

**Die Expedition ARKTIS VII  
mit FS „Polarstern“ 1990  
Bericht vom Fahrtabschnitt ARK VII/2**

**The Expedition ARKTIS VII  
of RV "Polarstern" in 1990  
Report of Leg ARK VII/2**

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**Herausgegeben von Gunther Krause  
mit Beiträgen der Fahrtteilnehmer**

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**Fahrtabschnitt ARK VII/2 Tromsö - Tromsö**  
**10.07.90 - 14.08.90**  
(G. Krause, Chief Scientist)

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## **Cruise leg ARK VII/2 Tromsø - Tromsø 10.07.90 - 14.08.90**

(G. Krause, Chief Scientist)

### **1. Ship's operations**

"Polarstern" left the bunker pier at Tromsø in the evening of July 10, and returned to Tromsø as planned on August 14. During most of the cruise we had calm but foggy weather, which made the ship-based work much easier to carry out. Travelling through ice in thick fog placed however a heavy strain on the ship's officers, and somewhat hindered the use of the helicopter for the ice work. Without the excellent ice distribution maps of the Canadian remote sensing group from York University in Toronto it is unlikely that we would have been able to reach the Northeast Greenland Polynya. The cruise track is plotted in Figure 1.

### **2. Work achieved**

Much of the oceanographic, chemical and biological work carried out during this leg continued work which had begun on the MIZEX expeditions in 1983 and 1984 and continued with the arctic cruises in 1987 and 1989. As part of the international Greenland Sea Project we continued and concluded the seasonal studies of the physical, chemical and biological situation in the Greenland Sea.

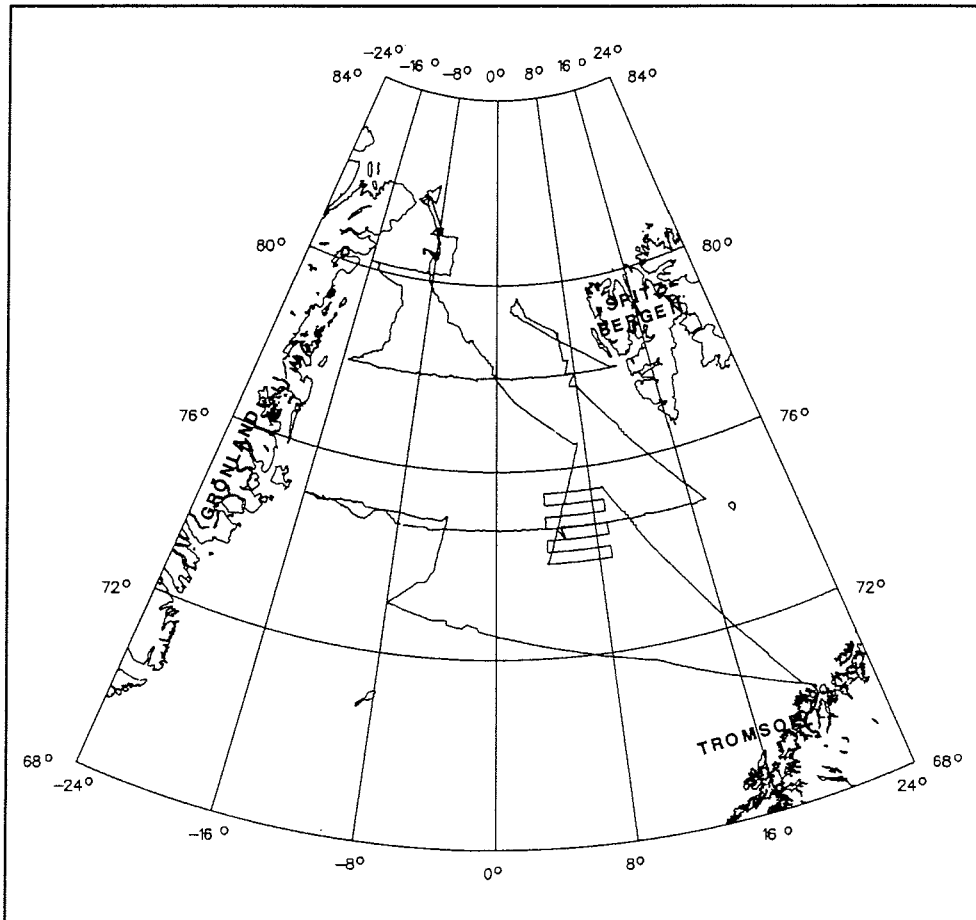
As in the previous year we performed hydrographic traverses at 74°45 'N and 78°N with stations every 10 nm. In the upper 200 m of the water column we took closely-spaced samples for nutrient studies, chlorophyll determination, and phyto- and zooplankton investigations whilst at the same time measuring temperature, salinity, light intensity and chlorophyll fluorescence. Following this shallow sampling, a CTD profile was measured to the seafloor using a bathysonde. As this bathysonde was only used in conjunction with a rosette sampler during calibration it was possible to work very quickly - during 75 working hours the winch processed 410 km of cable, which gives an average winding speed of 1.5 m/s. The efficiency of this CTD work contributed greatly to the success of the expedition. Multinets and Bongo nets were used for plankton sampling.

