribution of the ice formed by currents (a latent heat polynya). In practice many polynyas are a combination, heat being supplied from both sources. Most frequently the continuous source of sensible heat results from surface water exchange from below (turbulent mixing, or upwelling); tidal currents often provide the energy source for ice spicule redistribution. It is clear that the size of a polynya may vary from changing air temperature or with wind and water velocities.

Thus polynyas will be indicators of climate change and in practice, one of the most obvious ones. A general global warming would extend polynya areas, possibly cause new polynyas to form at suitable geographical locations, and this in an area where it is thought that the temperature signal of climatic change will be greatest.

Mission 1: *To understand how a polynya stays open. This requires detailed knowledge of water movements within the polynya and these can be categorized as density driven or forced. Examples of the former are vertical motion induced by the rejection of salt during sea ice growth and the damping produced by fresh water flow from land onto the sea surface. Examples of the latter are advection currents in the water, tidal or otherwise, and wind. These advective and convective processes are also basic to studies of carbon dioxide balance and nutrient transport. They are essential to all polynya studies. If allied with measurements of ocean/ice/atmosphere heat flux, they may be used to estimate the local and regional effects of the polynya on the weather and climate: the polynya, as well as being an indicator of climatic change, will be a contributor to it.*

Core measurements:

1. Extensive measurements of water movement and density profiles should be made at all polynyas to be studied

2. Where possible complete interface heat balance measurements should be made, including net radiation balance and fluxes of sensible and latent heat, and standard meteorological observations

3. When the extensive instrumentation required for (2) is not available and it is known that sensible heat is negligible, an attempt at a simple integrated measurement of heat flux, such as the ice tray described by den Hartog et al., (1983) should be undertaken

1.1.2 Carbon dioxide flux

In ice-covered waters, polynyas are areas where gas exchanges are accelerated, and where the pumping of carbon dioxide is, presumably, initiated and maintained through high primary production over an extended season. The major processes involved in the export of carbon dioxide to deep waters are: gas exchange between the atmosphere and the ocean, and subsequent transport from the surface by deep water renewal; and photosynthetic production in the surface layers, and later removal by sinking (intact cells, detritus, fecal pellets, marine snow etc.), by vertically migrating organisms and by physical mechanisms. In the event of global warming, the prevalence of polynyas and other ice-free waters is likely to increase, so that the processes of carbon dioxide export presently active in polynyas may then make an even greater contribution to the sequestration of carbon dioxide in the oceans. The deep water of the Arctic Ocean may not be a major sink for carbon dioxide, so that intermediate waters flowing out of this ocean could be exporting dissolved carbon (Anderson et al., 1990). The Northeast Water and North Water polynyas, being located in areas where waters are flowing out of the Arctic Ocean, may have a significant influence on the fate of dissolved carbon, and may provide a window to observe the various processes involved. The major goal of the Joint Global Ocean Flux Study (JGOFS) is "to determine and understand on a global scale the time-varying fluxes of carbon and associated biogenic elements in the ocean and to evaluate the related exchanges with the atmosphere, the sea floor and the continental boundaries."

Mission 2: *To study in and downstream from polynyas, the physical, chemical and biological mechanisms controlling the transfer, conversion, and fate of carbon dioxide.*

Core measurements:

1. Gas exchange between atmosphere and water, with comparison between open and ice-covered environments.

2. Primary production, comparing, if possible, new vs. regenerated and / or exported vs. recycled production.

3. Total carbon flux including
   a. sedimentation of particulate matter in whatever form
   b. transport of living organisms by migration and water movement and
   c. Solution of carbon dioxide, and physical transport of both dissolved inorganic and organic carbon by convection and water movement.

1.1.3 Community structure and productivity

Polynyas support characteristic biological communities associated with their special physical conditions. It is hypothesized that polynyas are sites of intense biological activity, in part because the physical processes that lead to their local recurrence also lead to high nutrient input and accumulation, elevated rates of primary production, and higher fluxes of organic matter to the benthos than are found in the surrounding ice-covered areas. Polynyas provide crucial habitats for marine mammals and birds, and essential hunting areas for the past and present indigenous peoples. Historical data indicate that climate controls the geographic location, size, and temporal development of polynyas, and these variations affect the local terrestrial climate. Detailed understanding of the biological communities and their interrelationships with their physical environment is essential to predicting the effects of climatic change.

Mission 3: *To determine how the physical and chemical environment of polynyas controls the distribution, productivity, and community structure of the organisms in these systems. An important goal is to compare how differences in the factors which control the generation of polynyas are reflected in their biological communities.*

Core measurements

1. Physical environment
   a: meteorological observations (wind, air temperature, atmospheric pressure, cloud, precipitation, ice cover and thick-ness)
   b: oceanographic observations (CTD, water and nutrient concentrations)
   c: photosynthetically active radiation

2. Ice and the ice-water boundary
   a: ice type and crystal structure
   b: fluorescence and derived estimates of chlorophyll
   c: primary productivity
   d: community structure of ice algae
   e: bacterial biomass and productivity and microheterotroph biomass, and biomass-based estimates of microheterotrophic grazing rates

3. Open water
   a. fluorescence and derived estimates of chlorophyll
   b. primary productivity
   c. community structure of phytoplankton
   d. bacterial productivity, microheterotroph biomass and biomass-based estimates of microheterotrophic grazing rates
   e. meroplankton biomass, emphasizing sampling in coastal areas
   f. macrozooplankton biomass and community structure (gelatinous zooplankton should not be neglected.)
   g. macrozooplankton grazing rates and egg production
   h. sinking rates of fecal material

i. sediment flux to the bottom (using sediment traps). This estimate should be compared to information from f and g.

