The Expedition ARKTIS-XI/2 of RV "Polarstern" in 1995

Edited by Gunther Krause
with contributions of the participants

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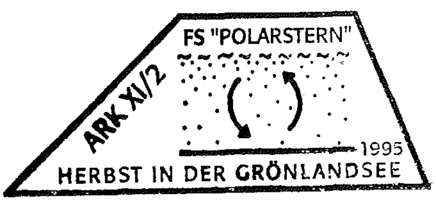
ARK XI/2

TROMSØ - BREMERHAVEN

22.09.1995 - 29.10.1995

Chief Scientist: Gunther Krause



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CRUISE REPORT ARK XI/2
Tromsø - Bremerhaven
22.9. - 29.10. 1995
"Autumn in the Greenland Sea"
Chief Scientist: Gunther Krause

1. INTRODUCTION

1.1 Scientific Background

With the theme "Autumn in the Greenland Sea" the expedition had set out to improve our knowledge of meteorological, physical, chemical and biological processes during the season of rapidly decreasing solar radiation and onset of the cooling phase. Previous field observations during this generally uncomfortable time of the year are fragmentary, and it was intended to close some of the gaps in the annual cycles of processes in the physical and biological arctic environment.

In the polar atmosphere, autumn provides the first strong outbreaks of cold air from Greenland onto a structured sea surface consisting of stretches of open water and new ice. There is little information on the near-ground turbulence of the atmospheric boundary layer which determines the exchange of momentum, heat and water vapour under such conditions.

The principal goal of Physical Oceanography was to study the water mass stratification just before and possibly during the onset of convection. The measurements of temperature and salinity were supplemented by nutrient sampling for multiparameter water mass analyses. These investigations continue observations on a long section from 13°W to 17°E with a station spacing of 10 nm at 75°N, occupied 1989 for the first time during the international Greenland Sea project.

Besides nutrient analyses the investigations of Marine Chemistry concentrated on lipids, the energy reserves of copepods for surviving the Polar Night. In a second project naturally produced volatile halogenated organic trace compounds (e.g. chloroform, trichloroethylene and related substances) were studied.

The largest project focused on the role that autumn plays in the vertical flux of particles which originate in the ice-associated and pelagic production and their fate in the sediment.

In addition to the above projects, which were specifically designed to profit from autumn conditions, a bathymetric survey of a region in Fram Strait was planned, and numerous current meter moorings were to be recovered and partly to be deployed. That task has fallen to this expedition because only the occasional research ship makes it this far to the north and is able to complete the work due to the ice-cover.

1.2 Strategic considerations and narrative of the cruise

The onbreak of winter from the Northwest and the rapidly decreasing duration of daylight determined route and schedule of this autumn expedition in the first place. Daylight is followed by the Polar Night at 80°N on the 22nd of October. Even at 75°N the times between sunrise and sunset decrease from 12 to 6 hours during the time of the expedition.

Daylight was a necessary preposition for many of the planned investigations. This included all work on the ice, the flight operations with the HELIPOD which carries delicate turbulence sensors through the air 15 m below a helicopter, the flights with laser altimeter and line-scanner, and the recovery of moorings. In the ice some of the shipbased work which is normally done round the clock relies on daylight as well, e.g. the towing of bottom gear like Agassiz trawl and the epibenthos sledge. Naturally, there has been much pressure on the precious hours of daylight.

Fortunately, the large working group of Kiel University had planned for extensive station work up to 20 hours at few locations. These stations were called the "SFB stations", and they formed the backbone of the daily work during much of the first phase of the expedition. During the daylight time the flight operations and work on the ice could be done in parallel, and it has been possible to interrupt some of these stations to recover moorings.

Compromising on the demand to head North as fast as possible, to ensure daylight for respective work, and to minimize steaming, the following work sequence was adopted (Fig.1.1):

- Complete half of the bathymetric survey
- Try to recover moorings at 79°N while occupying SFB stations perpendicular to the slope of the Greenland Shelf from East to West
- In the ice, perform ice investigations parallel to ship operations, fly HELIPOD, laser altimeter, line-scanner and employ bow mast for turbulence measurements
- Work on stations in the Northeast Water Polynya (NEW) and supply fuel to Eskimonaes summer camp
- Perform SFB station work along the 2000 m isobath
- Complete second half of bathymetric survey
- Revisit mooring sites at 79°N to provide a second chance to recover moorings in the pack ice
- Steam to 75°N and recover 7 moorings in the area
- Intensive turbulence measuring campaign, complete ice investigations, SFB station and trawling with Agassiz net
- Work the long CTD transect at 75°N including several plankton net stations, deploy 1 and recover 2 moorings on depths of 3200 m

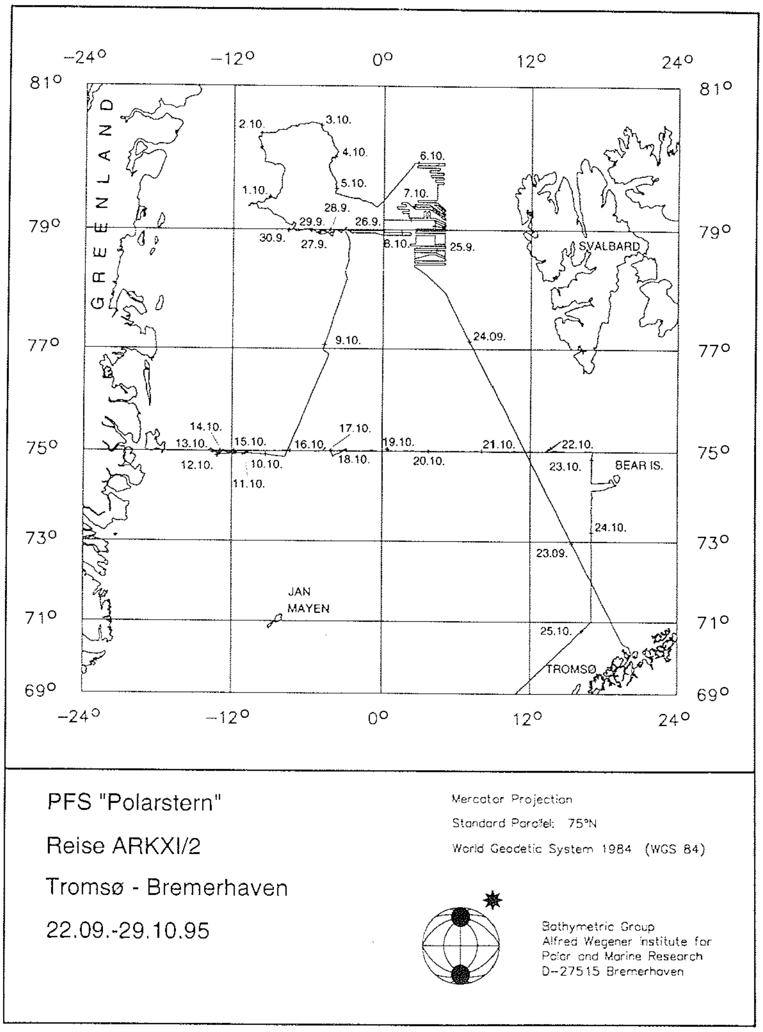


Fig. 1.1: Cruise track of the expedition

"Polarstern" left Tromsö in the morning of the 22nd of September. Due to a strong and favourable SW wind the bathymetric survey began only 1.5 days later at 79°N. On September 26, we found the first mooring at 79°N under such thick and compressed pack ice that one could not even think of recovering the instruments, even though free water was tantalizingly close to the east. The same situation was found 12 days later, when the area was revisited. Out of five instrument moorings at 79°N, three were brought on deck. Otherwise the recovery of all the other moored instrument strings on the list has been a great success so late in the season.

Due to an almost 100% coverage by very thick and very large old ice floes in the area of the NEW Polynya the summer camp at Eskimonaes could not be supplied. Only little station work in the vicinity of the planned positions was possible.

1.3 Weather Conditions

At the southeast side of a large low the wind increased to Bft 8, in gusts 9, when we were leaving the Norwegian fjords. The characteristic height of the waves reached about 3 m. Close to the center of the low the wind speed decreased on the following day to Bft 5, while the first snow showers appeared and the temperature dropped to 0°C.

During the night between 24th and 25th of September the ship arrived at its working area west of Spitsbergen. On the northeast flank of a low that was located west of Spitsbergen the wind shifted to easterly direction with force Bft 5. Over the night the wind velocity rose up to Bft 7 shortly.

On September 26, the wind shifted via north to northwest, while a new low coming from Spitsbergen moved slowly westward. As a result of cold air advection from the northeast Greenland area the temperature dropped below 0°C for the first time during this journey. The thermometer showed -8°C at noontime. Temporary snow flurries occurred. The lows were controlled by high rising cold air turbulence. Starting in the northern Greenland Sea the center of this turbulent region moved slowly southward towards the waters of Jan Mayen. Thereby the Fram Strait was influenced by an upper-level-airflow. This and the bottom low were moving southwestward and weakening.

On September 27, the wind shifted shortly to southwest and decreased to a force of Bft 3, when we were in the operation area at 78°N, 5°W. The stratiform clouds broke up simultaneously. On 28th of September a new low moved westward via Bear Island while its pressure dropped below 980 hPa. Heavy warm air advection at the front of this low caused a quick change in weather with snowfall and temperatures increasing close to 0°C. The wind shifted to north and increased to Bft 6. Since the controlling power of the upper level vortex over the Northern Polar Sea was still not diminished this low moved slowly southward while weakening to 1000 hPa in its center.

Towards the end of the month a temporary pressure increase caused the formation of a high over 1015 hPa that was slowly spreading in the direction of the Fram Strait. The wind velocities within the working area decreased to Bft 2 -3. However, simultaneously sinking air strengthened a near bottom inversion, which in turn caused deep Stratus clouds with fogbanks. The helicopter work was hindered by this weather situation.

On the 2nd of October, a weak convergence was forming within the older polar air, which was partly damp while it was reaching high. The convergence was swinging around the filling low southwest of Spitsbergen. Thereby the operation area of "Polarstern" was influenced by snowfall and low visibilities. The wind shifted to northeast and had a strength of Bft 3. During the night between 2nd and 3rd October the sky was clearing up. As a consequence a thin cold air layer was forming at light winds because of a negative balance of radiation. In the morning the fog point was reached. The shallow fog persisted over the day while temperatures were around -9°C. The ship was covered with strong hoarfrost.

On October 4, the high over Greenland continued to increase and the area where "Polarstern" was working was influenced by sinking processes. This resulted in a very stable stratification with stratus clouds resting almost on it and 'white out' conditions occurred.

By the 6th of October the center of high bottom pressure moved from the northeast of Greenland to Spitsbergen. Therefore the wind shifted quickly to northeast. Simultaneously a weak lee low developed north west of the mountains of Spitsbergen because of a southeasterly airflow. In the vicinity of the center of this low wind velocities of Bft 3 to 5 occurred only. There were partly also snow showers and temperatures of about 0°C. However, the southeasterly swell increased. On the 8th of October the ship reached the ice edge again at about 79° N while visual flight conditions were prevailing. The southeasterly winds of Bft 3 to 4 were continuing, and the sun was shining for the first time since days.

When the operation area at 75°N and 11°W was reached the weather conditions were worsening at the edge of a northatlantic low pressure complex. This resulted in winds with Bft 6 to 7, and in the evening of the 9th October of Bft 8. The visibility decreased simultaneously accompanied by partly rain showers developing into snow. Meanwhile one low split from the complex and moved to the Northern Norwegian Sea. At the same time a high over Greenland developed. Increasingly cold air reached "Polarstern" from the nearby ice edge together with backening winds coming from the northwest. Within a few hours the temperature dropped by 8 K to -6°C. The gustiness of the wind increased over relatively warm water (+2°C). The ship's weather station reported winds of northwest Bft 8 with gusts up to Bft 10 on the 10th of October. However, the characteristic wave height did not reach beyond 3 m, since the fetch from the nearby ice edge to the ship was relatively small. On the following day the wind decreased very slowly only because another weaker low moved quickly from Iceland to the North Cape. No air traffic was possible in light snow flurries with low visibilities.

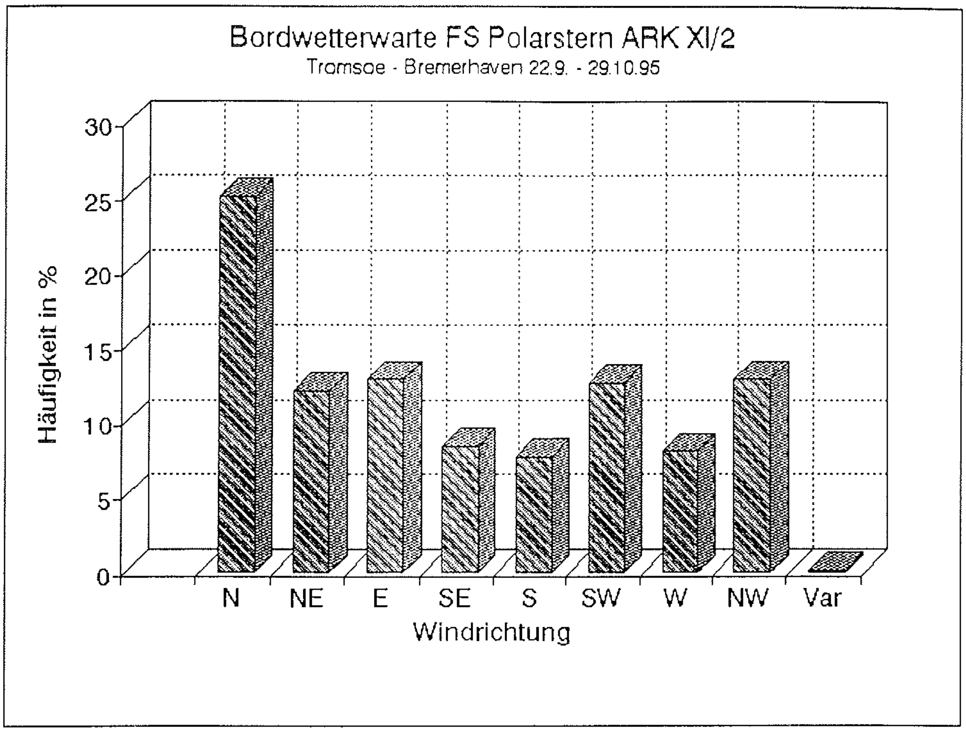
On the following two days the area of operation was influenced by an eastward spreading Greenland high. Light winds from northwest to southwest were blowing, there were little clouds, and at temperatures of -13°C there were good visibilities in dry air. The area at the ice edge at about 75°W 9°W was influenced by favourable weather, because the high over Greenland was increasing over 1025 hPa.

On the 14th October the wind came from northwest with Bft 4, the sky was without clouds and the visibility was very good. Towards the middle of the month the area of investigation was influenced shortly by a storm low that was moving slowly to the northeast. The wind which was shifting right to the northeast reached only Bft 6 on the 16th of October, since the low was slowly decreasing. There were heavy snow showers in a labile layered cold air mass at the backside of the low at -2°C to -4°C air temperature. Because of the relatively small fetch characteristic wave heights of 1 to 2 m were reached. On the following day the wind blew consistently from one direction, but the speed decreased to 4 to 5 Bft.

On October 18 the wind shifted to the right to southeasterly direction because of a low development in the Fram Strait. The wind blew with Bft 7 with snow showers. A new storm low which developed on the 17th of October in lee of Greenland near Cape Farvel moved under decreasing via Iceland towards the Northern Norwegian Sea. It reached a low pressure of 980 hPa at the 19th of October. "Polarstern" stayed at first at the outer edge on the north side of this cyclone.

On the 20th of October the wind was backing to the northwest and increased within a few hours to Bft 8. This was due to our location at the backside of this storm low. The temperature dropped from -4°C to -8°C simultaneously because of cold air advection. This led to a turbulence development over the 5°C warm sea water. The wave height increased rapidly. During the night of 21st/22nd of October a marked cold air front passed "Polarstern". It caused a sudden shift in the wind direction from west to eastnortheast and an increase in the wind velocity from Bft 3 to Bft 9. There was no work possible at the station due to snow flurries and crossing seas up to 5 m in height. But the the weather calmed down quickly.

On the way home several cyclones influenced the track of the ship. They developed into storm lows partly below 970 hPa in the vicinity of Iceland. Strong southerly winds prevailed south of 70°N.



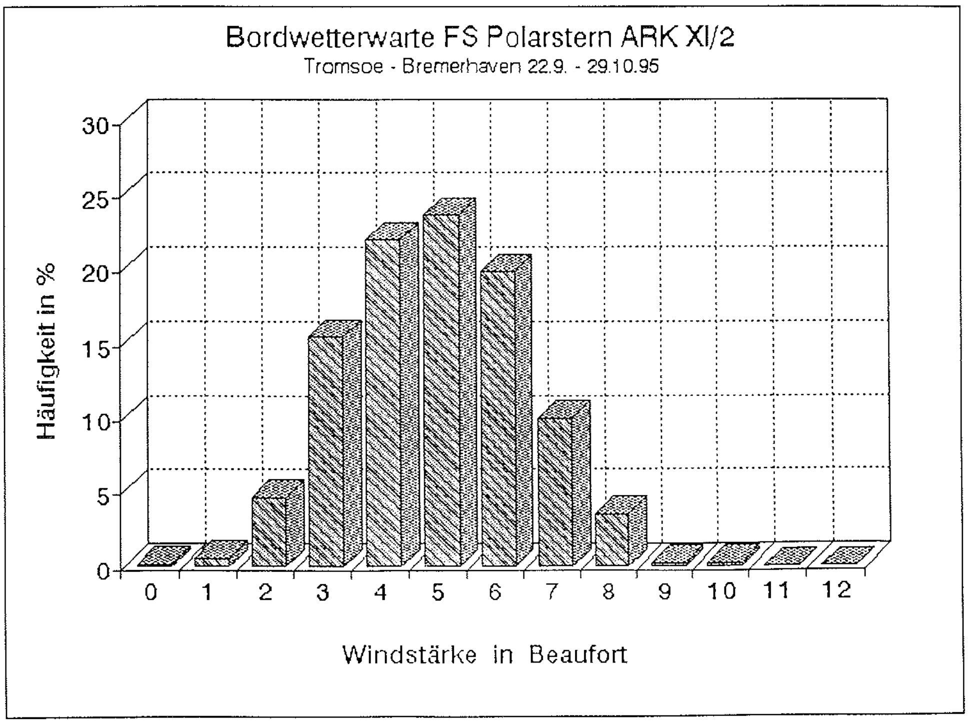
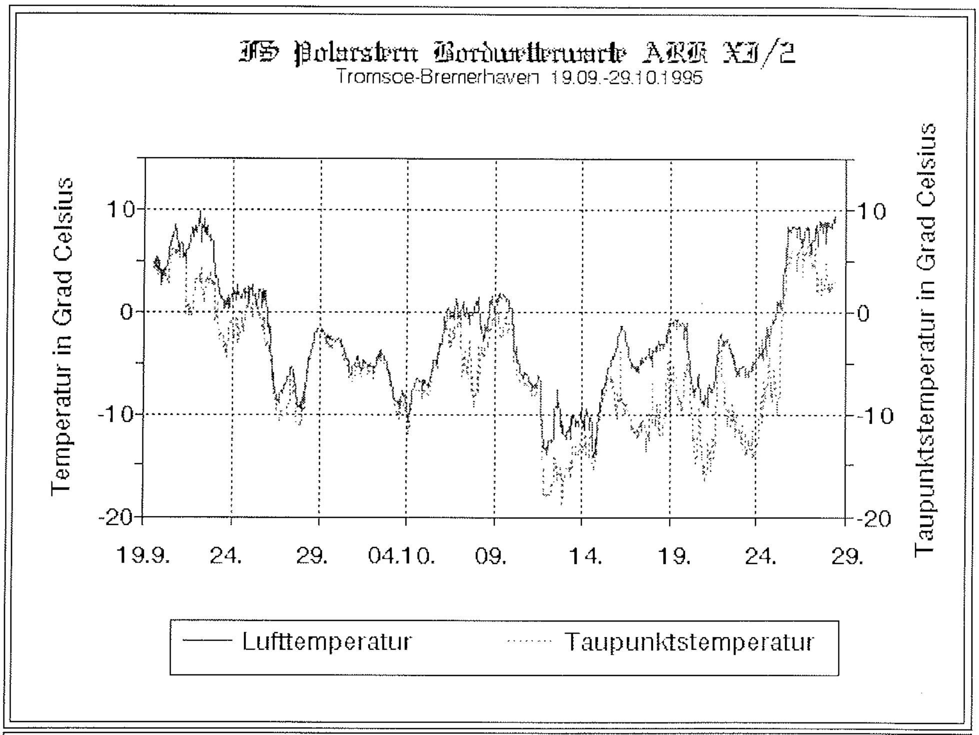


