Scientific Cruise Report of the Arctic Expedition ARK-XIII/1 of RV "Polarstern" in 1997

Wissenschaftlicher Fahrtbericht über die Arktis-Expedition ARK-XIII/1 von 1997 mit FS "Polarstern"

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Contents

1 **Introduction** (Spindler)

The thirteenth Arctic expedition of RV "Polarstern" began on May 14 1997 and ended on September 29 of the same year. The cruise consisted of three legs of multidisciplinary research with regional concentrations in the areas of the Greenland Sea, the western Barents Sea and the Fram Strait.

The first leg (ARK XIII/1) began on May 14 in the homeport of "Polarstern", Bremerhaven and ended on June 24 in Tromsø, Norway. It was divided into two subunits ARK XIII/1a and ARK XIII/1b by a short visit of port in Longyearbyen (Svalbard) to exchange some scientific personnel.

Our first research area during ARK XIII/1a was the marginal ice zone of the Barents Sea east of Svalbard. Here, our main research effort concentrated on the coupling of the different compartments sea ice, water column and sea floor in an interdisciplinary approach. The main goal was the elucidation of the situation during late winter and beginning of spring in areas without and with sea ice cover. This investigation played an essential part for the pilot phase of the European project "The Arctic Ocean System in the Global Environment" (AOSGE), which is supported jointly by Norwegian and German funding (German Science Ministry, BMBF).

After the exchange of some scientists in Longyearbyen we sailed towards the eastern coast of Greenland. The programme there was mainly carried out in the framework of the Special Research Programme (SFB 313) of Kiel University: "Environmental changes, the northern North Atlantic". The interest here focused on four areas:
1) Investigations on particle production in the sea ice and upper water column, their modification on the way to the seafloor, and their final sedimentation.
2) Determination of distribution and activity patterns of organisms on and within the seafloor as well as of carbon dynamics and interactions between sediment and water column.
3) Measurements of nutrients within the water column and the sediment and of transport mechanisms of oxygen and carbon into the seafloor.
4) Investigations on distribution, sedimentation and geological evidence of plankton organisms with fossilisation potential.

Most of the research took place during two transects at 75°N and 81°N. In addition, two long-term sediment trap deployments were recovered from 75°N and 7°W. The first leg ended in Tromsø (Norway) on June 24 1997.

Captain U. Pahl was the master of RV "Polarstern". We are grateful to him, the officers and the crew for excellent, committed work and their willing assistance, which contributed significantly to the success of the cruise.

2 **Itinerary** (Spindler)

On May 14, 1997 RV "Polarstern" left Bremerhaven as planned at 17:00, with 42 scientists (including a televison crew of 3), 4 technicians testing and installing new systems, and 43 crew members on board. Two of the technicians were flown back by helicopter to Bremerhaven on the same day, the other two on May 17 to Trondheim. The passage through the calm North Sea was used to set up the laboratories. On May 19 we reached our investigation area East of Svalbard and started station work in open water approximately 40 miles off the ice edge (Fig. 2.1). The ice was encountered later during the night and from then on stations followed in rapid succession every 6 miles. Most of the ice was relatively thin and algal growth had produced brown water underneath most ice floes. Our intended northernmost station 50 miles within the pack ice zone was reached on May 22. Since at this station algae were also thriving in the ice and the upper water column, we decided to sail another ten miles north to 77°25'N. Only at this position the amount of algae actually decreased remarkably. Our last station for the ARK XIII/1a leg was completed during May 24 and "Polarstern" headed towards Longyearbyen for an exchange of scientists.

Fourteen persons including the television crew left the ship on May 26 while 12 newcomers arrived on board. Most of the remaining crew and researchers used the short stay of three and a half hours in the harbour to visit the city of Longyearbyen. Two days later we reached our mooring position at 75°00'N, 7°30'W, deployed a sediment trap and started a transect at 75°N towards the westcoast of Greenland. Station depths ranged from 3500 m to 200 m at our shallowest station close to the coast on June 2. After a second visit of the easternmost station along the 75° transect we headed North to 78°20'N, 5°00'W to deploy a sediment trap at an ice floe. This trap was supposed to collect material sedimenting from the floe until recovery some 14 days later. We steamed further North under heavy ice conditions and reached 81°N on June 10. Here again a transect of stations from East to West was carried out until we had to stop, only obtaining few samples at a water depth of 400 m. On June 13 we were heading back South to relocate the ice floe with the attached sediment trap. We were able to trace the floe at all times via satellite and by helicopter survey we could find and recover the trap after ten days of deployment. Two additional larger sediment traps were recovered on June 19, one was deployed a few weeks ago at the beginning of ARK XIII/1b, the other trap was deployed in August 1996. Since both moorings were quickly detected and brought up much faster than we anticipated, we finished our scientific programme and headed in southeasterly direction. The time saved due to the fast recovery of the traps was used for an excursion to Bear Island situated close to our cruise track towards Tromsø. Scientists and crew enjoyed Zodiak trips to the magnificent rock formations and busy bird cliffs on a sunny day.

After 42 days at sea, many of them under heavy ice conditions, "Polarstern" arrived safely in Tromsø in the morning of June 24. For most of us it was the end of a scientifically very successful cruise. Two scientists and several crew members were looking forward to joining the next leg, ARK XIII/2.

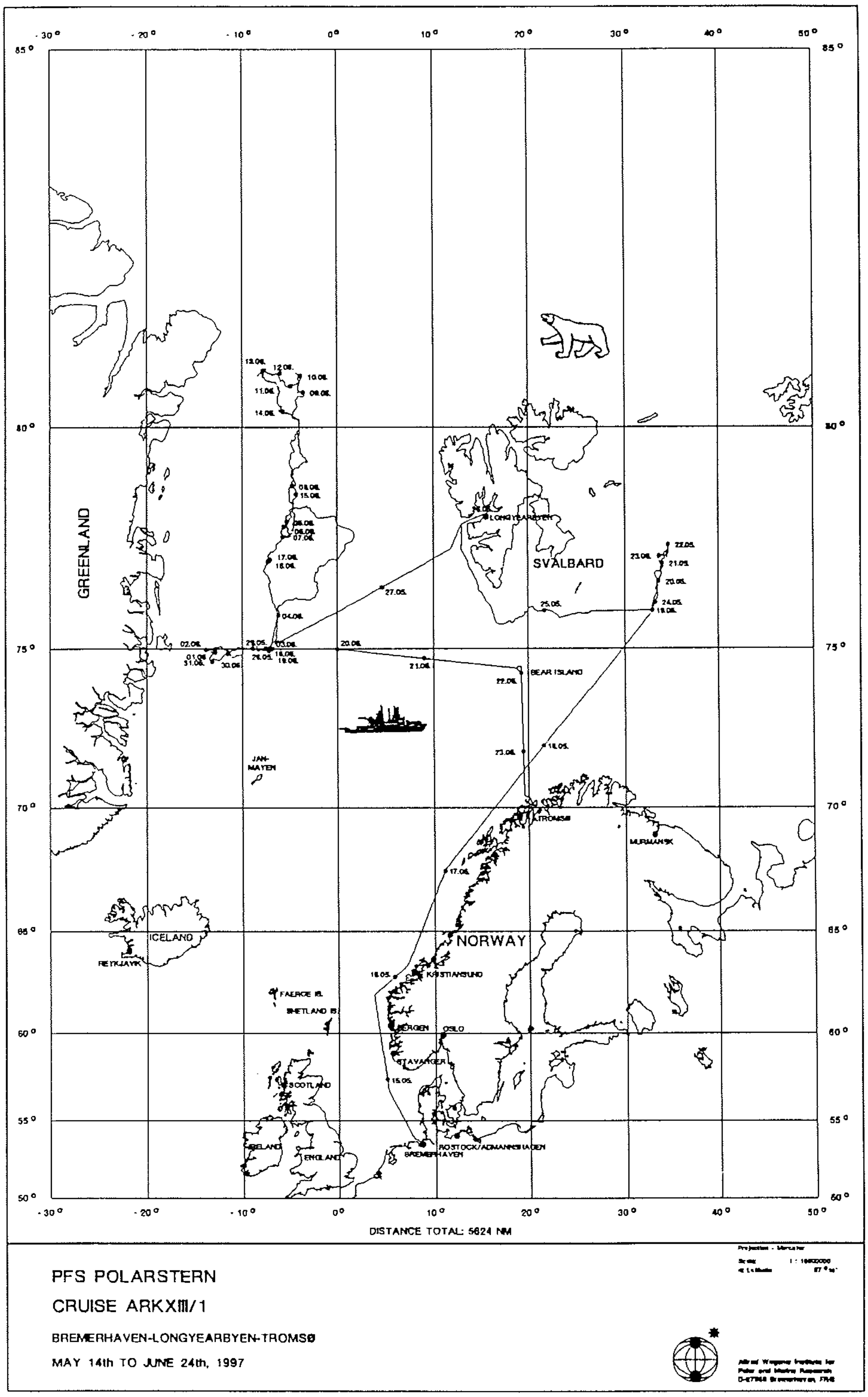

Fig. 1.1: Cruise track.

3 Metereological Conditions (Buder)

Weather and ice conditions during the cruise
Under hazy weather conditions "Polarstern" left Bremerhaven for the North Sea on the evening of 14.5.97. The North Sea welcomed us with an anticyclone, plenty of sunshine and weak winds from Northwest. We reached a foggy area off southern Norway, which was also clearly visible by satellite imagery. The cruise continued under foggy conditions until in the afternoon of 16.05. we arrived at full sunshine and NW 3-5 Bft in an area to the west of Trondheim. On 17.05 the influence of the anticyclone weakened temporarily. Satellite imagery indicated a circulation to the South of Spitsbergen, suggesting the formation of a cyclone. Near the Lofoten Islands the wind changed from NE to W/SW at 4-5 Bft. The cyclone continued eastward, while the wind changed to NW in the evening increasing from 6 to 7 Bft. We passed a cold front with rain and showers. On 18.05. "Polarstern" was located to the North of the cyclone which moved SE at northeasterly winds of 6-7 Bft and frequent rain and snow showers. The temperature gradually decreased below 0°C. On 19.05. we reached the first research area to the East of Spitsbergen at 76°N and 33°E. The eastern flank of a stable anticyclone over Greenland brought northeasterly winds of 6-7 Bft with temporary snow showers and temperatures down to -4°C. First ice floes were sighted in the evening and we had arrived at the marginal ice zone of the central Barents Sea.

The stable anticyclone over Greenland slowly weakened during the next two days and moved towards the East, while the NE wind decreased to 4-5 Bft. The temperature dropped further to -8/-11°C. The weather was controlled by a complete stratus cover with lower limits at 200 m and 600 m and occasional light snowfall. Ice conditions changed between open water and densely packed ice fields.

On 22.05. we remained for a longer time period close to an extended ice field due to station work. We were now at the northernmost point of the first leg at 78°N and 34°E. On the next day we returned to the South. On 24.05. we finished the first section to the East of Spitsbergen and headed for Longyearbyen on Spitsbergen.

After a small cyclone passed our way, sunshine returned with NW 3-4 Bft. The passage to Longyearbyen was temporarily hampered by severe ice conditions. In the morning of 26.05. we arrived in Longyearbyen under a low ceiling of clouds and light snowfall, where we anchored due to the shallow depth of the harbour basin. At 17.00 "Polarstern" left Longyearbyen towards the area off East Greenland at 75°N and 6°W for the second leg of the cruise.

The passage was calm under the influence of an anticyclonic wedge near Scotland with 3-4 Bft. On 28.05. we arrived at our research area, again surrounded by ice. The influence of the anticyclone weakened and during the next days we were affected by several moderate cyclones which passed from the area around Iceland towards the NE. The wind changed between SE and SW with 3-5 Bft. At the same time mild air was advected and the temperature rose to +1°C. Temperatures on Iceland locally even reached +20°C. Our weather was dominated by low stratus clouds and frequent fog. On 1.6. the last cyclone from Icelandic regions moved East towards Spitsbergen. Air pressure increased over Greenland and allowed the formation of an anticyclone. On

2.6. mild air was advected again within the lower 1000 m. Air temperatures rose to +4°C for two hours, accompanied by plenty of sunshine. On 3.6. a cyclone developed to the west of Jan Mayen, slowly proceeded eastward and was located to the South of Bear Island on 6.5. "Polarstern" was positioned on its northern side at a weak NE wind of 3-5 Bft and plenty of sunshine, but temperatures sank again to -4°C. The cyclone gained intensity on its way to northern Norway causing the NE wind to increase to 6-7 Bft, accompanied by temporary and at times longlasting snowfall. On 7.6. the anticyclone slowly moved from Greenland to Spitsbergen. The wind from NE decreased to 3-4 Bft and the cloud cover slowly opened up. We were on our way to the northernmost point of leg 2 at 81°N and 4°W, but the cruise was interupted every once in a while, due to severe ice conditions with ice thicknesses of 2-3 m.

We reached the northernmost point at 81°N on 10.6. "Polarstern" was now positioned to the North of a marginal cyclone, which switched from a strong cyclone south of Iceland to Jan Mayen. The deep cloud cover of the northward advancing warm front approached us from the South with lower limits between 600 and 1000 ft. The wind remained weak between 2-4 Bft from southerly to easterly directions. We remained at 81°N until 13.6. During this period our weather was dominated by the typical grey of the Arctic with lower cloud limits sometimes below 100 ft. The easterly wind prevailed between 2-4 Bft. Station work was finished in the evening of 13.6. and the vessel returned to the drift station on an ice floe. A station with a radiotransmitter had been set up on this ice floe on our way north. At the same time an anticyclone formed over NE Greenland, which slowly moved eastward. Apart from some short interruptions, the weather was further determined by deep stratus clouds and at times fog. Our progress was slow, since ice thicknesses increased to over 3 m. On 16.6. we arrived at the drift station and the equipment was recovered. At the same time the preparations for the polar baptizing started. The anticyclone had moved to Spitsbergen and remained stationary until 18.6. Southerly winds blew with 3-5 Bft. On 17.6 the baptizing ceremony took place. In the evening the cruise continued to 75°N, where two long-term moorings from "Meteor" were recovered and two stations completed. This activity ended the scientific programme of the cruise. With ample time left until our arrival in Tromsø, we left the position 75°N 3°W on 20.6. and steamed towards Bear Island. In the morning of 22.6. we reached Bear Island from the West at beautiful sunshine and NE wind of 4 Bft. We stopped for eight hours at the most attractive SE side of the island. Magnificent entrances of grottas exhibited a wonderful panorama. Zodiak trips are offered to the grottas and surroundings. In the evening we continued with our voyage to Tromsø.

Activities of the Meteorological Office
The main task of the meteorological office was to provide the ship´s leaders, the chief scientist and the helicopter pilots with meteorological advice.

Self-generated ground pressure maps of the data 06 UTC and 15 UTC were the basis for the daily weather forecast. If needed, especially during poor radio reception, the data were supplemented by 09 and 18 UTC observations. In addition, ground analyses from Offenbach were available via fax.

Every day in the morning and in the evening, the meteorological office provided 12 hour forecasts and 12 hour expectations, together with an overview of the weather at home as a service for the participants. The weather development was presented to the chief scientist and the captain or the officers on duty. Copies of the weather charts and of the weather reports were also given to the chief scientist and the bridge.

During helicopter flight activities the pilotes received oral advice of the flight weather as well as written overviews, Metars, Tafs and a vertical presentation of the aerological ascent.

Hourly weather observations were automatically compiled and fed into the net via DCP. During duty hours these messages were supplemented by eye sight observations and maritime parameters, especially during main and in-between dates. A radio probe ascent was performed daily at 12 UTC. The temperatures were also fed into the net via DCP. It was evaluated by the TLOP programme and it was a valuable help for the flight weather forecast.

The images of NOAA and especially METEOR satellites provided important information for the assessment of the ice situation. In contrast, the ice charts provided by BSH were obsolete and presented the ice situation only insufficiently. We cancelled their supply during the cruise.

Additional charts for the daily weather forecast were offered by Offenbach via fax especially for this Arctic cruise. This included circumpolar charts of the ground pressure and wind for a forecast period of up to four days. They were an important help for the forecast activities, since the forecasted ground pressure and wind fields were in good agreement with the real data.

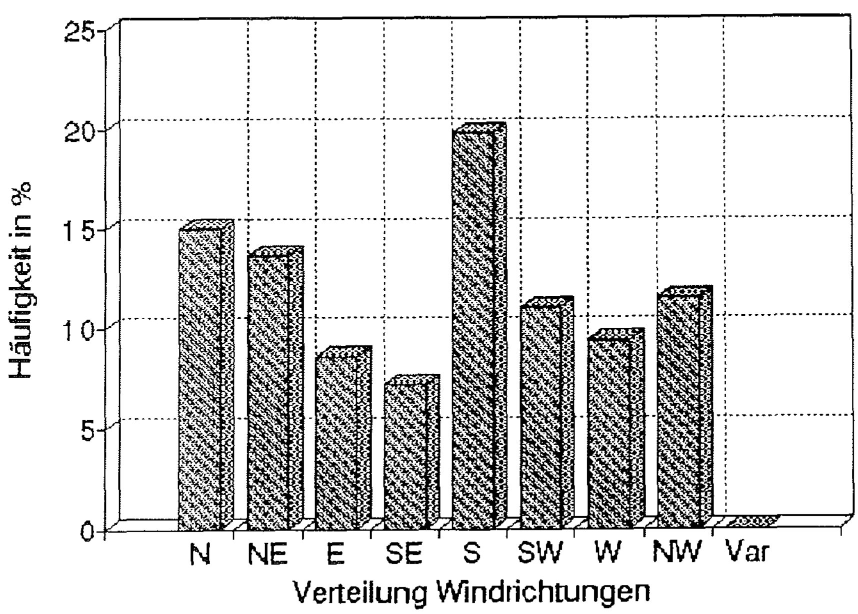

Fig. 3.1: Wind directions during ARKXIII/1.

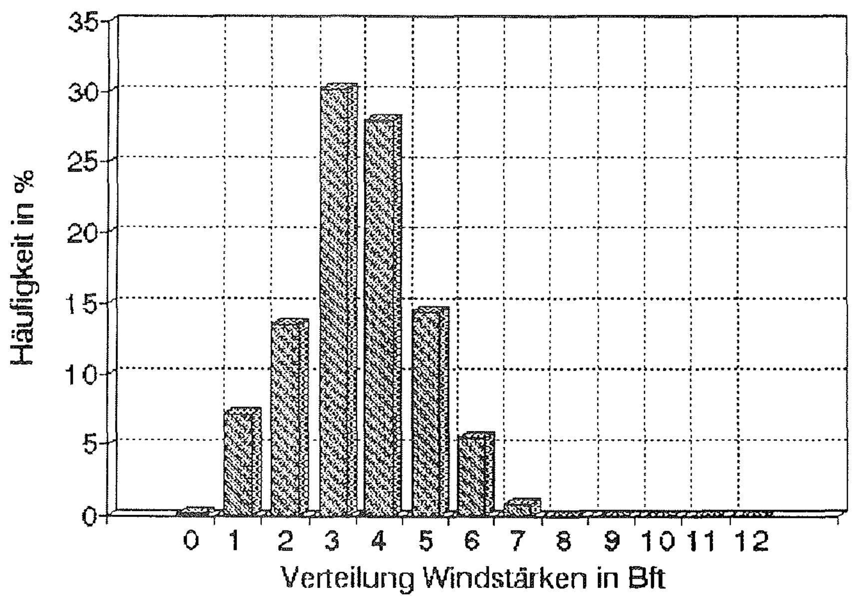

Fig. 3.2: Wind velocities during ARK XIII/1.

4 Sea Ice Studies

4.1 Remote Sensing (Garrity, Whritner)

The main task of the remote sensing program was to support the ARK XIII/1a,b objectives by providing ice information to the Captain and Chief Scientist for planning purposes. It was also our intention to investigate specific problems in order to better understand remotely sensed data. The main objectives were:

- to support the ARK XIII/1a,b program with "real time" strategic ice information by using NOAA-AVHRR (Advanced Very High Resolution Radiometer) satellite data
- to support the ARK XIII/1a,b program with remote sensing helicopter flights by using the Line Scan Camera (LSC) system

There were a number of sub-objectives:
- study of the on-set of melt in the snow cover for various ice types by measuring the electrical and physical properties of the snow
- study of the Special Sensor Microwave Imager (SSM/I) 85 GHz satellite channel data for variations due to a changing snow cover and/or the amount of moisture in the atmospheric column
- the integration of AVHRR, and Operational Line Scan (OLS) satellite images, as well as LSC data, with the derived high frequency SSM/I ice concentration maps for first year ice, old ice and total ice in order to further the understanding of the relatively new SSM/I algorithm.

Methods

NOAA-AVHRR: The NOAA series of weather satellites have an orbital period of approximately 102 minutes, carrying the AVHRR, and the TIROS Operational Vertical Sounder, along with different smaller instruments. The data is transmitted in digital format directly from the satellite to the SeaSpace (SeaSpace Corporation, San Diego, CA) TeraScan system located on the ship. The AVHRR has 5 channels scanning a swath of 1400 km to both sides of the sub-satellite track (SST). The geometric resolution is 1.1 km near the SST. The spectral ranges for each of channels 1 to 5 follow as: 580-700 nm, 700-1000 nm, 3.5-3.9 μm, 10.3-11.3 μm, and 11.5-12.5 μm. These channels enabled visible images of the ice, and meteorological parameters for determining the progression of weather fronts. Numerous overpasses of the NOAA series satellites were processed and archived daily.