4. Bottom sediments and benthos
   a. total sediment respiration as a measure of organic carbon remineralization
   b. meiofaunal community structure and biomass
   c. macrofaunal community structure and biomass (productivity will be calculated from biomass). For both b and c, common quantitative sampling techniques should be employed.

5. Top predators
   a. population size and its spatial and temporal distribution of benthic-feeding birds and mammals (three dimensional acoustic techniques are suggested as a basic tool for marine mammal census).
   b. study of diet and feeding distribution of planktivorous and piscivorous predators to provide additional information on fish species composition within polynyas and to identify prime sites for sampling these species.

2 The Northeast Water Polynya (NEW)

The North East Water is the largest (maximum area of about 44,000 km^2) and northernmost of several similar polynyas on the East Greenland Shelf and is bounded by the Arctic Ocean in the north and the Polar Front in the Greenland Sea to the east. Its main extension is usually between roughly 81°45′N (Nordostrundingen, Greenland′s northeasternmost point) and southwards to between 80°N and 79°N. In the northwest it is often connected with a system of shore leads which run along the north coast of Kronprins Christian Land and along the east and north coast of Peary Land, sometimes all the way up to Kap Morris Jesup on 83°45′N. In some years the open water may extend over the width of the whole Greenland Shelf all the way to the Polar Front. Water depth is highly variable (10 to 500 m), bottom topography is complex. The polynya appears to be associated with local circulation patterns, topography and possibly winds (the upwind effect of the Nordostrundingen). The NEW is a summer polynya, reaching its maximum extent in August, although it has been observed at other times of year and appears to be an area of weak divergent ice cover even in winter. Vinje (1984) has shown, based on ice analyses from satellite imagery, that the polynya usually appears in late spring (May till July), or, less frequently, in early winter (October - December, Gudmandsen and Zhang, 1991). It may persist for several months and is quite variable in size. Its largest spatial extent occurred in the late 1970's when an ice barrier formed consisting of a mixture of tabular icebergs with heavily ridged sea ice (Vinje, 1984). This barrier clearly influenced the ice drift pattern in Fram Strait until the end of September 1980, when it disappeared.

The hydrography of the East Greenland Current has been studied recently by Bourke et al. (1987). The East Greenland Current is the main outflow from the Arctic Ocean with an estimated annual mean mass transport of 1.6 Sv. Most of the ice that leaves the Arctic Ocean is carried by the East Greenland Current with about 85% consisting on an average of multi-year and second-year ice (Vinje and Finnekasa, 1986). The formation of the NEW must be affected by coastal topography south of Nordostrundingen, as well as by the local anticyclonic gyre which exists close to shore (Wadhams, 1981). An anticyclonic rotation of the upper layer centered on Belgica Bank has been documented by Bourke et al., 1987 and Vinje and Finnekasa (1986). It would tend to remove ice from the polynya area. Mechanisms by which this gyre keeps the area free of ice and the degree to which offshore wind stress contributes are uncertain. The offshore wind stress may generate upwelling, which would contribute to maintaining the polynya. Warm Atlantic Water, present deeper than about 100 m below the surface, might be made available to the surface at some times of year through upwelling or mixing. The available heat would melt ice, contributing to the formation of the polynya. In this case, the polynya would serve as a site of cooling for underlying water. It is also likely that in winter, due to the locally divergent ice field, brine rejected from freezing ice contributes to vertical mixing and deep water formation.

Recent release of classified bathymetric data for the East Greenland Shelf showed the summer position of the polynya situated on top of a trough system formed by the Westwind and Norske Troughs and Belgica Dyb. These three troughs form a continuous deep water path around Belgica Bank, into which penetration of the warm Arctic Intermediate Water can occur (Bourke et al., 1987). Preliminary results from "Polarstern" cruise ARK VII in summer 1990 show relatively warm (0°C) water as shallow as 50 meters overlying Ob Bank, in the area where the polynya may first open.

More detailed biological investigations on the East Greenland Shelf and in the area of the polynya were recently conducted during the 1983, 1984 and 1985 cruises of "Polarstern". The flora and fauna have been identified as of Arctic Ocean origin, with some admixture from the Arctic Intermediate Water, possibly via the deep troughs in the shelf. A diatom bloom occurred at the end of June 1984 with high primary production values comparable to those found in the North Sea. In contrast, the surrounding pack ice contained mostly flagellates and dinoflagellates with low biomass and low primary production. Both biomass and production increased again toward the marginal ice zone (Hirche et al., 1991). Three weeks later, at the western margin of the NEW, a phytoplankton bloom was found at the receding ice edge, whereas stations in the open water near the ice were deeply mixed and had a very low biomass (Spies, 1987). This confirmes the importance of ice melt and wind effects, the latter mixing the water column and blowing the ice away. At the end of July, 1985, Diel and Buma (1987) again found a well-developed diatom bloom in the polynya region with nutrients almost depleted in the euphotic zone.

The herbivorous zooplankton is dominated by two Arctic copepod species, *Calanus hyperboreus* and *C. glacialis,* and the Atlantic species *C. finmarchicus*, the latter most likely an expatriate (Hirche et al., 1991). Using *C. glacialis* as a proxy for food abundance, June/July egg production was found highest in the polynya, whereas no eggs were produced in the pack ice (Hirche and Bohrer, 1987). *C. hyperboreus* usually spawns before the onset of the spring bloom.