Fig. 1.2: Frequency distributions of wind direction and wind speed



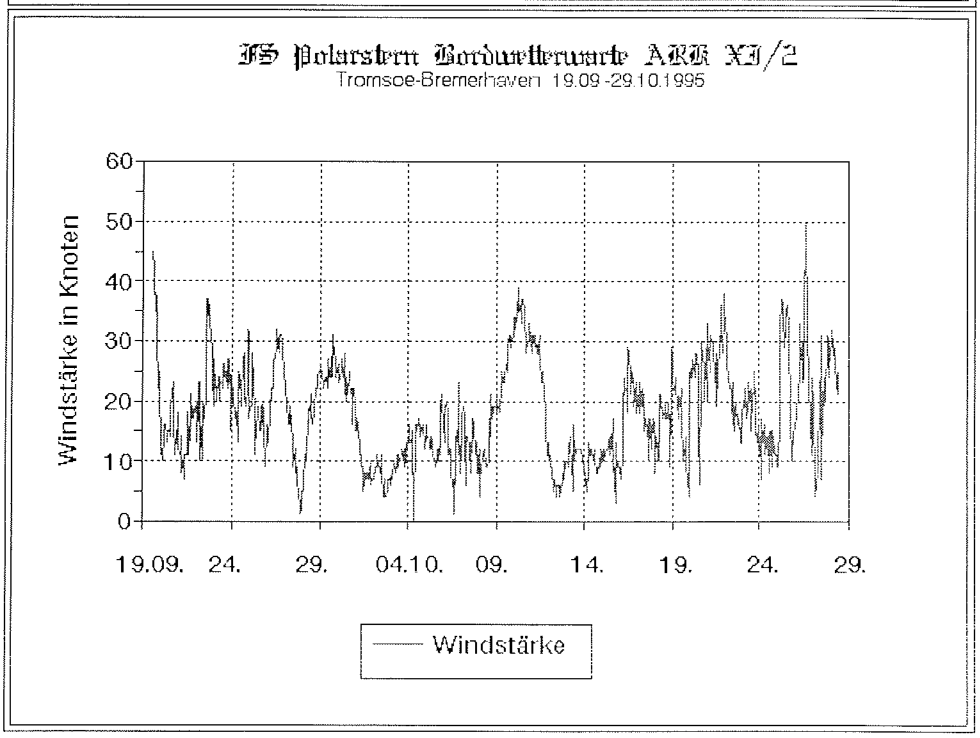


Fig. 1.3: Air temperature, dew point temperature and wind velocity

2. METEOROLOGY

2.1 Turbulence measurements

(C. Wamser, W. Cohrs, C. Wode, M. Hofmann, M. Schürmann)

Current efforts in numerical climate predictions require that the knowledge of global near-surface turbulent energy fluxes be improved by about one order of magnitude. Since the earth's polar regions have great influence on the oceanic deep-sea water circulation, the atmosphere-ocean heat and momentum exchange is also of special interest. Due to the inaccessibility of these regions, most of the relevant parameters, needed for model calculations, are poorly investigated.

In order to help filling this gap, two quite different but complementary meteorological turbulence measuring systems were operated together for the first time: the helicopter-borne sensor system HELIPOD, and the newly constructed shipborne turbulence measuring system TMS. Both systems aim at high-resolution in-situ measurements of near-surface turbulent fluxes of mass, momentum, sensible and latent heat. The turbulence measurements were supplemented by a helicopter-borne colour line-scan camera, which provided digital images of the ice cover in order to record the different ice situations during the flux measurements.

The TMS consists of a 17 m mast, installed on the ship's bow crane. This mast usually is fixed horizontally during the cruise, but for operation it can be moved forward and turned into a vertical position by a hydraulic and a tackle system. At five heights between 3 and 20 m above the sea surface, five USAT sonic sensors (METEK) are mounted to measure the turbulent fluctuations of wind and temperature. Five Pt-100 temperature sensors determine the mean temperature profile. Additionally, a Lyman-alpha hygrometer is installed at a height of 3 m to measure the turbulent humidity signals. An acceleration sensor determines disturbing frequencies of mast oscillations or even of slow ship movements.

HELIPOD is an autonomous meteorological turbulence measurement system, about 5 m long and 240 kg in weight, which is constructed for operation on a 15 m rope below almost any helicopter. The system is the first worldwide, and the only one which combines the aerodynamical and logistical advantages of a helicopter as towing aircraft with high-tech meteorological, navigational and technical sensor equipment. HELIPOD possesses an internal power supply, an active rudder stabilization, a DGPS-based and an inertial navigation system, and an extensive sensor equipment including real-time data processing and recording. It carries the following meteorological sensors: A 5-hole probe for static pressure and wind measurements, 2 temperature sensors with different response times, an independent humidity measuring channel containing a humicap (i.e. a capacitive humidity sensor), a dewpoint mirror and a Lyman-alpha sensor, and a radiation thermometer for surface temperature measurements.

The navigation system equally comprises sensors with different response times and long-term stabilities: a static and a radar altimeter, an inertial navigation system and two different GPS systems providing the determination of both position and altitude.

As HELIPOD contains some quasi-redundant sensors each with different time behaviour, even long-term data can be obtained within a wide frequency range through complementary filtering of corresponding signals. For additional improvement, the digitizing error of the fast sensors is reduced by storing 10-value averages calculated on-line from a 1000-Hz oversampling.

Meteorological and navigational raw data, technical system parameters and on-line calculated secondary quantities are recorded in up to 160 channels. Sampling frequencies reach from 1 Hz (GPS navigation) up to 100 Hz (turbulent fluctuations of meteorological quantities). Data preprocessing is done simultaneously by different transputers, while the final data storing is real-time controlled by the VC6 main computer. For data storing, magneto-optical discs are used with a recording capacity of 300 MB each side, corresponding to about 3 hours or 450 km flight path length. A special software package allows an on-line display of arbitrary data channels on a laptop computer inside the helicopter and an in-flight calibration of different sensors.

The objectives for the HELIPOD operations during ARK XI/2 were:

(1) system tests and calibration flights,
(2) measurements of the near-ice edge atmospheric boundary layer structure,
(3) airborne near-surface measurements within a stably stratified boundary layer over different types of surfaces and comparison of the results with those, gathered simultaneously by the shipborne TMS,
(4) investigations of the dependence of some statistical meteorological properties from different types of flight patterns,
(5) comparisons of HELIPOD vertical profiles with data from GPS-wind finding radiosondes.

In total, during the ARK XI/2 cruise 10 different HELIPOD measurements were performed. The locations of the flights are marked in Figure 2.1.

The main objectives of the TMS measurements were the analysis of the turbulent fluxes in the marginal ice zone and a general in-situ system test. During the whole cruise, the TMS was operated at 8 stations each of 2 to 3 hours duration. At these stations the ship was either at a fixed position in the ice or moved very slowly against the wind. During the measurements, very different structures of ice cover could be investigated with regard to their influences on the heat, moisture and momentum exchange between the ocean and the atmosphere. All the elements of the TMS including mast, hydraulic and tackle parts, sensors and the data acquisition system were tested under various meteorological situations.

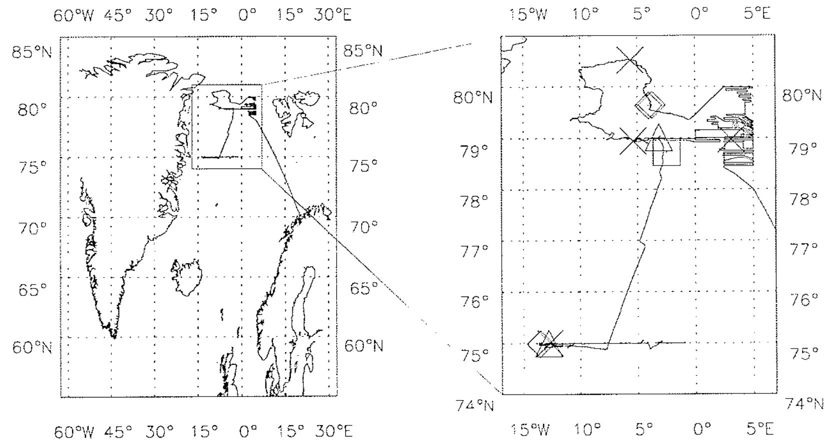


Figure 2.1: Locations of HELIPOD flight areas during ARK XI/2. The inserted symbols denote in particular:

cross:	test measurements and calibration flights,
triangle:	measurements of the near-ice edge boundary layer structure,
diamond:	HELIPOD, TMS and radiosonde comparisons,
square:	test of statistical flight pattern properties.

It turned out that different modes of operation of the ship's propulsion system (main engine, bow and stern thrusters) cause different vibrations of the ship, which also are conducted to the mast and the sensors via the bow crane. High resolution acceleration measurements provided the spectral distribution of all the various vibrations which possibly may influence the turbulence signals. By means of spectral analysis of the acceleration measurements, two dominant frequencies were detected. These vibrations were mainly caused by the rotation of the main shafts and the thrusters, and they are at 3 and 14 Hz, respectively. The amplitudes of the corresponding acceleration have turned out to be typically about 0.05 g.

The evaluation of the collected HELIPOD and TMS data comprise plausibility checks, elimination of outliers and trends, correction for potential data losses and resulting spectral gaps, cutting of longer time series into sections, spectral analysis of the resulting time series, and finally the calculation of some statistical properties which provide information about the investigated turbulent exchange processes. For this purpose also the weather analyses of the "Polarstern" weather-station are used, as well as some further radiosounding data, satellite images and ice charts.

First steps of data evaluation of both HELIPOD and TMS data were started directly after the measurements on board "Polarstern". Since a total amount of about 2500 MBytes of binary HELIPOD raw data and about 700 MBytes of TMS data were

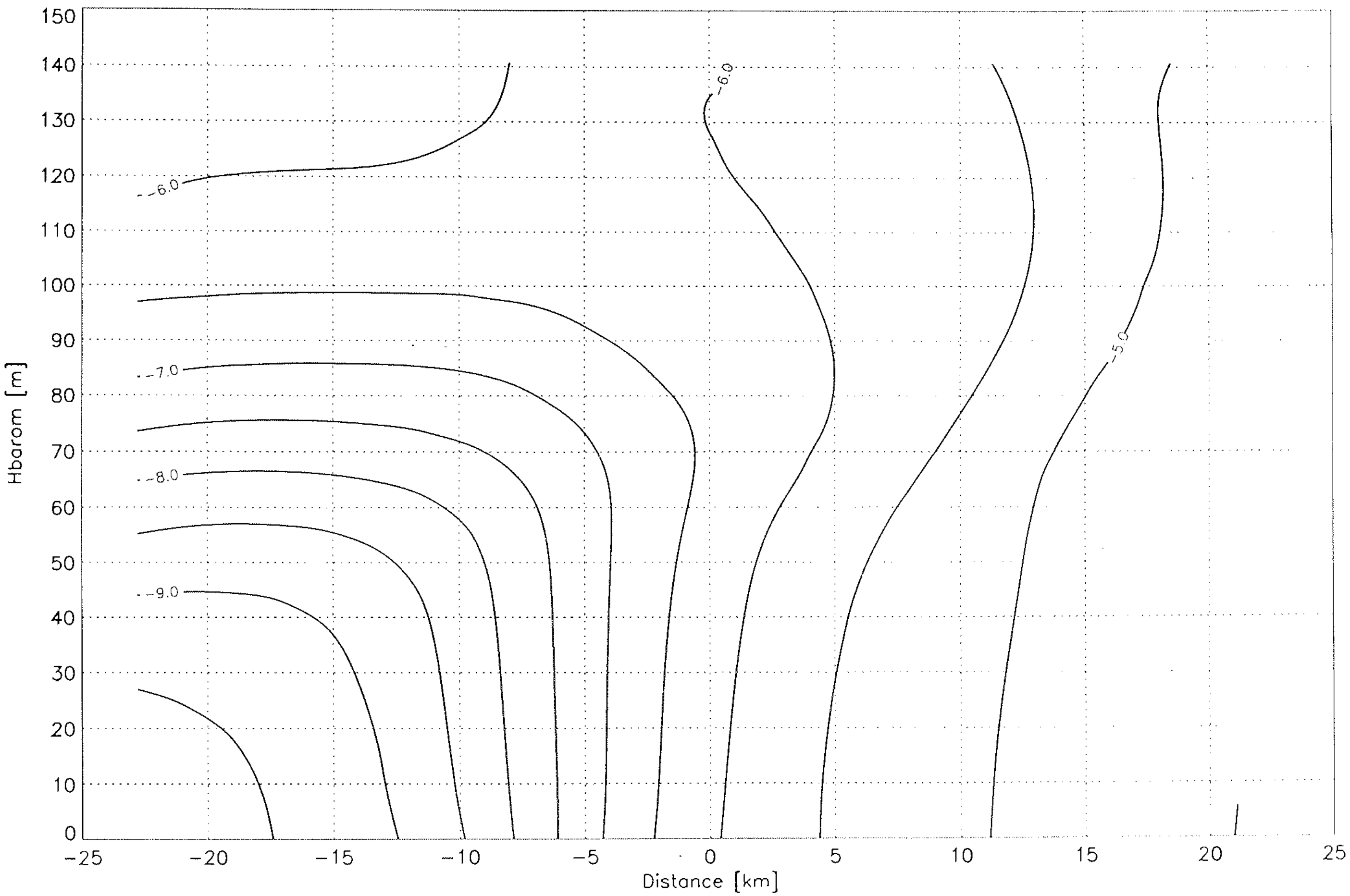


Figure 2.2: Isotherms of the potential temperature in a vertical plane perpendicular to the marginal ice zone. The abscissa origin indicates the transition between the ice edge and open water. Positive distances denote open water, negative ones denote ice cover.
(HELIPOD flight 8, 75.0° N / 12.8° W, 12 October 1995, 10:50 - 12:30 UTC)

collected during this cruise, the final evaluation of these data will take some time. However, some preliminary results are already presented in the following.

In Figure 2.2 isotherms of the potential temperature in a vertical plane perpendicular to the marginal ice zone over the ice edge are presented. The basic data were measured by the HELIPOD on October 12, 1995 at about noontime (Figure 2.1, triangle at 75°N). The ice edge was in NNE-SSW direction, and during the measurement the surface wind came from 340°, i.e. blowing nearly in off-ice direction. The wind speed at 10 m height was only about 5 knots, resulting in a very widely spread marginal ice zone. Stable stratification developed above the ice and unstable stratification above the open water. Figure 2.2 shows that under weak wind conditions significant horizontal temperature differences develop over the transition zone between sea ice and open water.

An example of the TMS measurements is presented in Figure 2.3 a,b. During the station on 4 October 1995 "Polarstern" sailed with an approximate speed of about 0.5 knots through a newly frozen lead towards a huge, snow-covered, thick old ice flow. The mean thickness of the new ice was about 5 cm, the water temperature was -1.2° C. The wind came from starboard ahead and so the fetch over the thin new ice reduced from 1700 m at the beginning to about 300 m at the end of the measurements. Figure 3a shows the development of the sensible heat flux h_S at three levels. From most of the data, a decrease of h_S with height and with the approach to the ice edge is obvious. The deviation from the expected development of h_S at the two lower levels at 1000 m is obviously caused by a right-hand turning of the wind during that period, which leads to a decrease of the fetch. The corresponding temperatures, measured at five heights, are presented in Figure 3b. The continuous decrease is consistent with the decrease of the sensible heat fluxes during "Polarstern's" approach to the huge flow.

Figure 2.4 shows a comparison of the standard deviation sigw of the vertical wind component and the friction velocity ustar in the height range from 3 to 50 m, measured simultaneously with the TMS (black bars) and the HELIPOD (white bars). The corresponding measurements were performed above a newly frozen homogeneous lead of a width of about 10 km in the wind direction. The ice thickness was about 20 cm (Figure 2.1, diamond at 75°N). The ship's position was fixed, and the HELIPOD flight pattern consisted of 5 horizontal legs, each about six miles long, orientated parallel to the wind and situated very close to the ship. The heights of the legs were about 8, 15, 25, 33 and 52 m. The wind velocity during the measurement in the covered height range was about 6 to 10 knots. The measured statistical wind and turbulent quantities between these two systems agree surprisingly well.

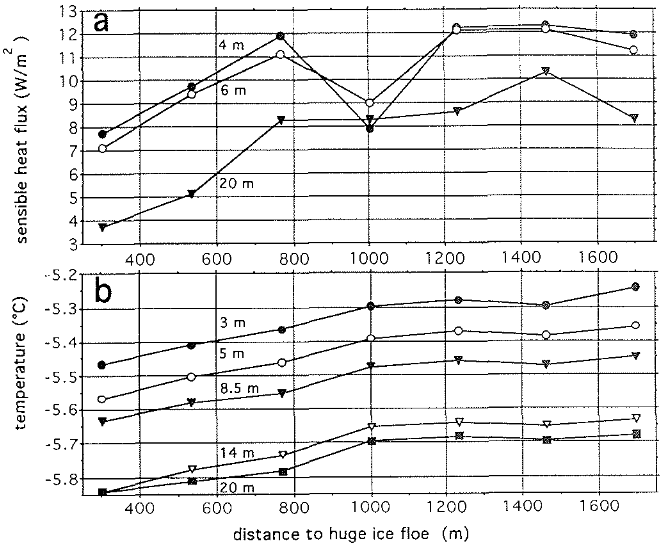


Figure 2.3a,b: Sensible heat flux (3a) and temperature data (3b) vs. distance to a huge homogeneous ice flow. The data show the effect of a lead, covered with thin new ice, on the lower boundary layer.

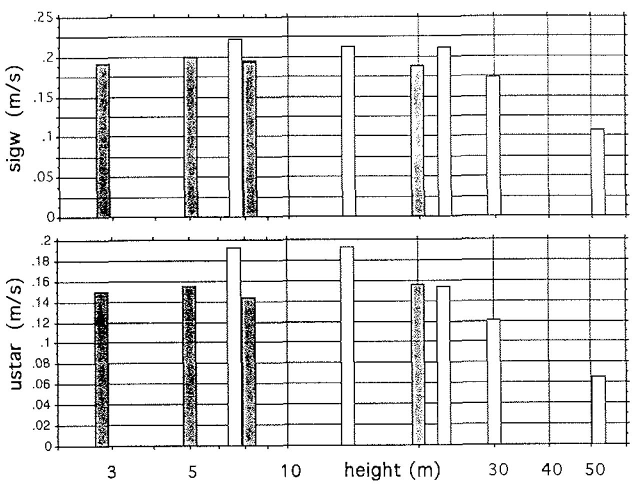


Figure 2.4a,b: Comparison of the standard deviation sigw of the vertical wind component w (4a) and the friction velocity ustar (4b) in the height range 3 to 50 m, measured simultaneously with the TMS (black bars) and the HELIPOD (white bars). (HELIPOD flight 10, 75.0° N / 13.5° W, 13 October 1995, 14:10 - 16:20 UTC)

During the measuring period corresponding to Figure 2.4, some GPS radiosondes were launched, each measuring vertical profiles of wind, temperature and relative humidity. Figure 2.5 gives an example of a temperature profile from the surface up to 700 m. Data from the radiosounding and from the HELIPOD's parallel ascent agree even better than the HELIPOD's upward and its immediately following downward soundings.