Special Sensor Microwave/Imager (SSM/I): The SSM/I sensor is part of an operational United States Defense Meteorological Satellite Program (DMSP). The 1400 km swath width provides excellent coverage for a given satellite overpass. The channels of particular interest to us is the 85 GHz vertical and horizontal polarizations. This is the highest microwave frequency of the SSM/I, thus has the best ground resolution (12.5x12.5 km grid spacing) as compared to the other microwave channels: 19, 22, and 37 GHz. Sea ice concentration products are conventionally derived using these lower frequency channels, for example, the NASA Team and the Atmospheric Environment Service (AES, Canada) algorithms.

The 85 GHz channels have a wavelength of 3 mm which is influenced by the atmospheric moisture to a greater extent as compared to the 19 and 37 GHz SSM/I channels. To date, the SSM/I data cannot be received in a useful format in real time on a non-US military platform when north of 60 degrees. During ARK XIII/1b, the SSM/I channel data was received directly from the f-series DMSP satellites using the same antenna as used for the capturing of the AVHRR data, however, the SSM/I data could not be used on the ship. The SSM/I data will be "decoded" at SeaSpace Corporation for scientific use in the near future. The SSM/I satellite overpasses were captured as close as possible to 1000 UTC, due to the launching of the radiosonde balloon by the ship's meteorological office. The advantages of using SSM/I data is the end product, providing a sea ice concentration map, day and night and for all weather conditions. Under the correct conditions, the sea ice can be quantified by ice type. This is the only type of data to date, that can produce sea ice concentrations within minutes after a satellite overpass.

Operational Linescan System (OLS): The OLS sensor is also part of the DMSP f-series satellites. Of particular interest is the visible channel that provides a 600 m cross track resolution. There is an infrared 1.1 μm channel with the same resolution, the highest-resolution meteorological instrument in space. The variable scan provides an equal distance between pixels for the same scan line. The visible channels 1 and 2 of the AVHRR is covered by the broader bandwidth OLS visible sensor, thus more radiation from a given scene can be sensed as compared to an AVHRR scene.

Helicopter Mounted Line Scan Camera: The LSC operates in the visible range to obtain reflectance information from ice and water. A pixel of an image is stored as a byte value, thus they are represented by a radiometric value between 0 and 255. The swath width depends on the altitude of the helicopter, generally being one third of the altitude. For our purposes, it was best to fly around 3300 ft, providing a 1000 ft swath width along the flight path. However, since it was our aim to fly during cloudy conditions, in order to have different atmospheres for the microwaves to travel through enroute to the SSM/I, we also flew below the cloud cover from 1000-2500 ft. Generally, the flight path extended to 35 nm on two sides of a rectangle with 10 nm on the short sides, thus there would be at least a few SSM/I 85 GHz footprints (field of view) on the earth's surface crossed during a flight. A LSC flight was generally done at the time of the radiosonde balloon launch. The analysis software package for the LSC can distinguish between three gray tone ranges, thus open water from young ice and either first year or old ice. The result provides a total sea ice concentration as well as by ice type, depending on the image scene.

Resometer: The resometer is the only in-situ instrument that can be used to obtain the amount of free water by volume in a snow cover. Once a snow cover has physically been disturbed, the properties will change as compared to its natural state. It is for this reason that the snow measurements were made in-situ using an instrument developed at the University of Bern, Switzerland. The resometer enables an accurate and rapid measurement of the resonance properties of the resonator sensor which depends on the amount of moisture between and around the snow grains. A description of the resometer can be found in Mätzler (1996).

Results

Satellite Remote Sensing: The AVHRR images collected and processed during the cruise were used to meet the primary objectives. Satellite over-passes were captured when updated sea ice conditions were required for navigational purposes and scientific planning. This could range from hourly to a few times a day. There were only a few days when there was too much of a cloud cover for the reflection in the visible channels to be received from the ice and water. As the cruise progressed, there was an increasing amount of fog, however, the visible channels were still able to receive reflectance through the fog from the sea ice. An example of an AVHRR image showing part of the cruise track through the sea ice is shown in Fig. 4.1.1 The dark line is the ship's track and shows the deviation of the ship around smaller and larger sea ice floes. This image is from June 02, when there was fog and low level cloud cover over the sea ice to the north of the ship's track. This is just one example out of many showing how the Captain and Nautical Officers used the satellite image to aid the navigation through the changing sea ice conditions.

The AVHRR images were used to locate a suitable ice floe in order to place a sediment trap below the ice surface. The floe size, drift and location from the ice edge was important in order to ensure that the ice floe would not break-up and/or escape into the warmer waters. A large ice floe was chosen as a prime candidate near 78°N and 7.5°W. The ice floe was tracked using daily AVHRR images and argos tramsmitters and was then able to be located by a helicopter flight when in travel range of the helicopter from the ship. However, when the ship was approaching the large ice floe, thick fog did not permit easy navigation to the floe. A smaller floe was used for the scientific work, in close proximity to the large floe. The smaller floe was tracked using argos buoy positions which were received using the TeraScan antenna. Fig. 4.1.2 shows

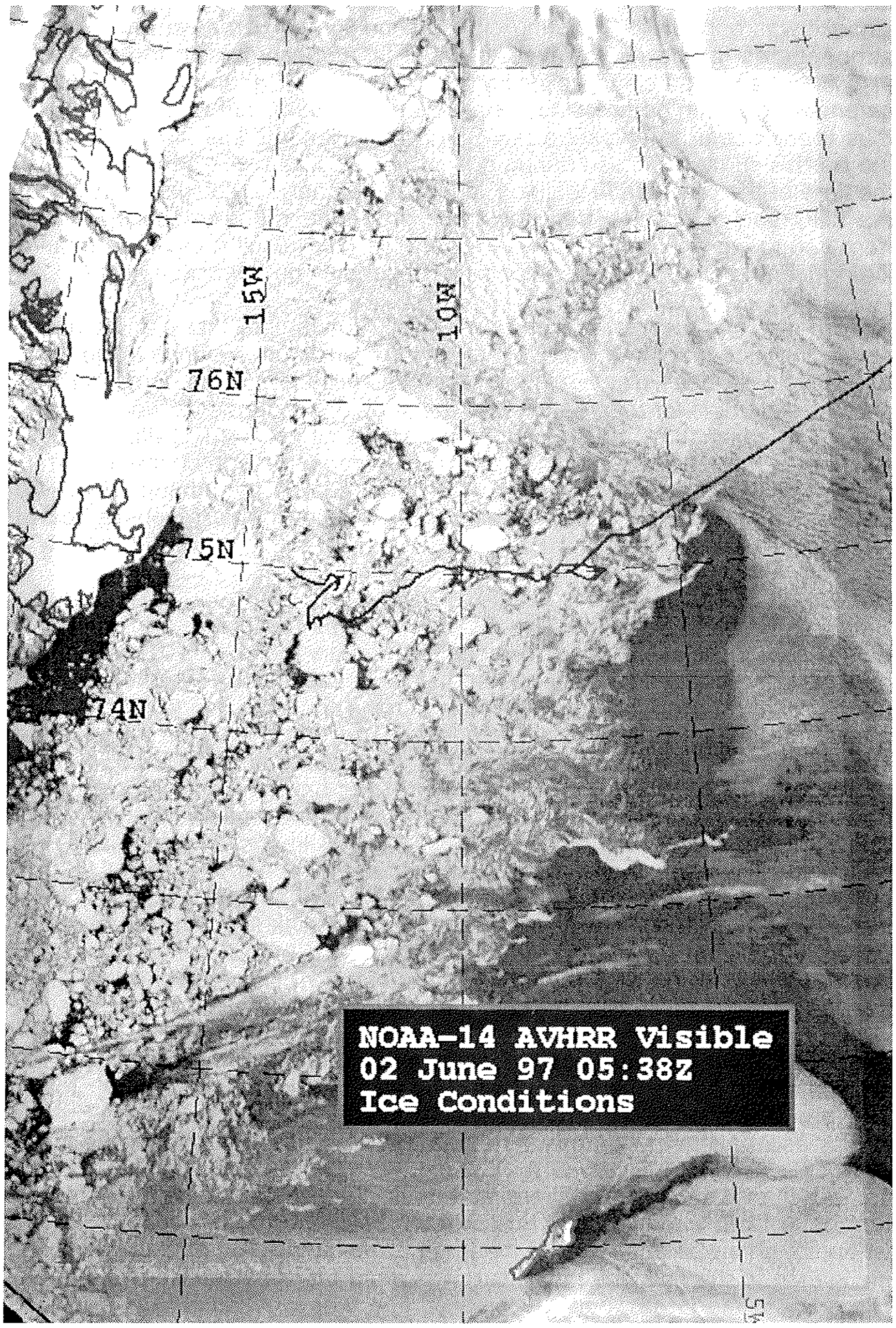

Fig. 4.1.1: Satellite image of ice conditions on 02 June 1997 with cruise track.

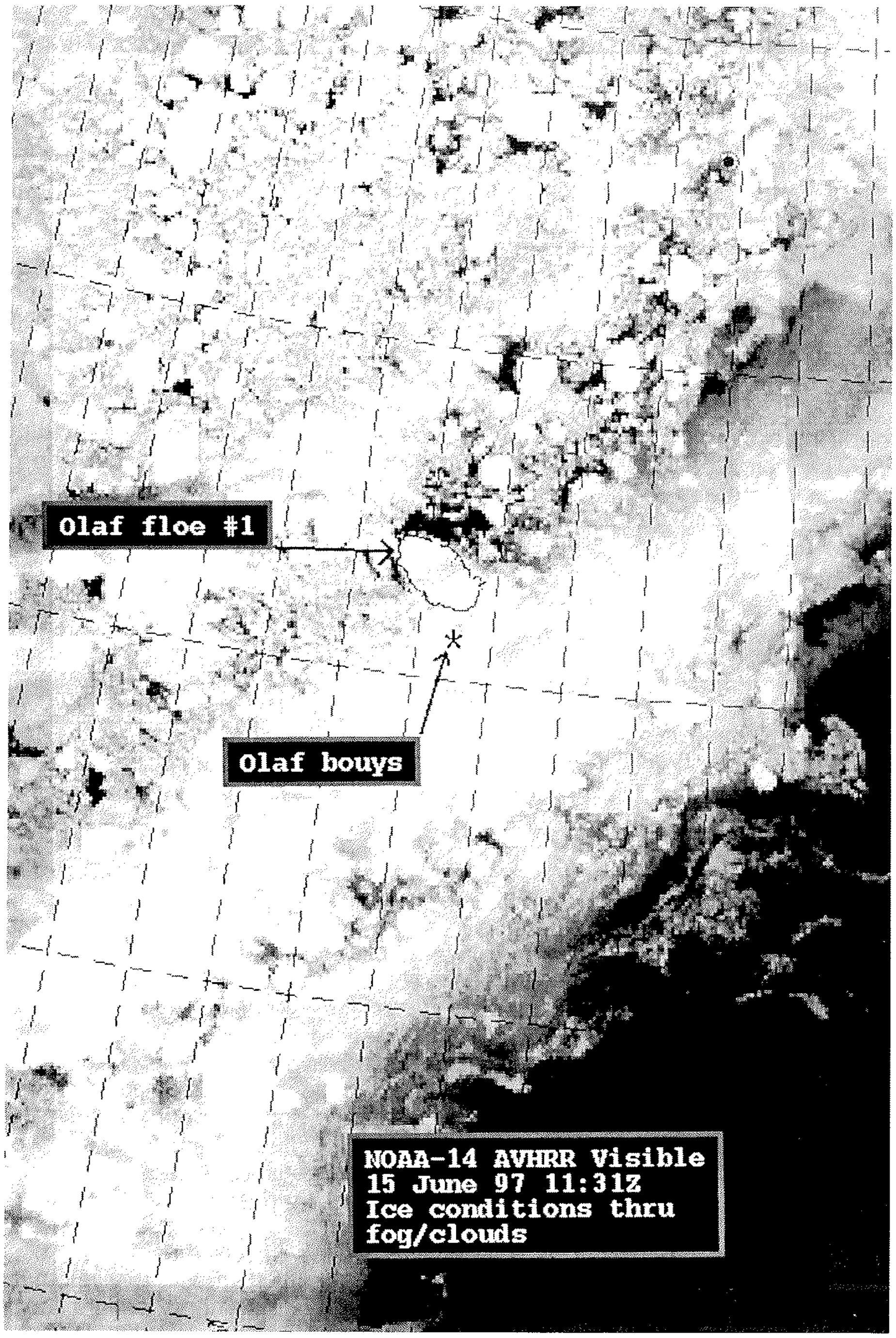

Fig. 4.1.2: Satellite image of ice conditions on 15 June 1997 with Olaf floe #1 and Olaf buoys.

the large ice floe (Olaf floe #1) as well as the smaller floe (Olaf buoys). By June 15, the ice movement caused the ice in the area of the buoys to drift south-westwards at an average rate of 0.5 knots.

Once the ship returned from the station work a few degrees to the north, about two weeks later, the under ice deployed sediment trap was located with no difficulties (June 16).

Snow: The snow cover influences the microwave signatures received by the SSM/I sensors for the 37 GHz (8 mm wavelength) polarization channels (Garrity, 1992), and it is expected that the 85 GHz channels with a smaller wavelength (3 mm) would be influenced even more by the snow cover due to the smaller penetration of the 3 mm microwaves being emitted from the ice surface. As the snow cover evolves from winter to spring conditions it will eventually act as a blanket, masking the microwave energy being emitted from the ice surface. In order to monitor the on-set of melt in the snow cover, 34 snow pits provided 186 snow wetness measurements from May 21 to June 16. Days May 24-27 (Svalbard - science change), June 5 (fog) and June 17 (baptism) are the only days missing snow measurements during the time in the ice. The more free water between the snow grains, the less microwave energy from an ice surface will be received by the SSM/I sensors, and more from the snow, which can result in an overestimation in the derived sea ice concentration maps.

During the ARK XIII/1a,b, the snow cover on first year and old ice gradually changed from winter snow, which was dry and can be described as "igloo" snow (blocky) to wet corn snow, typical of spring conditions. The on-set of melt was "turned on" and well established by Julian Day 149 (May 29), when the air temperature was just above 0°C. The permittivity of the snow surface (5 mm depth) rose significantly (Fig. 4.1.3), indicating a surface snow wetness of about 4.5% by volume (Fig. 4.1.4). The snow wetness calculations are preliminary for this report, since the different layers in the snow cover must be included in the calculation in order to get a representative snow wetness for the entire snow depth. During this cruise, the melt season can be described radiometrically (in the microwave region) as the "preconditioning phase" (Ramseier-Garrity model, not published) progressing into the beginning of the snow melt to eventually form melt-ponds. The preconditioning phase causes fluctuations in the 37 GHz microwave signatures, followed by black-body radiation. It is expected that there will be black-body radiation for Julian Day 168 (June 16), and possibly thereafter, when the total snow depth showed a high permittivity (Fig. 4.1.5). Black-body radiation occurs when the snow cover will emit as much microwave energy as it absorbs (physical temperature). The black-body radiation will stop during the drainage of water out of the snow cover, aiding the growth of melt-ponds, but this did not occur during cruise Leg 1. There was only a trace of melt-ponds, and it is difficult to note if these were "true" melt-ponds formed from surface melt or caused by flooding due to ridging activity (i.e. cracks, deformations) by the ice movement.

The interesting part of the results from the snow measurements will occur during the comparison of the SSM/I 85 GHz channel data with the calculated snow permittivity. The largest error in the snow measurements occurs for the snow density, which is required for the calculation of snow wetness. Thus, it is better to use permittivity with an error close to 0.003. Fig. 4.1.5 shows the

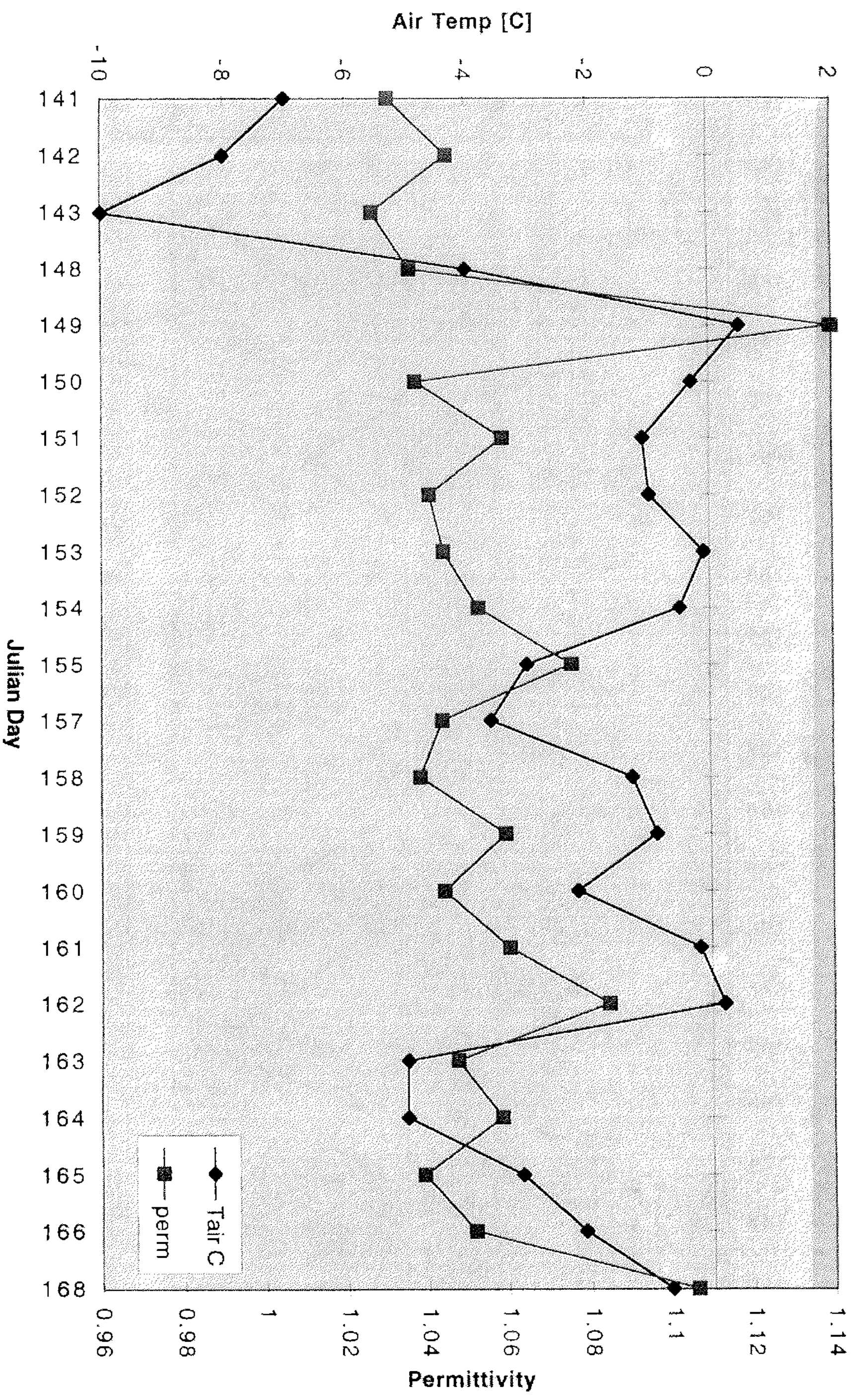

Fig. 4.1.3: Snow surface permittivity.