Along with the routine station work, studies of the secondary production and of lipid metabolism in the dominant Greenland Sea calanoid copepods were performed. A gas chromatograph was employed for this work on board.

The cruise also saw, despite often difficult weather conditions (fog, ice) the recovery and in some cases further deployment of 7 moorings which had been set out in 1989 equipped with current meters, sediment traps, ADCP, and one upwards-looking sonar for ice-thickness measurements.

A further important project on this cruise was the study of benthos on the Greenland Shelf (Belgica Bank), where zooplankton and pelagic fish fauna were also studied. The work was carried out using RMT, Bongo net, Multinet, Agassiz-Trawl, a large bottom trawl and an underwater camera.

Figure 1



Fahrtroute der Expedition ARK VII/2, 10.07. - 14.08.1990  
Ship's track of expedition ARK VII/2

Due to good ice conditions we completed our planned work so quickly that we managed to pass 79°N and entered the Greenland Polynya (Northeast Water) where we carried out a pilot study for the 1993 International Arctic Polynya Project (IAPP). We made oceanographic, chemical and planktonic profiles perpendicular to the Greenland coast along 80°, 81° and 82°N with stations every 10 nm. In order to study the bottom fauna on the shelf and continental slope we deployed the underwater camera, and Agassiz trawl at 18 stations, and the bottom trawl at 9 stations.

For a high resolution XBT-study of the Arctic Front frontal zone over a 200 x 200 km area we met, as planned, the "Planet" and "Valdivia".

We continued studies of the microwave emissions of water, ice and atmosphere. Included in this work were also flights with a line-scan camera to determine the concentrations of ice and melt pools. Fog greatly hindered this work, and only through the dedicated work of the helicopter team it was finally possible to collect some useful data.

Collection of ice cores for the determination of the sediment content of the ice occurred generally in parallel with the hydrographical measurements. By using the helicopter it was also possible to collect samples from Greenland icebergs. In total we recovered 75 m of ice core (750 kg ice) and 69 surface sediment samples.

A further geological aim was to dredge samples from the Knipovich and Molloy Ridges. We recovered basalt from the southern Knipovich Ridge and serpentinite/peridotite from three stations on the Molloy Ridge.

For the first time on an arctic "Polarstern" expedition we measured biological sulphur compounds (DMS, COS, CS<sub>2</sub>) in both the atmosphere and sea water, in order to determine their fluxes through the sea surface. The tropospheric reaction products of DMS (sulphate, METHANSULFONSÄURE) were collected on filters. Using a laser fluorescence method the concentrations of nitric acid and ammonia were constantly measured above the bridge, whilst samples for the determination of ammonium nitrate were also collected.

Throughout the cruise sea birds were observed and counted. Finally, a part of a film on "Anthology of Water" was completed during cruising in the ice and on ice stations.

### **3. Fahrtverlauf**

"Polarstern" legte am 10. Juli abends von der Bunkerpier in Tromsø ab und kehrte planmäßig am 14. August in den Ausgangshafen zurück. Auf der gesamten Reise herrschte ruhiges Nebelwetter vor, das die schiffsgebundenen Arbeiten erleichterte. Das Fahren im Eis bei Dauernebel bedeutete dagegen eine große Belastung für die Nautiker des Schiffes und erschwerte den Einsatz des Hubschraubers für die Arbeiten im Eis. Ohne die ausgezeichneten Eisverteilungskarten der beteiligten kanadischen Fernerkundungsgruppe der York Universität in Toronto wäre es wohl kaum gelungen, bis in die Nordostgrönland-Polynya vorzudringen. Die gesamte Fahrtroute ist in Abbildung 1 dargestellt.

### **4. Durchgeführte Arbeiten**

Ein Großteil der ozeanographischen, chemischen und biologischen Aktivitäten dieses Fahrtabschnitts führten Arbeiten weiter, die mit den Expeditionen MIZEX 1983, 1984 begannen und auf den Arktisreisen in den Jahren 1987 und 1989 weitergeführt wurden. Als Beitrag zum internationalen Grönlandsee-Projekt beinhalteten sie die Fortsetzung und den vorläufigen Abschluß der saisonalen Erfassung des physikalischen, chemischen und biologischen Zustands der Grönlandsee.

Dazu wurden wie im Vorjahr hydrographische Schnitte auf 74°45'N und auf 78°N mit 10 m Stationsabstand bearbeitet. Auf den oberen 200 m wurden engabständig Wasserproben für nährstoffchemische Untersuchungen, Chlorophyllbestimmungen und Phyto- und Zooplanktonproben gewonnen sowie Profile der Temperatur, des Salzgehalts, der Lichtintensität und der Chlorophyll-Fluoreszenz gemessen. Danach wurde jeweils ein CTD-Profil mit einer Bathysonde bis zum Meeresboden aufgenommen. Da die Sonde nur gelegentlich für Kalibrierungszwecke mit einer Rosette eingesetzt wurde, konnte dabei sehr schnell gearbeitet werden. Die ausgezeichnet funktionierende Winde zeigte beim Abschluß der Arbeiten, daß 410 km Draht bei 75 Betriebsstunden einschließlich der Umrüstzeiten bewegt wurden, was einer Durchschnittsgeschwindigkeit von 1.5 m/s entspricht. Dieser Umstand hat wesentlich zum Erfolg der Expedition beigetragen. Für Planktonfänge auf diesen Schnitten kamen Bongo- und Multinetz zum Einsatz.