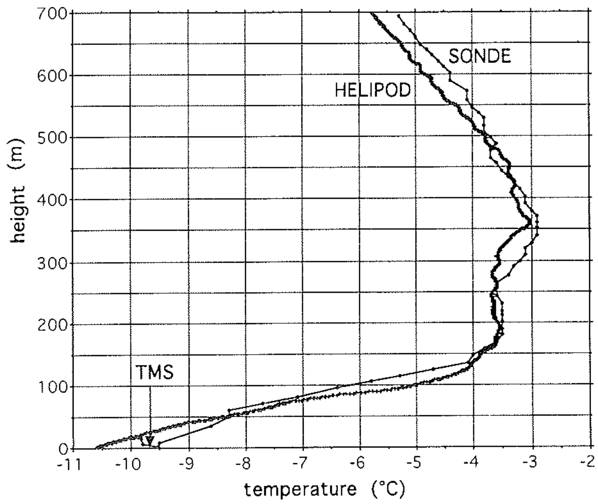


Figure 2.5: Example of a temperature profile from the surface up to 700 m, measured simultaneously by HELIPOD and a GPS radiosonde. (HELIPOD flight 10, 75.0° N / 13.5° W, 13 October 1995, approx. 16:10 UTC)

2.2 Remote Sensing of Sea Ice

(T. Martin, L. Kaleschke)

The horizontal extent of the sea ice in the Arctic Ocean and the bordering seas changes seasonally from up to 12-13 $10^6 km^2$ during winter time to approximately half that during the summer. The sea ice exported out of the Arctic Ocean via the East Greenland Current represents a prominent part of the fresh-water budget of the Greenland Sea and the North Atlantic. The stability of the circulation depends strongly on the surface fresh-water and salt fluxes. The surface fresh-water budget of the North Atlantic, and therefore the sea ice export out of the Arctic Basin, plays a critical role in the climate system.

To obtain an estimate of the sea ice mass flux, the sea ice distribution and the sea ice drift must be known as well as the ice thickness.

The aim of the programme was the observation of sea ice parameters which are relevant for the sea ice mass flux in the East Greenland Current. This includes the reception of satellite images and measurement of the sea ice surface structure. The combined processing along with data sets of sea ice thickness, sea ice concentration, sea ice extension and sea ice drift velocity should give an improved knowledge of the sea ice mass fluxes in this area.

AVHRR satellite images:

During the expedition, images of the Advanced Very High Resolution Radiometer (AVHRR) flown on the satellites of the National Oceanic and Atmospheric Administration (NOAA) have been received on board "Polarstern". The AVHRR is sensitive in the visible and thermal infra-red spectral range. The horizontal resolution in the nadir view is 1.1 km. All images are processed using routines for calibration and rectification on to a stereographic grid. These images were used to derive the sea ice distribution, and for planning the flight activities of the laser-altimeter (see below) as well as for ship navigation.

Sequences of cloud-free images allow the determination of the sea ice motion. Special image processing algorithms track common features in pairs of images. The investigations of the last years show a minimum of the sea ice drift velocity in summertime of 15cm/s. During autumn, the drift velocity increases and reaches a maximum during winter with approximately 30 cm/s.

Figure 2.6 - 2.9 give an overview of the sea ice conditions and their development during the expedition. Figures 2.6 and 2.8 show the difference between channel 1 (0.58 µm - 0.68 µm) and channel 2 (0.725 µm - 1.1 µm) which are both located in the visible spectral range. The signals in both channels are strongly influenced by the extensive coverage of semi-transparent clouds. Differencing these channels reduces this effect and results in information about the sea ice. Due to the reduction of sunlight during the field phase, only channel 4 (10.3 µm - 11.3 µm) and channel 5 (11.5 µm - 12.5 µm), which are located in the spectral range of the thermal infrared, gave reliable results at the end of the experiment (see Figure 2.7 and Figure 2.9).

Figure 2.6 documents the sea ice conditions at the beginning of the work in the ice. The image shows a clearly pronounced ice edge due to the easterly wind direction of the first days. The ice coverage was an assemblage of larger multiyear ice floes age shown as light areas in the image. Smaller ice floes with different ages combined with areas of a larger portion of new and young ice are seen as darker regions. During the following four weeks, the ice concentration increased and larger ice floes dominated this region. The ice edge also moves to the east (see Figure 2.7). A similar situation could be found in the southern area of interest at 75°N. At the beginning of our work in this region, the ice conditions were dominated by multiyear ice floes with smaller sizes. The satellite image shows no further structure because of the restricted resolution of the sensor (see Figure 2.8). Strong advection from the northern part of the East Greenland Current and decreasing temperatures very quickly formed a more extensive ice coverage. Our work was mainly located in the area of the ice edge, which was primarily covered by pancake ice of different sizes (Figure 2.9).

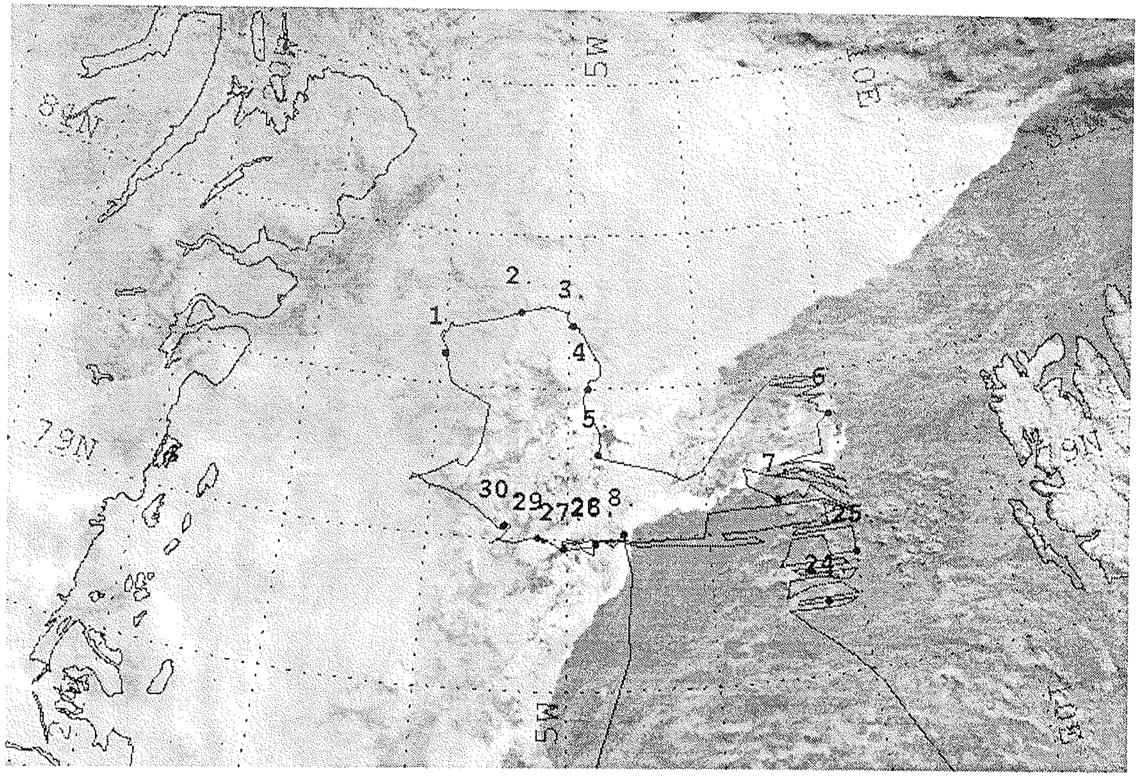


Figure 2.6: NOAA-12 AVHRR satellite image of September 24, 199514:06 GMT channel 1 - channel 2 and the ship´s track from September 24 to October 8

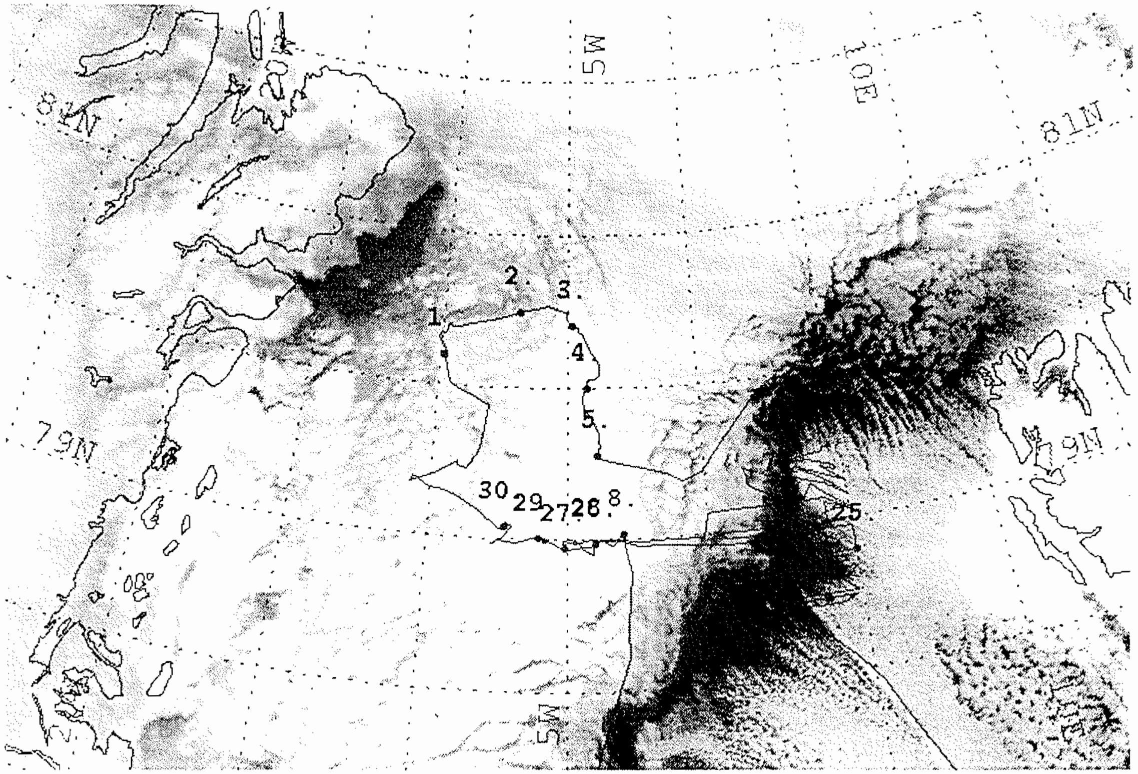


Figure 2.7: NOAA-12 AVHRR satellite image of October 24, 1995 08:12 GMT channel 5 and the ship´s track from September 24 to October 8

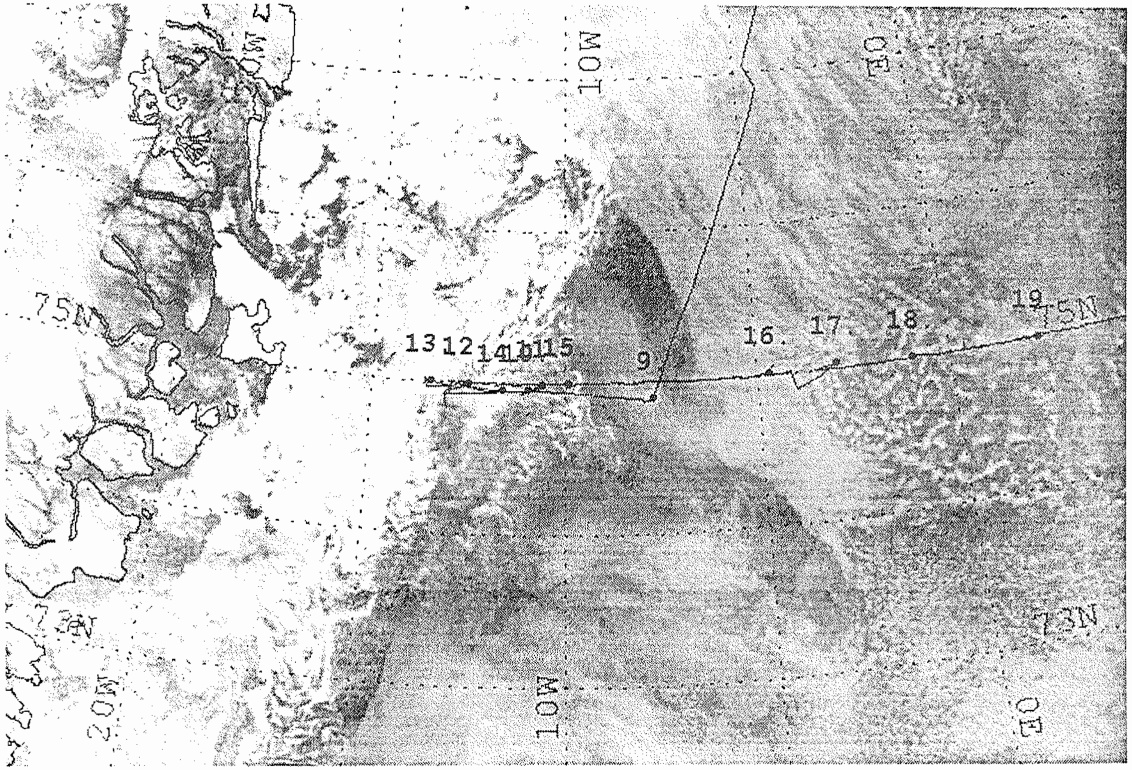


Figure 2.8: NOAA-14 AVHRR satellite image of October 1st, 1995 12:14 GMT channel 1 - channel 2 and the ship´s track from October 9 to October 19

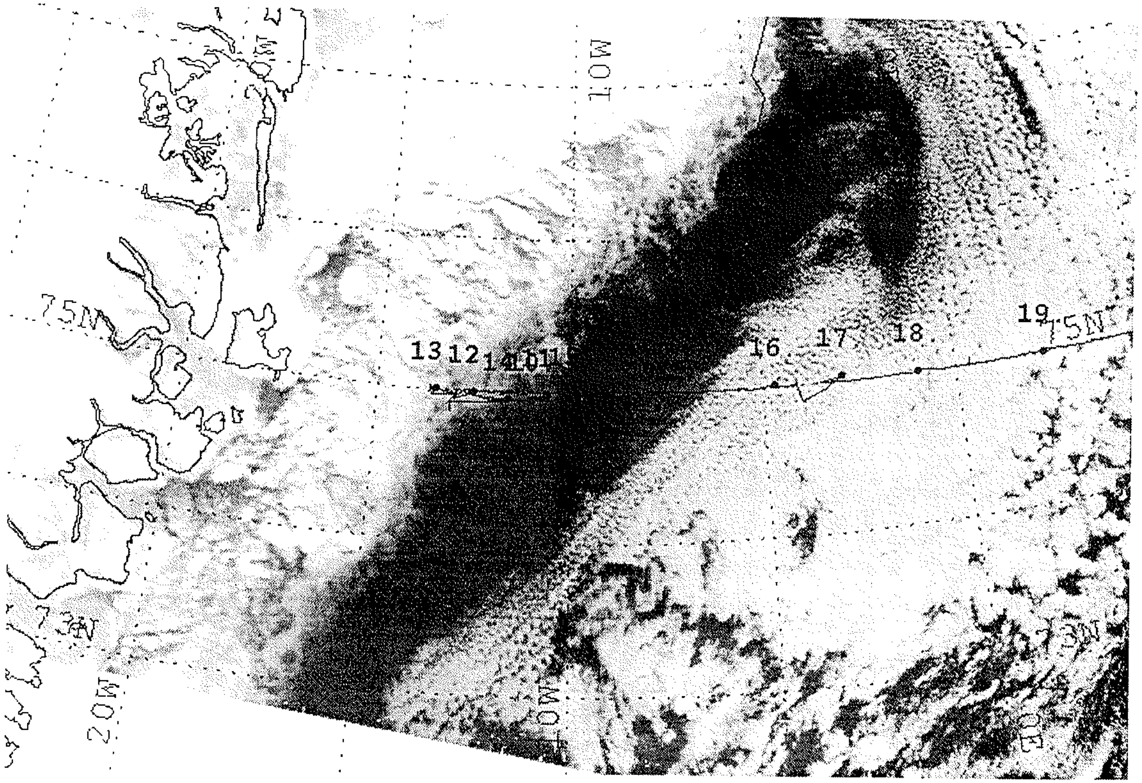


Figure 2.9: NOAA-12 AVHRR satellite image of October 24, 1995 08:12 GMT channel 5 and the ship´s track from October 9 to October 19

The laser-altimeter:
Laser profiling is a remote sensing technique in which the terrain surface elevation along a straight line path is monitored. In sea ice remote sensing, laser profiler data are used to investigate the roughness of the ice surface, in particular, height and spatial distributions of pressure and shear ridges. Profiler data can also be utilized to estimate the thickness of ridged ice. Given the roughness statistics, it is also possible to determine the contribution of form drag on ridges to the momentum transfer from the atmosphere to the pack ice.

The laser profiler used during this experiment was an Ibeo PS 100 EL mounted on a helicopter. The laser diode generates pulses with a wavelength of 905 nm. The ice surface elevation profiles were collected at a sampling rate of 2000 Hz and a vertical resolution of 2 cm. A flight speed of 80 kn yields a horizontal resolution of 2 cm. During the expedition, we have had 12 flight missions with a total profile length of 1150 km. The table below gives the date and the location of every mission. The laser altimeter measures the distance between the helicopter and the ice surface (Figure 2.10 top). Thus the raw laser profiles express the variation in flight altitude and surface undulation. A criterion for the classification of the signal from the ground is the echo amplitude. Open water and very thin new ice are not detectable with this instrument. Light Nilas or snow-covered new ice results in lower echo amplitudes than thicker ice. A special filtering method separated the different signal components (see Figure 2.10 bottom). The zero is set to the mean flat surface of the floe. The deflection of the signal is now equivalent to the height of the ridges on the floe. At 400 m a layer of thin ice is detected. This point represents the border line between two larger multiyear ice floes. We hope that this kind of data will allow us to obtain more knowledge of the freeboard of ice floes in the East Greenland Current.

Table of the flight missions:

Flight No.	Date	Start Position	Comment
1	26.09.95	78 59.90 N 03 42.87 W	small ice floes in the area of the ice edge
2	27.09.95	78 56.00 N 05 06.00 W	Video flight in the same area
3	28.09.95	78 59.00 N 03 59.00 W	
4	29.09.95	79 02.37 N 07 17.36 W	
5	02.10.95	80 32.56 N 05 42.69 W	Video flight in the same area
6	04.10.95	80 03.04 N 04 18.42 W	
7	05.10.95	79 33.22 N 03 54.73 W	Line-scan flight in the same area
8	08.10.95	79 02.00 N 02 02.60 W	
9	12.10.95	05 00.00 N 13 00.00 W	
10	12.10.95	75 00.00 N 13 00.00 W	
11	13.10.95	74 59.86 N 14 01.04 W	
12	14.10.95	75 00.00 N 12 50.00 W	

All flight missions took place over ice conditions which are typical for the early autumn. The 8 missions at 79°N describe a homogeneous situation of wide-spread areas of multiyear ice floes of different sizes. The ice floes were covered with refrozen melt ponds and a thin snow layer. Between these floes, different types of new ice were still forming. Due to the dynamics in this region, the most dominant phases of ice development were pancake ice of different sizes and slush ice. Most of the pressure ridges covering multiyear ice floes were old and hummocky. Due to the increasing ice velocity during autumn, some ridging could be observed at the floe edges.