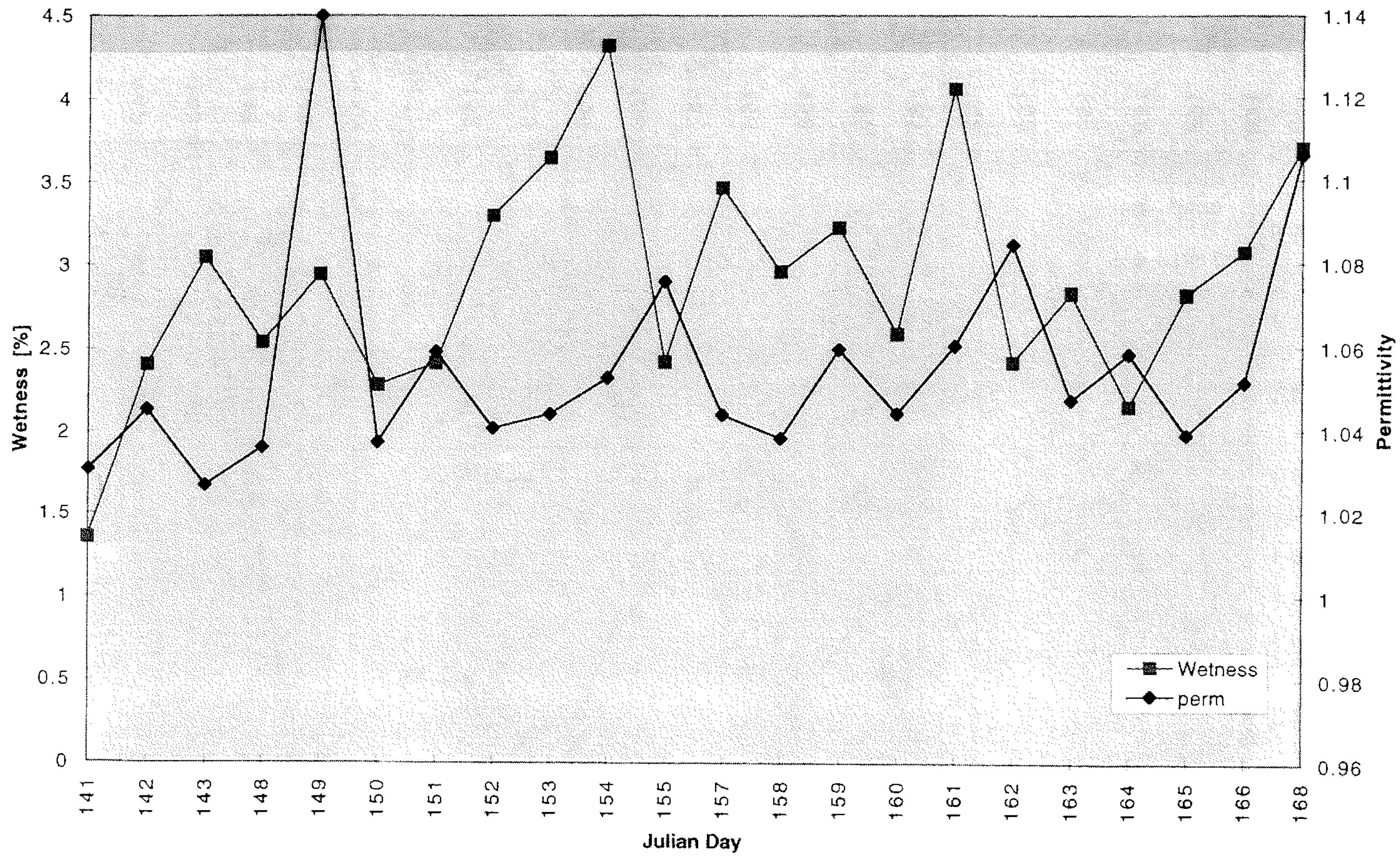

Fig. 4.1.4: Surface snow wetness and permittivity.

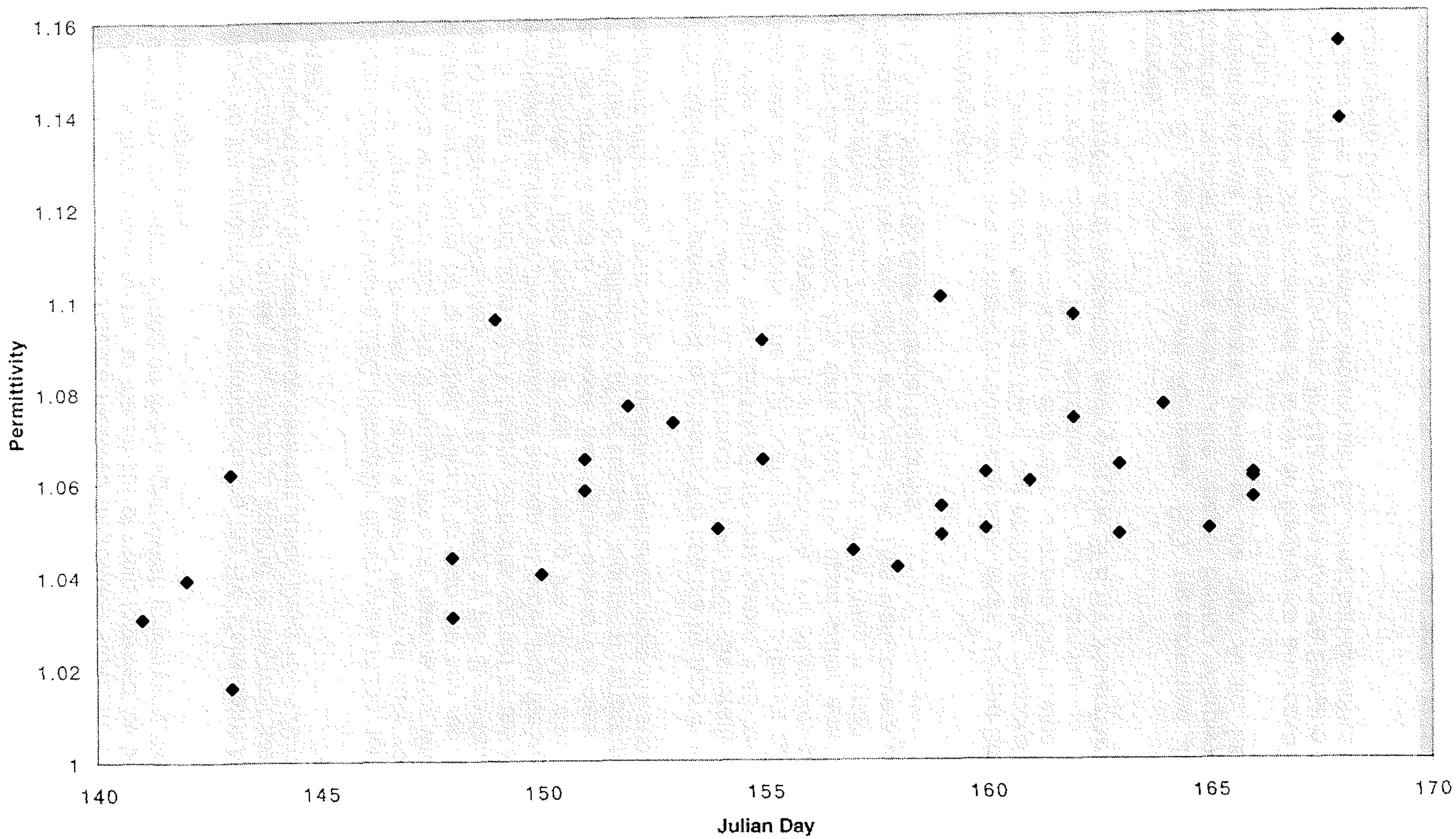

Fig. 4.1.5: Snow permittivity.

preconditioning phase in snow melt, except towards the end of the cruise. The slope of the linear regression is small (0.002) and y-intercept 0.79, with a standard deviation of 0.02. It will be very interesting to see if these small changes in the snow permittivity of the snow pack during time will have a significant influence on the satellite received microwave signature at 85 GHz. The change from winter snow, to the on-set of melt, followed by late spring melt conditions are each turned on like a light switch influencing most SSM/I microwave signatures.

Compared to the amount of melt-ponds during the RV "Polarstern" North East Water Polynya (NEWP) cruise, this cruise is behind in the melt season. The NEWP showed up to 5% melt-ponds between Julian Days 160-170 (El Naggar et al., 1997).

Line Scan Camera: Extensive LSC helicopter flights were made, totally 1,180 nm during 13 flights over the sea ice, with a swath width of data from 300 to 1000 ft. There was one test flight of the system over open water where white caps due to wind could be quantified. Flights to map the sea ice conditions started in the Barents Sea, May 22 and 24, followed by the Greenland Sea for June 1-5, June 7-8, and June 10-11. Nearly all flights started at the time of the meteorological launch of the radiosonde balloon, in order that the influence of the atmosphere on the mapping of sea ice using the SSM/I can be determined. On June 2 and 3, there were two flights due to the clear conditions which will be used as a calibration of the sea ice "algorithm" where there is no atmospheric influence, thus only a possible "hindrance" from the snow cover.

The LSC data will be processed to quantify the sea ice by type in the area of the scientific stations, which is of interest to the SFB. Generally, the flight pattern was a rectangular box, 35x10x35x10 nm (about 1.45 hr), covering variable sea ice conditions. The LSC can map three different parameters: open water, young ice types, and first year/old ice. For example, on May 24 there was 5% open water, 8% dark nilas, 8% open water and dark nilas mixture, 23% white nilas, 7% open water and white nilas mixture, 64% gray ice, 0% gray white ice, and 28% first year ice. This flight covers about nine 12.5x12.5 km SSM/I 85 GHz channel footprints.

Acknowledgments
The authors would like to thank the helicopter team pilots, Jürgen Büchner and Burkhard Zepick, for not only safe flying, but enthusiastic cooperation and a special thank you to the helicopter engineer, Joachim Böhm who made the vehicles operate reliably. The dedication of Prof. Spindler to the cruise provided a smooth and successful ending for the SFB RV "Polarstern" cruises.

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4.2 Sea Ice Biological Studies (Gradinger, Donner, Haaß, Meiners, Mock, Peeken, Werner, Zhang)

General introduction

Sea ice floes are the habitat for the so-called sympagic community which consists of bacteria, protists and metazoans. During this expedition we studied physical, chemical and biological properties of ice floes to characterize the seasonal changes occuring in the winter-spring transition. Ice samples were obtained by means of ice coring or brine sampling, under-ice studies were done with a pump system and an under-water video camera. A total of 13 stations were sampled during this expedition. At four stations we sampled first-year ice floes in the Barents Sea (ARK XIII/1a), all other sampling activities focused on multi-year ice floes in the Greenland Sea (ARK XIII/1b). First of all, our data set will allow for a detailed comparison of first-year versus multi-year ice communities based on the conducted biomass and activity measurements. Secondly, the results will be included in data sets from earlier "Polarstern" expeditions to describe the seasonal cycle of ice biota development in Arctic seas.

Sea ice observations

A total of 73 observations on the state of the sea ice cover were made while the ship was in ice-covered waters. We determined the contribution of certain ice types (new ice - young ice - first-year ice - multi-year ice) as well as size of ice floes, snow thickness and sediment load.

In the Barents Sea, we observed new ice, young ice and first year ice. No sediment inclusions were seen at any location. The average ice thickness distribution along the northwards going transect is given as an example of the available data (Fig. 4.2.1). First-year ice thickness ranged from 40 to 110 cm with a strong longitudinal increase. The average floe size increased towards the north from smaller than 10 m at the southernmost observation point to more than 1000 m at the northernmost location. New ice formation was observed at all locations due to the low air temperature (median of observations: -7.8°C).

The ice cover in the Greenland Sea was dominated by multi-year ice floes. At nearly all locations we saw floes including sediment. The mean ice thickness was around 300 cm with additional 40 cm snow cover. No formation of melt ponds was observed during the entire expedition, although snow melting occurred during the last days in the study area.

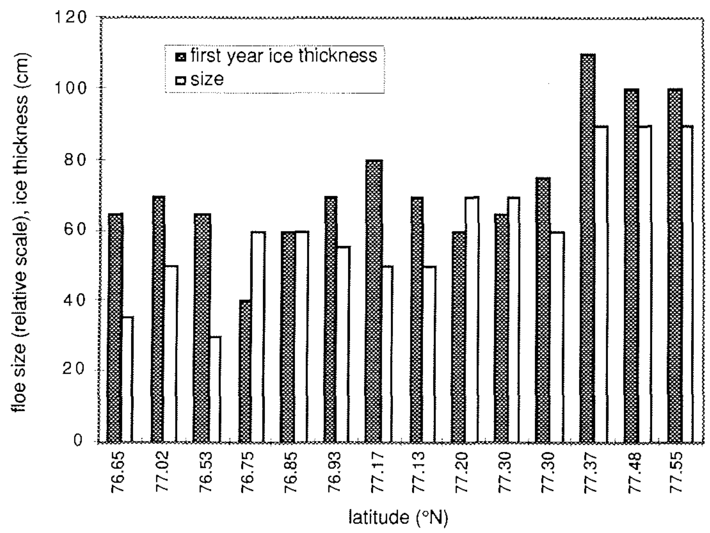


Fig. 4.2.1: Ice thickness and floe size along the northward heading transect of ARK XIII/1a

We frequently observed strong coloration of ice floes due to algal growth. Not only the bottom sides of ice floes showed a slight brownish color, but also the interface between snow and ice. Therefore, we hypothesize that the formation of infiltration layers also occurs in Arctic seas as described for Antarctic regions. However, we did not have the opportunity to study such floes by taking ice cores. Large mats of *Melosira arctica* were frequently observed while the ship was steaming through new and young ice of thicknesses of 20 to 40 cm.

4.2.1 Light Measurements (Gradinger)

UV-A and UV-B radiation measurements were conducted with 2π surface GRÖBEL-sensors. The intensity of the photosynthetic active radiation (PAR) was measured using a 2π LICOR surface sensor and a 4π LICOR under water sensor which was lowered to the underside of the ice floes through a core hole. Light intensities were recorded as 1 min averages with a LICOR data logger over time periods of 4 to nearly 12 hours at 6 stations. Fig. 4.2.2 shows the results from the ice station 157. Surface light intensities varied strongly with daytime and increased from initially 250 $\mu E\ m^{-2}\ s^{-1}$ to around 1150 $\mu E\ m^{-2}\ s^{-1}$ at noon. The under-water light intensities showed the same variations, but reached on average only 0.2% of the incoming radiation. The final compilation of the light measurements will be used to understand the spatial differences of ice algal occurrences in different ice floes.

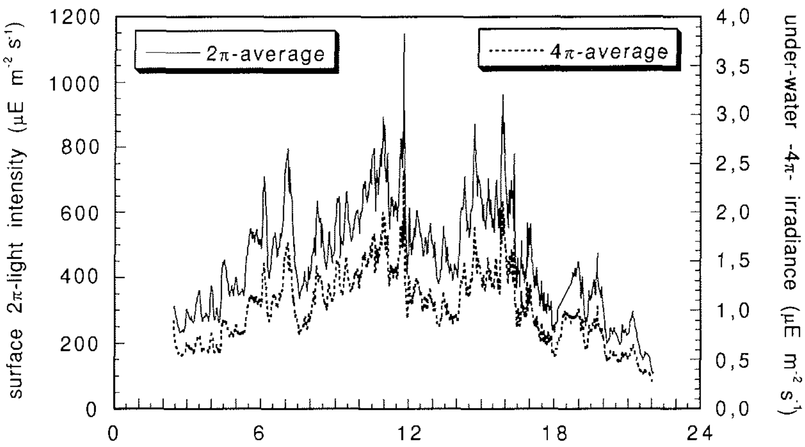


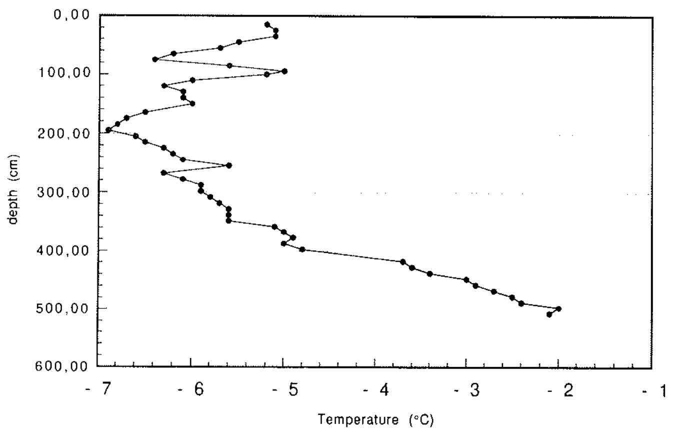
Fig. 4.2.2: Light (PAR) irradiance at St. 157

4.2.2 Physical, Chemical and Biological Properties of Arctic Sea Ice (Donner, Gradinger, Haaß, Meiners, Mock, Peeken, Werner, Zhang)

At 13 stations we sampled several ice cores to measure vertical profiles of the following parameters:

- ice temperature
- ice bulk salinity
- nutrient concentrations (NH_4, NO_3, NO_2, SiO_4, PO_4)
- chlorophyll *a* and phaeopigment concentration
- algal pigments (by HPLC analysis, see report by Peeken)
- particulate silicate
- particulate organic carbon (POC) and nitrogen (PON)
- organism abundances (bacteria, protists, metazoans).

Most of the analyses will be conducted in the home laboratories, onboard "Polarstern" we could only determine the first four parameter sets mentioned above. A typical example of the available data set is given for ice station 148 (Fig. 4.2.3). Lowest temperatures were mostly observed in the middle part of the ice cores, still representing winter values, while a slight warming of the ice surface had already occurred. Highest algal biomass was always found in the bottom parts of the ice floes with maximum values in first year ice floes of the Barents Sea (830 mg Chl *a* m^{-3} ice at St. 140).



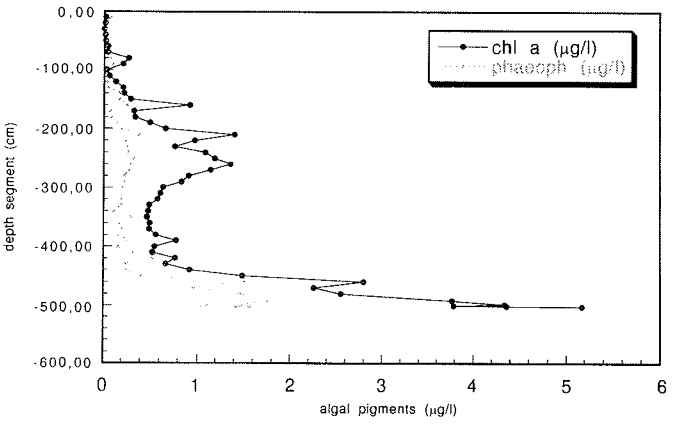


Fig. 4.2.3: Vertical distribution of temperature and algal pigments in the ice floe at St. 148.

4.2.3 *In situ* Primary Production Measurements (Mock)

A new method enabled us to obtain the first data about *in situ* primary production of sea ice algae in the bottom meter of sea ice. This part of the ice included the highest biomass of algae within Arctic first-year and multi-year sea ice.

We measured the production at four stations in both types of sea ice. Seven distinct horizons of one centimeter thickness were selected within the last meter of the ice. Each of them was put into a petri dish and incubated with $NaH^{14}CO_3$ for eight hours in a new device directly within the ice floe.

The *in situ* primary production of ice algae varied due to the snow and ice thickness as well as to the different locations of the petri dishes. Nevertheless, the highest production was always found within the bottom one centimeter of each investigated ice floe.

4.2.4 Production of Lipids by Arctic Sea Ice Algae (Mock)

An experiment was carried out to investigate changes in the physiological state of sea ice algae during the growth process using ice algae of the bottom 5 cm of the sea ice. The experiment was conducted under natural light and temperature conditions for about four weeks. After two weeks of rapid growth, the added nutrients were depleted and thus the biomass of ice algae decreased during the last two weeks. To examine the change in physiological state during the time of investigation, the accumulation of $NaH^{14}CO_3$ into proteins, polysaccharides, low-molecular weight metabolites and lipids was determined. All these metabolites increased during the first two weeks of rapid growth. The strongest increase was observed for the lipid fraction, especially for the glycolipids, but not for triacylglycerols or phospholipids.Under nutrient depletion, the total lipid production remained high, whereas the other metabolites decreased more or less at different rates. A strong decrease was also observed for the proteins.

4.2.5 The Response of Arctic Sea Ice Micro-Organisms to Changes of Salinity Under Different Light Conditions (Zhang)

Polar marine ecosystems are subject to strong seasonality and interannual variability of environmental factors, especially ice cover and irradiance. Sea ice covers between 7-14 million km^2 of the Arctic Ocean and is a crucial parameter for the modelling of environmental changes in polar areas. Micro-algae from the water column and the sea ice are important primary producers in polar oceans, in which diatoms are dominant and contribute more than 90% to the total microalgal biomass. The seasonal development of the polar marine algae is mainly controlled by abiotic parameters. The onset of microalgal growth in spring is dependent on the increase of the available light intensities after the dark polar winter.

Micro-organisms that inhabit the interstices and underside of sea ice are exposed to wide variations of salinity, in particular during the periods of brine drainage and ice melting. Numerous studies at Arctic, Antarctic and sub-Arctic sites have shown that light is the principal factor limiting the onset and early development of bottom ice algal blooms. It was reported that four Arctic diatoms were euryhaline and maintained growth rates of 0.6 to 0.8 divisions per day over a salinity range of 10‰ to 50‰.

During "Polarstern" cruise ARK XI/2, we carried out an experiment to study the salinity tolerance of Arctic algae in a range of 1‰ to 100‰ under natural light conditions. The results showed that most species of the natural ice microalgal community in the Greenland Sea exhibited net growth within a salinity range of 4.0‰ to 74.0‰, and that the maximum net community growth rate was obtained at salinity 20‰. Data on the response of Arctic sea ice micro-organisms to changes in salinity lower than that of normal sea water under different light conditions is limited.

Our experiment was designed to study the response of Arctic sea ice micro-organisms, i.e. algae and bacteria, to salinity below normal Arctic sea water. For that purpose ice cores were taken from an ice floe at the location of 77°22'N, 0°22'E in the Greenland Sea. The top 10 cm segments melted and filtered through a 0.2 µm Nuclepore filter were used as the low salinity melt water (LSMW, 0.2‰). The bottom 2 cm sections thawn in an excess of 0.2 µm filtered sea water were used as the natural Arctic sea ice micro-organisms. Larger metazoans were excluded by filtration through 60 µm silk mesh.