The benthos was studied quantitatively by Piepenburg (1988) using a combination of Agassiz trawls and underwater photography. Biomass of brittle stars in the polynya region was of the same order of magnitude as comparable communities in the North Sea.

These preliminary data support the hypothesis that the NEW has enhanced biological activity as compared to the pack ice zone of the East Greenland Current. In addition to the specific features of the polynya, this area also offers unique access to study Arctic plankton and benthos under varying ice conditions and light properties.

Higher trophic levels have so far been studied only on a small scale in the NEW. In the polynya region the northernmost breeding populations of Fulmar (*Fulmarus glacialis*) and Common Eider (*Somateria mollissima*) were found, together with the largest population of Sabine´s Gull (*Xema sabini*) and Brent Goose (*Brenta bernica*) in Greenland, together with Ivory Gulls (*Pagophila eburnea*) and Ross´ Gull (*Rhodesthetia rosea*) (eg. Pedersen, 1942; Hjort et al., 1983, 1987, 1988). Before the breeding season, large numbers of King Eiders (*S. spectabilis*) congregate there. For the marine mammals, the species of importance include Walrus (*Odobenus rosmarus*), Ringed Seal (*Phoca hispida*) and Bearded Seal (*Erignathus barbatus*) and to some extent also the Hooded Seal *(Cyssophora crustata)* among the pinnipeds, Polar Bear (*Ursus maritimus*), and a small population of Bowhead Whales (*Balaena mysticetus*). In the Arctic Ocean, basic information was gathered on the distribution at sea of seabirds (Mehlum, 1989; Joiris and Tahon, 1990) and of marine mammals (Joiris and Tahon, 1990).

For the Thule eskimoes the NEW system was probably always a very important post on the immigration route southwards into Northeast Greenland. They disappeared from Northeast Greenland finally at the beginning of the last century, eventually due to climatological reasons. But they may have abandoned the NEW region much earlier. In the coastal area ruins from two different paleoeskimo cultures have also been found.

3 Research Programmes

The main field phase for the NEW project has been planned for 1993. In addition to RV "Polarstern" cruises ARK IX/2+3 there will be a cruise of the US Coast Guard Icebreaker "Polar Sea" to the polynya. At the same time a land based project, NEWLAND, on East Greenland is planned. All three activities are closely coordinated. Below only the research plan for RV "Polarstern" is described.

3.1 Remote Sensing

The remote sensing activities will concentrate in providing ice information for direct support of the NEW participants as well as investigating specific problems affecting a better understanding of remotely sensed data using a compatible family of sensors. The main objectives are:

1. To support the NEW program with strategic ice information for planning purposes using active and passive satellite sensors (ERS-1 SAR and DMSP SSM/I and NOAA´s AVHRR),

2. to support the NEW program with helicopter remote sensing flights by using the line scan camera (LSC) and infrared scanner (ILS),

3. to provide ice information in support of "Polarstern" using SSM/I, AVHRR and if needed ice reconnaissance flights with the helicopter.

NOAA AVHRR data will be received directly on the ship several times a day, weather permitting. During cloud free periods the ice is clearly visible with a resolution of 1.1 km. Similarly DMSP SSM/I data will be sent to the ship via INMARSAT from Ottawa (K. Asmus) where they will be further processed in form of ice information charts showing total ice concentration, ice edge and polynya boundaries for a grid point of 25x25 km. This data will be available every day, regardless of weather conditions. The two data sets will provide a good data base during the entire experiment for decision making concerning the scientific and ships activities. Occasionally we may receive ERS-1 SAR images received and processed at the Bundesamt für Seeschiffahrt und Hydrographie, Hamburg, by K. Strübing. These images will be of particular interest, first because of the very high resolution of about 100 m, and secondly for validating SAR images during summer conditions. During times when the SAR images are not available, our collegues at IFREMER, Brest (Drs. Ezraty, Gohin, Cavanie), will be processing the ERS-1 scatterometer mode data for comparison with the surface observations, line scan camera and SSM/I data. Images pertinent to the various group leaders requirements will be collected and put into a folder as a take home package for each group. Thus each group will be able to draw some conclusions concerning the effect ice has on the particular parameter studied.

4. The sub-objectives deal primarily with the study of the melt puddle regime during the entire NEW period as well as the air-ice interaction as coupled with meteorological measurements, conducted from different ice types.

Little is known of the quantitative distribution of melt features on top of major ice types (old and first year ice) during an entire melt cycle. The major sensor used for the study will be the LSC flown on the helicopter at times of SSM/I, ERS-1 SAR and AVHRR coverage. During most of the period, when the ship is under way, radiometric measurements using a 37 GHz passive microwave radiometer are going to be collected for assisting in the evaluation of the satellite data. With the use of the LSC we expect to quantify the amount of puddles on top of old ice, how they change with time and how they affect the retrieval of ice concentration from satellite data.

	leg 1	**leg 2**
SSM/I, ERS-1	Ramseier	Ramseier
Radiation	Ivanov	
Microwave	Garrity	Garrity
Linescan camera	Bochert	El Naggar
AVHRR	König	König
Telecommunication	Geiger	

3.2 Oceanography

The objectives of the physical oceanography component are to map the three dimensional current structure using ship-mounted ADCP, to make hydrographic measurements relative to the prevailing currents and topography to better understand the details of the current regime, and to contrast these measurements with similar measurements made beneath ice covered waters from selected ice stations. These objectives are important not only to the physical oceanographers, but will be central to other scientists studying the polynya because the currents help establish the property distributions being measured during the cruise.