The sea ice thickness:

During the last years, AWI has deployed several oceanographic moorings at 75°N in the ice covered part of the East Greenland Current. Most moorings were equipped with an Upward Looking Sonar mounted in a depth of 50 m. The ULS's operate like inverted echo sounders and measure the ice draught during one whole year. Five of these instruments were recovered during these field experiments. For further information see section 3.2.

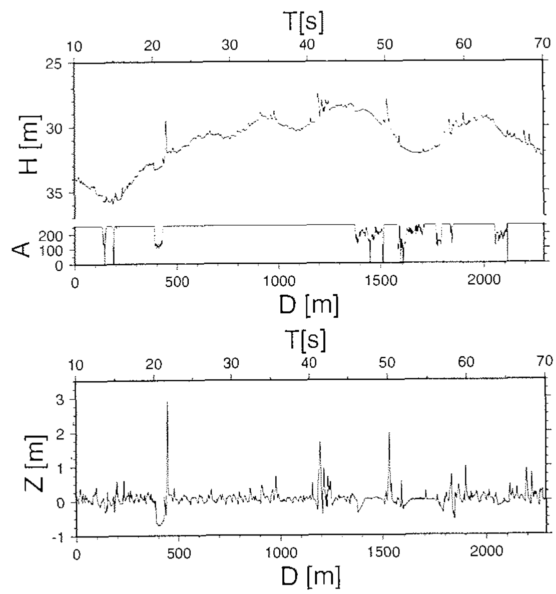


Figure 2.10: Time series of the laser-altimeter flight mission of 27.09.95. The time series cover a period of T=50s, which is equivalent of a measuring distance of D = 2300 m. Each data point represents a mean of 100 measurements. Top: Original distance measurements between the helicopter and the sea ice surface. Bottom: The retrieved surface structure of the ice floe.

3. PHYSICAL OCEANOGRAPHY

3.1 Stratification and circulation in the Greenland Sea

(G. Budéus, B. Cisewski, R. Plugge, S. Ronski, S. Ufermann, H. Wehde)

Aims

The physical oceanography programme continued the work performed during the Greenland Sea Project and provided pre-information for ESOP-2, starting in 1996. Thus it has been an important link between the two projects, avoiding an observational gap between them. The measurements aimed at the understanding of the convective processes in the central Greenland Sea and their dependence on the climatological status of the Nordic Seas/Arctic Ocean system.

Since the beginning of the Greenland Sea Project in 1988, winter convection has only penetrated to mid-depths of the Greenland Sea. No bottom water renewal could be observed up to now. It is now generally believed that such a renewal does not occur continuously but rather bears the character of a distinct event taking place every 10 to 20 years. Therefore long term efforts are demanded in order to answer the questions whether convective activity in the Greenland Sea has ceased in the last decade or whether it undergoes a normal cycle of necessary preconditions. It is not possible yet to state which preconditions are necessitated to initiate deep convection and bottom water renewal.

Consequently, considerable efforts are undertaken by AWI to repeat a standard transect across the Greenland Sea once per year and to complement these investigations by mooring-based measurements.

Methods

A prototype self-profiling deep sea instrument for mooring purposes to be employed within the frame of ESOP-2 has been tested during the cruise. Seven test casts have been performed and will be evaluated later.

The methods of the ship-borne oceanographic work are modern standard and are listed below.

CTD, Water sample rosette

The CTD-system used is a Seabird 911+, equipped with dual temperature and conductivity sensors, and a number of additional optical sensors including chlorophyll and yellow substance fluorescence. The dual sensors allow for an immediate cross check of calibration consistency and sensor drift. The water sample rosette was a Seabird Carousel that underwent its first expedition. Its peformance was faultless during an uninterrupted use of about four months. Bottles were 12 l Niskin with coated steel springs. They proved not to contaminate samples taken for tracer measurements (by K. Abrahamson and A. Ekdahl, Chalmers University Gøteborg).

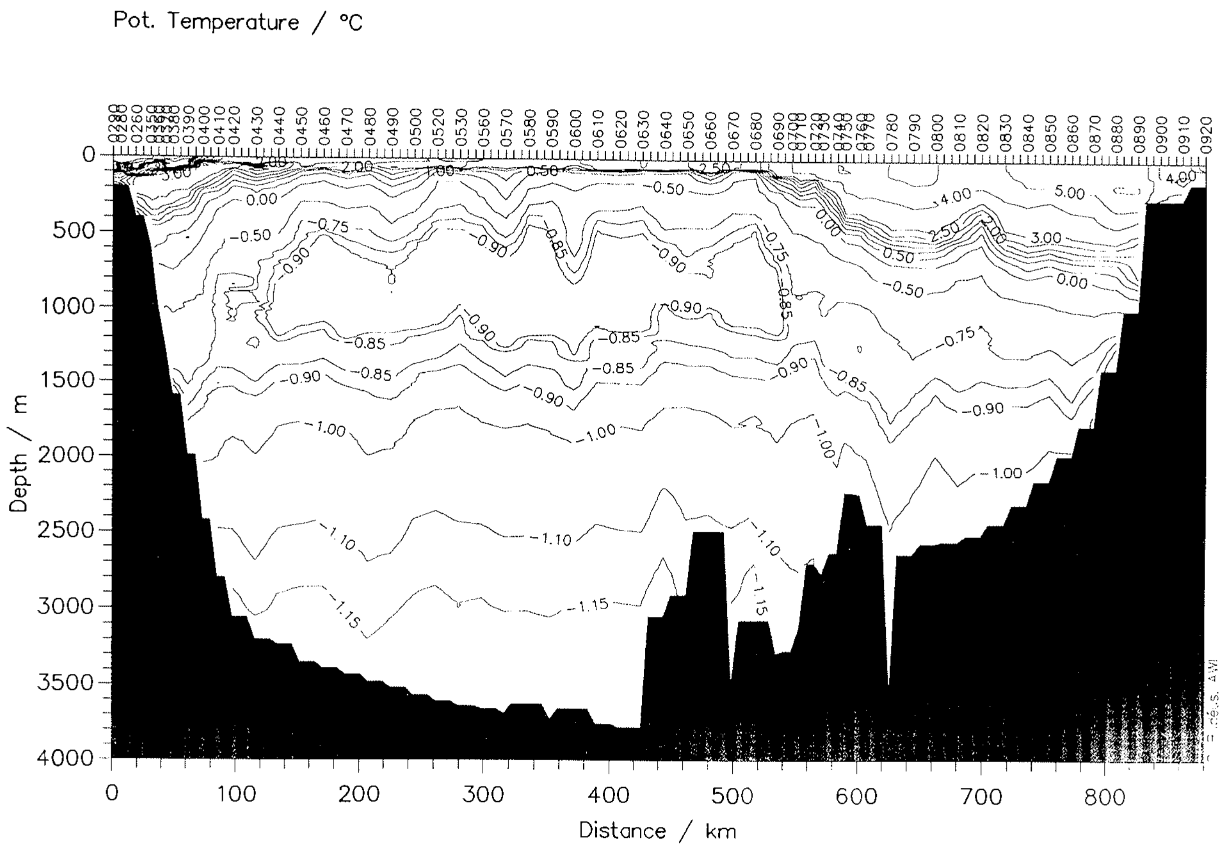


Fig. 3.1: Preliminary data of potential temperature across the Greenland Sea at 75° N. Final calibration may lead to minor changes.

Some salinity checks were performed at sea. We prefer however to do the major part of the in-situ conductivity calibration under laboratory conditions later. Reversing thermometers were used to control the stability of the CTD temperature sensors. Spacing of the hydrographical stations was generally 10 nautical miles, but was enhanced at certain locations according to prior experience with the hydrographic structure of the Greenland Sea.

Our naming convention for the hydrographic stations is as follows: There is a four character prefix ('ar11'), followed by a three digit station number ('xxx', coinciding with the ship's station numbers, except after station 096) and a cast number ('y') starting with 0 for the first cast of a station. So 'ar110991' would denominate the second cast on station 099. First casts are usually to the bottom, later casts usually to smaller depths.

<u>ADCP</u>
A ship mounted ADCP (RDI, 150 KHz) has been operated in ice-free areas and on stations in the ice. In most regions a vertical range of slightly less than 400 m has been achieved. The data will be used for transport estimates of the major currents in the Greenland Sea. The north-south transect west of Bjørnøya allows to determine the Atlantic Water outflow towards the Barents Shelf.

First results

First results must be seen as qualitative information only, since the post-cruise calibration of the CTD data could not be applied yet. Therefore no estimates of e.g. watermass volumes or geostrophic speeds are given here. Based on the high primary quality of the data, some immediate conclusions can nevertheless be presented.

Since the standard transect on 75°N has been performed with a high spatial resolution it allows for a sound estimate of the convective status of the Greenland Sea and of the modifications in the absence of deep water renewal. In the upper layer, no indication of last winter's convection could be observed. This stays in contrast to preceding years, where remnants of convective events could be traced to depths of e.g. about 2000 m in 1989 and 800 m in 1993. From the latter date on, Atlantic Water seems to spread from the boundaries into the center of the Greenland gyre in a layer close to the suface and to hinder convective activity. The body of fresher and colder water between station 44 and 69 in a depth range from 500 to 1000 m (Fig. 3.1) can be identified as not to stem from last winter's convection. The formation of these waters dates back to at least the winter 1993/94 if not to the preceding one.

Below this layer a temperature maximum is found that might be related to parts of the Arctic outflow which shows a prominent signal over the East Greenland slope. The deeper waters in the Greenland Sea keep changing their properties towards higher temperatures and salinities, i.e. towards the properties of the Arctic Deep Water. Potential temperatures below -1.20°C are not observed anywhere in the deep water any more, and the -1.15°C isotherm is found roughly 200 m deeper than in 1994. Waters with salinities below 34.90 are found only as very small remnants that endure close to the bottom in the center of the Greenland gyre.

3.2 Transport of mass, heat and freshwater

(C.H. Darnall, R.A. Woodgate)

The East Greenland Current determines the flow of polar water masses from the Arctic Ocean via the Greenland Sea into the Iceland Sea. This flow gives rise to significant transports of mass, heat and fresh water. The fresh water transport is especially important in setting the conditions for water mass formation, as it affects the stability of the water column. Ultimately, it is the export of the newly formed water masses into neighbouring parts of the North Atlantic which determines the role of the Greenland Sea in the global circulation.

To assess these transports of mass, heat and fresh water, current meter moorings have been maintained for several years in the Fram Strait at 79°N and along a transect across the East Greenland Current at 75°N. A long-term measurement programme is required as the transports are subject to sizeable fluctuations. The seasonal fluctuations are certainly significant, but it is expected that the interannual variations are also important.

These mooring arrays have been recovered and partly redeployed during this cruise. Of the 9 planned recoveries, 8 moorings (FWA-2 '94, M1-94, AWI410, 411, 412, 413, 414 and GSM-05), have been successfully retrieved, with all instruments being recovered without damage. However, one mooring (FWA-1 '94) was under too much ice for recovery despite several visits to the site, and has been left for recovery by another ship next year. The only two redeployments planned (FWA-1'95, FWA-2'95, both at 79°N) have also been successfully completed.

The moorings recovered are part of an international programme with participation of Germany (AWI, Kiel IfM and Hamburg IfM), USA (APL/UoW) and Norway (Norsk Polar Institute). In total, some 7.5 tonnes of equipment have been recovered, including 23 current meters, 7 SeaCats, 7 ULS (Upward Looking Sonars) and over 10 km of line.

4. CHEMISTRY

4.1 Investigation of Nutrients

(C. Albers, B. Hollmann, M. Stürcken-Rodewald)

The concentrations of the dissolved inorganic nutrients, nitrate, nitrite, phosphate and silicate, were determined during this cruise in high spatial resolution. The distributions of nutrients are closely connected with the biological and physical investigations. The different water masses with their different nutrient concentrations influence the development of phytoplankton blooms. During this study the variability of nutrients in the surface water was determined to find out whether there was a limitation of phytoplankton growth by nitrate or silicate during this late season of the year.

The change in nutrient concentrations was followed during the Fram Strait transect and the transect across the Greenland shelf, slope and Greenland Sea. In comparison with similar transects the years ago, the seasonal and interannual variability was determined. In view of the water mass determination, especially silicate is an excellent tracer of the outflow of upper halocline Arctic surface water along the Greenland slope. This water mass is especially rich in silicate compared to Atlantic and Arctic waters. On 80°N and 75° two transects with a high spatial resolution of hydrographic and chemical stations were performed across the Greenland slope and the Greenland Sea to determine the structure of this outflow as well as the nutrient concentrations and distributions in the entire Greenland Sea. Additionally nutrients were determined on a transect from Bear Island to North Norway. In cooperation with the ice group and the geologists nutrients were analysed in large numbers of samples from ice cores and various ice types as well as pore waters.

Water samples taken with CTD casts were analysed immediately on board for nitrate, nitrite, phosphate and silicate with a Technicon Autoanalyzer system according to standard methods. Nutrients were determined at nearly all stations from usually 24 depths distributed between surface and bottom. The sampling schedule follows standard oceanographic depths, and in addition samples were obtained from casts for biological investigations.

First interpretations of the results give no clear indication on high silicate values along the East Greenland slope neither at 80°N nor at 75°N. Unfortunately a transect at 77°N was not possible due to heavy ice conditions. In the surface layer nutrients were reduced compared to winter concentrations but never totally exhausted. In the surface water of the East Greenland shelf and across the slope silicate and phosphate values were 2 to 3 times higher than in the central Greenland Sea. These enhanced concentrations are typical for the Polar Water in this region.

4.2 Naturally Produced Volatile Halogenated Organic Compounds

(K. Abrahamson)

Objective:

The main objective of our investigations is to understand the fate, distribution and formation of naturally produced volatile halogenated compounds. These compounds are ubiquitous trace constituents of the oceans and the atmosphere. Their role in the global circulation of halogens and in atmospheric chemical reactions has been discussed extensively within the last few years in connection with their ability to affect the atmospheric ozone budget.

Bromine is the halogen found most often in marine-derived compounds, even though its concentration is much lower than that for chlorine. The presence of organo-chlorine compounds in the marine environment is usually attributed to human activities, through their use as pesticides, anti-freezing agents etc. However, our recent investigations have shown that both macroalgae and microalgae produce chlorinated compounds, too.

Our investigations during ARK XI/2 can be divided in three parts:

- Formation of halocarbons by pelagic micro-organisms
- Estimation of the flux of naturally produced compounds from the sea surface to the atmosphere
- Distribution of halocarbons in the water column

Sampling:
In accordance to the objectives, sea surface water samples were collected through the sea surface inlet of the ship along the cruise track. Also, water from the entire water column was collected from the rosette sampler. In addition water was sampled from the multicorer. Table 4.1 summarizes the work performed during the first part of the cruise. Along the two transects, 75°N, and 75°N to 71°N, 38 out of 58 and 14 out of 24 stations were sampled respectively. Due to the relatively long analysis time, 26 minutes, effort was made to sample every other station, and at least 12 different depths. To avoid contamination of the preconcentration unit with micro-organisms, all samples were filtered through a GFC filter prior to analysis.

In order to be able to calculate fluxes of the compounds between the air-sea interface, air samples were also analysed.

The formation of naturally produced halocarbons by different-sized micro-organisms, were studied. Surface water was filtered through a filtration unit equipped with 5 different-sized filters, 1000, 150, 12, 2 and 0.4 µm. Each fraction contained 250 ml. After the filtration of approximately 25 l of water, during a period of 4 hours, the water from the different compartments was put in 60 ml glass bottles. Care was taken to avoid any headspace volume, in order to minimize losses of the compounds to air. The glass bottles were then put in a refrigerator, with a mean temperature of 0.5°C, and a light intensity of approximately 70 mol photons m^{-2} s^{-1}. The formation of halocarbons was then measured after 6 to 60 hours. Prior to injection, the water was filtered through a GFC filter, and the chlorophyll content was measured according to standard procedures.

It was also possible to measure the formation rates of halocarbons by two macro-algae, *Laminaria digitata* and *Dilsea* sp., collected at Bear Island.

All samples were preconcentrated with a purge-and-trap technique prior to the final determination with capillary gas chromatography.

Table 4.1 Summary of samples collected at stations during the first part of the cruise.

Station	Rosette	Multicorer	algae filtration
06	x		
08	x	x	
10	x		
14	x	x	x
15	x	x	x
16	x	x	x
17	x		x
18	x		
19	x		
20	x	x	x
21	x	x	
22	x	x	x
23	x		x
24			x
25	x		x
26	x		x
28	x		x
29	x		x

Preliminary results

One of the main goals is to get information regarding the surface water concentrations of naturally produced halocarbons, in order to be able to estimate the ocean source strength. We have earlier pointed out that not only do the formation of these compounds vary between different parts of the world, but also with seasons, and even, within a day. Therefore, care should be taken when global estimates are to be made.

In an autumn situation, one is likely to believe that the algae responsible for the formation of these compounds should not be as active as during summertime. Surprisingly, we found that the mean surface concentrations of the biogenic compound bromoform was approximately around 8 ng/l, which should be compared with an investigation made in the high Arctic in 1991, where the mean concentration was around 4 ng/l. The levels of bromoform found during this cruise are also higher than mean concentrations measured in the coastal sea of the Skagerrak.

The high values are supported by the results from the filtration experiments. As can be seen in Figure 4.1, all the different-sized fractions produced bromoform in significant amounts. It can also be seen that the ability to produce the two chlorinated ethenes trichloroethylene and perchloroethylene increases with decreasing size of the micro-organisms.

The distribution of halocarbons in the water column is exemplified in Figure 4.2. Carbontetrachloride (CCl_4) is a compound of mainly anthropogenic origin. Consequently, the concentration is highest at the surface, and decreases towards the sea floor. The complicated distribution of a compound with both an anthropogenic and a biogenic source is exemplified with the depth profile of perchloroethylene.

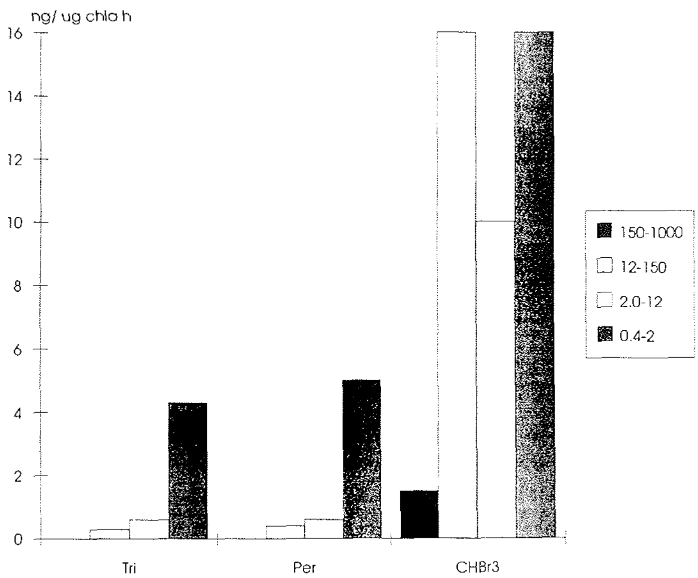


Figure 4.1 The production rates of three halocarbons by different sized micro-organisms (stn 25).
Tri: trichloroethylene
Per: perchloroethylene
CHBr3: bromoform

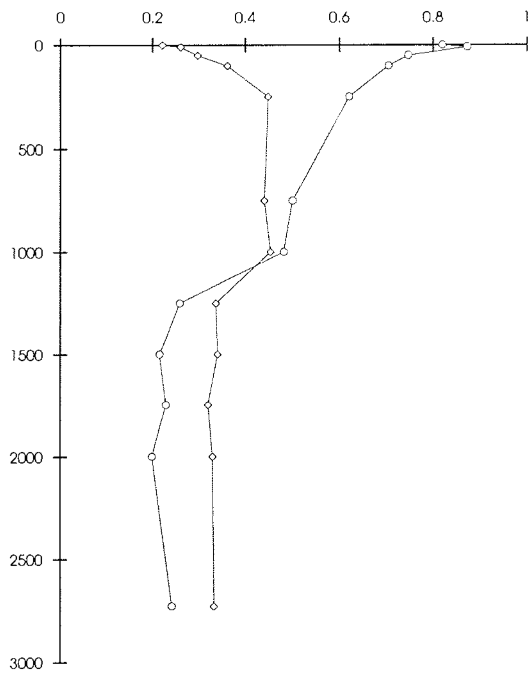


Figure 4.2: Depth profiles of two halocarbons (stn 41)
Perchloroethylene
Carbontetrachloride

5. ZOOPLANKTON
(C. Albers, H. Auel, B. Niehoff, B. Strohscher)

Bongo-net hauls (mesh size: 200 and 310 µm) and Multi-net hauls (mesh size: 150 µm) were performed at 20 and 6 stations respectively. The investigations concentrated on the vertical distribution, reproduction, overwintering strategies, lipid storage and composition of dominant copepod species in different parts of the Greenland Sea.