The eight steps of salinity were achieved by the addition of LSMW to normal Arctic sea water (34.2‰). 200 ml of the melted bottom sea ice water with the natural sea ice biota was added into 1000 ml medium. After mixing, the final salinity was measured with a WTW-salinometer. The final eight steps of salinity were 4.7, 8.3, 12.8, 16.6, 21.4, 25.2, 29.6, 33.1‰. Then the samples were divided and filled into four Corner polystyrene tissue culture vials with a volume of 250 ml each and cultured at 0°C at four different light conditions: 1) normal irradiance (41.61 $\mu E/m^2s$) with 24 hours light, 2) normal irradiance (41.61 $\mu E/m^2s$) with a light:dark cycle of 14:10 hours, 3) lower irradiance (14.74 $\mu E/m^2s$) with 24 hours light, and 4) lower irradiance (14.74 $\mu E/m^2s$) with a light:dark cycle of 14:10 hours.

The experiment will be continued during ARK XIII/2. Subsamples (25 ml) were collected every five days after the start of the experiment and were fixed with borax-buffered formaline with 1% final concentration. Then a 10 ml subsample was filtered onto 0.2 µm Nuclepore filters and stained with DAPI. The species composition, abundance and growth rates of the algae, the bacterial sizes, shapes, abundance, biomass and growth rates will be analysed at the home lab in the IPÖ Kiel using a Zeiss Axiovert 135 inverted light and epifluorescence microscope, equipped with a Sony DXC-930P 3-CCD video camera and a Sony SVO-9500MDP recorder.

4.2.6 Grazing Experiments with Arctic Sea Ice Protists (Meiners)

In order to improve the general knowledge about sympagic organisms we took four ice cores in the Barents Sea and seven ice cores in the Greenland Sea to determine abundances of bacteria, protists and meiofauna. Ice cores were cut into sections of 1-20 cm. These sections were melted in the dark by addition of sea water to avoid osmotic stress. Melted samples were subsampled and fixed either with formaline (1% final concentration) or with Bouin's fluid (1% final concentration). Bouin fixed samples will be used for meiofauna investigations and taxonomy of ciliates. Formaline-preserved samples were filtered onto 0.2 µm and 0.8 µm polycarbonate filters and stained with DAPI. These filters will be counted in the home laboratories using epifluorescence microscopical techniques to obtain vertical profiles of cell numbers and biomass of bacteria and protists. The estimated biomass of protists will be used to calculate the grazing impact by general allometric equations.

These indirect estimates will be compared with the results of direct grazing measurements which were conducted during the cruise. Fluorescently labelled bacteria were added to melted bottom ice sections. We measured the short-term uptake of fluorescently labelled bacteria by heterotrophic protists. In addition, we measured the long-term disappearance of fluorescently labelled bacteria within the samples to provide data about the grazing impact of the total community. Both experiments were run as time-course experiments. The short-term uptake experiments were performed for 90 minutes; the long term disappearance of fluorescently labelled bacteria was observed over a period of 24 hours. Subsamples of the experiments were taken after 0, 1, 5, 10, 30, 60 and 90 minutes (short-term uptake protocol) and after 0, 6, 12, 18, 24 hours (long-term disappearance protocol). Subsamples were fixed either with formalin (1% final concentration) or with Lugol's solution to avoid egestion of already ingested prey in the short term uptake experiments. Subsamples were filtered on polycarbonate filters and stained with DAPI. Counted heterotrophs will be checked for ingested fluorescently labelled bacteria in the short-term experiments. The decrease of the concentration of fluorescently labelled bacteria will be determined for the long-term experiments in the home laboratories.

In addition to this program we took bottom sections for the cultivation of different groups of sympagic biota (algae, protozoans and metazoans). Cultivated organisms will be used for supplementary taxonomic work and additional grazing experiments in the home laboratories.

4.2.7 Under-Ice Studies (Werner)

The under-ice habitat was investigated at a total of eleven stations during this cruise, three of these in the Barents Sea and eight in the Greenland Sea. Temperature and salinity profiles were measured in the water layer beneath the ice down to 5 m depth with a WTW sensor, the morphology of the ice underside as well as amphipods living at the ice underside were recorded by a video camera, and a pumping system was used for quantitative sampling of the sub-ice fauna suspended in the water layer directly under the ice. At five stations, the under-ice pump was deployed at two different depths (0 m and 5 m) to find out how deep the ice-associated fauna migrates, and at one station, an 18 hour sampling scheme was conducted to detect possible diurnal variations.

Temperature and salinity did not show any gradients in the upper 5 m under the ice. The temperature varied from -1.8 to -1.7°C (Barents Sea) and -1.7 to -1.4°C (Greenland Sea), salinity from 33.9 to 34.2 (Barents Sea) and 31.8 to 33.7 (Greenland Sea). There was no evidence of meltwater under the ice.

The ice undersides at the sampling sites were always quite level, although sometimes pressure ridges were observed in the vicinity. Most undersides were very smooth, only a few holes and depressions were observed, which are typical of the melting season. In the Barents Sea, the ice underside was often quite green due to high algal biomass, whereas in the Greenland Sea no such intense colouration was observed.

In the water column directly beneath the ice, two major groups of organisms occurred: sympagic sub-ice fauna which enters this water layer from the ice, e.g. turbellarians, nematodes, harpacticoid copepods, and pelagic sub-ice fauna typical of surface waters, e.g. calanoid and cyclopoid copepods, pteropods and foraminifers. Many juvenile stages were observed during this spring cruise, e.g. various copepod nauplii, larvae of the pteropod *Limacina* spp. and juveniles of the hyperiid amphipod *Themisto libellula.* In both areas (Barents and Greenland Seas), high numbers of eggs of the copepod *Calanus glacialis* were found under the ice, where they seem to concentrate due to a positive buoyancy. The under-ice habitat might act as a nursery ground for different pelagic species.

Regarding the occurrence of under-ice amphipods, the two sampling areas were clearly different: Very few under-ice amphipods were observed in the Barents Sea, and only the small species *Apherusa glacialis* was found. In contrast, the ice undersides in the Greenland Sea were often densely populated by amphipods. Here all four common species occurred, with *Gammarus wilkitzkii* being dominant, followed by *Onisimus* spp. and *A. glacialis.* Juveniles of all species were abundant. Surprisingly, high numbers of *G. wilkitzkii* were caught twice in the Rectangular Midwater Trawl (RMT) run by the zooplankton group in ice-free waters (0-500 m depth) at 75°N, 7°W. However, the retreating ice edge was only 10-30 miles away from that sampling location. These amphipods may have originated from the melting ice in this region.

Under-ice amphipods were used for experimental work on grazing, particle production and respiration, as well as for measurements of length, dry weight and lipid content.

The significance of the under-ice habitat for the vertical particle flux was investigated by means of several deployments of small, short-term (12 hours) sediment traps, as well as by one large sediment trap moored to a drifting ice floe for nine days (see report of the SFB plankton and particle flux group).

5 Planktology

5.1 Bio-Optics (Dijkman, Kroon)

During the first leg of the ARK XIII cruise we determined biophysical characteristics of phytoplankton based on fluorescence measurements. The phytoplankton samples were taken at stations characterized as ice-free water masses (mainly Atlantic water) and at stations covered with ice floes, where samples were taken from ice-cores. The geographical separation of these stations in fact reflected an environmental transition from late winter to early spring.

Planktonic algae almost continuously experience changes in light intensity, caused by the position of the sun in the sky, weather conditions and mixing through the water column. On a relatively short time scale light intensities can vary from total darkness underneath the euphotic zone to 2000 $\mu Em^{-2}s^{-1}$ at the surface. Ice algae live in a relatively more stable environment since no mixing through the water column takes place.

Algae can use several processes to optimise photosynthesis under the prevailing light conditions and avoid damage to the photosynthetic apparatus. As a reaction to slow changes in light intensity (time scale > day) they can optimise the concentration of components of the electron transport chain like the concentration of plastoquinone relative to photosystem II, or change the pigment content of the cells and thereby change the size of the light harvesting complex. On shorter time scales (minutes to hours) relatively quickly reversible processes take place. State transitions can optimise the division of light between photosystem II (PSII) and photosystem I (PSI) and influence the connectivity between PSII centra. The conversion of the pigment diadinoxanthin to diatoxanthin in diatoms or violaxanthin via antheraxanthin to zeaxanthin in green algae increases heat dissipation in the light harvesting complex (LHC).

A small part of the light absorbed in the LHC is dissipated as fluorescence, most of it originating in PSII. Fluorescence is at a minimum when all PSII centra are oxidised (ca. 0.6%) and at a maximum (ca. 3%) when all PSII centra are reduced. The processe described above that regulate photosynthesis are reflected in the fluorescence signal, so that fluorescence can be used to monitor the status of the photosynthetic apparatus.

Work at sea

Light intensity on deck was measured continuously with a 2pi sensor (LiCor) connected to a LI-1000 data logger. Fluorescence was measured with a pulse amplitude modulated fluorometer (PAM fluorometer; Heinz Walz, Effeltrich). From fluorescence induction curves in the absence of DCMU (3-(3,4-dichlorophenyl)-1,1-dimethylurea) the quantum yield of charge separation at PSII ($f_{II,e}$) and the fraction of inactive PSII centra can be determined. Fluorescence curves in the presence of 20 μM DCMU will be fitted to a model yielding among others the size of the antenna delivering light to PSII and the degree of connectivity between PSII centra. Photosynthesis versus light intensity (P/I) curves were made by determining the rate of electron transport ($=f_{II,e}$*light intensity) after 2 minutes illumination in the cuvet of the fluorometer at 12 light intensities. For each light intensity a new subsample was used.

At the open-water stations fluorescence measurements were performed on water samples from 0-100 m taken with a rosette sampler connected to a CTD. We made depth profiles of the various parameters. If possible several depth profiles were made during a day. P/I curves were usually made from one depth (10 m).

For the measurements on ice algae the bottom 10 cm of the ice cores were quickly tranferred to the ship in the dark. Approximately 0.5 cm of the bottom was scraped off and diluted with filtered sea water to prevent osmotic shock. On these samples we performed the fluorescence measurements.

Preliminary results

On both an open-water and an ice-covered station biophysical properties were investigated with a high time resolution. A preliminary interpretation indicates that the photosynthetic efficiency was inversely related to light intensity. The aim of these measurements is to make an estimation to what extent the phytoplankton enclosed in the ice can contribute to the total primary production of the water column. From the fluorescence measurements an estimation will be made of carbon fixation, which will be compared to measured carbon fixation by other groups during the cruise.

Preliminary analysis of depth profiles of biophysical parameters in the open-water stations shows that highest efficiencies are reached in the upper 10 meters of the water column. With further analysis we will try to determine whether physiological changes are related to the geographical location of the samples.

5.2 **Pigments** (Peeken)

Objectives

Measurements of pigment fingerprints by HPLC (High performance liquid chromatography) can be used to determine the spatial and vertical distribution of algae assemblages in the water column, ice cores and with limitations in sedimentary particles and sediments. All algal groups have pigments like chlorophylls and carotinoids. Some of these pigments are distributed over all algae taxa, but a few are characteristic for specific algal groups, like peridinin for dinophyceae, alloxanthin for crytophyceae, 19-hexa-noyloxyfucoxanthin for prymnesiophytes. The measurements with reversed HPLC allow a rapid determination of there different pigments and therefore a rapid qualitative and with limitations also quantitative description of phyto-plankton biomass and composition. The detection of chlorophyll degradation products allow to describe the senescence and the pathways through zoo-plankton communities on the different levels of grazing. With limitations the history of sedimented particles can therefore be evaluated.

The retreating ice edge releases algae cells to the phytoplankton community. Detailed investigations of the ice algal distribution in first and multi-year ice aimed at describing the potential influence of seeding of algae populations on the water column. Experimental studies were intended to analyse the different pigment patterns of ice algae as compared to open-ocean pigment finger-prints. The influence of seeding or fall-out of algal populations was to be des-cribed and followed during transects crossing the ice edge.

Work at sea

Water column

To describe the vertical and horizontal distribution of the phytoplankton assemblages, sea water samples were taken at each station from the euphotic zone down to 200 m (see Haupt *et al.*). To compare between the trap samples and the water column additional samples were taken below 200 m at the mooring position. Sea water samples (1-8 l) were filtered onto 25 mm GF/F filters and frozen at -30°C. Additional samples of sedimentary particles will be provided from traps (see Haupt *et al.*).

Ice treatment

For detailed studies of the ice algal communities three ice cores were cut in different horizons (see Gradinger *et al.*), usually pooled and about 2 l filtered sea water was added to every 10 cm length of ice. After melting the resulting water volume was determined, filtered onto 25 mm or 47 mm GF/F filters and frozen at -30°C.

Sediment cores
To investigate the input of fresh sedimentary particles with regard to benthos organims, sediment cores were taken. According to availability 4-8 sediment cores from leg ARK XIII/1a were cut in 1 cm slices, pooled and frozen at -30°C for later pigment determination.

Experiments
Different experiments were conducted to investigate special pigment adaptations of algae from the water column and the ice, and the pigment destruction of ostracods. In some regions the marker 19-hexanoyloxyfucoxanthin is not valid for prymnesiophytes (Buma *et al.*, 1991). To verify the pigment fingerprints of *Phaeocystis pouchetii* in the Barents Sea, colonies were isolated from Apstein net tows and cultured with F/2 medium under *in situ* conditions for later pigment analyses.

Ice algae show a higher carotenoid and chlorophyll *c* to chlorophyll *a* ratio as compared to phytoplankton (Boczar & Palmisano, 1990; Robinson & Arrigo, 1995). These differences affect the calculation of ice algal distribution by marker pigments. To investigate the influence of different light conditions on these ratios, under-ice algal communities were melted in filtered sea water and cultured at 35 $\mu Em^{-2}s^{-1}$. After five days subsamples (3 replicates each) were transferred to different light conditions (54, 35, 8 and 3 $\mu Em^{-2}s^{-1}$), sampled every day and stored at -80°C for later pigment analyses.

After 14 days, the algae adapted to high light intensities (37 and 54 $\mu Em^{-2}s^{-1}$) were transferred to low light conditions (3 $\mu Em^{-2}s^{-1}$) and vice versa for the algae adapted to low light intensities. The sample adapted to 8 $\mu Em^{-2}s^{-1}$ was transferred to light conditions below 1 $\mu Em^{-2}s^{-1}$ to investigate very low light conditions observed in the field (see Gradinger *et al.*).

Ostracod fecal pellets sampled at a mooring from the Barents Sea continental slope showed high chlorophyll and phaeopigment contents. These organisms usually occur between 200-500 m and are therefore not directly grazing on phytoplankton. To study the general capability of these organisms to feed on algae, grazing experiments were conducted with natural phytoplankton assemblages. Addidional *in situ* animals were collected, rinsed with filtered sea water and frozen for later pigment analyses.

Preliminary results
Detailed information about the pigment distribution in the experiments, water column, ice cores, sedimentary particles and the sediment will be produced in the home laboratory.

Preliminary experiments conducted with the ostracods using fluorometric measurements of chl *a* showed gut contents of 8 ng chl *a* and 31 ng phaeopigments per *in situ* animal, as compared to 24 ng chl *a* and 52 ng phaeopigments per animal fed with algal cultures.

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5.3 Phyto- and Protozooplankton Ecology and Vertical Particle Flux During ARK XIII/1a (Nöthig, Barwich, Marquardt)

Objectives
The phytoplankton community structure as well as the vertical particle flux will be investigated in open water, in the marginal ice zone, and in the pack-ice zone of the central Barents Sea. The main aim of these investigations is to understand the coupling between phyto- and zooplankton as well as the particle flux, coupling the pelagic and the benthic sub-systems and providing food for the benthos during late winter to spring conditions. The biological properties of the water column will be studied in relation to hydrographical, chemical and other environmental conditions.

The following major questions were addressed:

- Are there regional differences in the seasonal distribution patterns of phyto- and protozooplankton?
- What is the influence of abiotic factors such as hydrographical structure of the water column, nutrient availability and ice coverage?
- How much of the phyto- and protozooplankton biomass as well as fecal material and other organic matter is transported to deeper waters and down to the sea floor?

Work at sea
At sixteen stations water was sampled with the rosette sampling system attached to the CTD. Subsamples were obtained from at least seven different water depths from the surface (5 m or 10 m) close to the bottom.

- Species abundance: Samples (ca. 200 ml) were fixed with hexamine-buffered formaline (final concentration 0.5-1.0%). Microscopical analyses will be carried out in the home laboratory.
- Chl *a* and phaeopigments: Pigment concentrations were measured onboard with a Turner Designs fluorometer after homogenisation and cold extraction in 90% acetone.
- Particulate organic carbon/nitrogen and biogenic silica: Samples were filtered on precombusted glassfibre filters (POC/PON) or cellulose acetate filters (silica) and stored at -30°C for later analysis in the home laboratory.
- Seston: Samples were filtered on preweighed glassfibre filters and stored at -30°C for later analysis in the home laboratory.

•• Seasonal particle flux will be investigated by means of one long-term sediment trap deployment at the northernmost station (St. 11). The same parameters as mentioned above will later be analysed in the home laboratory.

Preliminary results

The transect across the marginal ice zone showed the beginning of a spring bloom at Stations 3 to 10. Maximum chlorophyll *a* values ranged from 0.8 to 3.2 $\mu g l^{-1}$. At the northernmost station (St. 11) in the pack ice chlorophyll *a* values were still below 1 $\mu g l^{-1}$. On the way back the spring bloom was at its maximum at Stations 13 to 16, maximum chlorophyll *a* values ranged from 5.1 to 7.2 $\mu g l^{-1}$. Along the transect a typical picture of the phytoplankton development at the receding ice edge could be observed. In order to study the seasonal progression of the plankton community at about the same location, the same stations (Sts. 2 ,16) were sampled on the way back from the pack ice zone (Fig. 5.3.1).

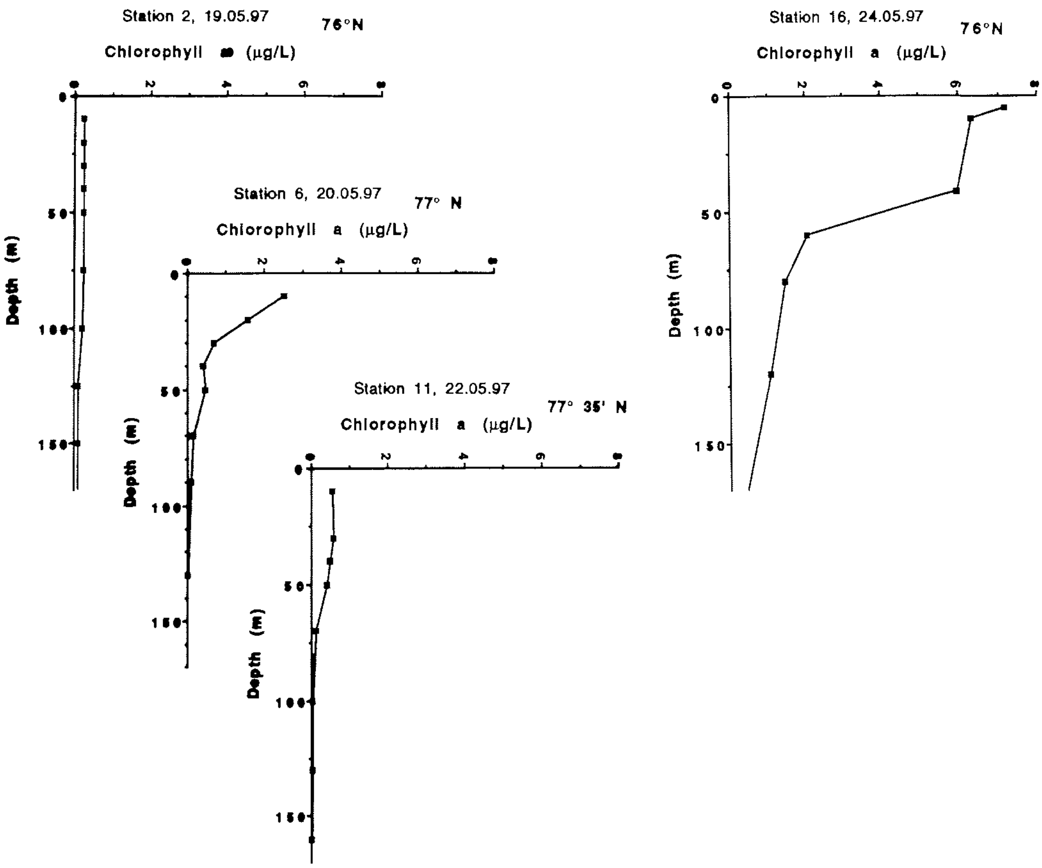

Fig. 5.3.1: Vertical chlorophyll *a* distribution along the northbound transect at three selected stations (left diagrams) and of St. 16 (approximate position of former St. 2) (right diagram).

5.4 Conditions of Primary Production and Vertical Particle Flux in the Sub-Ice Boundary Layer and the Epipelagial During Spring (Haupt, Beese, Donner, Krumbholz, Lorentzen, Marquardt, Peeken, Thordsen)

Objectives

Planktological investigations on particle production, modification and sedimentation were carried out within the marginal ice zone (MIZ). In spring, the most important season for biological particle production, these ecosystem investigations will help to increase our knowledge about the different particle sources in the ice and the pelagial and to close the data gaps. Our studies focussed on the pelagic and ice-associated processes within the surface water column and their reflection in deeper water layers. To characterize the different production regimes, water samples were taken on transects from the open water to the pack ice of the Barents Sea and the eastern Greenland Sea. Measurements on vertical particle flux and on the composition of sinking material as well as particle modification during sinking to deeper water layers will help to understand the dominant processes within the biologically active layer of the water column.