Neben den routinemäßigen Stationsarbeiten wurden Untersuchungen der Sekundärproduktion und zum Lipidmetabolismus der dominanten calanoiden Copepoden der Grönlandsee durchgeführt. Dazu wurde direkt an Bord die Zusammensetzung der Lipide mit Hilfe eines Gaschromatographen untersucht.

Das Programm sah weiterhin die Aufnahme und teilweise Wiederauslegung von 7 Verankerungsketten vor, die 1989 ausgelegt wurden und Strommesser, Sedimentfallen, ADCP-Geräte und ein aufwärtsschauendes Echolot (ULS) für Eisdickenmessungen enthielten. Unter teils schwierigen Bedingungen (Nebel, Eis) wurden alle Geräte geborgen und einige erneut verankert.

Einen weiteren Schwerpunkt der Reise bildeten benthologische Arbeiten auf dem Grönlandschelf (Belgica-Bank), wo auch Untersuchungen des Zooplanktons und der pelagischen Fischfauna durchgeführt wurden. Die Arbeiten erfolgten mit RMT, Bongo- und Multinetz, Agassiz-Trawl, dem großen Grundschieppnetz und einer Unterwasserkamera.

Begünstigt durch geringe Eiskonzentrationen konnten die vorgesehenen Arbeiten so schnell erledigt werden, daß wir über 79°N hinaus die Grönland-Polynya (Northeast Water Polynya) erreichten und dort in offenem Wasser eine Pilotstudie zum Internationalen Arktischen Polynya-Projekt (IAPP) im Jahr 1993 durchführen konnten. Dabei wurden bei einem Stationsabstand von 10sm die ozeanographischen, chemischen und planktologischen Arbeiten auf Schnitten senkrecht zur Küste auf 80°N, 81°N bei 82°N weitergeführt. Für die Untersuchung der Bodenfauna auf dem Schelf und dem Kontinentalabhang wurden auf 18 Stationen die Unterwasserkamera, das Agassiz Trawl und 9 mal das Grundschieppnetz eingesetzt.

An der hochauflösenden XBT-Vermessung der Frontalzone der Arktikfront in einem etwa 200 x 200 km großen Areal nahmen außer "Polarstern", wie geplant, die Forschungsschiffe "Planet" und "Valdivia" teil.

Fortgeführt wurden ferner Studien über die Mikrowelleneigenschaften des Wassers, des Eises und der Atmosphäre. Dazu gehörten auch Vermessungsflüge mit einer Line-scan-Kamera zur Ermittlung der Konzentration des Eises und der Schmelztümpel. Diese Arbeiten wurden durch Nebel stark beeinträchtigt. Nur durch den flexiblen und engagierten Einsatz der Hubschraubermannschaft konnte dennoch ein zufriedenstellendes Beobachtungsmaterial gewonnen werden.

Die Gewinnung von Bohrkernen zur Ermittlung von Sedimenteinschlüssen im Eis fand hauptsächlich parallel zu den hydrographischen Messungen statt. Durch Hubschraubereinsätze kamen zusätzliche Proben von grönländischen Eisbergen hinzu. Insgesamt betrug die Ausbeute 75m Bohrkern (750kg Eis) und 69 Sedimentproben von der Oberfläche.



Ein weiteres geologisches Programm hatte das Ziel, mit einer Dredge Gesteinsproben aus dem Knipovich-Rücken und dem Molloy Deep zu gewinnen. Aus dem Südteil des Rückens wurden neben viel Sediment alterierte Basalte und im Molloy Deep an 3 Stellen Serpentin und Peridotit gefunden.

Erstmals auf einer Arktisreise der "Polarstern" wurden biogene Schwefelverbindungen (DMS, COS, CS<sub>2</sub>) in der Atmosphäre und parallel dazu im Seewasser gemessen, um den Fluß dieser Stoffe durch die Meeresoberfläche zu bestimmen. Als troposphärische Reaktionsprodukte von DMS wurden Sulfat und Methansulfonsäure auf Filtern angereichert. Mit der Laserphotolyse-Fragmentfluoreszenz-Methode wurden auf dem Peildeck kontinuierlich die Konzentrationen von Salpetersäure und Ammoniak gemessen sowie Dauerproben für die Bestimmung von Ammoniumnitrat gewonnen. Während der gesamten Reise wurden Seevögel beobachtet und gezählt. Schließlich wurde ein Teil eines Films über die "Anthologie des Wassers" während Fahrten im Eis und auf den Eistationen gedreht.