The Northeast Water Polynya on the East Greenland Shelf has been the subject of the International Arctic Polynya Project (IAPP) studies since 1993. During ARK XI/2 Multi-net hauls were taken to study the stage composition and vertical distribution of the overwintering population of herbivorous copepods under autumn conditions. Net samples were fixed in 4% Formalin and transported to AWI for final evaluation. Together with the summer data of the previous cruises, this will allow us to estimate the development and growth during the productive season and to reconstruct life cycles of dominant species. The results will also improve our understanding of the overwintering strategies of different species. About 640 samples of different Calanus species and stages were frozen for later analysis of carbon and nitrogen content and dry mass. The results will increase knowledge of the standing stock of biomass and the secondary production.

In the Greenland Sea Gyre, Multi-net and Bongo-net hauls were taken to study *Calanus hyperboreus,* which is a key species in the food web of the Greenland Sea due to its size and abundance. In contrast to other calanoids, gonadogenesis and egg production is based on lipid reserves accumulated during the previous summer. Observations during ARK XI/2 showed that nearly 50% of the females were mature and produced eggs in October. To study the spawning physiology and molting behaviour in detail, females and copepodid stages IV and V were collected for laboratory experiments. Of special interest is the role of the lipid metabolism in the egg formation.

Lipids are of major importance for the survival of zooplankton organisms in polar regions. Extensive lipid storage acts as an energy reserve for overwintering and, in some cases, reproduction. Herbivorous species especially depend on lipid reserves to survive long starvation periods, when the darkness of the polar winter or ice cover prevent primary production. In addition, lipids are important components of biomembranes.

In order to study the seasonal lipid storage of zooplankton organisms, individuals were collected and sorted on board according to species, ontogenetic stage and sex. In total, 360 samples were frozen (-80°C). Their lipid content and composition will be analysed in the Institute for Polar Ecology, Kiel. Research concentrated on the polynya region and two transects (79 and 75°N) in order to elucidate the effects of sea ice coverage on lipid storage. Comparisons between different oceanographic domains, e.g. polar East Greenland Current, arctic Greenland Sea Gyre and boreal-atlantic West Spitsbergen Current, are also possible.

Data obtained under autumn conditions will complete the investigations of seasonal energy storage of zooplankton in high latitude ecosystems from late winter, spring and summer. Using these data it is possible to calculate the energy demands of overwintering and the role of lipids for the energy flux within the ecosystem. These results contribute to the ecosystem studies of the Joint Reseach Programme 313 (SFB 313) at Kiel University. In addition, the potential of specific lipid components as trophic biomarkers will be studied in co-operation with the AWI.

Wax esters serve as long-term energy reserves, whereas triacylglycerols act as short-term fuels. In order to determine the molecular species of these lipid classes, zooplankton samples, especially *Calanus spp..* have been stored in dichlormethane/methanol (2/1) at -30°C, until gas chromatographic analysis can be performed in Bremerhaven. In comparison to other marine taxa, polar copepods contain highly unsaturated phospholipids, which are very important in maintaining the fluidity of biomembranes even under low ambient temperatures. Investigations should elucidate the composition of these molecular species.

Hitherto, research has focused on larger species that dominate the biomass, e. g. *Calanus spp.*. The aim during the expedition ARK XI/2 was to determine the fatty acid and fatty alcohol composition of abundant smaller species, e. g. *Oithona spp.* and *Oncaea spp.*. Altogether 21 Bongo net hauls were conducted and more than 6300 animals of the species *Calanus hyperboreus*, *Calanus glacialis*, *Calanus finmarchicus*, *Oithona spp.* and *Oncaea spp.* were collected for investigations in Bremerhaven.

6. MULTI-DISCIPLINARY SEA ICE INVESTIGATIONS

The Greenland Sea area is the major outflow region of pack ice from the central Arctic Basin. Our studies aimed to outline the physical, chemical and biological properties in Arctic drifting ice floes in the autumn/winter transition time which is characterized by decreasing air temperature and light intensities.

Our studies focused on three major questions: a) What kind of organisms are incorporated into newly forming sea ice, b) What are the characteristics of the sea ice biota in late autumn, and c) What organisms are found in the ice-water interface at this period of the year.

6.1 Formation of sea ice

(R. Gradinger, E.J. Ikävalko, T. Mock, Q. Zhang)

Studies on the sea ice formation in Antarctica have revealed, that protistan organisms are incorporated already into the initial stages of newly forming sea ice.

During the sea ice formation, a succession of several characteristic stages has been described as the "pancake ice cycle", and suspended particulate matter including microorganisms accumulate in newly forming ice primarily due to physical concentration mechanisms. It has been shown that algal populations are "scavenged" by frazil ice crystals rising through the water column. Furthermore, incorporation of plankton organisms may be supported by wave fields that pump water through the new ice layer, thus enmeshing cells between ice crystals.

During our cruise we studied the physical (temperature, salinity), chemical (nitrate, nitrite, phosphate, silicate) and biological characteristics (Chlorophyll a, cell abundances, species composition) of different types of new ice (grease ice, pancake ice, nilas ice). Preliminary information on the variability of protists inhabiting the different stages of sea ice formation was gained by light microscopy of live material. The most versatile communities were found in pancake ice, with numerous phototrophic and heterotrophic flagellates, whereas grease ice was mainly dominated by pennate and centric diatoms. The variability of protist communities in the surface water was generally lower than in the other samples studied. Thus, the phototrophy seems to prevail in the early stages of the sea ice formation, whereas heterotrophy increases in importance in the later phases.

Two experiments were made in order to understand a) the effect of freezing rate on organism inclusion and b) the early succession patterns after an ice sheet has formed.

6.2 Effect of freezing rate on organism incorporation

(E.J. Ikävalko, R. Gradinger)

An experiment on the new ice formation was made in order to study the effect of slow and fast ice formation processes on the incorporation of protists into the sea ice. Slow ice formation was achieved by placing an experiment tank with 40 liters of freshly collected surface sea water onto the working deck (air temperature -11,4 °C). The ship's cold room of -30 °C was optimal for establishing fast ice formation. Measured environmental variables in the beginning of the experiment were water salinity and the temperature of both the water and the air. The ice formation was allowed to continue in both tanks for ca. 4 hours, after which, together with the variables mentioned above, the surface and bottom ice temperature and the brine salinity was measured. In the beginning and the end of the experiment water samples were collected. These, together with brine samples serve in the species identification and enumeration of the protists. The obtained material was studied live and documented by photography and video recordings shortly after the sampling. Further examination on the preserved material will be done both light, epifluorescence and transmission electron microscopically.

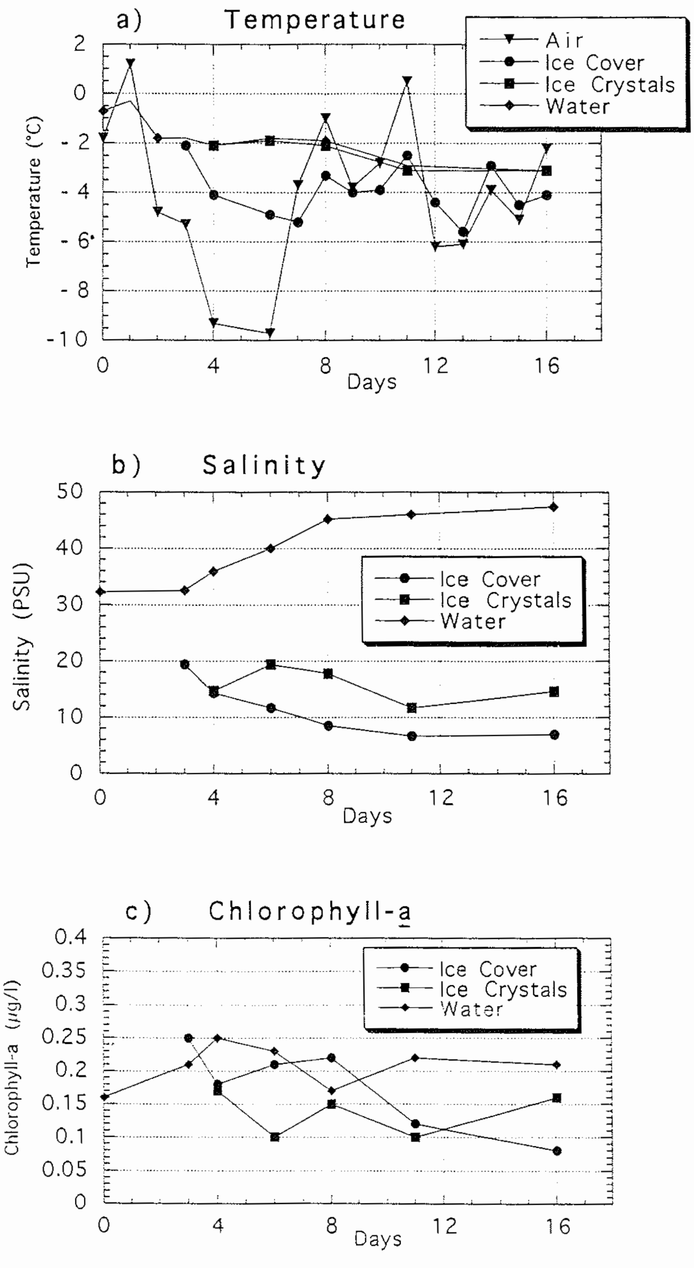
6.3 Microcosm Sea ice formation experiment

(Q. Zhang, R. Gradinger)

In this experiment we wanted to follow the evolution of a nilas ice layer on a larger water body (900 l) over a period of at least two weeks, monitor the related changes of the abiotic and biotic parameters both in the sea water and inside the ice cover under natural light and temperature conditions.

A plastic tank (100 x 70 x 150 cm) was fixed on the working deck of RV "Polarstern" and filled with 900 l of 64 µm filtered sea water at the location of 79°2'N, 2°59'W on 8 October 1995. Ice formation started with the air temperature below -5°C, and an ice sheet grew rapidly from initial 1.5-1.8 cm (after 12 hours) to 11 cm after three days. The maximum ice thickness of 16 cm was reached after 16 days, when the last sampling was done and the experiment was finished.

In the experiment tank, the surface was covered with a solid ice sheet. A layer of ice crystals, each of about 1 mm thickness and different shapes, had formed in the interface between the solid ice and the water body below. Thus, three different types of samples could be obtained: 1) ice cover, 2) ice crystal layer, and 3) water body. Temperature, salinity, nutrient (NO_3, NO_2, PO_4, Si) and chlorophyll a concentrations were measured in all sample types every second day. Subsamples were fixed



Figures 6 a/b/c: Results of a tank experiment with borax-buffered formalin (1.0 % final concentration) for further analysis of the abundance of algae and bacteria by light and epifluorescence microscopy.

The air temperature varied in the course of the experiment between +1°C to below -9.5°C. While the temperature of the solid ice sheet followed the air temperature changes but in lower magnitude, the temperature of the water body and the ice crystal layer were nearly stable at about -2 to -3°C (Fig. 6.1a). As an effect of the ice growth the salinity of the water body increased with time, while the salinity of the ice sheet decreased due to desalination processes (Fig 6.1b). The chlorophyll a concentrations in the water column and the ice crystal layer were relatively constant, whereas in the ice cover a decrease was observed (Fig. 6.1c).

6.4 Autumn/winter conditions within Arctic sea ice floes

(R. Gradinger, E.J. Ikävalko, T. Mock, Q. Zhang)

The Arctic sea ice is inhabited by a diverse community of bacteria, protists and metazoa. Our main scientific concern was to determine the physical and chemical properties of the ice cover which correspond to the observed distribution of the biota within the ice column.

At 8 stations ice cores were drilled from Arctic ice floes with a 10 cm ice auger. The vertical distribution of temperature, salinity, nutrients and biological properties (Chlorophyll a, species abundances and composition) was investigated with a vertical resolution of 1 to 20 cm. A particular emphasis was on a detailed study of the protistan community. In order to survey the versatility of the protists inhabiting the sea ice biota samples were collected from both the ice floes and the beneath lying water column. Thus, the material consists of brine, together with 50 and 10 µm net samples. Immediately after the sampling the material was concentrated by a centrifuge, and protists were examined live with an interference microscope. Documentation was done photographically and by video-recording using an inverted microscope. Based on light and electron microscopical preparations made on board further identification of e.g. scale- and lorica-bearing protists will be done at the University of Helsinki, Finland. A total of three serial dilution experiments were conducted using brine water. These experiments will give estimates for the in-situ growth and grazing rates of sea ice bacteria and protists.

Two experiments (dark survival and salinity tolerance) were conducted to test the reaction of ice algae onto decreasing light and temperatures which are both typical for the autumn/winter transition.

Experiment 1: Dark survival of Arctic algae

(Q. Zhang, R. Gradinger)

Polar marine ecosystems are characterized by strong seasonal and interannual variations of environmental factors like the extent of the ice cover and solar irradiance. With the onset of polar winter, the available light intensities are reduced to nearly total darkness for periods of up to 6 months. It has been suggested that algae overwinter as resting spores with reduced metabolic rates. Although winter survival of the ice algal community is necessary for the seeding of the annual spring development, dark survival in polar marine algae has received little attention. Thus, an experiment was designed to investigate the survival strategies of Arctic algae in the darkness over a period of 5 months.

Grease ice was collected at a position of 79°2'N, 2°59'W in the Greenland Sea, melted and filtered through a 64 µm gaze to exclude larger zooplankton. 40 bottles (50 ml each) were filled with the water and stored in the dark at a temperature of +2°C. Measurements on abiotic and biotic parameters will be carried out every seven days in the first month, every 14 days in following four dark months, and every five days after the total five dark months. In the end of the experiment the algae will be exposed to increasing light intensities at a temperature of +4°C. The microscopical analysis will focus on the identification of different adaptation strategies.

Salinity tolerance of Arctic algae
(Q. Zhang, R. Gradinger)

Particularly during the periods of brine drainage and ice melting microorganisms inhabiting the brine channels of the Arctic sea ice are exposed to strong seasonal variations in the brine salinity. Ice algae are known to have adaptations to low water temperatures and increasing salinity which take place during wintertime in the ice. Earlier studies have demonstrated that Arctic sea ice diatoms are relatively euryhaline and can maintain growth rates of 0.6 to 0.8 divisions per day over a salinity range of 10 psu to 50 psu. In the Antarctic, the bottom community of ice algae have shown a positive correlation between the growth rate and water salinity, the latter ranging from 11.5 to 34 psu. Culture experiments have revealed that ice algal growth continued even in temperatures of -5.5°C and a brine salinity of 95 psu.

Our experiment was designed to study the response of the growth of Arctic sea ice algae to salinities ranging from 1 to 100 psu. For that purpose ice cores were taken from an Arctic ice floe at the location of 79°59'N, 4°14'W in the Greenland Sea. The bottom 1 cm of two ice cores were let thawn in an excess of 0.2 µm filtered sea water. Salinities of 1, 10, 20, 32, 40, 50, 60, 70, 80, 100 psu were achieved by the addition of either high salinity brine (124 psu) or low salinity meltwater from the same ice floe (1 psu salinity). Larger metazoans were excluded by the filtration of the samples through 64 µm gaze. The algae were incubated at a light/dark cycle of 8:16 hours and a temperature of +1°C.

The experiment was continued for 19 days. Subsamples (25 ml) were collected 1, 3, 6, 9 and 14 days after the start and in the end of the experiment. These were fixed with borax-buffered formalin (1% final concentration) and will be used for light and epifluorescence microscopical analysis of species abundances and biomass.

Autumn Under The Roof - The Under-ice Community
(I. Werner)

The world under an Arctic ice floe is a habitat with special and variable conditions. The underside of the ice is not an even and homogenous surface, but rather characterized by a variety of cracks and crevices, undulations or rafted pieces of other floes. Even entire floes can underlay each other, thus building a complex under-ice landscape. This is the environment for a specialised under-ice community.

During ARK XI/2, a total of 5 ice stations on multi-year ice floes were used to investigate the characteristics of the Arctic under-ice community. Temperature and salinity profiles were recorded over the upper 5 metres of the water column under the ice and the underside of the ice was sampled for measurements of chlorophyll a and the C/N ratio. In order to gather information on the morphology and structure of the habitat as well as on abundance and distribution of under-ice amphipods, a videocamera was deployed under the ice. A pumping system delivered quantitative samples of the sub-ice fauna, caught from the waterlayer directly under the ice. Furthermore, under-ice amphipods recovered from Bongo net catches (200 and 310 µm) done by the zooplankton working group were deep-frozen for lipid analyses. On board "Polarstern", experiments with under-ice amphipods were carried out to gain insights into the feeding ecology and fecal pellet production of this group.

In contrast to the summer situation, where melting processes occur, neither temperature nor salinity gradients were measured under the ice floes during this autumn expedition. Water temperature ranged from -1.3°C to -1.6°C with salinities of 30.6 to 32.8 psu.

The morphology of the underside of the floes was characterized by a quite smooth structure and only shallow undulations. Dense aggregations of decaying algae were frequently observed in depressions here, as well as patches of algae inside the ice itself. Chlorophyll a concentrations in the lowermost 1 cm of the ice ranged from 0.7 to 195.8 µg/l between stations.

Based on net samples and video observations, *Apherusa glacialis* was the most abundant species of the under-ice amphipods, followed by *Gammarus wilkitzkii*, while *Onisimus* spp. was quite scarce. First results of the feeding experiments indicate that *A. glacialis* is probably the only herbivorous under-ice amphipod, whereas the other species are rather omnivorous. *G. wilkitzkii* showed even a pronounced preference for feeding on crustaceans.

There was virtually no makrozooplankton (> 200 µm) in the waterlayer below the ice. During the summer, sometimes dense swarms of pelagic copepods (*Calanus glacialis*) or pelagic amphipods (*Themisto libellula*) can be found here, probably feeding on ice algae sloughing off from the floe. However, a very diverse and abundant community of smaller zooplankton (>50 µm) seems to dominate this habitat during both seasons, e.g. naupliar stages, cyclopoid copepods (*Oithona* spp.)

and above all, several groups of harpacticoid copepods (*Tisbe* sp., *Halectinosoma* sp., *Microsetella* sp.), which are partly described to live also inside the ice.

Further analyses and experimental work on all members of the under-ice community, which is thought to function as a mediator for the production and transport of organic matter between the ice and the water column will hopefully throw some light onto the cryopelagic coupling processes. In particular, the fecal pellet production and sedimentation of particles from the ice are important points for the multidisciplinary approach of the SFB 313.