Barents Sea: Methods

During ARK XIII-1a seventeen stations were sampled in the northern Barents Sea. With a CTD and a rosette sampler we collected water samples and data on the vertical distribution of temperature and salinity, chlorophyll, nutrients (Lunau, Gutthann) and on the carbon, nitrogen, silicate and pigment contents of the particulate material. Samples for microscopic analyses of the plankton community as well as for algae culture were taken at different stations. In addition, the undisturbed sub-ice boundary layer was sampled from the bow crane with a micro CTD and a new self-constructed high-resolution surface water sampler HRSWS (5 depths within the first 7 m of the water column) called "milking-machine". On the northernmost station (77°34.45'N, 34°42.07'E) a sediment trap was moored at 150 m. This mooring will be recovered during ARK XIII/2.

First results

First hydrographic results indicate a layer of cold and less saline water above water masses influenced by the North Atlantic Current, which increases towards the northern stations. In the open water at the southern stations chlorophyll and nutrient concentrations (nitrate, silicate) and their vertical distribution show more or less winterly values and indicate a very early stage of phytoplankton development. As expected for the spring, chlorophyll concentrations within the MIZ increased (up to 2.5 $\mu g l^{-1}$) and the nutrient concentrations showed a distinct decrease within the upper 40 m. St. 44-007 deviated due to meltwater intrusion as shown by the low salinity and a phytoplankton accumulation with chlorophyll concentrations above 3 $\mu g l^{-1}$ in the surface layer. The very low phaeopigment concentrations indicated the freshness of this phytomaterial. Even at the northernmost station (St. 44-011) we found conditions typical of phytoplankton development in spring.

Vertical profiles of temperature and salinity, measured with the micro CTD within the upper 10 m of the ice-covered Barents Sea, showed gradients which indicated very shallow stratified layers at the surface (Figs. 5.4.1 and 5.4.2).

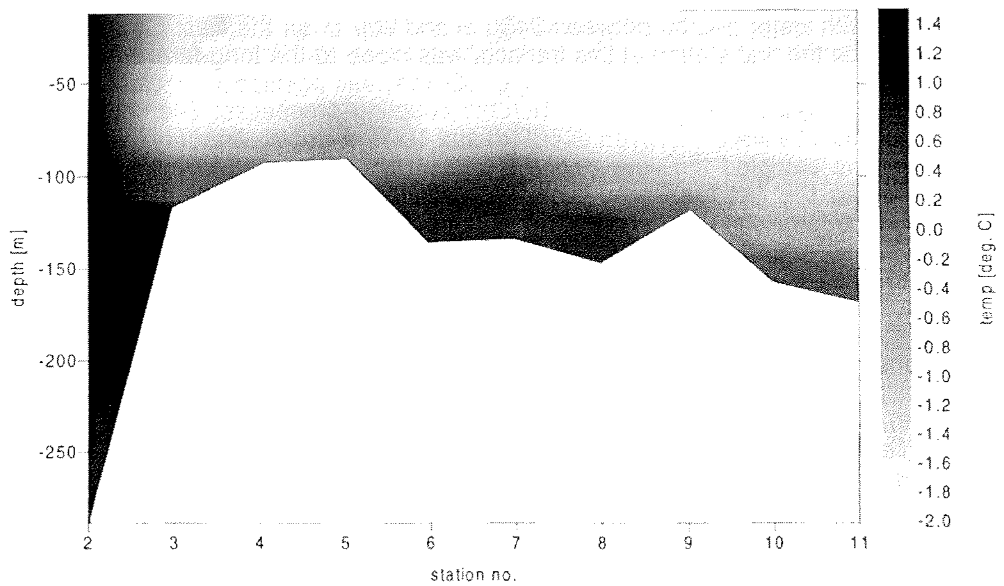

Fig. 5.4.1: Temperature distribution along the transect in the Barents Sea.

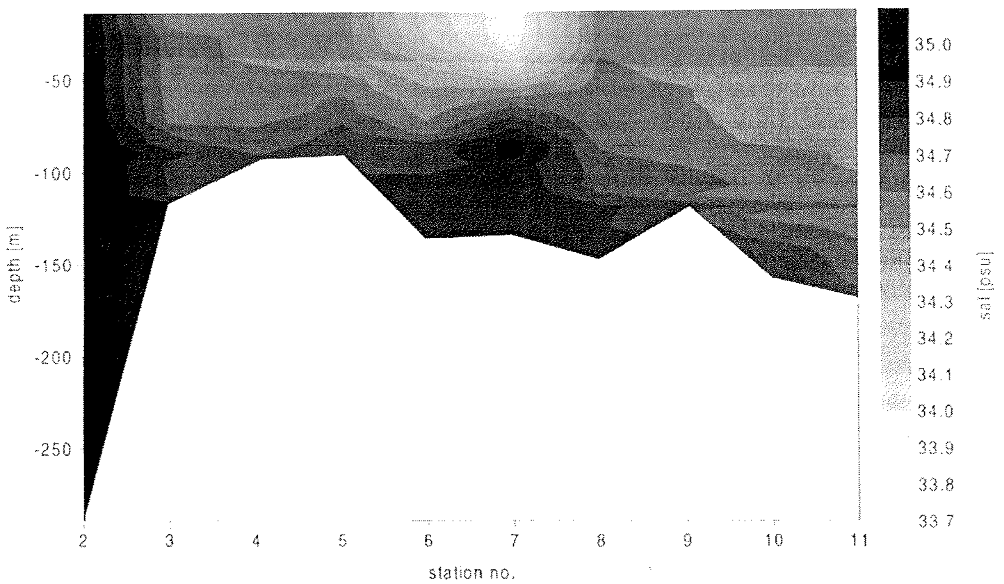

Fig. 5.4.2: Salinity distribution along the transect in the Barents Sea.

Greenland Sea: Methods
During ARK XIII-1b we sampled a total of eleven stations off East Greenland. On a transect across the East Greenland Current at 75°N we sampled six stations with water depths between 3450 m and 200 m on the East Greenland shelf. Since the first station of this transect was close to the long-term mooring OG 11 and the new short-term mooring OG 11a, this position was used as a time station to investigate pelagic-benthic coupling processes. The sediment traps of OG 11a were deployed at 500 m and 1000 m depth. After finishing the transect we sampled the time station a second time. The same devices were used as for the first leg. In addition, we used moored and drifting sediment traps to measure the vertical particle flux out of the ice and in the pelagial.

First results
At the start of our investigations on the 75°N transect the whole working area to the east of 2°W was ice-covered, which influenced all these sampling stations. The hydrographic survey along the transect showed the vertical formation of three major water masses: the Polar Surface Water (colder, less saline), the Return Atlantic Water (warmer, more saline) and the Greenland Sea Deep Water (colder, more saline) (Figs. 5.4.3 and 5.4.4). Depending on the degree of ice cover-age the chlorophyll (>1.5 μgl^{-1}) and nutrient concentrations of the mixed layer as well as their vertical distribution at the easternmost stations indicated a more advanced phytoplankton development than found for the western stations: at the time station the vertical nutrient profiles showed distinct gradients, whereas the concentrations at the western stations were more homogeneous and exhibited only winter values at the surface. In contrast to the loose ice cover at 75°N, at 81°N we found dense pack ice with 80-100% ice coverage. Supposedly due to the high degree of ice cover chlorophyll con-centrations reached values of only 0.1 μgl^{-1}. The nutrient distribution within the water column also emphasised the very early phase of phytoplankton devel-opment in this northern region.

Investigations of the sub-ice boundary layer indicated a high potential produc-tivity (Fig. 5.4.5). Its chlorophyll concentrations were up to 50% higher than those from 10 m depth, normally the first layer which can reasonably be sampled from the ship´s side. The nutrient gradients were highly correlated to the vertical density distribution. With additional data of other variables we hope to identify the small-scale connection between the ice cover conditions and the stage of the pelagic system.

Detailed biogeochemical and microscopical analyses of the material from the sediment traps will be done in Kiel. However, first results are available from the material of the small traps which were attached to drifting ice floes. We found a high flux of copepod fecal pellets indicating the high abundance of these crustaceans.
The ice floe with the attached multi-sediment trap covered a distance of about 80 nautical miles during eight days. The experiment was started under typical winter conditions, but we recovered the drifter at temperatures above the freezing point. The impact of this climatological change was indicated by changes in the chlorophyll flux: during the first four days we found only low rates but a sharp increase up to 21 $\mu gm^{-2}d^{-1}$ at the fifth day.

The short-term mooring was deployed at 75°0.7'N, 7°27.6'W during the whole investigation period. During this period the marginal ice zone moved from about 2°W to about 9°W. First results showed an unexpectedly high vertical particle flux, but further analyses on the quality and quantity of the particle flux will be carried out at the home laboratory. The long term mooring OG 11 (74°59.7'N, 6°57.4'W) was also successfully recovered, but again the results are not yet available.

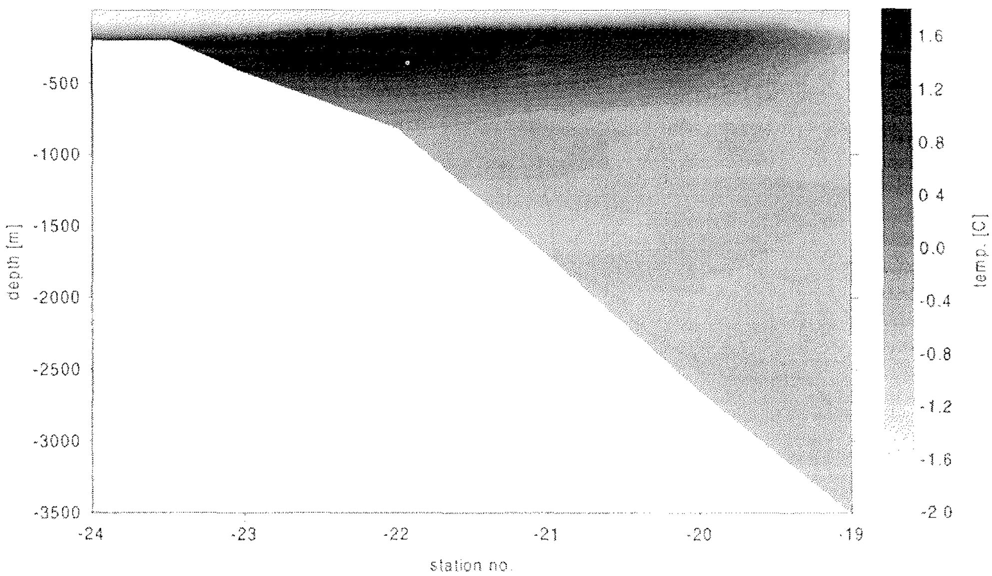

Fig. 5.4.3: Temperature distribution along the 75°N transect in the Greenland Sea.

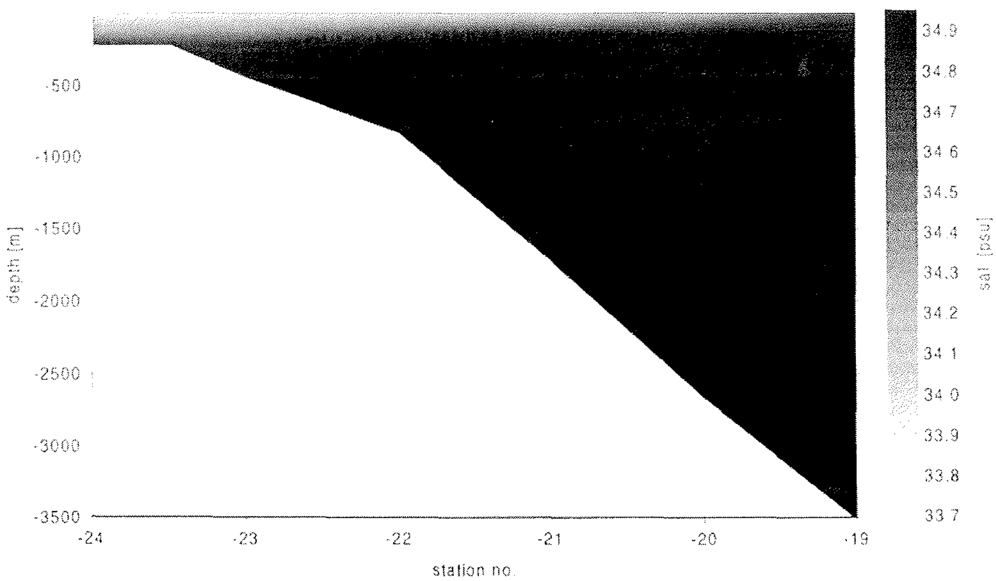

Fig. 5.4.4: Salinity distribution along the 75°N transect in the Greenland Sea.

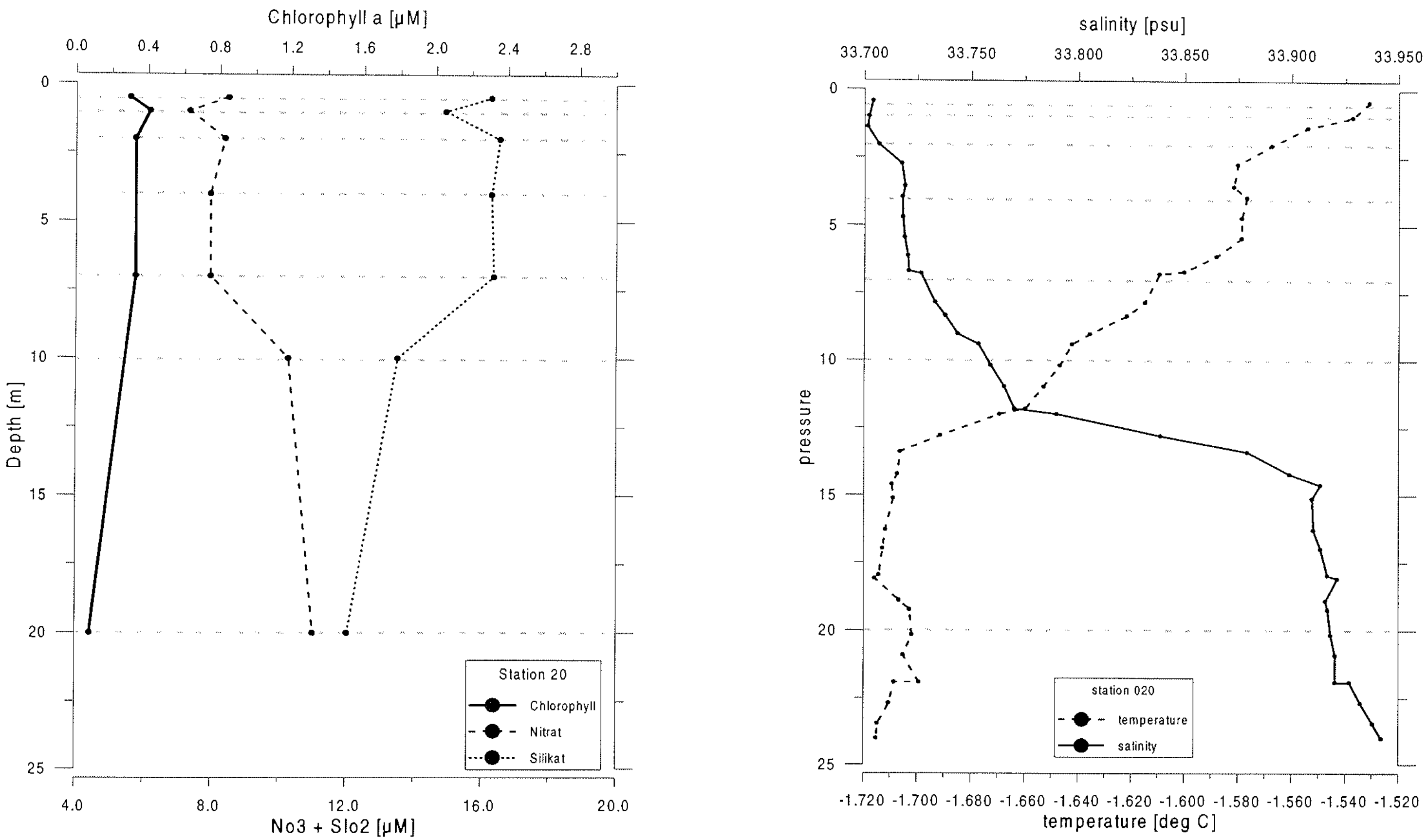

Fig. 5.4.5: Vertical profiles of chlorophyll, nitrate, and and silicate as well as of temperature and salinity from samples of the high-resolution surface water sampler (down to 7 m), from the rosette sampler, and the Mini CTD at t. 20.

5.5 Distribution and Production of Dominant Calanoid Copepods Across the Marginal Ice Zone of the Barents Sea
(Hirche, Strohscher)

Samples for abundance and vertical distribution of copepods and total mesozooplankton biomass were collected vertically with a multinet (150 µm mesh) in five depth strata from close to the bottom to the surface. In addition, copepods were collected for experimental studies by bongo nets (200 and 300 µm). Single specimens were sorted and deep-frozen for the determination of carbon and nitrogen.

Preliminary results show that both *Calanus finmarchicus* and *C. glacialis* were present at all stations, but there was a decreasing trend of *C. finmarchicus* abundance towards the north, reflecting the decrease of the Atlantic water mass.
Measurement of egg production has been proven a useful tool to assess mesoscale variability of secondary production in frontal areas and marginal ice zones. During this study two approaches were used to study egg production. In the water column copepod eggs were collected using a large-volume bottle sampler (30 L) at six depth layers. In the laboratory onboard egg production of the two dominant copepods *Calanus finmarchicus* and *C. glacialis* was measured by incubation of single females in beakers and/or in petri dishes. In the beakers eggs were removed after about two days, petri dishes were inspected in 6 hour intervals. Egg production was measured at 13 stations. As an unexpected result we observed egg production at all stations regardless of ice cover. *C. glacialis* spawned at near maximum rates (30-50 eggs female^{-1} d^{-1}) at all stations, except for the northernmost St. 11. In contrast, egg production was only high at St. 2 in *C. finmarchicus* and further to the North very few or no eggs were layed. It has been shown earlier that *C. glacialis* is able to spawn from lipid reserves in spring, whereas later they switch to freshly assimilated food to fuel egg production. To distinguish between these two reproductive modes, female *C. glacialis* were exposed to starvation for several days. In all six experiments egg production rates decreased dramatically after two days, clearly indicating the dependence on food supply.

Data on abundance and egg production rates will be used to calculate secondary production and food requirements of herbivorous zooplankton. From these calculations the effect of zooplankton grazing on the phytoplankton stock will be estimated. From these results the partitioning of phytoplankton between the pelagic and benthic food chain can be derived. This study was a contribution to the pilot study for AOSGE.

5.6 Characteristics of Arctic Mesozooplankton Communities
(Obermüller)

Objectives
During ARK XIII/1 the horizontal and vertical distribution of the dominant meso-zooplankton species including different developmental stages were investigated with regard to the hydrographical situation. The study aimed at characterizing the actual seasonal situation (late winter or spring) of the zooplankton in the different domains (Atlantic, Arctic, polar) and at elucidating

possible spatial or temporal differences in the species composition and distribution. In addition, samples were collected to analyze physiological and biochemical parameters (lipid content and composition, digestive enzyme activity) of some copepod species to determine the physiological condition and the activity of these organisms.

Material and methods

Sampling was carried out during ARK XIII/1a and b on transects near the ice edge in the Barents Sea and in the northern Greenland Sea. Abundance and vertical distribution of the mesozooplankton were investigated with a Multinet (mesh size 150 µm). In addition, individuals for experiments and biochemical analyses were sampled with a bongo net (100, 150, 200 µm) and a Rectangular Midwater Trawl (RMT 8, 8 m^2 mouth opening, 4500 µm). A total of 22 Multinet, 66 bongo net and 5 RMT hauls were carried out. The evaluation of these samples will take place in the home laboratory in Kiel.

Preliminary results

There tend to be differences between the two transects at 75°N and 81°N concerning species composition and biomass. On the 75°N transect different water masses (surface layer, intermediate water and deep water) could be defined according to species distribution and ecological niches. On the 81°N transect, species were distributed more homogeneously, except for the surface layer.

5.7 Ecology of Meso- and Bathypelagic Copepods (Auel)

Objectives

As part of the interdisciplinary AOSGE project, life cycles and distribution of important zooplankton species were investigated. During ARK XIII/1 studies focused on the spatial and ecological niches of meso- and bathypelagic copepods. In addition, trophodynamics and energetics of these mainly omnivorous and carnivorous species and their effect on the carbon and energy flux from the surface into the deep-sea (cryo-pelagic-benthic coupling) were examined.

Materials and methods

The vertical distribution of meso- and bathypelagic copepods (Euchaetidae and Aetideidae) was studied by stratified mesozooplankton hauls on a transect from 75°N 7°W to 75°N 14°W (6 stations). The investigation area extended from the central Greenland Sea (water depth >3500 m) onto the East Greenland Shelf (200 m depth).