Additionally current meter moorings and sediment traps deployed by "Polarstern" and "Polar Sea" are to recover. The moored current meters will have recorded current speed and direction with temperature and pressure for one year and will provide the first year-long records from within the NEW. Four of the six moorings have sediment traps and these will also give year long records of the particle flux. The moorings were deployed in two lines of three moorings across the northern trough system, with the intention of measuring possible sources of heat that form the polynya, measuring the tidal component, and measuring the seasonal cycle within the polynya.

A ship mounted ADCP will be used while the ship is on station. Hydrographic mesasurements will be made at each station along the cruise track. Estimates of the baroclinic and the total transport through the trough system and along the Greenland shelf will be made. We expect to obtain detailed information along the shelf break because measurements here, along with measurements northward of the main polynya site, act as boundary conditions to the polynya. Such measurements will be essential for the numerical modelling effort.

The under ice program will focus on describing the upper water column T-S and velocity structure under large ice floes at some distance from the ship in areas of high ice concentration. The goal is to compare conditions in the polynya with those found in the adjacent ice covered regions. Because of ship influence on the near surface layer and its interest to the biologists, physical measurements at the ice camps will concentrate on the 20m depth interval below the ice-water interface. CTD, velocity and turbulence profiles will be taken through holes in the ice from inside a tent for periods of 24-48 hours. Small T-S probes and current meters will record time series throughout the sampling period at each station. Extensive biological measurements will also be taken at each site. Access to the study locations will be by helicopter from "Polarstern". A self-recording meteorological station will be installed on one of the Henrik Krøyer Islands during both legs of the cruise.

CTD (Ice)	Bélanger	Galbraith
CTD (Ice)	Galbraith	Aota
Turbulence	Shirasawa	NN
CTD/ADPC	Budeus	Brunßen
CTD/ADPC	Schneider	Schneider
CTD/ADCP	Plugge	Damm

3.3 Geology

Sedimentological investigations and sediment echosounding (SFB 313)

The runoff of dense water formed in areas of open water on the shelf may occasionally carry suspensions topographically controlled into closed basins on the shelf via the Westwind Trough and - a suitable current system provided - probably also across the shelf breaks towards final deposition on the continental slope. In areas of high accumulation rates a unique geological documentation for aspects of recent and ancient climatic conditions is stored.

Soft sediments accumulating predominantly in the Westwind Trough in water depths exceeding 280 m were probably recently discharged assymetrically from the banks adjacent to the trough due to more intense new ice formation and dense brine water runoff during the nearshore opening of the NEW early in the year. The question is, whether polynya dynamics or the East Greenland Current pattern with relatively moderate bottom current velocities in greater depth is controlling accumulation of silt and clay from bottom nepheloid layer transport. For interpretation of recent and ancient sedimentological records we will analyse recent near bottom sediment dynamics from source areas towards accumulation areas in the Westwind Trough and on the continental slope.

Methods: A side scan sonar survey will be carried out on sections across the trough and profiles along the slope, where downslope transport is expected, to evaluate the influence of local topography on bottom currents, sediment and benthic biology parameters.

Subbottom profiling work using a 3.5 kHz system on a mapping grid and between stations will improve the bathymetric data base and the knowledge of the regional subbottom sediment characteristics and thickness distribution.

Sampling of bottom sediments with short cores and of the bottom nepheloid layer by in situ filtration pumps will be carried out in areas of sediment export, transport and import on the shelf sections and the adjacent upper continental slope. Several downcore parameters will be measured in the laboratory: water content, grain size distribution, carbonate content, total organic carbon and isotopic composition of foraminifer shells for stratigraphic determinations, SEM particle character of suspended and bottom sediments.

Paleoceanographic and paleontological investigations (AWI)

Paleoceanographic/paleontological studies will include the investigation of modern distribution patterns of planktic and benthic foraminiferal tests, sediments and sedimentary organic matter in relationship to different environmental conditions in polynya and non-polynya areas. This research is to calibrate downcore analyses of long sediment cores to be taken from troughs on the continental shelf and margin. The sediment cores will be analyzed to monitor changing climatic conditions as reflected in paleoproductivity and nutrient inventory during the Late Quaternary glacial/interglacial cycles.

The paleontological and paleoceanographic research includes detailed sedimentogical and organic geochemical analyses, such as clay mineral analysis and Rock-Eval pyrolysis, as well as kerogen microscopy. The stable isotopic composition of carbon in organic matter, foraminiferal calcite and total dissolved inorganic carbon of sea water, will also be determined.

In addition to sites in sedimentary troughs on the continental shelf, 3 to 4 transects running from the inner polynya area on the shelf, perpendicular to the continental slope down into the deep sea, are planned to be sampled at five stations each, with a gravity corer and a multiple corer. Appropriate sampling positions will be determined with the aid of Parasound echosounding.

Sediment transport	Rumohr	Rumohr
Coring, respiration	Antonov	Struck
Photogr., bathym.	Beese	Seiss
Photogr., bathym.	Blaume	
Geochemistry		Notholt
Paleoceanography		Mackensen
Paleoceanography		Kopsch
Sedimentology		Nam

3.4 Chemistry

Inorganic nutrients

The determinations of nutrients are closely connected with the planktological and physical investigations. The development of phytoplankton blooms is especially dependent on the available nutrients. The change in nutrient concentrations will be followed during the opening of the polynya and the retreating of the ice edge. In addition, the nutrient concentrations below the ice and within the ice of the surrounding ice covered areas will be measured. In view of the water mass determination especially silicate is a good tracer for the outflow of upper halocline Arctic surface water into the polynya region. The determination of the nitrogen containing nutrients is used as basic measurements for the investigations of dissolved organic nitrogen (DON) and for establishing a nitrogen budget.