7. BATHYMETRIC MAPPING IN THE FRAM STRAIT

(U. Lenk, J. Monk, V. Sackmann)

Introduction

The area of the Fram Strait between Spitsbergen and Greenland plays a key role for the water exchange between the North Atlantic and the Arctic Ocean and is therefore subject of investigations of various disciplines. Besides the collecting of samples and the observation of physical parameters, it is necessary to have reliable depth information as a description of the sea bottom topography, i.e. bathymetric data available for planning and conducting of detailed studies of the region.

One project of the Bathymetric Group of AWI is concerned with the preparation of bathymetric charts scale 1:100000 of the Fram Strait as a basis for further investigations by other sciences. The surveys conducted during ARK XI/2 were intended to fill existing gaps in the bathymetric data and to provide the opportunity to check and adjust the results of previous surveys with less accurate navigation using the newly gathered data as a reference.

The HYDROSWEEP measurements were started at position 74.8°N, 12.0°E on the 23th of September 1995 at 0830 Universal Time Coordinated (UTC). The system was running continuously during the whole cruise with some minor exceptions caused by system failures or the requests of other disciplines to stop the transmission of acoustical signals into the water column, as the HYDROSWEEP signal caused difficulties in finding the moorings deployed in the Greenland Sea for the subsequent recovery. Another reason for interrupting the logging of data was given when the ship was steaming through heavy ice, and no reasonable signal could be recorded.

As a result of ARK XI/2 about 1205 nautical miles of run lines were sailed resulting in an area of about 10 500 km^2 being surveyed.

Data storage was conducted on a daily basis. The raw bathymetric data is stored on magnetic tape by HYDROSWEEP; additionally, an interface to the VAX-cluster is installed where the profiles are recorded. The latter files are used as the basis for further processing. Navigational data is also stored separately on disk, and all data is time-tagged with regard to UTC in order to relate the different types of data to each other during the subsequent post-processing.

Survey Instrumentation

During several expeditions in 1984, 1985, 1987, 1990 and 1991 hydrographic surveys were conducted with RV "Polarstern". Until 1989, the SEABEAM system was used to gather bathymetric data, and positioning was mainly based on the TRANSIT satellite system operated by the US Government Department of Defence.

The TRANSIT satellite system forms a "birdcage" of circular, polar orbits about 1075 km above the Earth. Thus, fixes can only be recorded every few hours depending on the number of available satellites and the latitude of the ship's position. The time gaps between the fixes had to be filled by dead reckoning systems. Problems involved with these systems include their decreasing accuracy with time, and offsets are likely to occur in the positioning data when the next TRANSIT satellite fix occurs. These offsets can be in the range of several nautical miles.

As a result of the offsets and the overall accuracy of TRANSIT, the accuracy of positioning is likely to be in the range of 500 m and worse in poor conditions, even after substantial interactive post-processing. This accuracy is unacceptable for the planned charts at a scale of 1:100 000, as a displacement of 500 m in position would result in 0.5 cm on the chart.

Nowadays, the NAVSTAR GPS system is used for positioning, and the ATLAS HYDROSWEEP system has replaced the SEABEAM system in 1989. HYDROSWEEP operates at a frequency of 15.5 kHz and measures athwardship oriented profiles consisting out of 59 preformed beams (PFB) from 10 m down to 10 000 m depth.

The opening angle of the swath across the ship's axis varies between 90° and 120°, and the aperture along the main axis is about 2°. Thus, the footprint of PFB beam covers an area of approx. 2° by 2° squared. The system is automatically calibrated for speed of sound in a patented procedure called cross-fan calibration where the mean sound velocity is determined in a Least Squares process by comparison of a swath measured along the ship's main axis to the standard survey cross-profile as observed by the centre beam. In addition to this calibration, a keel sonde is installed for the determination of speed of sound at the surface.

The use of NAVSTAR GPS for navigation and positioning has led to dramatic changes in the seafloor topography from previous surveys in regions with bad navigational aids. Today real-time differential positioning with GPS (D-GPS) provides absolute positions referenced to the World Geodetic System 1984 (WGS84), with an accuracy of up to ±5 ... 6 m, depending on the mode in which the system is operated and the reference station which is used. However, in remote areas such as the Greenland Sea, where no differential reference station is yet available to achieve these high accuracies, positions are only accurate to ±100 m. During the commissioning phase of GPS, there was no full coverage by the system, and the situation was similar to the time when navigation was based on TRANSIT, i.e. the gaps had to be bridged by dead reckoning systems, and offsets resulted from new fixes.

As the overall accuracy of positioning is now far better than at the beginning of hydrographic surveys on board "Polarstern", it is possible to check existing low accuracy data using the new high accuracy data as a reference.

Survey operation

In order to achieve the best coverage of the survey area, a box survey was planned prior to the expedition (see Fig. 1.1) with regards to the time schedule and altered according to the conditions prevailing on the cruise.

During the actual survey operation, the system has additionally to be observed to ensure the best results possible and to prevent a break-down of the system. One major error source in bathymetry is the use of a wrong value for the mean speed of sound. As the quality of the determined depth is directly dependent on quality of the latter value, it is of vital importance to check the applied sound speed value in regions with a hillocky underwater topography.

Problems were observed when the sea bottom is flat without much topographic variation. In case that a wrong value for the speed of sound is used, the measured profiles will be bent symmetrically to the centre beam. If the speed of sound used by the system is too high, both ends of the profile will be bent upwards, and if the value is too small, they will be bent downwards. This will result in an apparently symmetric shape of the sea bottom indicated by contour lines which are parallel to the ship's track.

To check the data obtained, the measured cross-profiles are displayed on-line, and a bottom map is scrolling over a screen. In addition, on-line charts are plotted in order to observe the quality of the data by comparing of adjacent swath-profiles and to check the coverage achieved by neighboured swathes.

System Test

In addition to the normal survey operations, a system test was performed as it seems that there are still some systematic errors causing distortions in the measured profiles. These distortions occur symmetrically to the centre beam of HYDROSWEEP near the pre-formed beams No. 14 and 46 and result in an hill-like effect. They are sometimes referred to as "the dikes of the profiles". The manufacturer of HYDROSWEEP, STN ATLAS ELECTRONIC, Bremen, Germany, asked to record deep sea data from a flat sea bed in order to investigate these distortions which also occur on other research vessels with HYDROSWEEP. This data will be processed after the cruise at ATLAS for further improvements of the system.

8. JOINT RESEARCH PROGRAMME AT KIEL UNIVERSITY

8.1 Pelagic production regimes of open water, marginal ice zone and under the ice

(O. Haupt, G. Donner, M.Krumbholz)

Planktological research within the SFB 313 at Kiel University focused on processes that control the formation and modification of particles in the upper layers of the Northern North Atlantic, their settling through the water column and their fate before they finally reach the deep sea floor. The investigations conducted during ARK XI/2 focused on the relation between pelagic processes and vertical particle fluxes in the marginal ice zone of the Greenland Sea. Special attention is given to the pelagic and ice-associated production regimes which are expected to differ with respect to quantity and composition of matter exported from the euphotic zone.

Stations had been sampled at 2000 m, 1200 m, 800 m and 200 m depth on a transect normal to the continental slope within the marginal ice zone. Also a slope parallel transect at 2000 m depth from 80°30'N to 79°N with ice cover from about 10/10 to 1/10 were sampled. Water from different depth was taken with a rosette water sampler and filtered to measure phytoplankton biomass, suspended particulated matter (Seston), elements (C, N, P, Si) and algal pigments (HPLC analysis). Water samples for microscopic investigations of species composition were fixed with borax-buffered formalin. At two mooring positions at 75°N with water depths of 400 m and 3000 m which were already investigated during the summer cruise ARK X-1 for long term explorations of the seasonality and the interannual variability of bentho-pelagic coupling. Additionally, water samples were collected along a transect at 75°N extending from 13°40'W to 17°E with a total of 19 stations to measure the already mentioned planktological parameters within the upper 500 m of the water column.

First results of chlorophyll measurements show a system state which is typical for low light conditions in fall. In the northern part of the Eastern Greenland Sea we found values mostly below 0.1 microgram per liter and chlorophyll a/phaeopigment ratios of about 1 within the upper 100 m.

The area at 75°N shows chlorophyll values below 1 microgram per liter and a more divers chlorophyll a/phaeopigment ratio with mean values greater 1. Figure 8.1 shows the chlorophyll a and phaeopigment distribution of the 75° transect. Highest chlorophyll a values were found in the upper cold Arctic water mass in the marginal ice zone. Depending on the ice cover the low light level of the surface layer results in a sharp decrease of chlorophyll concentration with increasing depth. Chlorophyll a as well as phaeopigment concentrations shows homogeneous tendency in deeper water layers of the warmer atlantic water masses. Relatively high pigment concentrations in a depth of about 60 to 100 m may be caused by fecal pellets and aggregates rather then by living phytoplankton cells.

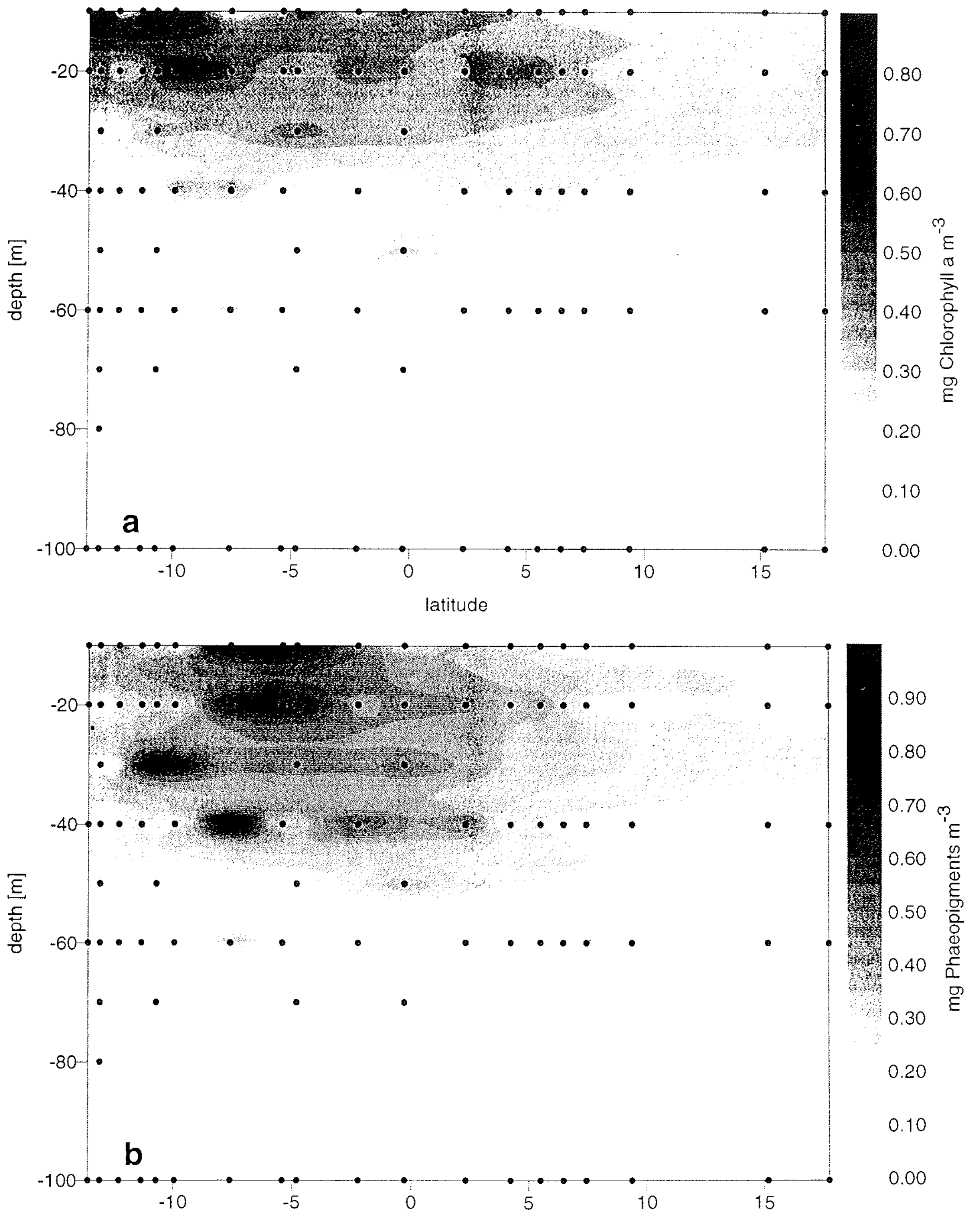


Fig. 8.1: Vertical distribution of chlorophyll a (a) and phaeopigments (b) at 75°N

Measurements of vertical particle fluxes from the various regimes in the marginal ice zone

Within the last years the field work of the SFB 313 has focused on the seasonally ice-covered region of the Greenland Sea. Measurements of vertical flux in this region are conducted to collect particles exported by different pelagic production regimes in relation to seasonal retreat of the ice. During this cruise, moorings which were deployed in cooperation with AWI in 1994 during the expedition ARK X/1 were recovered successfully with a total of 4 sediment traps (AWI 413-4/OG 7 at 3000 m and AWI 410-2/OG 8 at 400 m depth). A mooring deployed in Mai 1995 at 75°N, 3°55'W with RV Johan Hjort (OG 9) was also successfull recovered. A first look at the collected material in the sampling glasses shows a clear annual cycle of vertical particle flux with high rates during spring and summer.

A long term mooring (OG 10, collecting time 1 year) at a position of 75°03.4'N, 04°35.7'W was deployed with 3 sediment traps in 500, 1000 and 2000 m depth as well as 3 current meters each about 20 m below the traps. This area is within the seasonal ice-covered part of the Greenland Sea. Because of the influence and the variability of the ice cover on the production of biogenic matter we predict a direct relation between the location of the marginal ice zone and the sedimentation of organic particles. The mooring will be recovered in August 1996.

Experimental studies with dominant organisms

To analyse changes in pigment signature and composition of other biogenic compounds and for comparison with sediment trap samples, experiments for fecal pellet production were made on board with the dominant zooplankton species (copepods, amphipods and euphausiids) to analyse changes in pigment signature and composition of other biogenic compounds and for comparison with sediment trap samples.

Dominant copepods (*Calanus hyperboreus* and *Calanus glacialis*) were sampled with a Bongo Net and cultivated for different experiments which will be conducted at Kiel University

8.2 Bentho-pelagic coupling

(Angelika Brandt, Jörg Stefan Berg, Michael Gedamke, Angela Lunau, Eberhard Sauter, Annette Scheltz, Klaus Schnack, Susanne Wanner)

Background

Quality and quantity of organic carbon reaching the seafloor have a direct effect on the benthic community. Organic particles are enriched in the BNL (bottom nepheloid layer) and in the upper sediment layer, where they are the main food source for benthic organisms. Composition and quality of these particles are influenced by the vertical sedimentation, by lateral advection, by biological and chemical modification of the particles in the water column and at the seafloor, by the bottom topography, as well as the seasonal deposition of particles due to spring blooms and the production of ice algae at the floes margins.

Objectives

Our work will focus on the interactions between the BNL and the upper sediment layer. In this respect it is crucial to investigate composition, abundance, diversity, and community patterns of benthic organisms, which take up organic particles, incorporate them into the sediment by biodeposition and bioturbation processes and also play an important role in the recirculation of organic material by resuspension. Therefore we will also try to scrutinize the interaction of the amount, the composition and the flux of particles in the BNL and the patterns and activity observed in the benthic communities.

Moreover our program encompasses work on the following aspects:

- evaluation of the degree of bentho-pelagic coupling along the Northeast Greenland continental margin
- investigations of the composition, abundance and diversity of macrobenthic communities, especially peracarid crustaceans and polychaetes (which are most important in terms of numbers) and seafloor/BNL-properties
- assessment of micro- and mesoscale dispersion patterns of benthic populations
- investigation of metabolic activities and bioturbation potential of the total sediment communities by measurements of biochemical parameters at certain sites, as well as the macro- and megabenthic (i.e. sponges) communities
- the analyses of BNL characteristics in terms of the amount and composition of particles in relation to near bed current velocities and direction
- impact of biodeposition and bioentrainment on the particle composition in the sediment in in situ experiments

In order to reach these goals, a normal transect at 79°N, at 2000 m, 1200 m, 800 m, and 200 m depth had been sampled, and additionally a slope parallel transect in about 2000 m depth consisting of 4 stations and extending from 80°30'N to 79°N, off the Greenland continental slope. We hope that this slope parallel transect will cover different conditions of particle supply to the benthos due to variable surface production in areas of permanent ice cover, ice edge situations and open water. The normal transect will provide information on the depth distribution and dispersion patterns of benthic communities and characteristics of the BNL. Additionally we will investigate bentho-pelagic coupling processes at 2 revisited SFB-mooring stations at 75°, NE Greenland.

A set of various benthos equipment has been used to serve our purposes. For faunistic studies and comparison the giant box corer, the Agassiz trawl and an epibenthic sledge with a newly constructed supranet at about 1 m above the bottom (additionally to the epinet), will be employed. The vertical distribution of chemical and biogeochemical parameters will be assessed by deploying a multiple corer and a newly designed O_2-profiler called "Floorian". For the characterization of the BNL a modified bottom water sampler will retrieve water samples and thus provide in formation on current velocity and direction within the last meter of the BNL, i.e. just above the sediment water interface.

First results

AGT (Agassiz trawl)
During last year's cruise of "Polarstern" into the arctic waters some evidence of high sponge densities was found. Sponges are filter-feeding organisms that feed on phytoplankton, detritus and bacteria. Some of the sedimentary organic matter will eventually reach the BNL, where it might be available to sponges. However, size classes of the consumed particles as well as the composition of the food and the influence of the flow velocity to the particle retention rate are only known for very few species (see e.g. Witte, U., 1995). Therefore we have only little information about the possible contribution of sponges to sediment formation. These question will be approached in a laboratory study with living sponges (*Geodia mesotriaena*) that were caught in the Greenland Sea.

On five stations we employed the Agassiz-Trawl, three of these were taken on the transect from 2000 m to 200 m depth onto the Greenland shelf. The three trawls on the transect running perpendicular to the shelf were taken at 1200 m, 700 m and 200 m depth. All three trawls were successful, but no or only few sponges came up with it. At the 1200 m station, most of the catch consisted of fine mud, but we also found some shrimps and bottom living fishes (e.g. ray). The trawl contained Ophiuroidea and Priapulida, we tried to keep them alive in aquaria. Actinians, brittle stars, decapods and some fish were sampled at the 700 m station. The diversity and biomass was highest in the 200 m trawl, where we found 3 species of sponges, several amphipod species, 1 *Sclerocrangon ferox*, many *Heliometra*, 5 Holothuroidea and a few polychaetes. All of the *Heliometra* died after 20 days of being kept in the aquaria, although they have been observed feeding. The water volume might have been too small, and flow velocities too weak for these animals.

Two further trawls were taken 75°N at 800 m and 400 m depth. The first one at 800 m was very successful as the catch consisted almost completly of sponges (*Geodia mesotriaena)* and a few octocorals. Except for five sponges, all of them are still alive in aquaria for later experiments in the laboratory. About 900 m^2 of seafloor were sampled, therefore I could calculate a sponge density in this area of about 0.3 individuals per m^2. The last trawl taken consisted of two *Gorgonocephali* in very good condition, few fishes, and some sponges.

BWS (bottom-water sampler)
In order to receive information about the hydrodynamic sorting of the organic matter near the seafloor, we took samples from 7 cm, 12 cm, 20 cm and 40 cm height above the seafloor with the bottom-water sampler. The water was filtered to analyse its content of chlorophyll, POC (particulate organic carbon), PON (particulate organic nitrogen), and total supended matter. 200 ml of each sample were fixed with formalin to count bacteria and phytoplankton (e.g. diatomes). On

each deployment of the BWS, a video camera was installed in 40 cm height above the seafloor as well as a current and a turbidity profiler. The hydrodynamic sorting of the organic matter is crucial for the benthic animals, because it determines the quantity and quality of food they receive. The whole sedimentation regime is influenced by the hydrodynamic processes near the seafloor.