To estimate the energetic demands of the carnivorous genus *Euchaeta*, feeding and starvation experiments were conducted onboard and supplemented by respiration measurements in the home laboratory. Additional material for biochemical analyses was collected by bongo net and rectangular midwater trawl, processed and frozen at -80°C. The analysis of these samples will be continued at the Institute for Polar Ecology (IPÖ) in Kiel.

Preliminary results

A total of four *Euchaeta* and seven aetideid species could be identified. *Gaidius tenuispinus* was the most abundant aetideid copepod, reaching 24 ind. 100^{-1} m^{-3}. Closely related or congeneric species occurred in different depth layers, so that interspecific competition was avoided. Among the carnivorous copepods of the genus *Euchaeta* a similar partitioning of the water column was observed. The upper 500 m layer was restricted to *Euchaeta norvegica* and *E. glacialis.* In contrast, *E. barbata* and *E. polaris* prevailed in deeper waters.

5.8 Lipid Biochemistry of Meso- and Macrozooplankton (Hagen)

Objectives
Investigations of the lipid biochemistry of Arctic zooplankton continued previous studies of the IPÖ in the Fram Strait and the Greenland Sea. The major objective during ARK XIII/1 (May-June) was to characterize the energetic status of the various zooplankton species during the critical transitional period of late winter/early spring. Together with the lipid data from winter (ARK IX/1b, February-March), spring (June, ARK VIII/1), summer (ARK VII/2, July-August) and autumn (ARK XI/2, October), we will be able to describe essentially complete seasonal cycles of the various species. Together with the other data, the results of this cruise will be important to understand the seasonal processes of lipid accumulation and depletion of meso- and macrozooplankton in the northern North Atlantic. The importance of these high-energy compounds for the life cycle of the species and their influence on the energy flux in general will be highlighted. In addition, the potential of specific lipid components as biomarkers in the food web as well as in energy flux studies will be studied.

Methods
Mesozooplankton for lipid analyses was mainly sampled by vertical bongo hauls (100, 150 or 200 µm, resp.) in the Barents Sea and along the Greenland Sea transects on 75°N and 81°N. Maximum hauling depth was usually 1500 m. Macrozooplankton was collected at five stations using oblique RMT 8 tows (4500 µm mesh) down to 500 m depth. The organisms were identified to species level (if possible), sexed and sorted according to developmental stage, gonad maturity and body size. The samples were immediately frozen at -80°C. A total of almost 600 samples was collected, including hydromedusae, ctenophores, pteropods, ostracods, copepods, euphausiids, decapods, amphipods and chaetognaths. The determination of total lipid content, lipid classes and fatty acid/alcohol composition will be carried out in close cooperation with the AWI (Dr. Kattner) in the laboratories in Kiel and Bremerhaven.

5.9 $^{13}C/^{12}C$ Distribution in Lipids of Arctic Copepods (Albers)

Objectives
^{13}C-marked algae were fed to the three herbivorous copepods *Calanus hyperboreus, C. glacialis* und *C. finmarchicus* to follow the incorporation of this heavy isotope in specific fatty acids and alcohols. The investigations focused on differences between these compounds with respect to their dietary and *de novo* origin.

Fatty acids, which are ingested with the food and directly incorporated, exhibit a different $^{13}C/^{12}C$ ratio than *de novo* synthesised fatty acids. The results of these feeding experiments allow conclusions about the biosynthesis of fatty acids and alcohols as well as comparisons with natural $^{13}C/^{12}C$ ratios of calanoid copepods. Copepod samples for the determination of natural isotope ratios were collected during "Polarstern" expeditions ARK XI/2 and ANT XIV/2.

In addition, samples were taken to analyse the largely unknown lipid compositions of cyclopoid and poikilostomatid copepods. Of particular interest is a comparison of these Arctic (ARK XI/2, ARK XIII/1) species with Antarctic (ANT XIV/2) cyclopoids und poikilostomatids.

Material and methods
Copepods were collected by bongo net in the upper 100 m of the Barents Sea and during a 75°N and a 81°N transect in the Greenland Sea. The specimens were immediately sorted to species and stages. Cyclopoid and poikilostomatid copepods were put in solvents and kept frozen under nitrogen at -30°C. Calanoid copepods were fed with ^{13}C-marked diatoms. Subsamples were taken at fixed intervals and also stored frozen at -30°C. The $^{13}C/^{12}C$ ratios and the fatty acid and alcohol compositions will be analysed in Bremerhaven. A total of about 700 samples were collected and about 6000 specimens sorted.

6 Benthology

6.1 Activity Patterns and Species Composition of Benthic Communities at the Continental Margin of Northeast Greenland (Ritzrau, Gutthahn, Scheltz, Seiler, Stübing, Treude)

Major focus of the benthos work was set on the influence of vertical and lateral particle flux on the activity pattern and the community structure of the benthic communities across the continental slope of Northeast Greenland in the biological spring. A wide variety of equipment, like a bottom water sampler, a camera for bottom photography, a multiple corer, a box corer and at selected stations an epibenthic sledge or an Aggazzis trawl were used to retrieve the samples for the diverse analyses. These instruments were deployed at six stations on a transact with water depths ranging from 3500 m to 200 m across the continental margin of Northeast Greenland at 75°N. For comparison, the effect of a higher degree of ice cover on the benthic communities was studied on a transect at 81°N. Applying the same sampling strategy three stations at 3400 m, 1500 m and 400 m water depths were sampled. To study the temporal activity pattern of a benthic deep sea community a time series station at 3500 m water depth was revisited three times (Sts. 44-19, 44-25 and 44-35). A short term mooring in close proximity of these stations will allow to relate the benthic activity pattern to the corresponding vertical particle flux.

Preliminary results of the biogeochemical parameters at the first sampling period with low concentrations of chlorophyll equivalents in the sediment (Fig. 6.1) and low oxygen consumption rates suggest, that the sediment community at 75°N had not received significant input of phytogenic material and appeared to be in a state of low activity. A similar pattern was observed at the northern transect at 81°N, indicating the influence of the higher degree of icecover on the availability of phytogenic material to the benthic communities. A small increase in the concentrations of chlorophyll equivalents in the sediments at the time series station (St. 44-25) at 75°N observed at the second

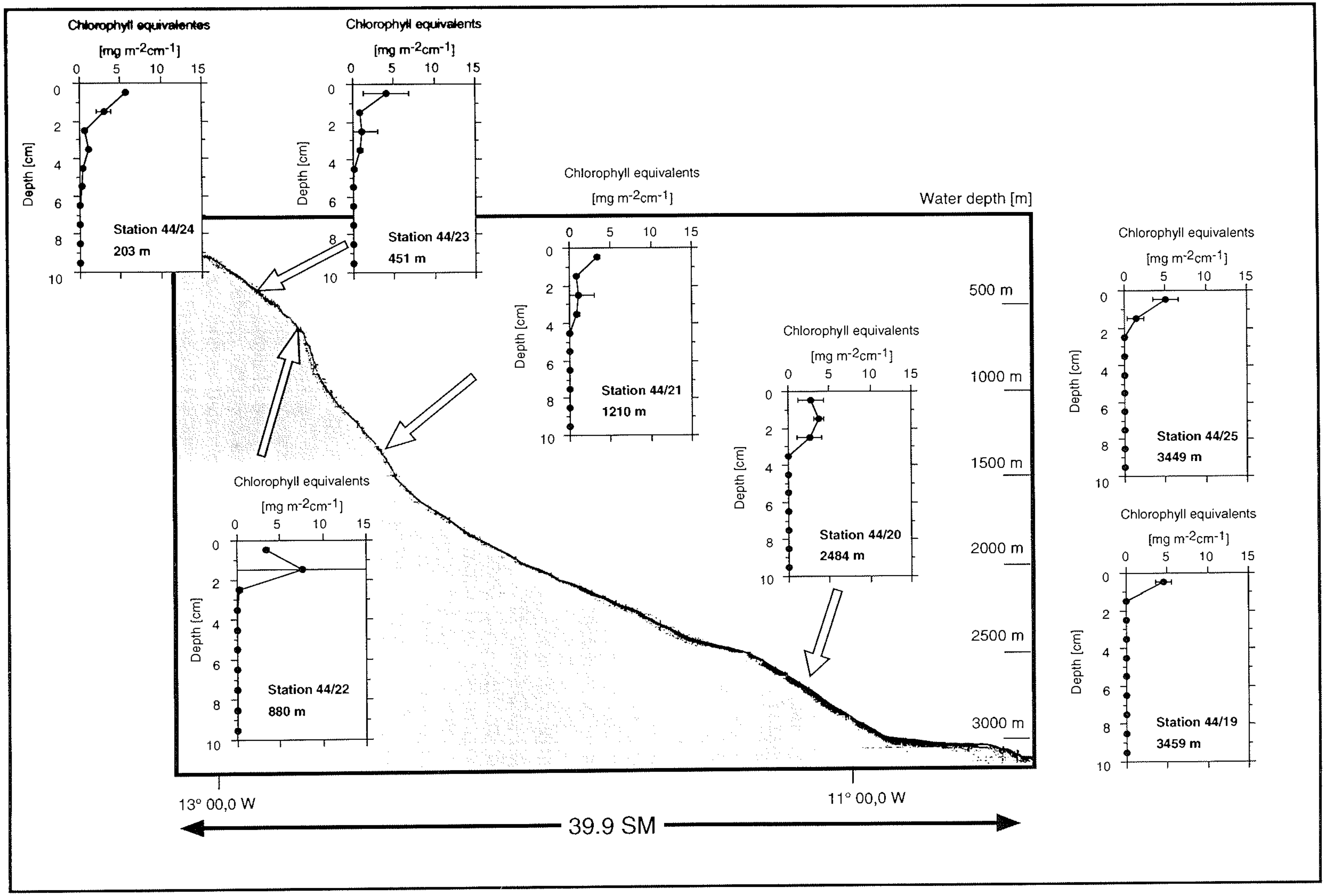

Fig. 6.1: Vertical profiles of clorophyll equivalents in the sediment along the 75°N transect.

sampling indicated a potential input of phytogenic material, a result which will be considered in the context of the results of the vertical particle flux of the adjacent mooring position. The results of the biogeochemical parameters will be completed with measurements of ATP and DNA from frozen samples at the laboratory. The results on the composition of particles, abundance and activities of microbial communities in the benthic boundary layer will be finalised at the home institute in Kiel.

Subsamples from box corer deployments will be analysed for the biomasses and the size spectra of the benthic macrofauna communities across the continental margin of Northeast Greenland at 75° and 81°N. Applying allometric functions on these biomass and size distributions will allow to estimate the contribution of the benthic fauna to the carbon demand of sediment communities in the area. The deployment of an epibenthic sledge provided samples for similar analyses of the epibenthic communities. The faunistic analysis of samples the will advance the information on the structure of benthic communities of continental margins in polar regions.

6.2 Cryo-Pelagic-Benthic Coupling in the Marginal Ice Zone of the Central Barents Sea During Early Spring (Rachor, Bluhm, Barwich, Hirse, Klages, Klein, Pörtner, Schlüter, Stübing)

The main aim of the benthological investigations were studies on processes involved in coupling of sea ice, the pelagic zone and the seafloor in the marginal ice zone of the central Barents Sea (BS) during early spring. This approach will help us to gain a better understanding of the ecology of Arctic shelf seas, e.g. concerning the timing, intensity, extent, and spatial distribution of the primary production, its fate during sinking through the water column and finally its relevance for benthic consumers at the seafloor.

During ARK XIII/1a the epibenthic sledge (EBS) and the Agassiz Trawl (AGT) were used at six and three stations, respectively, at water depths between 130 and 320 m. The EBS consists of two net devices which are designed to sample epibenthic and suprabenthic organisms. Usually a mesh size of 500 µm was used for the lower (epi-) net and 90 µm for the upper (supra-) net which is located 30 cm above the lower net case. The 90 µm net was used to sample demersal meroplanktic larvae which were kept alive for some hours or days in a cooled laboratory container, and sorted out under a stereomicroscope. Additionally, larvae were sampled by a multi net (55 µm mesh size) and a simple hand net (30 µm mesh size). In the first EBS samples analysed some polychaete larvae were found, most of them in a final stage of their larval development. As expected abundances decreased from open water areas sampled at southern stations to ice covered stations in the north. Polychaete larvae have been found to dominate the samples obtained in the near bottom layer of the Greenland Sea (GS) investigated during leg 1b. Echinoderm and bivalve larvae were most frequently collected close to the sea surface, but in low numbers at greater water depths. During the second leg of ARK XIII some stations in the Barents Sea were sampled again so that temporal differences of abundance and developmental stages of certain larval types might be detected.

Macrobenthic organisms obtained with the 500 µm EBS net and the AGT (10 mm mesh size in the cod end) were sorted subsequently after catch for selected taxa to be transferred into two cooling containers for long term life maintenance (ophiuroids, asteroids, decapods and amphipods). The most abundant organisms collected were ophiuroids, pantopods and decapods. Peracarid crustaceans were scarce although numerous juveniles of amphipods, isopods and mysids were found in the suprabenthic net. At first glance these juveniles were more abundant at the southern stations than at the ice covered northern ones.

Benthic communities depend upon food supply produced in the euphotic zone of the upper water column. In polar oceans this signal is of extreme seasonality. In order to improve our knowledge about population dynamics and activity patterns of abundant Arctic epibenthic species living under these special conditions we will apply new techniques in ageing of crustaceans and ophiuroids. Furthermore, analyses of seasonal differences in growth rates, together with analyses of gut content and identification of feeding strategies will be carried out. Respiration measurements at the institute will give some insights on the routine metabolism of selected target species. Especially large specimens of echinoderms were transferred to the laboratory container for this approach, since they belong to the most important groups concerning energy pathways and flows within benthic communities. The following species were sorted out from 12 EBS (6 BS + 6 GS) and 7 AGT catches (3 BS + 4 GS): *Ophiacantha bidentata, Ophiura sarsi, Ophiocten sericeum, Ophiopholis aculeata, Ophiopleura borealis, Ophiopus arcticus* (Ophiuroidea), *Strongylocentrotus pallidus* (Echinoidea), *Ctenodiscus crispatus, Urasterias lincki, Pontaster tenuispinus* (Asteroidea), *Sclerocrangon ferox, Pandalus borealis* (Decapoda), *Epimeria loricata, Rhachotropis aculeata* (Amphipoda) and *Onuphis conchylega* (Polychaeta). Ophiuroid and echinoid specimens were incubated for 24 hours in a calcein-seawater solution. Calcein is incorporated into the skeleton during calcification and forms visible bands which can be used for analysis of growth. This approach can help to verify whether growth rings in echinoderms are formed annually or not.

Analyses of total lipid content and lipid class composition in selected species will elucidate mechanisms of energy storage and the trophic role of zoobenthic organisms inhabiting high polar ecosystems. Fatty acids are used as biomarkers for pathways in the food chain and as useful indicators for energy flow calculations on species representing various feeding and life form types (suspension and detritus feeders, predators and necrophagous scavengers). Selected specimens were dissected at 1°C and different organs preserved at -80°C for further investigation at the institute. Gut content analysis on formalin preserved specimens will serve for additional information on the feeding ecology.

The material collected with quantitative gear, such as a van Veen grab (0,1 m^2 sampled area) and a multicorer (MUC), will be used for studies on species diversity, abundance, dominance and biomass calculations. The van Veen grab was used at nine stations (2-3 times each) and the MUC at five stations. The data will be correlated and combined with results obtained by incubation experiments on MUC cores aiming at an energy budget of the Barents Sea benthos. Sediment Community Oxygen Consumption (SCOC) measurements were performed on MUC tubes collected at 5 stations during ARK XIII/1a.

These tubes (60 mm in diameter) were incubated for a minimum of 3 up to 5 days. Oxygen content, salinity and temperature were measured soon after sampling (using microelectrodes and couloximetry). After incubation at 1 ± 0,5°C the final oxygen content and the temperature were measured. The overlying water was removed and fixed with formalin (final conc.: 4 %), the upper part of the sediment core was divided into three sections of 2 cm thickness each and also preserved in formalin seawater solution. These samples will be investigated for meiofauna, juvenile macrofauna and bacteria at the institute .

Parallel to the sampling programme of RV "Polarstern" colleagues from the Russian Murmansk Marine Biological Institute (MMBI) used also quantitative gear on their vessel and sampled further to the south ("Kola transect") of the "Polarstern" - transect. Both combined result in a N-S transect covering a large area of the Barents Sea.

For detailed physiological studies tissue and blood samples were taken and preserved under appropriate conditions for analysis later on at the institute. As formerly in the Antarctic, the use of a "squid jigger" failed in the Arctic because no animals were collected. The use of baited traps to collect eel pouts was not successful either. Trawl catches contained some bivalve specimens of *Astarte sulcata*, eel pouts and decapods (*Pandalus borealis*) for future physiological experiments. Some sensitive species such as *P. borealis* were succesfully transferred by aircraft from Svalbard to the Alfred Wegener Institute in Germany in order to test this kind of transport. These animals will be investigated concerning their cold adaptation at cellular level.

6.3 **Phylogeny of Pycnogonids** (Suck)

The aim of this cruise was to collect as many pycnogonids (or Pantopoda) as possible, in order to do proper histological and comparative studies. To obtain these animals it was necessary to use dredged gear.

During this cruise the epibenthic sledge (EBS) and the Agassiz trawl (AGT) were used to collect the animals at six stations.

Station	Date	UTC	°N	°W	Ice cover	Depth (m)	Gear
44-021	30.5.97	20:11	74°39′	13°23′	<1/10	1340	EBS
44-023	2.6.97	4:56	74°54′	13°8′	9/10	437	AGT
44-024	2.6.97	17:02	74°56′	13°50′	8/10	198	EBS
		17:57	74°57′	13°52′		196	AGT
44-029	7.6.97	15:17	77°48′	5°37′	8/10	360	AGT
44-031	12.6.97	9:27	80°56′	6°2′	9/10	1221	EBS
44-032	13.6.97	9:54	80°59′	7°48′	9/10	347	EBS

From earlier studies (Piepenburg, 1987) we suspected that pycnogonids would be quite abundant in the Greenland Sea, especially on the shelf.

This, however, turned out to be not the case, which is possibly due to a slightly different area, which was investigated. Among other reasons the sediment, the ice coverage and the structure of the benthic community might have played an important role.

In total 16 individuals larger than 5 cm in diameter were found:
021: (EBS): 1 *Boreonymphon* spec.
023: (AGT): 1 *Nymphon* spec.; 8 *Boreonymphon* spec. (different age classes)
024: (EBS): 1 *Nymphon* spec. (+ 10 very small individuals)
024: (AGT): 1 *Chaetonymphon* spec. (+2)
029: (AGT): 2 *Boreonymphon* spec.
031: (EBS): --
032: (EBS): --

Live animals were transferred to one of the cooling units. Six of them (plus two collected during the first leg) survived and were brought back to Göttingen, where we will try to keep them alive for as long as possible. They are to be observed and video taped concentrating on movement, feeding and other behavioural traits.

Most if not all animals found during the cruise leg 1b belong to the family Nymphonidae, which was expected.

The 10 animals which unfortunately did not survive were fixed in Bouin and will at first be identified down to species level if possible. Subsequently they will be investigated by using histological staining techniques combined with light microscopy and scanning electron microscopy. The structures on which the investigations will be concentrated have yet to be chosen, as they are dependent on the species and number of individuals found.

After sieving the sediment which was brought up by the EBS at St. 024, 10 more individuals were sorted out. These are very small and could not be found by the sorting by hand. They are probably juvenile animals. They are predestined by their size to be used for the scanning electron microscopical investigations.

In addition, I got the chance to sort through reference samples, collected during the first leg in the Barents Sea, where the abundance of pycnogonids was, at least locally, much higher than in the Greenland Sea.

From these samples I obtained another 73 individuals, most of which were smaller than the ones found in the Barents Sea. Due to lack of time I was not able to identify the genera. They probably also belong to the family Nymphonidae. It will also have to be decided at home whether they are small adults or juveniles.

As there was no quantitative sampling during the first leg no proper comparisons can be made (the used gear only allows quantitative statements to a certain degree), it is just possible to notice some trends:

The abundance of pycnogonids seems to be higher in the Barents Sea, and the species spectrum and the age spectrum also differ.

7 **Micropaleontology** (Hass, Jensen)

Original scientific objectives
Since 1991 subproject B3 of the SFB 313 at Kiel University is involved in investigating recent distribution, changes during sedimentation processes, as well as the the geological record of fossil preservable plankton groups in order to reconstruct plankton communities of the northern North Atlantic throughout the latest Quaternary. Investigated plankton groups include coccolithophores, foraminifers, dinoflagellates, diatoms, and radiolaria. The primary goal of the Expedition ARK XIII/I was thus to obtain a large number of samples (including water samples, multiple- and plankton net samples, as well as sediment cores) from as many locations as possible. Samples obtained during ARK XIII/I will be integrated in a large collection of samples that cover crucial areas of the northern North Atlantic. They also include an important transect at 81°N that forms part of the gateway between the Arctic Ocean and the North Atlantic. During earlier expeditions it was not possible to sample the water column during the early spring ice break-up. ARK XIII/I provided this opportunity in the form of excellent samples that were taken at two transects in the Greenland Sea and the Fram Strait, respectively.