From water samples taken with the water cast at different depth, the nutrients - nitrate, nitrite, ammonium, phosphate and silicate - are determined routinely with an autoanalyser-system according to standard methods.

Dissolved organic carbon (DOC) and nitrogen (DON)

The role of dissolved organic substances in the marine environment is very important for the understanding of this ecosystem, particularly regarding their contribution to the global carbon and nitrogen cycles. The function of dissolved organic matter (DOM) and its major components, DON and DOC in the marine nitrogen and carbon cycles has received increasing attention in recent years. However, the dynamics and chemical composition of DOM in seawater remain unknown to a great extent. Particularly relevant is the understanding of the processes which control the fate and distribution of that part of CO_2, which is converted by photosynthesis into organic matter. Zooplankton and microbes transform this organic matter by grazing and degradation to multiple particulate and dissolved components. These may be partly transported out of the euphotic zone by sedimentation or deep-water formation and may be transformed into refractory compounds. The importance of these mechanisms for the role of the deep oceans as possible sinks of organic matter and hence of atmospheric CO_2 is still far from being understood and requires extensive investigations.

The simultaneous determination of DOC and DON will provide a deeper insight into their relationships, through the comparison of the C:N ratio in regions with different ranges of DON and DOC concentrations, and with specific hydrographic regimes which may influence the heterotrophic and autotrophic activities, the excretion of nitrogeneous compounds by zooplankton, the rate of formation of refractory compounds, etc.

For the determination of DON the wet oxidation method will be used which was tested with dissolved marine humic material. The high temperature catalytic oxidation seems to offer the most complete oxidation of DOM and therefore a Shimadzu TOC-Analyser will be used for the determination of DOC.

CO_2-system

Coastal areas are often sites of important air-sea CO_2 fluxes, and a global inventory is urgently needed for a better understanding of the oceanic carbon budget. The determination of the partial pressure of CO_2 in the surface layer allows to calculate the direction and magnitude of the CO_2 flux at the air-sea interface, using approximate exchange coefficients calculated from wind speed data.

The dissolved CO_2 system in seawater is strongly dependant on the biological activity and can be used to interprete photosynthesis/ respiration processes as well as calcification. CO_2 should be included in the whole data set related to indicators of biological activities such as chlorophyll, oxygen, primary production, nutrients, etc.

Total alkalinity (Talk)

Talk is determined by titrating GF/F-filtered seawater with 0.1N HCl according to the now classical GRAN-plots method. About 250 ml seawater are needed to process two titrations. The accuracy of the method has been estimated to 0.5%, using standard carbonate solutions.

Measurement of pH by two techniques

1. pH is measured on seawater from Niskin-bottle samples by a classical pH meter and a ROSS combined glass electrode calibrated with NBS phosphate and borax standards. The measurement is carried out as soon as possible. Sampling is done with a 250 ml BOD bottle, and after pH determination the same sample is used for Talk titration.
2. *in situ* pH measurements are performed using a probe conceived in Liège, which allows pH monitoring under pressure. The electrochemical cell is build to know and to keep constant the junction potential. The system can then be used to take into account the effect of salinity on measured pH. The accuracy is estimated to be 0.003 pH units.
Both pH and Talk are used to calculate the CO_2 speciation in seawater in combination with temperature and salinity data.

Nutrients	Stürcken-Rodewald	Michel
Nutrients	NN	Hollmann
Carbonate system	Gerlache	Theate
Carbonate system	NN	NN
DOC/DON	Lara	Richter
DOC/DON	Skoog	NN

3.5 Microplankton

Within the context of the NEW project, the microplankton team deals with several sub-disciplines, i.e. primary production (phytoplankton in the water column and algae in the sea ice), the processing of biogenic particles in the euphotic zone by the microbial food web (heterotrophic bacteria and protozoa), and the downward export of particles through sedimentation.

In the oceans, the photosynthetic activity of primary producers is limited by either irradiance or the availability of nutrients, which factors are under the ultimate control of physical conditions. Photosynthetic organisms take up dissolved inorganic carbon from the surrounding medium, and they exude organic compounds at the same time as they build up organic particles. In this way, the microplankton team interacts with both the physical and chemical oceanography teams. Phytoplankton carbon which is not respired in the euphotic zone by the microbial web may be exported towards zooplankton or benthic organisms. It follows that the microplankton team also interacts with the zooplankton and the benthos teams. Finally, sedimented particles that are not used by the benthos are incorporated in the sediments, so that the microplankton team interacts with the geology team.

The scientific questions addressed by the microplankton team are derived from the Mission Statement for the IAPP.

Mission 2: To study in and downstream from polynyas, the physical, chemical and biological mechanisms controlling the transfer, conversion and fate of carbon dioxide.

In and downstream from the polynya:
What is the rate of incorporation of carbon into primary producers?
How much of this carbon may potentially be exported from the euphotic zone?
How much of this carbon is mineralized (i.e. respired) directly in the euphotic zone?
What is the downward flux of biogenic carbon from the euphotic zone?
What are the main mechanisms controlling the above fluxes of carbon, especially primary production and its partitioning between the export and recycling of biogenic carbon?

Mission 3: To determine how the physical and chemical environment of polynyas controls the distribution, productivity, and community structure of the organisms in these systems. An important goal is to compare how differences in the factors which control the generation of polynyas are reflected in their biological communities.