## 5. Weather conditions

Fog was the prevailing element of the weather during this cruise to the Greenland Sea. About one third of the synoptic observations of the "Polarstern" Weather Station reported visibilities less than 1000 m.

The meteorological situation which caused this muddy weather consisted mostly in an "omega" shaped isobaric pattern: an extensive northwest atlantic low, high pressure over the British Isles with a ridge directed towards Spitsbergen (Svalbord), and an additional low over northeastern Europe.

The first two pressure systems led a southerly airstream into the "Polarstern" research area. Nearly two thirds of the wind observations during the voyage showed southerly components. Over ice or cold water these warm and moist airmasses from lower latitudes caused often relatively shallow but dense fog.

This stable "omega" situation was seldom interrupted. The first and almost only remarkable change of weather conditions took place on August 4/ 5, when a complex low over North Scandinavia / Svalbord/ Novaja Semlja brought northeasterly winds. For a short period with 33 kts almost Bft 8 was observed near the Greenland coast. That was the maximum wind speed during the cruise which usually was accompanied by wind forces about Bft 4.

## 6. Reports of the working groups

### 6.1 Physical Oceanography (H. Abelmann, J. Brunßen, G. Budeus, S. Catewicz, W. Dimmler, G. Hoeppe, P. Holloway, R. Plugge, I. Tandetzki and H. Weidemann)

The physical measurements during ARK VII/2 are related to the GSP-Project "The Seasonal Cycle and Annual Variability of the Arctic Front in the Greenland Sea". The aims of this project are described as:

- Examination of the seasonal and annual variability of the properties of the front
- Determination of the persistence and structure of the intrusions of Atlantic water into the Greenland Sea gyre and to understand its role in the formation of Greenland Sea deep-water

- Study of the convergence at the front leading to increasing gradients of properties
- Investigation of the hydrostatic stability in the vicinity of the frontal zone as well as the role of narrow jetstreams along the front.

In some aspects, however, the measurements during ARK VII/2 exceeded the stated objects mentioned above. To determine the general circulation in the Greenland Sea, into which the two frontal systems of the Polar and the Arctic Front are embedded, an East-West-section along 74°45' N has been carried out during ARK VII/2. This section ranges from Bear Island to the Greenland Shelf, covers the two frontal zones, and therefore their dynamical properties can be compared under similar summer conditions. CTD-stations with a spacing of 10 nm and current measurements with a Doppler current meter (ADCP) will be used for water mass analysis and determinations of the geostrophic and ageostrophic transport components. Convection depths of the last winter can be determined and the amount of relatively fresh water of EGC origin in the surface layer of the Greenland Sea can be estimated. Furthermore, an additional transect has been carried out across Fram Strait (78°N) with the same programme to determine the transport and the modification of the properties of the water masses on their way.

The CTD measurements were performed with a "Bathysonde LS" of Salzgitter Elektronik, Kiel with a sampling rate of 32 Hz. Normally the downcast measurements extended to the bottom. Lowering speed was 1 m/s for the upper 500 m and up to 2 m/s below that depth. The instrument was raised with a speed of 3 m/s. The fast handling of the CTD enabled us to work all sections with a resolution of 10 nm.

Four time intervals had been chosen for CTD calibration, station 113 to 116, 143 to 146, 171 to 174 and 210 to 219. To avoid miscalibration by vertical temperature gradients, calibration points and bottle samples lay generally below 1000 m depth. The temperature calibration showed an offset of -0.007 K for the whole cruise. Conductivity was compared to Guild Line Autosal measurements of the water samples and shows several inexplicable jumps of the CTD's sensor. As a consequence, calibration of conductivity has not yet been completed. Of special interest is an unusual additional sensor of the CTD: a fast temperature sensor with a time constant of only 4 ms which is supposed to reduce spiking considerably. The manufacturer Salzgitter Elektronik gives no calibration for this, as the sensor is still a prototype version. Since it is unprotected it is sensitive to pressure. Our attempts of calibration seemed to be quite successful until we discovered another cross-sensitivity to the lowering speed of the CTD. This effect is very likely due to the different bending of the thin and unprotected platin wire with different lowering speeds.

On four stations in Fram Strait (station 171 - 174) all 6 bottles with reference mercury thermometers have been released at approximately 3000 m depth to allow for intercomparison. The thermometers by Gohla, Kiel have a range from - 2.0 to + 2.0°C with a scaling of 1/100 °C. Only one older model with a range from - 2.0 to + 3.0°C and a scale division of 1/50 °C was used. All thermometers compare exceptionally well in a range of +/-2/1000 °C.