At seven out of nine stations we took water samples and employed the video camera with the BWS. At the 1200 m station of the slope-normal transect, the BWS could not be employed because of the strong ice drift. At the last station at 75°N (water depth: 400 m) the control unit broke down so that we could not get samples at that station either. The 200 m station remarkably showed very good video images of different species of mysids and 1-2 amphipod species. The parallel EBS-haul at that station enabled us to determine the most frequent mysid as *Boreomysis arctica*.

The chlorophyll contents of the water samples were already analysed on board. As expected for this time of the year, the chlorophyll a and phaeopigment values of the water were very low in all samples taken.

EBS (epibenthic sledge)

Within the macrobenthic communities, peracarid crustaceans play as important a role as polychaetes, as they occur in large numbers and are usually quite diverse. In order to catch a high number of individuals, an epibenthic sledge was employed, which was first modified after a construction of Rothlishberg & Pearcy (Rothlishberg & Pearcy, 1977). This sledge originally consisted of a single box. Its opening measures 33 x 100 cm and is at about 25 cm above the bottom. As many peracarids are vagile (e.g. Amphipoda, Isopoda, Cumacea migrate in the water column during the nights), or exhibit a suprabenthic mode of living (Mysidacea), an additional supranet with the same size was constructed and fixed above the epinet (Brandt & Barthel, 1995). It extends from 1 m to 1.33 m above the ground and helps to separate supra- and epifauna more clearly.

In total the epibenthic sledge had been employed at 10 stations, 8 of these have been sampled successfully. At 80°30'N about 2000 m depth, the sledge did not work properly and came up damaged. The second failure occurred at about 75°N around 2800 m depth.

Up to now it has only been possible to analyse the content of the supranets of the samples. As well as varying numbers of decapods, euphausiaceans, chaetognaths, ostracods and calanoid copepods, peracarids have been sampled at all successful EBS-stations. Within the Amphipoda, most species belong to the families Ampeliscidae, Amphilochidae, Calliopidae, Eusiridae, Isaeidae, Lysianassidae, Pardaliscidae, and Stegocephalidae. All Cumacea found in the supranet were specimens of the genus *Diastylis* (Diastylidae). *Eurycope* was the most frequent isopod genus in the supranet, however, a single, well preserved specimen of the deep-sea isopod *Munnopsis typica* (Sars) was found at station 37-018. Other common isopod families were the Ilyarachnidae, Nannoniscidae, and Munnidae; the Mysidacea were all members of the family Mysidae, the most frequent genera were *Boreomysis, Eryt--throps*, and *Pseudomma*. Only a single species of Tanaidacea, *Sphyrapus anormalus* (Sars), was found in the supranet.

The following table shows the differences in the supranets at the different stations. The values are total numbers collected and are not yet standardized for a 1000 m haul.

Peracarida in the supranet of the EBS

Station	Amphipoda	Cumacea	Isopoda	Mysidacea	Tanaidacea	Sum
37-008	37	0	0	2	0	39
37-012	5	18	16	4	1	44
37-014	3	0	1	52	0	56
37-016	14	0	1	1	1	17
37-018	47	0	1	2	0	50
37-019	10	0	0	21	0	31
37-020	1	0	failure	1	0	2
37-021	22	44	16	20	15	117
37-025	0	0	failure	0	0	0
37-027	51	20	115	0	9	197*

*The higher number of Peracarida at station 37-027 is an artifact, as the supranet contained some sediment in the cod end and must have been trawled partly upside down.

GKG (giant box corer)
To investigate the relationship between surface production and benthic community structure, the macrobenthos was sampled quantitatively with a box corer (50 x 50 cm surface). The box corer was employed at 9 stations, in total 25 cores were sampled. From each core 3 fractions were sampled:

- 1) the surface water above the sediment,
- 2) and a 25 x 25 cm subsample of the first cm of sediment, and
- 3) the next 5 cm of sediment.

These samples were sieved, fixed and partly sorted on board of "Polarstern". Some living polychaetes (eg. *Onuphis conchylega*) were kept in aquaria for further observations at home. Additionally, smaller amounts of sediment were taken for determination of various sediment parameters.

A very preliminary investigation of the infaunal distribution shows an impoverished community. This might be due to low food supply. Total abundance is estimated to 500 - 5000 animals/m^2. The main dominant infaunal taxa are polychaetes, followed in abundance by other groups including crustaceans, sipunculids, mussles and holothurians. Within the polychaete fauna, important families are Spionidae, Oweniidae, Maldanidae, Ampharetidae, Terebellidae, Lumbrineridae, Nephtyidae and Polynoidae.

There are strong indications that the observed macrofaunal community structure with low abundance and very low biomass reflects a low and variable food particle flux.

One sediment core of 19 cm inner diameter and length of approximately 30 cm was taken at each station and stored for further examination at 2°C. The cores were vertically dissected, the infaunal "Lebensspuren" were documented by photography and eventually found animals were fixed separately. Additionally at each station, samples for chlorophyll-equivalent analyses were taken.

MUC (multiple corer)

The MUC is able to take 8 sediment cores (10 cm diameter) simultaneously with in haul. It was deployed 15 times at 9 Stations. Where the gear was used more than once, the sediment was either too hard or too sandy to get proper sediment cores or additional sediment cores were needed for incubation or other experiments. The sediment cores were kept at a temperature of 0°C to 1°C after recovery until further analysis. The described sampling and incubations (see below) were performed at all stations except those, where insufficient sediment cores were recovered.

- sampling: The upper 10 cm of the sediment cores were cut into horizontal slices of 0,5 to 1 cm. Depending on the parameter the samples were taken for, the sediment disks were subsampled. Subsamples were taken for measurements of the following parameters: ATP-concentration (biological activity), chlorophyll-equivalent (sediment-food supply and bioturbation), C/N-ratio (geochemistry), DNA-content (sediment activity), ^{210}Pb (bioturbation), porewater nutrients (nitrate, phosphate and silicate) and porosity (both for geochemistry).

- shipboard measurements and incubations: The sediment oxygen demand was measured on three sediment cores. Oxygen profiles were obtained from another core for comparison with in-situ measurements (see FLOORIAN). Whenever possible, one core was incubated with addition of Br-Ions in the overlaying water to study sediment porewater exchange rates (bioirrigation/geochemistry). Luminophores (stained sediment particles) were used in three size-fractions (<63 µm, 63-125 µm and 500-1000 µm diameter) in order to study short-time (5 to 8 days) bioturbation capacities of the smaller infauna. The average half life of chlorophyll and its products of decay in the sediment column were also examined.

Additionally, the sediment surface was investigated for biological activity, for example burrow openings or tracks, which were documented photographically.

Floorian (O_2 profiler)
The diffusive boundary layer (DBL) is easily disturbed and compaction of sediment might occur during the coring process, for example of a MUC. Also, quality of samples changes during recovery from the seafloor to the surface. These were the reasons for the development of in situ measuring methods.

On this cruise we were able for the first time to deploy the newly developed oxygen in-situ profiler FLOORIAN in deeper water. In contrast to free falling lander systems, FLOORIAN is capable of measuring under ice covered water, because it is deployed via the winch. The device also records a resistivity profile of the sediment. Additionally two cores for laboratory experiments and porewater analyses are taken at each deployment.

FLOORIAN was deployed at eight locations. Four in-situ measurements were performed in the Fram Strait, and four at 75°N (where two deployments failed).

The in-situ data (Figure 8.2) will be used to calculate the fluxes of oxygen and organic carbon, respectively. Together with oxygen profiles taken from cores (measured on board), we will obtain information about the oxygen-penetration depth. These were 3-12 cm at shallower localities (e.g 37-014, 800 m; 37-016, 190 m) and some decimeters at deeper stations (e.g. 37-025, 2800 m).

Sometimes oxygen profiles show subsidiary maxima, which might be caused by oxygen irrigated due to burrows of infaunal animals (e.g. polychaetes).

The fingerprint-like resistivity profiles (figure 8.2) characterize the respective sediment and also determine sediment porosity.

Literature
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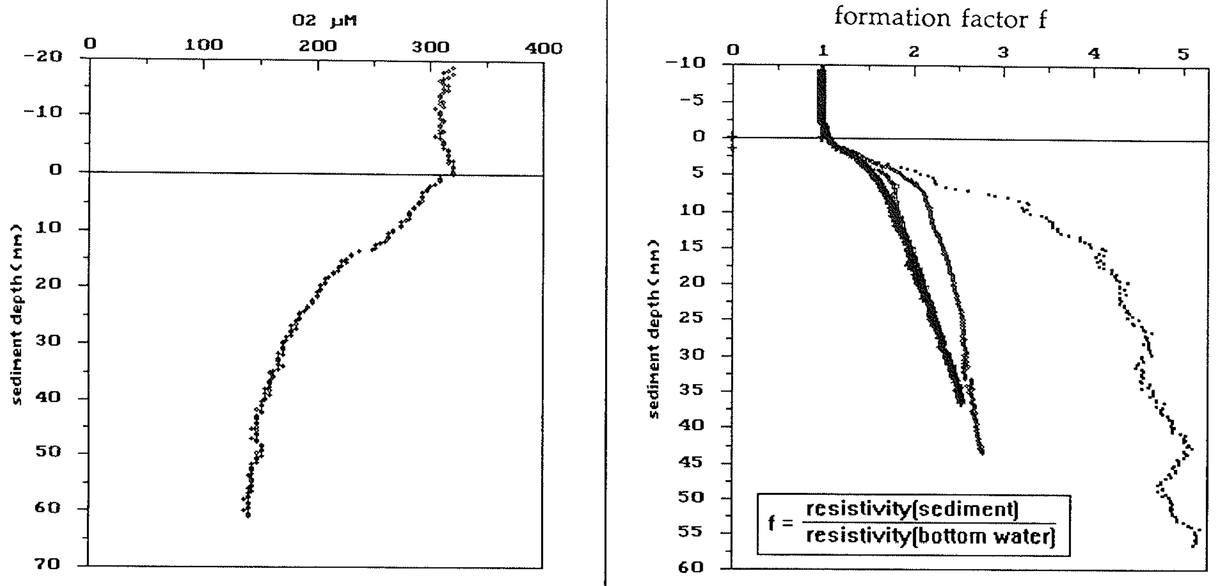

in situ oxygen profile at station 37-030.
580 m

formation factor of stations 37-12, 13, 14, 20

Figure 8.2: Example of profiles recorded with FLOORIAN.

8.3 List of benthos stations

37-008	27.09.95	78°56.07'N 05°11.72'W, 1098 m	GKG1	soft mud with forams
		78°56.33'N 05°11.67'W, 1102 m	GKG2	failure
		78°56.04'N 05°10.99'W, 1101 m	GKG3	soft mud, some tubes
		78°55.84'N 05°10.43'W, 1082 m	GKG4	soft mud, tubes, forams
		78°56.13'N 05°10.12'W, 1096 m	MUC	fine mud no stones light brown
		78°56.29'N 05°06.40'W, 1149 m -	EBS	fine mud with
		78°56.46'N 05°06.39'W, 1151 m		many amphipods, shrimps
		78°58.38'N 05°07.87'W, 1177 m -	AGT	fine mud with much
		78°58.41'N 05°09.37'W, 1161 m		fish and many shrimps
37-012	28.09.95	78°58.70'N 03°59.20'W, 2110 m	BWS	40 cm sample is missing
		78°58.59'N 03°58.49'W, 1961 m	GKG1	fine mud, forams, cumaceans, sponges
		78°57.88'N 03°58.09'W, 1965 m	GKG2	fine mud, forams, amphipods
		78°58.67'N 03°59.50'W, 1952 m	GKG3	fine mud, 1 decapod, 1 amphipod 2 sponges, many forams
		78°58.62'N 04°00.89'W 1939m	FLOORI	fine mud, first deployment at all
		78°58.62'N 04°00.89'W, 1930 m	MUC	light brown mud rare macrofauna
		78°56.78'N 04°18.14'W, 1760 m -	EBS	fine sediment, many peracarids
		78°56.89'N 04°18.53'W, 1756 m		
37-013	28.09.95	78°56.05'N 05°11.83'W, 1087 m	FLOORI	soft mud
37-014	29.9.95	78°59.48'N 05°39.93'W, 803 m	GKG1	fine mud, some tubes, forams
		78°59.60'N 05°42.02'W, 784 m	GKG2	some tubes, forams
		78°59.89'N 05°43.28'W, 774 m	GKG3	fine mud, holes from bivalves
		78°59.40'N 05°39.50'W, 784 m	MUC	fine mud
		78°59.35'N 05°40.32'W, 794 m	FLOORI	successful
		78°59.70'N 05°40.40'W, 845 m	BWS	successful
		78°59.49'N 05°40.69'W, 794 m -	EBS	peracarids, decapods, etc.
		78°59.60'N 05°39.95'W, 805 m		
		78°58.82'N 05°47.73'W, 677 m -	AGT	many actinians, brittle stars,
		78°58.69'N 05°47.27'W, 678 m		some fish, decapods
37-016	30.9.95	78°58.40'N 07°38.00'W, 200 m	BWS	successful
		78°57.96'N 07°41.06'W, 195 m	GKG1	failure
		78°57.91'N 07°41.37'W, 183 m	GKG2	soft sediment
		78°57.82'N 07°42.10'W, 183 m	GKG3	some polychaete tubes
		78°58.71'N 07°37.01'W, 189 m	GKG4	failure - stone damaged box
		78°58.63'N 07°37.27'W, 192 m	MUC	sandy sed., short cores
		78°58.25'N 07°39.42'W, 188 m -	EBS	many crinoids, octopus,
		78°58.33'N 07°40.05'W, 191 m		shrimps, many peracarids, fish
		78°58.27'N 07°40.00'W, 192 m -	AGT	many *Heliometra*, polychaetes
		78°58.34'N 07°39.29'W, 197 m		

37-018	1.10.95	80°11.16´N, 09°53.00´W, 311 m - 80°10.98´N 09°53.27´W, 310 m	EBS	many pantopods, crustaceans, polychaetes
37-019	2.10.95	80°22.93´N 09°20.80´W, 294 m - 80°22.80´N 09°20.35´W, 299 m	EBS	crustaceans, ophiuroids, ray, polychaetes
37-020	3.10.95	80°29.30´N 05°01.90´W, 2054 m	BWS	successful
		80°29.12´N 05°03.54´W, 1970 m	GKG1	very coarse sediment, surface slightly damaged
		80°29.03´N 05°04.19´W, 1951 m	GKG2	small samples, very coarse sed.
		80°28.97´N 05°04.75´W, 1943 m	GKG3	very coarse, much sand, stones
		80°28.96´N 05°04.58'W, 1944 m	MUC	stony sed., short cores
		80°28.86´N 05°04.42'W, 1948 m	FLOORI	no cores but in-situ profiles
		80°29.88´N 05°05.24´W, 1931 m 80°29.85´N 05°04.18´W, 1954 m	EBS	failure, sledge was upside down; coarse sed. with forams
37-021	4.10.95	80°01.38´N 04°14.90´W, 1854 m	GKG1	hard, corase sed., - megafauna
		80°01.09´N 04°14.63´W, 1858 m	GKG2	high sand content
		80°00.74´N 04°14.16´W, 1866 m	GKG3	high sand content
		80°00.37´N 04°13.93'W, 1862 m	MUC	failure
		80°00.01´N 04°13.90'W, 1854 m	MUC	second trial instead FLOORI
		79°59.40´N 04°14.20´W, 2170 m	BWS	successful
		79°58.96´N 04°19.15´W, 1809 m - 79°59.06´N 04°20.05´W, 1796 m	EBS	many forams, sponge spicules peracarids, polychaetes
37-022	5.10.95	79°35.00´N 03°51.20´W, 1983 m	BWS	successful
		79°34.24´N 03°52.49´W, 1957 m	GKG1	big tubes, sponge, forams
		79°33.93´N 03°53.06´W, 1950 m	GKG2	many cumacea, 1 hydrozoa
		79°33.67´N 03°53.60´W, 1944 m	GKG3	cumacea, forams, fine mud
		79°33.46´N 03°54.11'W, 1939 m	MUC	fine mud, rare macrofauna
		79°33.26´N 03°54.64'W, 1929 m	MUC	
37-025	10.10.95	74°57.91´N 10°52.44´W, 2851 m	GKG1	fine mud, many forams
		74°57.93´N 10°56.16´W, 2800 m	GKG2	failure
		74°57.64´N 10°52.24´W, 1855 m	GKG3	fine mud, many forams
		74°57.47´N 10°52.79´W, 2851 m	MUC	failure, no sediment
		74°57.47´N 10°52.79´W, 2851 m	MUC	fine, sandy mud, many forams
		74°58.65´N 10°55.98´W, 2791 m - 74°58.85´N 10°56.11´W, 2783 m	EBS	failure, sledge damaged
		74°57.11´N 10°54.83´W, 2842 m	BWS	successful
		74°56.98´N 10°57.52'W, 2828m	FLOORI	in-situ profiles
37-026	11.10.95	74°55.31´N 13°08.17´W, 404 m	GKG1	hard sediment, many stones
		74°55.00´N 13°09.35´W, 395 m	GKG2	-"-polychaetes, bivalves
		74°54.75´N 13°10.21´W, 402 m	GKG3	failure, empty box
		74°54.55´N 13°10.71´W, 402 m	GKG4	failure, empty box
		74°54.40´N 13°11.07´W, 413 m	GKG5	hard sediment, forams
	12.10.95	74°55.45´N 13°07.78´W, 400 m	MUC	hard sediment, many stones
		74°55.35´N 13°08.52´W, 393 m	MUC	failure, no sediment
		74°55.19´N 13°09.49´W, 396 m	MUC	failure, no sediment
		74°55.06´N 13°10.27´W, 390 m	MUC	hard sediment

37-027	12.10.95	75°00.45´N 12°38.57´W, 745 m - 75°00.50´N 12°39.32´W, 745 m	AGT	many sponges (*Geodia*)
		74°58.34´N 12°56.45´W, 424 m - 74°58.49´N 12°57.31´W, 401 m	EBS	sponges, crustaceans
37-030	14.10.95	74°59.52´N 12°46.15´W, 568 m	FLOORI	many matted sponge needles
37-032	14.10.95	75°00.10´N 12°54.59´W, 390 m	BWS	failure, control unit broke down
		75°00.18´N 12°54.57´W, 390 m - 75°00.22´N 12°55.48´W, 371 m	AGT	many big stones,gorgonocephali
37-053	17.10.95	75°00.11´N 04°07.83´W, 3587 m	FLOORI	failure
37-062	19.10.95	75°00.06´N 00°21.65´E, 3727m	FLOORI	failure (blocked by big stone?)