In the polynya and in the surrounding ice-covered environment:
What is the rate of primary production?
What is the community structure of primary producers, both in terms of size distribution and taxonomic composition?
Given the community structure of primary producers, how much of the production is channeled toward recycling in the microbial food web, and export to herbivorous grazers and large animals?
How much of the primary production is exported to depth, either directly as algal flocs or indirectly within faecal pellets?
What are the main mechanisms controlling primary production and its various export pathways?

Research program

The research program will include sampling in both the polynya and the surrounding ice-covered environment. At times, there may be no defined boundary (i.e. ice margins) between the two environments, since the ice cover will show a gradient between completely open waters and the pack ice. Ice covered areas, according to their location and the patterns of currents, may either be regions downstream from the polynya (mission 2) or not influenced by it (mission 3).

Primary production will be measured in terms of both carbon and nitrogen. Uptake of the various forms of nitrogen provide an estimate of the proportion of the production fueled by allochthonous (i.e. nitrate) versus autochthonous (i.e. ammonia and urea) nutrients, which gives an indication of the potential export from the euphotic zone. Another indication of potential export is provided by the production of large phytoplankton (i.e. >2-5µm), which may sink rapidly. Concerning ecological transfers, the small phytoplankton are more likely to be processed by the microbial food web, while large cells may be grazed by herbivorous copepods.

The activity of the microbial food web will be used to estimate the proportion of primary production recycled in the euphotic zone and the amount of biogenic carbon required there. In addition, some export of biogenic carbon may result from the use of dissolved organic compounds by heterotrophic bacteria and from enhanced primary production favoured by the regeneration of nutrients by microheterotrophic activity.

Sediment traps will provide direct information on the downward flux of biogenic carbon from the euphotic zone, and detailed analysis of the material in the traps will allow to identify the nature of sedimenting particles.

The above information will be combined with data on the physical and chemical conditions in the various sampled environments. This will allow to identify the main mechanisms controlling, in and downstream from the polynya, the rate of primary production and its partitioning between export and recycling. The same approach will allow to identify, in the polymya and in the surrounding ice-covered environment, the mechanisms controlling primary production and its various export pathways.

General methodology

The main aspect of the methodology is the simultaneous measurement of all variables, at all stations. Methods for primary production will include the carbon-14 and nitrogen-15 approaches, and samples will be systematically size-fractionated. Algal biomass (photosynthetic pigments and C:N) will be similarly size fractionated. Cells from both the water column and the ice will be enumerated by epifluorescence (small cells) and light (large cells) microscopy. Studies on the microbial food web will include estimates of bacterial productivity (H-3 thymidine) as well as microheterotrophic biomass and grazing rates. Finally, short-term floating sediment traps, at shallow depths, will allow to measure the flux of material from the euphotic zone at the sites and times of sampling. Long-term moorings, near the bottom, will provide information on the annual cycle of biogenic export to depth in the polynya area.

Primary production	Gosselin	Bergeron
Primary production	Pesant	Pesant
Primary production	Fraikin	McGuiness
Primary production	NN	Daly
Primary production	Yager	Sime-Ngando
Microbial loop	Björnsen	Thomsen
Microbial loop	Østergaard	Björnsen
Sedimentation	Haupt	Bauerfeind

3.6 Zooplankton

Assuming a north to south advection of Arctic waters in the surface layer (East Greenland Current) and a topographically forced anticyclonic circulation of Atlantic Intermediate Water at depth, two distinct zooplankton communities are expected to dominate in the polynya region: an Arctic community in the surface layer (100-0 m) and an Atlantic community at depth (> 100 m). Our central hypothesis is that the residence time of these communities in the polynya is sufficient for herbivores to exploit and incorporate a significant fraction of the high algal biomass that is assumed to develop in the open water. To address this general hypothesis our objectives are:

(1) to compare the seasonal development of zooplankton communities in relation to the spring-summer production cycle within and outside the polynya.
(2) to assess the importance of the polynya for the feeding and production of macrozooplankton and as a nursery area for fish larvae
(3) to obtain a preliminary estimate of the carbon flux through the herbivorous zooplankton compartment for both environments.

Community structure and assemblages: seasonal and spatial variations

A prediction of the empirical hypothesis is that the zooplankton communities inside and outside the polynya will differ in taxonomic composition, developmental stage structure, biomass and activity rates. Differences are also expected to exist on the vertical axis, between the Polar Surface Water (PSW) and the underlying Arctic Intermediate Water (AIW).

Comparable gear will be used to sample a wide spectrum of the zooplankton assemblages (from microheterotrophs to macroplankton) in open and ice-covered waters. The grid of stations should cover slope, trough and shelf areas, including ice-covered and open water stations. Vertical distributions will be established to compare the two main water masses (PSW/AIW) and assess the importance and extent of vertical migrations which may play a role in the vertical flux of carbon.

Carbon flux through herbivore zooplankton

Lipid accumulation by herbivorous zooplankton derives from the incorporation of phytoplankton carbon which will be stored for long periods. Earlier work suggests that large zooplankton populations can store significant proportions of the primary production in the pelagic domain. Thus, zooplankton communities may play a significant role in the regulation of the vertical flux of carbon in polynyas and Arctic waters in general. The organic carbon assimilated by zooplankton is either respired, stored, channelled to reproduction or somatic growth, or exported from the pelagic zone by the sedimentation of faecal pellets. The pelago-benthic coupling is to a large extent dependent on the food web structure in the water column. The central hypothesis predicts a change in the food web structure, with the short food web (diatoms - herbivorous copepods) dominating the open waters of the polynya, and a microbial web dominating the ice-covered areas.