A process study on cross frontal transport by means of an XBT-survey formed another leg of ARK VII/2. Three ships took part: "Polarstern", "Valdivia", "Planet". "Valdivia" and "Polarstern" carried out XBT measurements in a box with 14 East-West-transects (length: 200 km, distance between sections: 7.5 km). To enhance the accuracy of the temperature measurement by the XBTs each probe has been calibrated on a single point before launching. A calibration bath with an external pump for stirring and 3 places for a temperature pre-adjustment of the XBTs has been newly designed and used for the first time. A digital thermometer by Heraeus (accuracy 0.02°C) has been used as the reference. Correction of the XBT readings was automated by a PC program. The corrections of a number of XBTs is shown in Figure 2. Most - but not all - of the XBTs fall in the guaranteed of  $\pm 0.1^\circ\text{C}$ . The

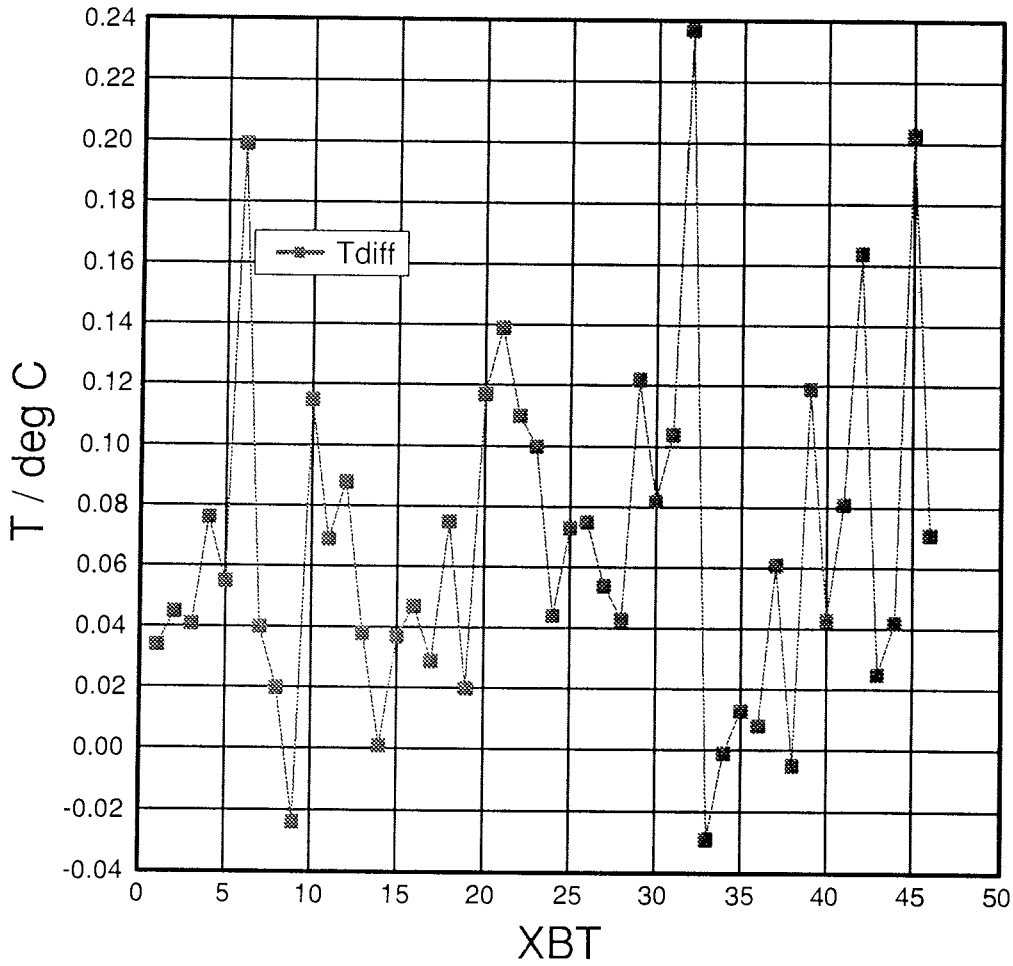
arrangement was most helpful in sorting out defective probes and as a consequence only 6 measurements out of approximately 250 launches had to be repeated.

ADCP measurements in the ice were only possible on stations, outside the ice the instrument worked continuously. To overcome the deliberate degradation of the GPS signal, a station for differential receiving was erected at Ny-Alesund, Svalbard. The processing will take time, especially as there appeared software problems with the postprocessing programs. The Codar working group (here K. W. Gurgel et al.), University Hamburg, Institut für Meereskunde, helps with the postprocessing what is acknowledged gratefully. 5 channel Trimble receivers have been used on "Polarstern" and "Valdivia", a 10 channel receiver at Ny-Alesund. Several calibrations of the ADCP, either with bottom tracking or by a zig zag route of the ship, have been performed.

The AWI-designed COMED (**C**ontinuously **M**easuring **D**evice) measured continuously temperature, salinity, chlorophyll fluorescence, Mie backscattering and Gelbstoff-fluorescence on the ship's track. For temperature and salinity measurements a CTD by ME, Trappenkamp has been used, for optical parameters sensors by Optik-Mikroelektronik Dr. Haardt, Klein-Barkau. Nitrate and silicate (Dr. G. Kattner, AWI) were recorded with a time lag of 2 to 4 minutes. The sampling period was adjusted to 100 ms and the time interval for averaging was 10 sec throughout the cruise for all parameters. The COMED hardware and software were used for the first time on a cruise and worked faultlessly. The software is based on ASYST and was designed by A. Bochert, AWI. Hardware is PC based.