9. STATION LIST

Date	Station	Time	Latitude	Longitude	Equipment employed
23.09.	001	13.05 15.51	75°43´N 75°43´N	10°09´E 10°12´E	CTD, BO
26.09.	004	07.25 08.54	78°58´N 78°57´N	03°20´W 03°22´W	Mooring FWA-1/95 deployed
26.09.	006	11.16 17.36	78°59´N 78°54´N	04°00´W 04°05´W	CTD, PLA, MN, SD
26.09. 27.09.	008	22.02 14.30	78°59´N 78°58´N	05°09´W 05°11´W	CTD, PLN, BO, MN, HN, GKG, EBW, AGT, MUC
27.09.	009	15.30 16.29	79°00´N 78°59´N	04°41´W 04°41´W	Mooring FWA-2 /94 recovered
27.09.	010	16.48 18.00	78°59´N 78°51´N	04°41´W 04°41´W	Mooring FWA-2/95 deployed
27.09.	011	18.37 23.00	79°00´N 78°58´N	04°45´W 04°47´W	CTD, BO, MN
28.09.	012	06.09 18.04	78°59´N 78°56´N	04°00´W 04°20´W	BWS, GKG, FLO, MUC, EBS
28.09.	013	20.37 21.37	78°56´N 78°56´N	05°11´W 05°13´W	FLO
28.09. 29.09.	014	22.37 11.32	78°59´N 78°58´N	05°41´W 05°49´W	CTD, PLN, BO, MN, GKG, MUC, FLO, EBS, AGT
29.09.	015	12.14 17.40	79°00´N 79°00´N	06°03´W 06°06´W	CTD, M1-94 recovered
29.09.	014 cont.	18.51 20.00	79°00´N 78°52´N	05°40´W 05°40´W	BWS
29.09. 30.09.	016	23.22 07.27	78°59´N 78°58´N	07°33´W 07°39´W	CTD, PLN, BO, MN, BWS, GKG, MUC, EBS, AGT
30.09.	017	10.50 14.25	79°06´N 79°03´N	07°15´W 07°22´W	IS, CTD, BO, TMS
01.10.	018	12.37 15.54	80°11´N 80°10´N	09°53´W 09°49´W	EBS, CTD, BO, MN
02.10.	019	02.09 04.34	80°23´N 80°23´N	09°21´W 09°20´W	EBS, CTD, BO, MN
02.10. 03.10.	020	16.00 16.17	80°30´N 80°23´N	05°07´W 04°35´W	EBS, CTD, MN, PLN, BO, BWS, GKG, MUC, FLO, IS, HELIPOD
04.10.	021	01.10 17.47	80°03´N 79°58´N	04°12´W 04°21´W	CTD, PLA, MN, BO, GKG, SD, IS, HN, MUC, BWS, EBS, TMS
05.10.	022	00.09 12.52	79°37´N 79°33´N	03°48´W 03°55´W	CTD, PLN, MN, BO, BWS, GKG, MUC, HELIPOD
08.10.	023	10.17 11.27	79°02´N 79°02´N	02°59´W 03°00´W	CTD, HELIPOD
09.10.	024	12.18 21.48	74°53´N 74°53´N	07°43´W 08°01´W	Mooring AWI/414-3 recovered, CTD, Jojo, BO, MN
10.10. 11.10.	025	02.26 14.15	74°57´N 74°57´N	10°44´W 10°44´W	CTD, GKG, MUC, EBS, BWS, FLO, BO, PLN, Mooring AWI/413-4 recovered
11.10. 12.10.	026	17.38 02.20	74°56´N 74°55´N	13°07´W 13°11´W	CTD, PLN, BO, HN, GKG, MUC
12.10.	027	08.06 16.16	74°58´N 75°00´N	12°59´W 12°42´W	Mooring AWI/411-2 recovered, AWI/410-2 recovered, HELIPOD

12.10.	026 cont.	17.40 19.13	74°58´N 74°59´N	12°56´W 12°58´W	EBS, CTD
12.10.	028	21.04 21.18	75°00´N 75°00´N	13°26´W 13°27´W	CTD
12.10.	029	22.59. 23.13	75°01´N 75°01´N	13°38´W 13°38´W	CTD
13.10.	030	08.48 12.52	75°01´N 75°00´N	13°27´W 13°28´W	IS
13.10.	031	13.52 20.00	74°59´N 74°58´N	13°36´W 13°35´W	TMS, Jojo, BO, HELIPOD
13.10. 14.10.	032	22.09 07.30	75°00´N 75°00´N	12°54´W 12°57´W	BWS, AGT
14.10.	033	08.16 08.44	75°00´N 75°00´N	12°44´W 12°45´W	CTD
14.10.	034	11.25 13.29	74°57´N 74°56´N	11°37´W 11°42´W	Mooring AWI/412-4 recovered
14.10.	035	16.17 18.22	75°00´N 75°00´N	12°46´W 12°44´W	FLO, CTD
14.10.	036	19.13 19.54	75°00´N 75°00´N	12°37´W 12°31´W	CTD
14.10.	037	20.41 21.25	75°00´N 75°00´N	12°19´W 12°20´W	CTD
14.10.	038	22.23 23.16	75°00´N 75°00´N	12°06´W 12°08´W	CTD
15.10.	039	00.17 01.25	75°00´N 74°59´N	11°47´W 11°51´W	CTD
15.10.	040	02.58 04.18	75°00´N 74°59´N	11°20´W 11°22´W	CTD
15.10.	041	05.17 06.41	75°00´N 75°00´N	10°55´W 10°56´W	CTD
15.10.	042	07.27 08.59	75°00´N 75°00´N	10°34´W 10°35´W	CTD
15.10.	043	10.15 14.33	75°00´N 74°59´N	09°57´W 09°54´W	CTD, HN, Jojo
15.10.	044	15.50 17.34	75°00´N 75°00´N	09°17´W 09°19´W	CTD
15.10.	045	18.51 20.29	75°00´N 75°00´N	08°38´W 08°38´W	CTD
15.10.	046	21.33 23.07	75°00´N 75°00´N	08°00´W 08°00´W	CTD
16.10.	047	00.07 01.38	75°00´N 75°00´N	07°23´W 07°22´W	CTD
16.10.	048	02.55 04.37	75°00´N 75°00´N	06°43´W 06°44´W	CTD
16.10.	049	06.05 07.51	75°00´N 75°00´N	06°04´W 06°04´W	CTD
16.10.	050	09.01 10.51	75°00´N 75°00´N	05°25´W 05°26´W	CTD
16.10.	051	12.20 14.44	75°02´N 75°03´N	04°40´W 04°37´W	Mooring OG-10 deployed
16.10.	052	15.17 18.29	75°00´N 75°00´N	04°46´W 04°49´W	Jojo, CTD

16.10. 17.10.	053	19.46 05.12	75°00´N 75°00´N	04°08´W 04°08´W	CTD, PLN, MN, BO, FLO
17.10.	054	07.31 09.58	74°53´N 74°53´N	03°57´W 03°58´W	Mooring OG-09 recovered
17.10.	055	12.03 14.15	75°03´N 75°02´N	02°55´W 03°00´W	Mooring GSM 05 recovered
17.10.	056	15.27 21.05	75°00´N 75°01´N	03°29´W 03°29´W	CTD, MN, BO
17.10. 18.10.	057	22.22 00.15	75°00´N 75°00´N	02°51´W 02°51´W	CTD
18.10.	058	01.34 03.17	75°00´N 75°00´N	02°12´W 02°12´W	CTD, HN
18.10.	059	04.40 06.34	75°00´N 75°00´N	01°34´W 01°34´W	CTD
18.10.	060	08.00 14.07	75°00´N 75°01´N	00°56´W 00°57´W	CTD, MN, Jojo
18.10.	061	15.21 17.10	75°00´N 75°00´N	00°16´W 00°15´W	CTD
18.10. 19.10.	062	18.27 04.00	75°00´N 75°00´N	00°22´E 00°21´E	CTD, MN, HN, BO, FLO
19.10.	063	05.27 07.10	75°00´N 75°00´N	01°01´E 01°02´E	CTD
19.10.	064	08.26 09.54	75°00´N 75°01´N	01°40´E 01°40´E	CTD
19.10.	065	11.06 17.04	75°00´N 75°01´N	02°18´E 02°20´E	CTD, HN, SD, Jojo
19.10.	066	18.17 19.47	75°00´N 75°00´N	02°56´E 02°56´E	CTD
19.10.	067	21.40 23.44	75°00´N 75°00´N	03°36´E 03°35´E	CTD
20.10.	068	01.09 02.45	75°00´N 75°00´N	04°14´E 04°13´E	CTD
20.10.	069	04.09 05.43	75°00´N 75°00´N	04°52´E 04°51´E	CTD
20.10.	070	06.40 08.16	75°00´N 75°00´N	05°13´E 05°11´E	CTD
20.10.	071	08.58 10.28	75°00´N 75°00´N	05°30´E 05°30´E	CTD
20.10.	072	11.16 12.45	75°00´N 75°00´N	05°51´E 05°51´E	CTD
20.10.	073	13.31 15.00	75°00´N 75°00´N	06°10´E 06°10´E	CTD
20.10.	074	15.44 17.11	75°00´N 75°01´N	06°29´E 06°30´E	CTD
20.10.	075	17.51 19.04	75°00´N 75°00´N	06°48´E 06°48´E	CTD
20.10.	076	19.46 20.56	75°00´N 75°00´N	07°08´E 07°08´E	CTD
20.10.	077	21.36 22.49	75°00´N 75°00´N	07°27´E 07°27´E	CTD
21.10.	078	00.09 01.50	75°00´N 75°00´N	08°05´E 08°05´E	CTD

21.10.	079	03.12 04.32	75°00´N 75°00´N	08°43´E 08°43´E	CTD
21.10.	080	05.50 07.13	75°00´N 75°00´N	09°22´E 09°22´E	CTD
21.10.	081	08.30 09.52	75°00´N 75°00´N	10°01´E 10°02´E	CTD
21.10.	082	11.06 12.26	75°00´N 75°01´N	10°39´E 10°39´E	CTD
21.10.	083	13.52 15.12	75°00´N 75°00´N	11°18´E 11°18´E	CTD
21.10.	084	16.39 17.54	75°00´N 75°00´N	11°56´E 11°56´E	CTD
21.10.	085	19.16 20.29	75°00´N 75°00´N	12°36´E 12°34´E	CTD
22.10.	086	06.14 07.24	75°00´N 75°00´N	13°15´E 13°15´E	CTD
22.10.	087	08.49 13.30	75°00´N 75°01´N	13°52´E 13°49´E	CTD, MN, BO
22.10.	088	14.50 15.39	75°00´N 75°00´N	14°31´E 14°31´E	CTD
22.10.	089	17.01 17.37	75°00´N 75°00´N	15°10´E 15°10´E	CTD
22.10.	090	18.56 19.15	75°00´N 75°00´N	15°50´E 15°50´E	CTD
22.10.	091	20.27 20.43	75°00´N 75°00´N	16°27´E 16°27´E	CTD
22.10.	092	21.58 22.31	75°00´N 75°00´N	17°04´E 17°05´E	CTD, MN
22.10. 23.10.	093	23.53 00.10	74°50´N 74°50´N	17°00´E 17°00´E	CTD
23.10.	094	01.29 01.39	74°40´N 74°40´N	17°00´E 17°00´E	CTD
23.10.	095	03.00 03.13	74°30´N 74°30´N	17°00´E 17°00´E	CTD
23.10.	096	04.37 04.52	74°20´N 74°20´N	17°00´E 16°59´E	CTD
23.10.	096a	08.04 08.30	74°21´N 74°22´N	18°32´E 18°31´E	CTD, MN, BO
23.10.	097	14.37 14.50	74°10´N 74°10´N	17°00´E 17°00´E	CTD
23.10.	098	16.29 16.44	73°59´N 73°59´N	16°59´E 16°59´E	CTD
23.10.	099	17.58 18.16	73°50´N 73°50´N	17°00´E 17°00´E	CTD
23.10.	100	19.40 20.00	73°40´N 73°40´N	17°00´E 16°59´E	CTD
23.10.	101	21.18 21.38	73°30´N 73°30´N	17°00´E 17°00´E	CTD
23.10.	102	22.53 23.13	73°20´N 73°20´N	17°00´E 16°59´E	CTD
24.10.	103	00.29 00.48	73°10´N 73°10´N	17°00´E 17°01´E	CTD

24.10.	104	02.07 02.26	73°00´N 73°00´N	17°00´E 17°00´E	CTD
24.10.	105	03.44 04.03	72°50´N 72°50´N	17°00´E 17°00´E	CTD
24.10.	106	05.25 05.46	72°40´N 72°40´N	17°00´E 17°00´E	CTD
24.10.	107	07.03 07.22	72°30´N 72°30´N	17°00´E 16°59´E	CTD
24.10.	108	08.40 08.58	72°20´N 72°20´N	17°00´E 17°00´E	CTD
24.10.	109	10.14 10.30	72°10´N 72°10´N	17°01´E 17°01´E	CTD
24.10.	110	11.52 12.09	72°00´N 72°00´N	17°00´E 17°00´E	CTD
24.10.	111	13.25 13.43	71°50´N 71°50´N	17°00´E 17°01´E	CTD
24.10.	112	14.57 15.11	71°40´N 71°40´N	17°00´E 17°00´E	CTD
24.10.	113	16.22 16.39	71°30´N 71°30´N	17°00´E 16°59´E	CTD
24.10.	114	18.08 18.27	71°20´N 71°20´N	17°00´E 17°00´E	CTD
24.10.	115	20.00 20.15	71°10´N 71°10´N	17°01´E 17°00´E	CTD
24.10.	116	22.00 22.28	71°00´N 71°01´N	17°00´E 17°00´E	CTD

10. Participants

Abrahamsson, Katarina	AMK
Albers. Carola	AWI
Auel, Holger	IPÖ
Berg, Jörg Stefan	SFB 313
Böhm, Joachim	HSW
Brandt, Angelika	IPÖ
Budéus, Gereon	AWI
Cisewski, Boris	AWI
Cohrs, Wolfgang	AWI
Darnall, Clark	APL
Donner, Gabriele	SFB 313
Ekdahl, Anja	AMK
Erdmann, Hilger	DWD
Gedamke, Michael	SFB 313
Gradinger, Rolf	IPÖ
Haupt, Olaf	SFB 313
Hofmann, Michael	IMK
Hollmann, Beate	AWI
Ikävalko, Eira Johanna	UNI HELSINKI
Jensen, Stefan	SFB 313
Kaleschke, Lars	AWI
Köhler, Herbert	DWD
Krause, Gunther	AWI
Krumbholz, Marita	SFB 313
Lahrmann, Uwe	HSW
Lunau, Angela	GEOMAR
Martin, Thomas	AWI
Mock, Thomas	SFB
Monk, Jürgen	AWI
Niehoff, Barbara	AWI
Plugge, Rainer	AWI
Riewesell, Christian	HSW
Ronski, Stephanie	AWI
Sackmann, Volker	AWI
Sauter, Eberhard	SFB 313
Scheltz, Annette	SFB 313
Schnack, Klaus	SFB 313
Schreiber, Detlev	HSW
Schürmann, Mathias	Aerodata
Strohscher, Birgit	AWI
Stürcken-Rodewald, Marthi	AWI
Takizawa, Takatoshi	JAMSTEC
Ufermann, Susanne	AWI
Wamser, Christian	AWI
Wanner, Susanne	GEOMAR
Wehde, Henning	AWI
Werner, Iris	IPÖ - SFB 313
Wode, Christian	IMK
Woodgate, Rebecca	AWI
Zhang, Qing	IPÖ

11 SHIP'S CREW

Captain	C. Allers
1. Officer	H. Pförtner
2. Officer	M. Rodewald
2. Officer	U. Grundmann
2. Officer	T. Hebekus
Doctor	Dr. Thoepser
Chief Engineer	D. Knoop
1st Engineer	G. Erreth
2nd Engineer	H. Schneider
2nd Engineer	O. Ziemann
Electrician	G. Schuster
Electron Engineer	U. Lembke
Electron Engineer	H. Muhle
Electron Engineer	J. Roschinsky
Electron Engineer	A. Greitemann-Hackl
Radio Officer	A. Hecht
Radio Officer	W. Kriemann
Mot.Man	E. Arias Iglesias
Mot.Man	M. Ipsen
Mot.Man	U. Husung
Mot.Man	E. Heurich
Mot.Man	G. Dufner
Carpenter	A. Brunotte
Store keeper	K. Müller
Boatswain	R. Zulauf
Seaman	B. Iglesias Bermudez
Seaman	J. Soage Curra
Seaman	S. Pousada Martinez
Seaman	L. Gil Iglesias
Seaman	E. Arias Iglesias
Seaman	K. Bindernagel
Seaman	M. Winkler
Seaman	H. Voges
Cook	H. Schuster
Cook Mate	H. Hüneke
Cook Mate	G. Rickert
1. Steward	H. Vollmeyer
Stewardess/Nurse	S. Hoffmann
Steward/ess	NN
Steward/ess	E. Golose
Steward/ess	C. L. Wu
2. Steward	J. M. Tu
2. Steward	K. F. Mui
Laundry Man	K. Yu

12. PARTICIPATING INSTITUTIONS

AWI	Alfred-Wegener-Institut für Polar- und Meeresforschung Columbusstraße 27568 Bremerhaven
Aerodata	Aerodata Flugmeßtechnik GmbH Rebenring 33 38106 Braunschweig
DWD	Deutscher Wetterdienst Hamburg Seewetteramt Bernhard-Nocht-Straße 76 20359 Hamburg
GEOMAR	GEOMAR Forschungszentrum für marine Geowissenschaften Universität Kiel Wischhofstraße 1-3 24148 Kiel
HSW	Helicopter-Service Wasserthal GmbH Kätnerweg 43 22393 Hamburg
IfMHH	Institut für Meereskunde Universität Hamburg Troplowitzstraße 7 22529 Hamburg
IMK	Institut für Meteorologie und Klimatologie Universität Hannover Herrenhäuser Straße 2 30419 Hannover
IPÖ	Institut für Polarökologie Universität Kiel Wischhofstraße 1-3, Gebäude 12 24184 Kiel
SFB 313	Universität Kiel Sonderforschungsbereich 313 Olshausenstraße 40 24118 Kiel
UNI	University of Helsinki Hydrobiol. Laboratory P.O. Box 4 FIN-00014 Helsinki

JAMSTEC	Japan Marine Science and Technology Center JAMSTEC Headquarters 2-15 Natsushima-Cho YOKOSUKA 237 JAPAN
NPI	Norwegian Polar Institute Dept. of Analyt. and Marine Chemistry Postboks 5072, Majorstua N-0301 Oslo
APL	Polar Science Center Applied Physics Laboratory University of Washington HN-10 Seattle, WA 98195
AMK	Chalmers University of Technology and University of Göteborg Analytical and Marine Chemistry S-412 96 Göteborg
SIO	Second Institute of Oceanography State Oceanic Administration P.O.Box 1207 Hangzhou, Zhejiang, 310012

13. Moorings serviced during "Polarstern" cruise ARK XI/2

Name	Latitude /degrees	Longitude /degrees	Depth /m (corr/uncorr)	Instruments
RECOVERED				
Fahrbach, AWI				
AWI 410-2	74 57.7N	12 58.7W	413 / 418	2 Current Meters 1 Sediment Trap 1 ULS
AWI 411-2	74 59.8N	12 31.9W	985 / 1002	3 Current Meters 1 ULS
AWI 412-4	74 57.5N	11 36.9W	2240 / 2283	4 Current Meters 1 ULS
AWI 413-4	74 59.5N	10 37.1W	3022 / 3073	4 Current Meters 3 Sediment Traps 1 Transmissometer 1 ULS
AWI 414-4	74 52.6N	7 45.6W	3342 / 3400	4 Current Meters 1 ULS
Meincke, IfM HH				
M1-94	79 0.2N	6 1.6W	542 / 547	2 Current Meters 1 ULS
GSM-05	75 2.3N	2 54.9W	3616 / 3678	1 Current Meter 5 Seacats 1 Thermistor Chain 1 ADCP
Aagaard, APL				
FWA-2 '94	78 59.3N	4 40.7W	1504 / 1534	3 Current Meters 2 Seacats 1 ULS
SFB, Kiel				
OG-9	74 52.9N	3 56.9W	/ 3550	2 Sediment Traps
DEPLOYED				
Aagaard, APL				
FWA-1 '95	78 57.1N	3 22.3W	2298 / 2339	2 Current Meters 1 Seacat 1 ULS
FWA-2 '95	78 59.3N	4 40.6W	1503 / 1534	2 Current Meters 1 Seacat 1 ULS
SFB, Kiel				
OG-10	75 3.4N	4 35.7W	/ 3650	3 Current Meters 3 Sediment Traps