Results of the analyses of the samples taken during ARK XIII/I and earlier expeditions will provide thorough insights into the processes that influence and alter plankton communities on their way through the water column. These results will be applied to the fossil record in order to improve interpretations as well as to better assess the climatic and oceanographic histories of the northern North Atlantic region and global paleoenvironmental changes. The interpretation of palaeoclimatic changes throughout the Cenozoic is based largely on microfossils, such as those investigated within Subproject B3. The results of this research will make a significant contribution to our understanding of the ecology and palaeoecology of marine micro-organisms and their use as indicators of changes in palaeoenvironmental conditions.

The following specific objectives are to collectively achieve this goal:
1) Determine the ecology and paleoecology of five groups of planktic organisms that presently live in the northern North Atlantic. Information about the ecology and resistibility of these organisms is essential for accurate assessment of fossil assemblages. This is especially relevant for Quaternary and Holocene fossil assemblages, as most of the species found in these assemblages are also found in modern oceans.

2) Decipher the processes that lead to changes and alterations of the present and former living plankton communities. This knowledge is crucial for any further interpretation of sediment-surface and fossil assemblages. In particular, this is important for organisms that are highly prone to dissolution; fossil assemblages may lack more than 30 % of the original number of species due to dissolution which might cause misinterpretation of fossil records.

Sediment samples
During the cruise, we collected six box cores and three multiple cores from a wide range of water depths (195 - 3703 m) on two transects at 75°N and 81°N including locations in between. Core lengths were between 22 and 50 cm. Due to extreme hard and partly dropstone laden sediments there were a couple of unsuccessful attempts to retrieve more cores.

Plankton samples
During the cruise, we collected 64 multiple net samples. Wherever possible the depth intervals 2000-1000 m, 1000-500 m, 500-150 m, 150-50 m, 50-0 m were subsampled. At shallower locations the five intervals were individually changed according to water depth. Using a 55µm mesh, these samples will be used not only to investigate the euphotic zone but also to investigate deep dwelling plankton such as radiolaria.

Wherever possible, the euphotic zone (0-50 m water depth) was subsampled using a 41 µm mesh plankton net. On this cruise 12 plankton net samples were recovered, most of them taken on the two transects. Basically, these samples will be used for dinoflagellate analysis.

Coccolithophores will be analyzed in water samples taken from Niskin bottles. A defined volume of water (2 l) was filtered immediately after recovery of the combined CTD/Niskin bottle carrier. The filters will be further prepared for SEM analysis. A total of 91 water samples were filtered from every possible location. Typically, the sampled water depth levels were at 10 m, 30 m, 50 m, 70 m, 100 m, 250 m, 500 m, 1000 m, 2000 m, but may be different owing to water depth.

Additionally, four surface samples for diatom analysis were taken using a hand net.

Table 7.1. Station list (CTD=water sample; NSN=plankton net; MN= multiple net; HN=hand net; MUC=multiple corer; GKG=box corer)

Station No.	Latitude	Longitude	Water depth [m]	Activity	Sampling depth
44-19	74°56.4 N	7°04.1 W	3454	CTD	10
					30
					50
					100
				NSN	0-50
				MN	2000-1000
					1000-500
					500-150
					150-50
					50-0
				CTD	250
					500
					1000
				MUC	Recovery: 38cm, (1) 15cm (2)
44-20	74°58.03 N	11°04.20 W	2774	CTD	10
					20
					30
					50
					70
				NSN	50-0
				MN	2000-1000
					1000-500
					500-150
					150-50
					50-0
				CTD	100
					250

					500
					1000
					2000
				MUC	Recovery: 32cm (1,2)
44-21	74°43.5 N	13°2.2 W	1515	CTD	10
					30
					50
					70
				NSN	50-0
				MN	1480-1000
					1000-500
					500-150
					150-50
					50-0
				CTD	100
					250
					500
					1000
				HN	surface
					1450
				GKG/ MUC	Recovery: 27cm
44-22	74°58.1 N	12°59.9 W	801	CTD	10
					20
					30
					40
					50
				NSN	0-50
				MN	780-500
					500-300
					300-150
					150-50
					50-0
				CTD	650
					500
					250
					100
					70
				HN	surface
				GKG	Recovery: 42cm (1), 50cm (2)
44-23	74°57.9 N	13°0.1 W	409	CTD	10
					20
					30
					40
					50
				NSN	0-50
				MN	390-200
					200-150
					150-100
					100-50
					50-0
				CTD	200
					150
					100
					80
44-24	74°59.22 N	13°50.8 W	194	CTD	10

					30
					60
				NSN	0-50
				MN	160-100
					100-50
					50-20
					20-0
				CTD	168
					100
					80
				GKG	Recovery: 22cm
44-25	74°56.6 N	7°7.6 W	3474	CTD	10
					30
					50
				NSN	0-50
				MN	2000-1000
					1000-500
					500-150
					150-50
					50-0
				HN	surface
				CTD	100
					250
					500
					1000
					2000
44-29	78°3.9 N	5°18.5 W	453	MN	420-300
					300-200
					200-150
					150-50
					50-0
44-30	80°54.5 N	4°3.5 W	3334	CTD	10
					30
					50
					70
				NSN	0-50
				MN	2000-1000
					1000-500
					500-150
					150-50
					50-0
				CTD	2000
					1000
					500
					250
					100
				GKG	Recovery: 40.5cm
44-31	80°58.1 N	5°54.9 W	1588	CTD	10
					30
					50
					70
				NSN	0-50
				MN	1540-1000
					1000-500
					500-150
					150-50
					50-0
				CTD	1500

					1000
					500
					250
					100
				HN	surface
44-33	81°0.6 N	7°47.6 W	391	CTD	10
					30
					50
					70
					100
				NSN	0-50
				CTD	350-200
					200-150
					150-100
					100-50
					50-0
				HN	surface
				CTD	344
					200
					150
44-34	77°12.7 N	7°17.8 W	277	NSN	0-50
				MN	250-200
					200-150
					150-100
					100-50
					50-0
44-35	75°00.0 N	6°58.9 W	3420	CTD	10
					30
					50
					70
				NSN	0-50
				MN	2000-1000
					1000-500
					500-150
					150-50
					50-0
				CTD	2000
					1000
					500
					250
					100
44-38	74°58.9 N	0°0.4 W	3703	GKG	Recovery: 41cm

8 **Geochemistry** (Sauter, Lunau, Queisser, Janssen)

Nutrients

Primary production in the euphotic zone requires nutrients like nitrate, NO_3^-, phosphate, PO_4^{3-} silicate, $Si(OH)_4$ and ammonium, NH_4^+ to be available in the water column or the brine channels of sea-ice respectively. In this context nutrients were measured in pelagic water samples (biorosette at 26 stations). In combination with CTD-data they allow the characterisation of water masses. Analogously ice samples of 11 stations were analyzed in respect to their nutrient content. Sediment sampling for geochemical analysis was performed with a multiple corer (MUC) at 10 sites along two transects on 75°N and 81°N. The retrieved cores were segmented and squeezed for porewater seperation in a cool-lab onboard "Polarstern". The nutrient depth distribution in the sediment porewater allows to deduce information about C_{org} influx and degradation. Fig. 8.1 shows the depth distribution of pore water nitrate, phosphate, and silicate at station 44/24 (200m) for example.

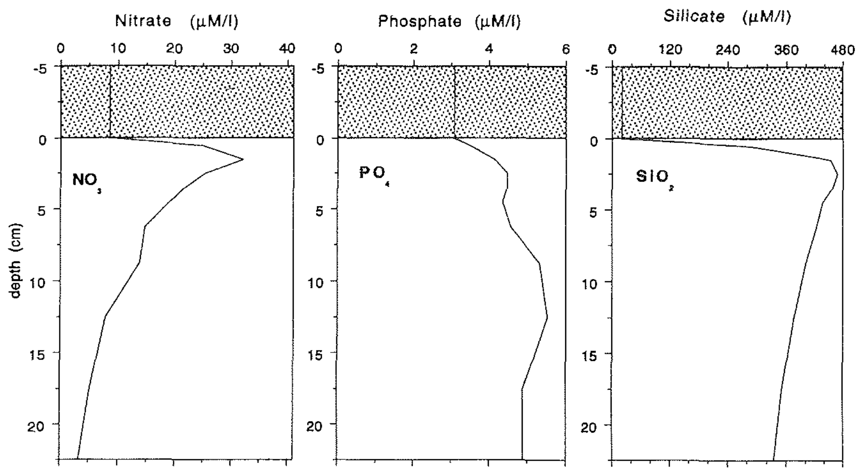

Fig. 8.1: Depth distribution of porewater nitrate, phosphate, and silicate at the 200 m St. 44/24 at 75°N.

The oxic zone is limited on the upper 5 cm of sediment column at this location, as indicated by the nitrate profile. Below this layer nitrate is consumed for organic matter oxidation (denitrification). In comparison to that shallow location, the sediment column is considerably deeper oxigenated at the deeper stations of the 75°N transect. The denitrification horizon was not reached over the entire core length at most of the stations. This is confirmed by the porewater oxygen depth distribution (Fig. 8.2). A correlation between water depth and redox zonation as found at 75°N was not detected at 81°N. In general phosphate and silicate often show a similar depth distribution compared to nitrate: For these porewater parameters a local concentration maximum was found only at the shallow stations. At deeper sites the concentration approaches a constant value at deeper sediment horizons.

Oxygen microprofiles

Beside nutrients the O_2-depth distribution was measured at the MUC-samples immediately after core retrieval (Fig. 8.2). For this purpose Clark-type microelectrodes of own manufacture were used. Out of the measured profiles C_{org} input and degradation rates will be determined. On this spring cruise oxygen often was found to penetrate deeper into the sediment and concentration gradients to be less steep below the sediment/water interface compared to summer and fall measurements performed in this region. This indicates lower oxygen consuption and thus lower C_{org} input upon the sediment surface. The data-base measured during earlier cruises was enlarged with important spring measurements during this expedition. Herewith we hope to improve our knowledge of the seasonal pattern significantly.

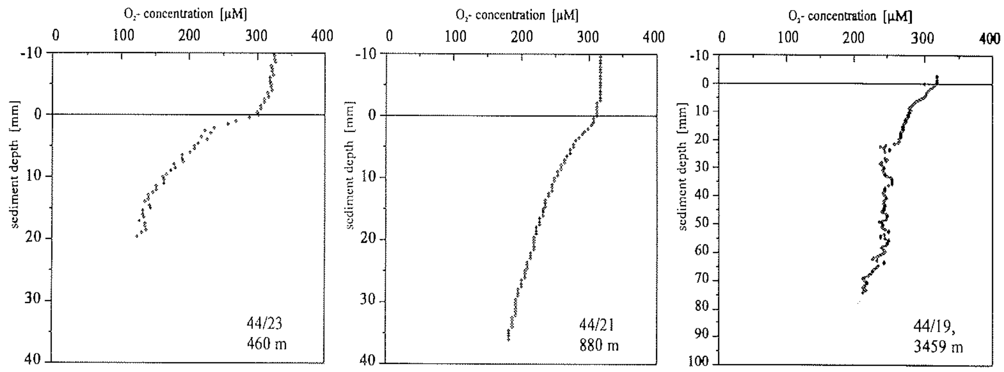

Fig. 8.2: Depth distribution of porewater oxygen at three locations on the 75°N transect east of Greenland.

9 Annex

9.1 Station List

ARK XIII/1 a

Station	Date 1997	Time (UTC)	Longitude	Latitude	Depth (m)	Gear
44-001	16.05.	16:06	63°31.6' N	07°14.8' E	314	BN
		16:11	63°31.6' N	07°14.8' E	314	JM
		16:22	63°31.6' N	07°14.8' E	314	BN
		16:39	63°31.6' N	07°14.8' E	314	MN
		16:41	63°31.6' N	07°14.8' E	314	AN
		17:15	63°31.6' N	07°14.8' E	314	BRS
		17:51	63°31.7' N	07°14.7' E	314	JM
		17:56	63°31.7' N	07°14.7' E	315	CTD
44-002	19.05.	10:29	75°59.9' N	32°58.8' E	313	BRS
		10:31	75°59.9' N	32°58.7' E	314	AN
		10:40	76°00.0' N	32°58.6' E	311	JM
		11:01	76°00.2' N	32°58.0' E	308	MN
		11:32	76°00.5' N	32°57.3' E	314	BN
		11:50	76°00.6' N	32°56.9' E	312	BN
		12:06	76°00.6' N	32°56.7' E	313	BN
		12:52	76°00.7' N	32°56.0' E	306	CTD
		13:06	76°00.8' N	32°55.9' E	307	Bucket
		13:16	76°00.8' N	32°55.8' E	307	MN
		13:41	76°00.9' N	32°55.7' E	305	JM
		13:52	76°00.9' N	32°55.6' E	306	BRS
		14:16	76°01.0' N	32°55.4' E	302	UWC
		15:08	76°01.1' N	32°54.9' E	307	BRS
		15:29	76°01.2' N	32°54.6' E	304	MUC
		16:02	76°01.1' N	32°53.9' E	304	VVG
		16:21	76°01.1' N	32°53.6' E	306	VVG
		16:45	76°01.2' N	32°53.1' E	304	BRS
		17:15	76°01.3' N	32°52.9' E	309	EBS
		18:20	76°02.0' N	32°52.9' E	319	BRS
		18:44	76°01.9' N	32°52.0' E	319	BT 1
		19:25	76°02.8' N	32°52.0' E	310	BT 2
44-003	20.05.	0:03	76°39.3' N	33°32.5' E	136	BRS
		0:37	76°38.9' N	33°31.3' E	140	MN
		1:00	76°38.9' N	33°30.0' E	130	MN
		1:20	76°38.7' N	33°29.4' E	131	CTD
		1:27	76°38.7' N	33°29.3' E	130	AN
		1:42	76°39.0' N	33°27.3' E	139	BN
		1:58	76°39.0' N	33°27.2' E	142	BN
		2:20	76°38.8' N	33°36.8' E	140	BRS
		2:44	76°38.5' N	33°26.0' E	146	UWC
		3:26	76°37.9' N	33°23.8' E	142	VVG

Station	Date 1997	Time (UTC)	Longitude	Latitude	Depth (m)	Gear
44-003	20.05.	3:26	76°37.9' N	33°23.8' E	142	JM
		3:41	76°37.8' N	33°23.6' E	144	VVM
		3:58	76°37.7' N	33°23.1' E	149	MUC
		4:25	76°37.3' N	33°22.1' E	152	EBS
		5:07	76°36.4' N	33°20.5' E	167	AGT
		6:07	76°33.4' N	33°25.6' E	162	BT
		6:36	76°32.5' N	33°22.9' E	186	BT
44-004	20.05.	10:33	76°44.5' N	33°39.4' E	115	BRS
		11:01	76°44.4' N	33°38.4' E	111	MN
		11:19	76°44.3' N	33°37.7' E	116	MN
		11:38	76°44.2' N	33°37.2' E	105	CTD
		11:55	76°44.2' N	33°36.8' E	109	BN
		12:09	76°44.1' N	33°36.3' E	109	BN
		12:13	76°44.1' N	33°36.2' E	108	AN
		12:26	76°44.0' N	33°35.8' E	113	BN
		12:47	76°43.9' N	33°35.1' E	119	BRS
		13:09	76°44.7' N	33°34.4' E	117	UWC
		13:45	76°43.5' N	33°33.2' E	127	VVG
		13:56	76°43.4' N	33°32.8' E	120	VVG
		14:25	76°43.5' N	33°32.9' E	126	EBS
44-005	20.05.	16:15	76°51.6' N	33°51.5' E	106	Mini CTD
		16:33	76°51.4' N	33°50.8' E	109	SWS
		17:09	76°51.3' N	33°49.6' E	106	BRS
		17:28	76°51.1' N	33°48.8' E	106	BN
44-006	20.05.	20:18	77°01.1' N	33°54.0' E	154	Ice Station until 00:50
		20:16	77°01.1' N	33°54.0' E	154	BRS
		20:51	77°01.0' N	33°53.2' E	156	MN
		21:11	77°00.9' N	33°52.6' E	160	MN
		21:16	77°00.8' N	33°52.3' E	160	AN
		21:34	77°00.9' N	33°52.2' E	156	CTD
		21:52	77°00.8' N	33°51.8' E	158	BN
		22:08	77°00.8' N	33°55.5' E	157	BN
		22:28	77°00.7' N	33°51.3' E	158	BN
		22:49	77°00.6' N	33°51.0' E	159	BRS
		23:05	77°00.5' N	33°50.7' E	159	UWC
		23:42	77°00.5' N	33°50.4' E	159	VVG
		23:56	77°00.4' N	33°50.2' E	159	VVG
	21.05.	1:09	77°00.5' N	33°50.6' E	158	EBS
44-007	21.05.	5:03	77°04.2' N	34°04.8 E	150	BRS
		5:27	77°04.1' N	34°04.4 E	153	BN

Station	Date 1997	Time (UTC)	Longitude	Latitude	Depth (m)	Gear
44-008	21.05.	9:30	77°10.3' N	34°04.4' E	164	Ice Station until 10:46
		11:27	77°10.0' N	33°59.0' E	163	BRS
		12:01	77°09.9' N	33°58.6' E	160	MN
		12:24	77°09.8' N	33°58.4' E	155	MN
		12:45	77°09.7' N	33°58.2' E	155	CTD
		13:09	77°09.6' N	33°58.0' E	154	BN
		13:27	77°09.5' N	33°57.9' E	152	BN
		13:39	77°09.5' N	33°57.9' E	153	AN
		13:43	77°09.5' N	33°57.8' E	150	BN
		14:06	77°09.2' N	33°57.7' E	149	BRS
		14:31	77°09.0' N	33°57.5' E	152	UWC
		15:11	77°08.7' N	33°57.0' E	146	VVG
		15:23	77°08.6' N	33°56.9' E	144	VVG
		15:46	77°08.8' N	33°56.6' E	163	EBS
44-009	21.05.	19:10	77°18.3' N	34°18.0' E	126	Mini CTD
		19:27	77°18.3' N	34°18.5' E	125	BRS
		19:49	77°18.3' N	34°18.0' E	128	AN
		19:53	77°18.3' N	34°18.0' E	130	BN
		20:07	77°18.3' N	34°17.8' E	130	AN
		20:11	77°18.3' N	34°17.8' E	129	JM
44-010	22.05.	5:07	77°23.3' N	34°39.6' E	178	Ice Station until 16:41
		8:08	77°21.6' N	34°35.9' E	174	BRS
		8:38	77°21.4' N	34°35.0' E	176	MN
		8:59	77°21.3' N	34°03.5' E	171	MN
		9:21	77°21.1' N	34°33.9' E	168	BN
		9:38	77°21.0' N	34°33.6' E	169	BN
		9:55	77°20.9' N	34°33.3' E	163	BN
		10:17	77°20.9' N	34°33.0' E	164	UWC
		10:50	77°20.8' N	34°32.7' E	163	CTD
		11:07	77°20.7' N	34°32.4' E	164	VVG
		11:19	77°20.7' N	34°32.4' E	163	VVG
		11:30	77°20.6' N	34°32.4' E	163	VVG
		11:42	77°20.6' N	34°32.3' E	159	MUC
		11:58	77°20.5' N	34°32.3' E	161	MUC
		12:43	77°20.3' N	34°32.1' E	160	JM
		14:11	77°19.8' N	34°32.3' E	157	BN
		14:30	77°19.3' N	34°32.4' E	159	BN
		14:48	77°19.6' N	34°32.3' E	158	BN
		15:07	77°19.5' N	34°32.4' E	160	BN
		15:31	77°19.3' N	34°32.6' E	155	MUC
		17:58	77°18.3' N	34°32.0' E	148	BT
		18:13	77°17.8' N	34°31.0' E	143	AGT

Station	Date 1997	Time (UTC)	Longitude	Latitude	Depth (m)	Gear
44-011	22.05.	23:03	77°35.4' N	34°37.3' E	179	BRS
		23:34	77°35.5' N	34°37.6' E	184	MN
		23:55	77°35.5' N	34°37.8' E	184	MN
	23.05.	0:17	77°35.6' N	34°38.1' E	186	CTD
		0:33	77°35.6' N	34°38.3' E	186	BN
		0:52	77°35.6' N	34°38.6' E	186	BN
		1:11	77°35.7' N	34°39.0' E	186	BN
		1:35	77°35.7' N	34°39.3' E	186	UWC
		2:16	77°35.7' N	34°40.1' E	185	BRS
		2:41	77°35.7' N	34°40.5' E	184	VVG
		2:53	77°35.6' N	34°40.6' E	184	VVG
		3:15	77°35.6' N	34°41.0' E	185	MUC
		3:30	77°35.5' N	34°41.2' E	185	MUC
		4:28	77°35.2' N	34°41.9' E	188	JM
		6:30	77°34.6' N	34°42.2' E	198	Mooring
44-012	23.05.	13:52	77°16.1' N	33°32.8' E	137	Ice Station until 18:00
		13:40	77°16.1' N	33°32.5' E	134	JM
		15:05	77°16.3' N	33°34.8' E	142	BRS
		15:34	77°16.3' N	33°35.6' E	143	MN
		15:56	77°16.3' N	33°36.2' E	139	MN
		16:19	77°16.3' N	33°36.7' E	138	BN
		16:33	77°16.3' N	33°37.0' E	139	BN
		16:50	77°16.3' N	33°37.3' E	142	BN
		17:15	77°16.2 ' N	33°37.7' E	145	BRS
		17:38	77°16.2 ' N	33°38.1' E	151	VVG
		17:55	77°16.1' N	33°38.2' E	152	MUC
		18:24	77°16.1' N	33°37.6' E	147	EBS
44-013	24.05.	1:45	76°34.4' N	33°26.9' E	161	Mini CTD
		2:00	76°34.3' N	33°26.9' E	161	SWS
		2:44	76°34.4' N	33°28.8' E	158	BRS
		3:07	76°34.5' N	33°29.1' E	156	MN
		3:28	76°34.5' N	33°29.2' E	158	CTD
		3:42	76°34.5' N	33°29.3' E	160	BN
		3:56	76°34.5' N	33°29.4' E	158	BN
		4:07	76°34.5' N	33°29.5' E	157	BN
		4:29	76°34.5' N	33°30.0' E	160	VVG
		4:42	76°34.5' N	33°30.3' E	157	VVG
44-014	24.05.	9:12	76°26.2' N	33°31.2' E	236	BRS
		9:43	76°26.4' N	33°31.3' E	236	BN
44-015	24.05.	11:41	76°12.9' N	33°15.3' E	295	BRS
		12:03	76°12.8' N	33°15.4' E	263	AN
		12:07	76°12.9' N	33°15.2' E	292	BN
		12:31	76°13.0' N	33°15.0' E	292	MN
		13:13	76°12.6' N	03°14.3' E	287	RMT