According to the hypothesis, the export of primary production to depth or higher trophic levels of the plankton should be inefficient where the microbial web dominates. An exception to this low efficiency may exist, when appendicularians "shunt" the microbial loop. Appendicularians, which filter picoplankton cells and bacteria, produce faecal pellets that can sink rapidly to deep waters. In addition, they are directly preyed upon by some species of fish larvae.

To estimate the fraction of the total carbon flux that transits through the herbivorous zooplankton compartment, a tentative carbon budget will be established. Rates of ingestion, egg and faecal pellet production will be measured in the laboratory. Somatic growth will be derived from seasonal variations in population structure (stage frequencies) and weight increases of developmental stages. The role of predation in controlling herbivorous biomass will be estimated by establishing a tentative budget for open and ice-covered waters.

Transfer of zooplankton biomass to higher trophic levels in and outside of the polynya

The concentration of birds and mammals in the polynya area suggests the increased availability of macroplankton and forage fish, although top predators could congregate in the polynya simply because this is the only area where they can access their food. The question then is whether or not macrozooplankton feeding and reproduction and fish reproduction are enhanced in the polynya relative to surrounding ice-covered areas. In the short plankton food chain, that we expect to dominate the polynya, the production of large diatoms favors the reproduction of herbivore copepods and the massive production of eggs and nauplii. Copepod eggs and nauplii are preyed upon by fish larvae, and because of the few trophic steps involved (diatoms - copepods - fish larvae), the transfer of primary production to fish larvae is efficient. In the microbial web, expected in ice-covered areas around the polynya, most of the primary production is respired by microheterotrophs before it is exported to large grazers, and the transfer of energy to macrozooplankton and fish larvae is probably not very efficient. An exception to this may be the "appendicularian shunt" (see above).

Larval fish feeding (gut content analysis) and growth (otolith analysis) will be compared over the spring-summer period in and outside the polynya. Similarly, the abundance and foraging of major macroplankton taxa (chaetognaths, jellies, amphipods, euphausiids) will be compared between the two areas.

Macrozooplankton	Fortier	Michaud
Egg production	Rowe	Rowe
Growth	Hirche	Wegner
Grazing	Acuna	Acuna
Predation	Øresland	Deibel
Microzooplankton	Nielsen	Nielsen
Faecal pellets	Daly	Wunsch

3.6 Benthos

Objectives

The benthos work will focus on interactions between the upper sediment layer and the bottom nepheloid layer (BNL). Recent investigations indicate that biological and physical resuspension results in higher particle concentrations in the BNL. Even at low flow velocities the lateral particle flux by far exceeds the vertical flux. For this reason, the final sedimentation of a particle depends not only on the bottom topography, but also on the benthic population, which can actively incorporate particles into the sediment by biodeposition. Focus of our work will be on the interrelationships between the lateral matter flux in the near-bottom BNL and the dispersion patterns of benthic communities.

The program encompasses
a) investigations on distribution and structure of meiobenthic and macrobenthic communities, related to the sea floor proper as well as to the BNL
b) assessments of micro- and meso-scale dispersion patterns of benthic populations
c) analyses of the benthic boundary layer characteristics
d) measurements of the metabolic performance on the level of both communities (micro- and meiobenthos) and individuals (macrobenthos),
e) biodeposition, bioturbation and bioentrainment rates of special benthic populations with the help of in-situ experiments.

Working program

Since the large scale benthos zonation of the Belgica Bank is quite well known from the "Polarstern" expeditions in 1985 and 1990, the field study in 1993 will focus on meso-scale investigations north of 80°N. Sampling will be confined to five short transects (max. 40 km), one outside and four inside the polynya.

For longterm analyses of pelago-benthic coupling and benthic community structure, two central stations located at the sites in the Westwind Trough, where sediment traps have been deployed in 1992, will be occupied at least once every 10 days to cover temporal variation.

For regional investigations with lower spatio-temporal resolution, standard benthic stations designed to provide a larger spatial coverage of benthic composition and processes in the study area will be occupied on the transects.

For the inventory of mega-epibenthos, an underwater imaging system combining photography and video will be employed as well as the traditionally used Agassiz trawl and epibenthic sledge, respectively. In addition, for the sampling of macrobenthic in- and epifauna, meiobenthos and sediment, a box corer and a multicorer will be used. A specially designed bottom water sampler, additionally equipped with current meters and a transmissiometer, will take samples in four depths within the last meter of the BNL, ie. the water column just above the sediment-water interface.

Macrobenthos	Ambrose	Renard
Meiofauna	Herman	Jensen
Epifauna	Piepenburg	Brandt
Bacteria	Ritzrau	Ritzrau
Bacteria	Graf	Scheltz
BNL	Queisser	Thomsen, L.
ROV, Makrofauna	Gutt	Gutt
ROV	Dimmler	Dimmler

3.7 Mammals & Birds

The main aims of the studies of seabirds and marine mammals are to identify the influence of the polynya on the distribution, migrations, breeding and feeding biology of the higher trophic levels. For this, the patterns of spatial and temporal uses of the polynya area will be investigated.

Particular attention will be paid to moving birds, migrating between breeding and feeding grounds. These results will be compared with similar observations at the bird cliffs such as flight direction, daily rhythms etc., which are part of the land based NEWLAND project. Observations will also include age structure and stage of molt.