A first quicklook of uncorrected temperature data for the two transects on 74°45'N and 78°N is shown in Figures 3 and 4. On the southern transect the warm water of Atlantic origin (east of station 134) and the associated front can be easily identified. The -0.5°C isotherm submerges for several 10 km under colder water in the central Greenland Basin at the Arctic Front. The coldest waters are found in intermediate depths (<250 m) in the central basin and are neighbored by the Return Atlantic Current to the west of it. This is centered around station 105, where it is submerged under the Polar Front, and its temperatures are up to 2.5°C there. The Polar Water again shows very low temperatures. In contrast, the Fram Strait section exhibits waters warmer than 0°C in the upper 400 - 500 m everywhere in the deeper parts of the strait. We expected a movement with westward components of the Atlantic influenced waters there to be measured with the ADCP. It is evident that warmer waters generally underlie the Polar Water except in very shallow depths, but including the stations in the Belgica trough.

Figure 2:



Temperaturabweichungen von XBT-Geräten gegenüber dem Referenzthermometer  
in einem Eichbad

Temperature deviations of XBT probes with respect to the reference thermometer  
in a calibration bath

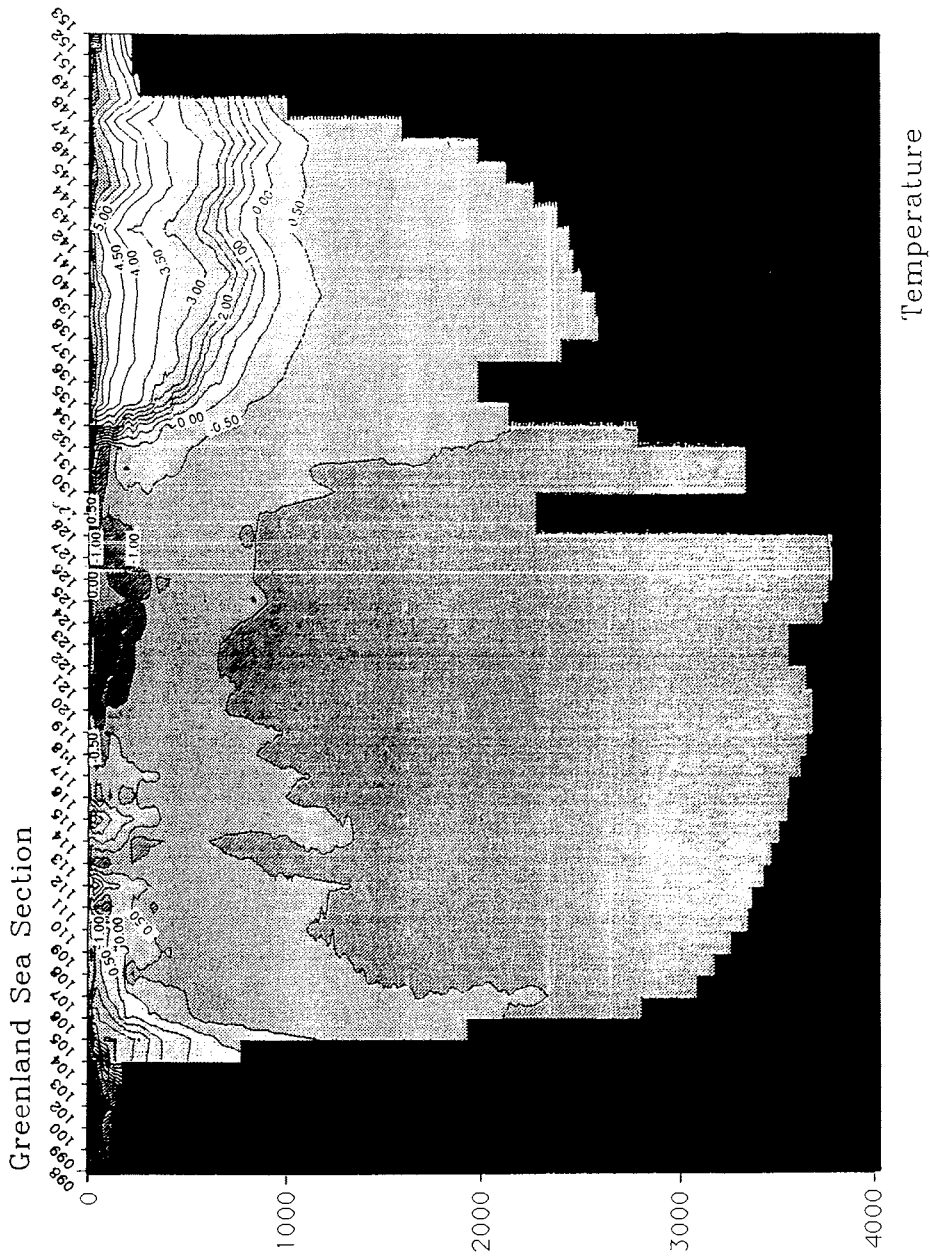


Figure 3: Temperaturschnitt durch die Grönlandsee bei 74°45'N. Die Entfernung zwischen den Stationen beträgt 10 sm.  
 Temperature section through the Greenlandsee at 75°45'N. Distance between stations is 10 nm.