Station	Date 1997	Time (UTC)	Longitude	Latitude	Depth (m)	Gear
44-016	24.05.	15:32	76°02.9' N	32°51.4' E	309	Retrieval BT 1
		16:37	76°01.8' N	32°51.2' E	323	Retrieval BT 2
		17:17	76°02.4' N	32°49.6' E	316	Retrieval Topp Unit
		17:27	76°02.4' N	32°49.0' E	317	BRS
		17:53	76°02.4' N	32°49.1' E	317	MN
		18:30	76°02.3' N	32°49.9' E	320	CTD
		18:49	76°02.1' N	32°50.1' E	317	BN
		19:30	76°01.9' N	32°50.3' E	317	MUC
		19:57	76°01.8' N	32°50.4' E	319	EBS
		20:49	76°01.3' N	32°49.8' E	309	AGT

ARK XIII/ 1b

Station	Date 1997	Time (UTC)	Longitude	Latitude	Depth (m)	Gear
44-017	27.05.	9:08	76°35.9' N	04°38.9' E	3111	BN
		9:45	76°35.8' N	04°38.8' E	3109	BN
		10:02	76°35.8' N	04°39.1' E	3112	MN
		10:40	76°35.7' N	04°39.8' E	3098	AN
		11:29	76°35.5' N	04°40.3' E	3081	BRS
44-018	28.05.	9:50	75°00.0' N	07°32.0' W	3419	Deployment Mooring OG 11a
44-019	28.05.	13:59	74°56.5' N	07°04.3' W	3455	BRS
		14:10	74°56.5' N	07°03.5' W	3454	Ice Station until 17:15
		14:22	74°56.5' N	07°03.9' W	3454	NCN
		14:34	74°56.7' N	07°03.0' W	3454	MN
		15:23	74°56.8' N	07°01.8' N	3457	AN
		17:46	74°57.2' N	06°57.3' W	3461	BRS
		18:06	74°57.2' N	06°56.5' W	3461	MN
		20:09	74°57.5' N	06°53.4' W	3465	MN
		20:35	74°57.8' N	06°52.9' W	3472	BRS
		22:43	74°58.4' N	06°50.7' W	3466	BN
		23:00	74°58.4' N	06°50.4' W	3469	BN
	29.05.	0:50	74°59.1' N	06°48.6' W	3472	BWS
		3:24	75°00.1' N	06°45.6' W	3479	MUC
44-020	29.05.	21:05	74°58.1' N	11°04.3' W	2775	BRS
		21:20	74°57.9' N	11°04.2' W	2778	NCN
		21:34	74°57.8' N	11°04.3' W	2780	MN
	30.05.	0:52	74°56.0' N	11°08.5' W	2793	BRS
		3:50	74°55.1' N	11°15.1' W	2715	MN
		5:00	74°54.6' N	11°19.7' W	2721	Ice Station until 18:00

Station	Date 1997	Time (UTC)	Longitude	Latitude	Depth (m)	Gear
44-020	30.05.	5:39	74°54.5' N	11°20.8' W	2659	MN
		6:06	74°54.5' N	11°21.6' W	2645	BN
		6:25	74°54.4' N	11°22.1' W	2639	BRS
		8:28	74°54.0' N	11°25.3' W	2615	UWC
		8:39	74°53.9' N	11°25.6' W	2613	UWC
		8:43	74°53.9' N	11°25.7' W	2612	UWC
		10:56	74°53.1' N	11°28.4' W	2613	BWS
		11:02	74°53.1' N	11°28.5' W	2614	BWS
		12:35	74°52.4' N	11°30.5' W	2603	AN
		13:23	74°52.1' N	11°31.8' W	2593	GBC
		13:49	74°52.0' N	11°32.7' W	2588	Mini CTD + SWS
		15:01	74°51.6' N	11°35.3' W	2581	GBC
		17:02	74°51.1' N	11°40.0' W	2530	MUC
		19:06	74°51.1' N	11°43.9' W	2462	MUC
44-021	31.05.	0:30	74°44.0' N	13°00.8' W	1500	Mini CTD + SWS
		1:06	74°43.8' N	13°01.5' W	1500	BRS
		1:28	74°43.6' N	13°01.9' W	1506	NCN
		1:38	74°43.6' N	13°02.2' W	1507	MN
		3:47	74°43.4' N	13°04.0' W	1477	BRS
		3:59	74°43.3' N	13°04.1' W	1478	Hand-held Nets
		4:57	74°42.9' N	13°05.8' W	1482	MN
		6:44	74°41.9' N	13°07.8' W	1549	MN
		7:02	74°41.7' N	13°07.8' W	1564	BN
		7:15	74°41.5' N	13°08.1' W	1572	BN
		9:08	74°40.6' N	13°08.7' W	1677	BRS
		10:26	74°40.0' N	13°08.7' W	1747	UWC
		10:45	74°39.7' N	13°08.6' W	1761	UWC
		11:13	74°39.5' N	13°08.7' W	1776	BWS
		13:46	74°43.3' N	13°12.6' W	1248	UWC
		15:27	74°42.5' N	13°15.5' W	1223	MUC
		16:51	74°41.6' N	13°18.1' W	1256	GBC
		17:57	74°40.9' N	13°20.7' W	1288	GBC
		18:57	74°40.3' N	13°22.4' W	1311	GBC
		20:10	74°39.8' N	13°23.1' W	1364	EBS
44-022	01.06.	3:00	74°58.1' N	12°42.0' W	809	Mini CTD + SWS
		3:40	74°57.9' N	12°43.0' W	807	BRS
		4:00	74°57.8' N	12°43.4' W	800	NCN
		4:13	74°57.6' N	12°43.9' W	803	MN
		6:43	74°57.3' N	12°48.5' W	651	Ice Station until 13:50
		6:58	74°57.2' N	12°48.5' W	668	BRS
		7:35	74°57.0' N	12°48.6' W	685	MN
		8:55	74°56.4' N	12°48.7' W	750	BN
		9:12	74°56.3' N	12°48.8' W	754	BN
		10:18	74°55.7' N	12°48.9' W	797	BRS
		11:04	74°55.2' N	12°49.0' W	846	UWC

Station	Date 1997	Time (UTC)	Longitude	Latitude	Depth (m)	Gear
44-022	01.06.	12:36	74°54.5' N	12°49.5' W	895	MUC
		12:43	74°54.4' N	12°49.6' W	893	Hand-held Nets
		13:40	74°54.0' N	12°50.3' W	904	GBC
		14:32	74°53.5' N	12°51.4' W	909	GBC
		15:21	74°53.1' N	12°52.4' W	904	GBC
		16:53	74°55.4' N	12°47.2' W	876	BWS
44-023	01.06.	19:43	74°58.3' N	12°59.7' W	390	Mini CTD
		19:58	74°58.2' N	12°59.7' W	393	SWS
		20:16	74°58.2' N	12°59.9' W	397	AN
		20:18	74°58.2' N	12°59.9' W	397	BRS
		20:36	74°58.1' N	13°00.0' W	399	NCN
		21:09	74°57.9' N	13°00.2' W	403	MN
		21:46	74°57.7' N	13°00.3' W	403	BRS
		22:19	74°57.4' N	13°00.4' W	427	MN
		23:07	74°57.1' N	13°00.7' W	423	BN
		23:21	74°57.0' N	13°00.8' W	420	BN
	02.06.	0:04	74°56.7' N	13°01.1' W	440	BRS
		0:45	74°56.4' N	13°01.3' W	446	UWC
		1:45	74°55.9' N	13°02.2' W	452	GBC
		2:42	74°55.5' N	13°03.2' W	454	GBC
		3:18	74°55.3' N	13°04.0' W	452	GBC
		4:02	74°55.0' N	13°05.0' W	454	MUC
		4:57	74°54.4' N	13°08.4' W	448	AGT
44-024	02.06.	7:48	74°59.2' N	13°50.8' W	197	BRS
		8:10	74°59.2' N	13°50.8' W	195	Ice Station until16:43
		8:12	74°59.2' N	13°50.8' W	195	NCN
		8:22	74°59.2' N	13°50.7' W	197	MN
		8:55	74°59.1' N	13°50.6' W	196	BRS
		9:26	74°59.1' N	13°50.5' W	194	MN
		9:48	74°59.0' N	13°50.5' W	196	BN
		10:02	74°59.0' N	13°50.4' W	196	BN
		10:29	74°58.9' N	13°50.3' W	195	BRS
		10:57	74°58.8' N	13°50.2' W	195	UWC
		11:42	74°58.6' N	13°50.0' W	195	GBC
		12:16	74°58.5' N	13°49.9' W	194	GBC
		12:37	74°58.3' N	13°49.8' W	195	GBC
		13:07	74°58.2' N	13°49.8' W	192	GBC
		13:10	74°58.2' N	13°49.8' W	192	AN
		13:26	74°58.1' N	13°49.7' W	195	GBC
		13:53	74°57.9' N	13°49.7' W	199	GBC
		14:14	74°57.8' N	13°49.6' W	202	UWC
		14:39	74°57.6' N	13°49.6' W	202	MUC
		15:12	74°57.5' N	13°49.7' W	203	MUC
		17:02	74°56.9' N	13°50.2' W	199	EBS
		17:51	74°57.0' N	13°51.7' W	197	AGT

Station	Date 1997	Time (UTC)	Longitude	Latitude	Depth (m)	Gear
44-025	03.06.	12:30	74°56.8' N	07°07.9' W	3476	Mini CTD + SWS
		13:01	74°56.6' N	07°07.6' W	3472	BRS
		13:17	74°56.6' N	07°07.5' W	3472	NCN
		13:26	74°56.6' N	07°07.4' W	3473	MN
		14:36	74°56.5' N	07°07.2' W	3472	Hand-held Nets
		16:10	74°56.1' N	07°07.5' W	3473	BRS
		18:22	74°56.7' N	07°09.9' W	3470	MN
		20:32	74°55.5' N	07°14.6' W	3465	MN
		20:56	74°55.4' N	07°15.6' W	3464	BN
		21:11	74°55.4' N	07°16.3' W	3463	BN
		23:05	74°55.3' N	07°21.0' W	3456	BRS
		23:31	74°55.3' N	07°21.9' W	3454	UWC
	04.06.	2:03	74°55.3' N	07°26.9' W	3449	MUC
44-026	04.06.	10:05	75°36.8' N	06°17.8' W	3407	BRS
44-027	04.06.	12:59	76°00.0' N	06°09.4' W	2879	BRS
44-028	04.06.	16:07	76°16.0' N	05°25.0' W	2536	BRS
44-029	06.06.	1:20	78°05.5' N	05°10.1' W	686	Ice Station until 22:55
		6:07	78°03.8' N	05°18.6' W	449	MN
		6:55	78°03.4' N	05°19.8' W	437	BWS Test
		7:15	78°03.2' N	05°20.4' W	428	BN
		7:30	78°03.0' N	05°20.9' W	419	BN
		8:17	78°02.5' N	05°20.9' W	383	MN
		13:17	77°59.3' N	05°40.8' W	342	BN
		13:31	77°59.2' N	05°41.6' W	343	BN
		13:48	77°59.1' N	05°42.4' W	344	BN
		23:07	77°53.0' N	05°51.9' W	342	EBS
	07.06.	6:10	77°50.5' N	05°49.6' W	349	Ice Station until 14:35
		15:16	77°48.5' N	05°37.5' W	363	AGT
		17:42	77°46.8' N	05°05.9' W	858	RMT
44-030	10.06.	1:14	80°54.5' N	04°03.4' W	3332	BRS
		1:38	80°54.5' N	04°03.2' W	3322	NCN
		1:53	80°54.5' N	04°03.1' W	3310	MN
		4:46	80°54.4' N	03°59.9' W	3291	BRS
		5:03	80°54.3' N	03°59.4' W	3309	Ice Station until 17:50
		6:42	80°54.2' N	03°56.8' W	3358	MN
		9:08	80°53.9' N	03°53.7' W	3375	MN
		9:34	80°53.8' N	03°53.4' W	3376	BN
		9:47	80°53.7' N	03°53.3' W	3374	BN
		11:49	80°53.4' N	03°52.7' W	3364	UWC
		14:25	80°53.1' N	03°52.0' W	3362	GBC

Station	Date 1997	Time (UTC)	Longitude	Latitude	Depth (m)	Gear
44-030	10.06.	16:21	80°53.0' N	03°50.5' W	3406	GBC
		18:16	80°52.7' N	03°58.8' W	3461	GBC
		20:20	80°52.3' N	03°47.7' W	3465	MUC
		22:06	80°51.8' N	03°47.8' W	3458	BRS
	11.06.	0:28	80°51.1' N	03°47.9' W	3341	BWS
44-031	11.06.	16:17	80°58.0' N	05°54.7' W	1588	BRS
		16:39	80°58.0' N	05°54.9' W	1583	NCN
		16:57	80°58.1' N	05°54.6' W	1584	MN
		16:58	80°58.1' N	05°54.6' W	1584	AN
		19:15	80°58.0' N	05°55.6' W	1567	BRS
		19:46	80°58.0' N	05°54.9' W	1572	Mini CTD
		20:03	80°58.0' N	05°54.4' W	1585	SWS
		20:16	80°57.9' N	05°54.5' W	1576	MN
		20:57	80°57.8' N	05°54.5' W	1563	Hand-held Nets
		22:00	80°57.8' N	05°55.0' W	1553	MN
		22:15	80°57.7' N	05°55.7' W	1546	BN
		22:28	80°57.7' N	05°55.8' W	1405	BN
	12.06.	0:29	80°57.0' N	05°58.3' W	1384	UWC
		1:42	80°56.9' N	05°59.5' W	1334	BRS
		3:07	80°56.6' N	06°00.2' W	1289	BWS
		4:47	80°56.6' N	06°00.4' W	1289	GBC
		4:58	80°56.6' N	06°00.1' W	1293	Ice Station until 07:39
		6:00	80°56.7' N	05°59.5' W	1306	MUC
		7:18	80°56.7' N	05°59.0' W	1318	MUC
		7:40	80°56.7' N	05°59.1' W	1316	Mini CTD
		9:29	80°56.7' N	06°02.1' W	1233	EBS
		11:54	80°56.1' N	05°59.7' W	1312	GBC
44-032	12.06.	15:06	80°53.5' N	06°50.0' W	1226	RMT
44-033	13.06.	0:20	81°00.6' N	07°47.6' W	391	Mini CTD + SWS
		0:23	81°00.6' N	07°47.5' W	391	BRS
		0:46	81°00.5' N	07°47.5' W	399	NCN
		0:54	81°00.5' N	07°47.3' W	394	MN
		1:36	81°00.3' N	07°47.5' W	376	BRS
		1:54	81°00.2' N	07°47.8' W	376	Hand-held Nets
		1:55	81°00.2' N	07°47.8' W	376	MN
		2:29	81°00.1' N	07°47.7' W	367	BRS
		2:58	81°00.0' N	07°47.6' W	364	BN
		3:12	80°59.9' N	07°47.6' W	363	BN
		3:53	80°59.9' N	07°47.1' W	372	BRS
		4:25	80°59.8' N	07°46.7' W	366	UWC
		4:51	80°59.8' N	07°49.0' W	347	BWS
		5:33	80°59.8' N	07°48.0' W	354	UWC
		5:52	80°59.7' N	07°47.4' W	358	GBC
		6:23	80°59.5' N	07°46.8' W	360	GBC

Station	Date 1997	Time (UTC)	Longitude	Latitude	Depth (m)	Gear
44-033	13.06.	6:49	80°59.3' N	07°46.4' W	354	GBC
		7:32	80°59.1' N	07°46.3' W	352	GBC
		7:54	80°58.9' N	07°46.1' W	349	MUC
		8:21	80°58.8' N	07°45.7' W	344	MUC
		8:54	80°58.6' N	07°45.3' W	342	MUC
		9:53	80°59.8' N	07°48.9' W	345	EBS
		11:55	80°58.5' N	07°48.6' W	262	Ice Station until 18:20
		13:07	80°58.5' N	07°51.8' W	313	GBC
		13:27	80°58.4' N	07°52.8' W	307	GBC
		13:44	80°58.4' N	07°53.8' W	295	GBC
		17:01	80°57.9' N	07°56.5' W	281	UWC
44-034	16.06.	10:20	77°12.7' N	07°18.7' W	279	Retrieval Ice Drogue
		12:08	77°12.8' N	07°18.1' W	278	Ice Station until 15:18
		12:10	77°12.8' N	07°18.1' W	278	BN
		12:55	77°12.7' N	07°17.9' W	279	BN
		13:26	77°12.7' N	07°17.8' W	281	NCN
		13:37	77°12.7' N	07°17.8' W	281	MN
		14:09	77°12.7' N	07°17.7' W	281	GBC
		15:58	77°13.5' N	07°16.1' W	282	EBS
		16:59	77°13.6' N	07°16.3' W	283	AGT
44-035	18.06.	11:53	75°00.0' N	06°58.9' W	3424	BRS
		12:20	75°00.1' N	07°00.6' W	3418	NCN
		12:30	75°00.1' N	07°01.1' W	3416	MN
		15:35	75°00.2' N	06°59.8' W	3419	BRS
		16:17	75°00.2' N	06°59.9' W	3416	AN
		17:53	75°00.0' N	07°00.5' W	3418	MN
		20:18	74°59.3' N	07°00.9' W	3415	MN
		20:44	74°58.9' N	07°01.2' W	3414	BN
		21:05	74°59.8' N	07°01.7' W	3412	BN
		23:27	74°59.8' N	07°01.4' W	3418	BRS
	19.06.	1:38	74°59.6' N	07°01.6' W	3416	BWS
		3:00	74°59.7' N	07°01.3' W	3417	Hand-held Nets
		4:07	74°59.7' N	07°00.9' W	3417	MUC
		6:14	74°59.7' N	07°00.0' W	3419	RMT
44-036	19.06.	8:20	75°01.2' N	07°27.8' W	3384	Retrieval Mooring OG 11a
44-037	19.06.	12:19	75°00.2 N	06°57.8' W	3416	Retrieval Mooring OG 11

Station	Date 1997	Time (UTC)	Longitude	Latitude	Depth (m)	Gear
44-038	20.06.	8:04	74°59.9' N	00°00.4' W	3704	CTD
		9:12	74°59.8' N	00°00.7' W	3703	CTD
		10:15	74°59.6' N	00°01.7' W	3704	CTD
		11:14	74°59.4' N	00°02.4' W	3706	CTD
		12:11	74°59.2' N	00°02.5' W	3706	BN
		14:19	74°58.9' N	00°01.4' W	3703	GBC

Abbreviations:
AGT: Agassiz Trawl
AN: Apstein Net
BN: Bongo Net
BRS: Biological Rosette Sampler
BT: Baited Trap
BWS: Bottom Water Sampler
CTD: Oceanographic Rosette Sampler
EBS: Epibenthic Sledge
GBC: Giant Box Corer
JM: Jigging Machine
MN: Multinet
MUC: Multicorer
NCN: Nansen Closing Net
RMT: Rectangular Midwater Trawl
SWS: Surface Water Sampler
UWC: Underwater Camera
VVG: Van Veen Grab

9.2 Participants

Participating Institutions

Address		Participants ARK XIII/1a	Participants ARK XIII/1b
Germany			
AWI	Alfred-Wegener-Institut für Polar- und Meeresforschung 27515 Bremerhaven	15	5
BRF	Bayrischer Rundfunk - Fernsehen Floriansmühlstr. 60 80939 München	3	-
DWD	Deutscher Wetterdienst Seewetteramt Postfach 301190 20304 Hamburg	2	2
HSW	Helikopter Service Wasserthal GmbH Kätnerweg 43 22393 Hamburg	3	3
IPÖ	Institut für Polarökologie Wischhofstr. 1-3. Geb. 12 24148 Kiel	6	8
SFB	SFB 313. Universität Kiel H.-Hecht-Platz 10. 24118 Kiel	11	20
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