The results, integrated into the interdisciplinary ecological study of the NEW cruise, will allow to use the higher trophic levels as indicators for the ecological structure of different regions in and around the polynya: "complete" food chain with dominating role of herbivorous zooplankton, pelagic fish, pelagic seabirds and cetaceans, versus "shortened" food chain with important recycling by planktonic bacteria, sedimentation, benthos, demersal fish and walrus.

A special study concentrates on polar bears. They occur at polynyas where they are thought to be attracted by an abundance of prey, especially ringed seals. The NEW is supposed to be a feeding area for female polar bears with cubs after they emerge from the maternity dens in April. The objectives of this study are to determine the seasonal and spatial habitat use of polar bears in the NEW, to locate denning areas used by females found in the NEW, and to study the connections between polar bear populations in NE Greenland and Svalbard.

Methods:
Around 20 polar bears will be immobilized ny narcotics and tagged. Among them, five females will be furnished with a satellite radio collar allowing for tracking of individual movements up to 1.6 years. When a bear is spotted from the ship, the bear will be rounded up by helicopter and darted with an immobilization agent. During immobilization the bear is given ear tags and provided with lip tattoos. Body measurements will be taken together with samples of claws, blood, and hair. A satellite radio will be attached around the neck. The whole operation is expected to last about 1 to 1.5 hours.

Birds	Joiris	Tahon
Birds	NN	NN
Polar bear	Born	
Polar bear	Thomassen	

4 Fahrtteilnehmer/Participants

ARK IX/2

Name	Institut/Institute
Acuna, Jose-Luis	MUN
Ambrose, Will	ECU
Antonov, M.	SFB
Beese, Helmut	SFB
Bélanger, Claude	MUN
Bjørnsen, Peter K	MBLH
Blaume, Frank	SFB
Bochert, Axel,	AWI
Born, Erik W.,	GFRI
Büchner, Jürgen	HSW
Budeus, Gereon	AWI
Daly, Kendra	GPE
Dimmler, Werner	AWI
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Fraikin, Chris	UW
Galbraith, Peter	MGM
Garrity, Caren	AES
Geiger, Sven	AWI
Gerlache, Marc	ULC
Gosselin, Michel	UQR
Graf, Gerd	SFB
Gutt, Julian,	AWI
Haupt, Olaf	SFB
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Hirche, Hans-Jürgen	AWI
Ivanov, Boris,	AARI
Joiris, Claude,	VUB
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Rumohr, Jan,	SFB
Schneider, Wolfgang	AWI
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Skoog, Annelie	GU/AWI
Stürcken-Rodewald, Martha	AWI
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NN	
NN	
NN	

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Brunßen, Jutta	AWI
Daly, Kendra	GPE
Damm, Michael	AWI
Darnell, Clarke	PMEL
Deibel, Donald	MUN
Dimmler, Werner	AWI
El Naggar, Saad	AWI
Galbraith, Peter	MGM
Garrity, Caren	AES
Gutt, Julian,	AWI
Hirche, Hans-Jürgen	AWI
Hollmann, Beate	AWI
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Mackensen, Andreas	AWI
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Michel, Andreas	AWI
Nielsen, Torkel Gissel	MBLR
Notholt, Hanne	AWI
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Rumohr, Jan,	SFB
Scheltz, Annette	SFB
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Wunsch, Marita	SFB
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NN	
NN	
NN	
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UCS University of Copenhagen,
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6 Schiffsbesatzung / Ship's Crew

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Kapitän	H. Jonas	E. Greve
1. Offizier	M. Müller	I. Varding
Naut. Offizier	U. Grundmann	M. Bürger
Naut. Offizier	M. Rodewald	S. Schwarze
Naut. Offizier	Block	Block
Arzt	Dr. Schuster	Dr. Schröder
Ltd. Ingenieur	V. Schulz	D. Knoop
1. Ingenieur	G. Erreth	W. Delff
2. Ingenieur	R. Pengler	H. Folta
2. Ingenieur	O. Ziemann	W. Simon
Elektriker	G. Schuster	R. Erdmann
Elektroniker	U. Lembke	U. Lembke
Elektroniker	H. Muhle	H. Muhle
Elektroniker	A. Piskorzynski	A. Piskorzynski
Elektroniker	Rabenhorst	Rabenhorst
Funkoffizier	K.H. Wanger	E. Müller
Funkoffizier	H. Geiger	J. Butz
Koch	E. Kubicka	W. Köwing
Kochsmaat	H. Hüneke	M. Kästner
Kochsmaat	N.N.	F. Roggatz
1. Stewart	G. Scheel	D. Peschke
Stewardess	N.N.	N.N.
Stewardess	N.N.	A. Hopp
Stewardess	J. Hasler	A. Neves
Stewardess	M. Hoppe	V. Kuhlmann
2. Stewart	K.Y. Yu	K.Y. Yu
2. Stewart	J. Tu	J. Tu
Wäscher	Ch. Chang	Ch. Chang
Bootsmann	R. Zulauf	W. Hopp
Zimmermann	K. Marowsky	P. Kassubeck
Matrosen:	J. Novo Loveira	L. Gil Iglesias
	J. Soage Cluna	A. Suarez Paisal
	M. Winkler	K. Bindernagel
	J. Pousada Martinez	S. Moser

	M. Schmidt	B. Pereira Portela
	B. Iglesias Bermudez	A. Prol Otero
	N.N.	N.N.
	N.N.	N.N.
Lagerhalter	K. Müller	F. Barth
Maschinenwart	M. Lesch	G. Fritz
Maschinenwart	U. Husung	F. Buchas
Maschinenwart	E. Heurich	S. Reimann
Maschinenwart	G. Dufner	G. Jordan