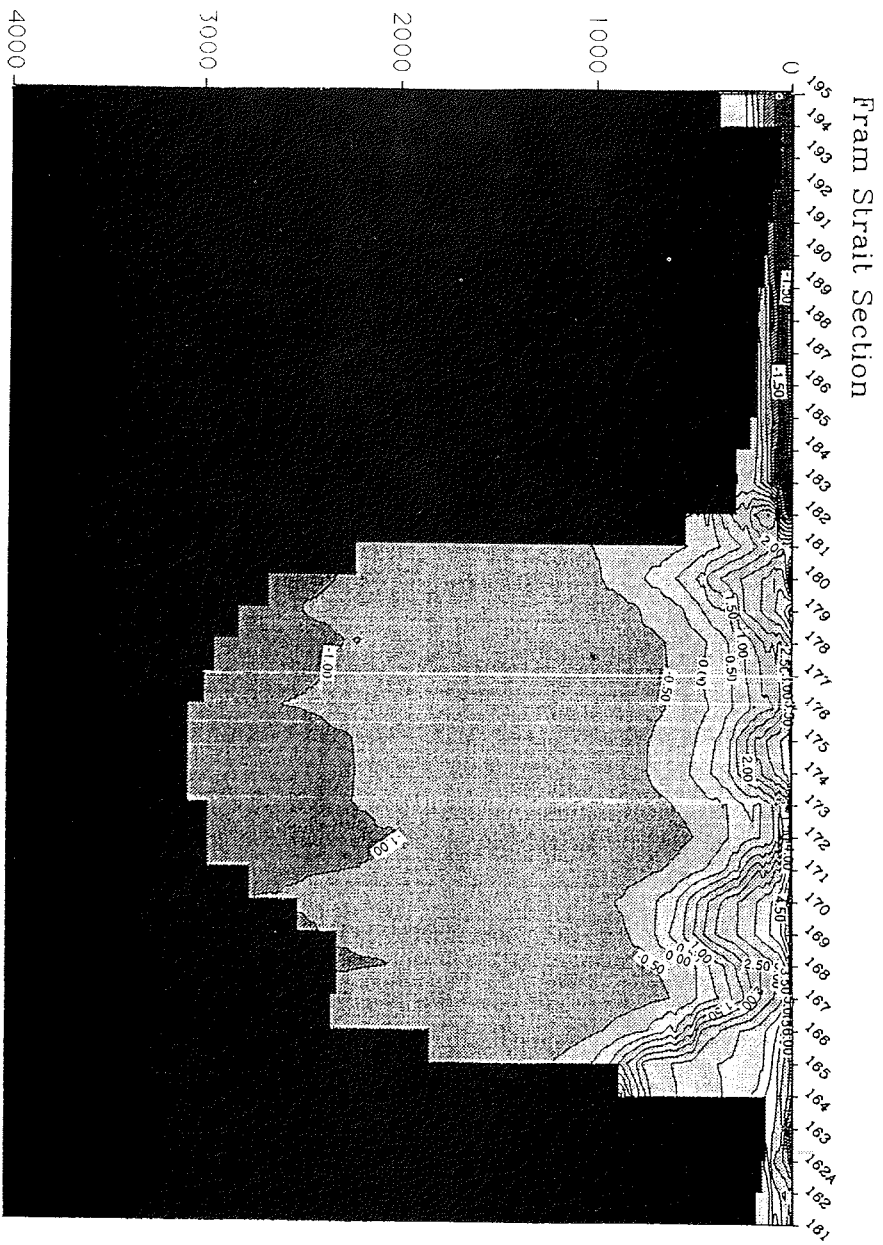


Figure 4: Temperaturschnitt durch die Framstraße bei 78°N. Die Entfernung zwischen den Stationen beträgt 10 sm.  
 Temperature section through Fram Strait at 78°N. Distance between stations 10 nm.

**6.2 Marine chemistry** (Martin Graeve, Gerhard Kattner, Andreas Michel, Andrea Murken, Christa Pohl, Martha Stürken, Urban Tillmann)

**Nutrients**

The determination of nutrients is closely connected with the biological and physical studies. Phytoplankton growth is dependent on light intensity, stratification of the water column and nutrient supply. Thus, nutrients play an important role controlling phytoplankton blooms which can be limited by the depletion of nutrients. On the other hand, e.g. ammonia is produced by zooplankton and bacterial activities and can thus further support the phytoplankton growth.

Furthermore nutrients may serve as an additional tracer for water mass identification. Thus major gradients are often found in the same layers as the thermo- and pycnocline. The different water masses of the Greenland Sea have characteristic nutrient concentrations, e.g. the Polar Water has higher concentrations of silicate than the Atlantic Water.

During the cruise the upper 200 m of the water column were extensively studied. At all CTD stations samples were taken with the CTD sampler system generally at depth of 0, 5, 10, 20, 30, 40, 50, 60, 80, 100, 150, 200 m. Nitrate, nitrite, ammonia, silicate and phosphate were determined with an autoanalyser system. In 10 nm distances at 53 stations nutrients were measured on the Greenland Sea transect along 74°45' N. On the Fram Strait transect along 78° N 36 stations were performed and 21 stations in the North East Water Polynya.

Additional nitrate and silicate were determined continuously at about 7 m depth throughout the cruise. The data were monitored together with the data from the continuously measuring CTD probe in the hydrographic well and stored in the COMED system.

A first interpretation of the results shows that the surface waters of wide areas of the Greenland Sea are reduced in nutrients during the summer season especially in the northern parts where nitrate and partly also silicate were totally depleted. Nitrate was only found in higher concentrations in the Atlantic Water west of the Arctic front. With the continuous recordings of nitrate and silicate an estimation of the nutrient distribution in the surface layer of the Greenland Sea will be possible.

Due to the high silicate concentrations in the Polar water the frontal zones could be clearly distinguished. In the Greenland Sea Polar water was found much further eastwards in the surface layer than in the year before, producing higher silicate concentrations. Along the Fram Strait transect the Polar front occurs between two stations shown by a strong gradient in silicate down to more than 200 m depth. In the Polar water the upper halocline Arctic water flowing out through Fram Strait could be very well detected by the high silicate concentrations which are, with up to 25  $\mu\text{mol/l}$ , more than twice as high as in the surrounding Polar water.

## Phytoplankton

At most of the stations phytoplankton samples were taken for a qualitative analysis with the small plankton net (20 µm mesh size). From these samples the phytoplankton composition was determined on board for a first overview. Additional samples were taken at 0 and 20 m depth from the CTD sampler. These samples will be used later for quantitative phytoplankton analyses by Utermöhl counting.

10 dominant phytoplankton species were isolated from the Greenland Sea water. The cultures were used for feeding experiments with the dominant calanoid zooplankton of the Greenland Sea and for the analysis of their fatty acid composition.

Additionally the diatom *Thalassiosira antarctica* was cultured in nutrient enriched filtered sea water containing C-14 bicarbonate. The cells were grown up for three days in order to reach the isotopic equilibration in the cells. The cultures were used for the lipid studies.

In the Polar water of the Greenland Sea transect diatoms and special ice diatoms were found whereas the central Greenland Sea gyre was dominated by heterotrophic dinoflagellates and ciliates. The Atlantic water reflects a late phytoplankton bloom with considerable amounts of fecal pellets, which is in good agreement with a large number of *Calanus finmarchicus*. The phytoplankton distribution of the Fram Strait transect was similar to those of the Greenland Sea transect but the phytoplankton was in a slightly earlier status because here in the Arctic water diatoms were still found beside the dominating heterotrophic microzooplankton. In the North East Water Polynya diatoms, flagellates and a small proportion of ciliates were found. Further north again typical ice diatoms occurred.

## Lipids

The phytoplankton is the fundamental food for the the major calanoid copepods of the Greenland Sea. The fatty acid composition of the lipids may serve as a food chain marker, because the fatty acids of the phytoplankton can be incorporated unchanged into the zooplankton lipids. Therefore it is possible to obtain more information about the energy flux between phytoplankton and zooplankton. At every second station in the frontal zones and at some stations in the Greenland Sea gyre samples were taken with the bongo net. *Calanus hyperboreus*, *C. finmarchicus* and *C. glacialis* were sorted out to analyse the spatial fatty acid and alcohol composition. Additionally 41 samples from 0 and 20 m depth were filtered through glass-fibre filters for the fatty acid analysis of the particulate material to obtain information about the food regime available for the zooplankton. Selected zooplankton were used for cultivation experiments. They were fed with phytoplankton cultures of diatoms, dinoflagellates and green flagellates, especially *Thalassiosira antarctica*, *Amphidinium* sp. and *Dunaliella tertiolecta*. The fatty acid and alcohol composition of the zooplankton organisms and phytoplankton were analysed on board after different periods of grazing time.

Further experiments to obtain information about the turnover of lipids were performed with *Thalassiosira antarctica* as food which was grown in C-14-containing seawater. The incorporation of C-14 into the zooplankton and their lipid components will be measured later.

The knowledge about the physiological adaption of benthic organisms is relatively scarce. Therefore 30 samples of different species were collected in cooperation with the IPÖ colleagues. The detailed lipid analysis of these samples will provide food web connections between the pelagic and the benthos and what kind of lipids are used for the energy storage.



About 90 gas chromatographic analyses were carried out for the determination of the fatty acid and alcohol composition of natural zooplankton and phytoplankton samples. The comparison of both showed a good agreement in their lipid compositions. Detailed results will be given after exact data calculation.

#### Transport of trace metals by water and plankton

On this cruise 98 surface water samples were taken on the two main transects through the Greenland Sea and the Fram strait with the Mercos sampler to supplement the data set from ARK VII/3-4.

Also water samples were taken out of the rosette on 5 deep sea stations. The concentration of all water samples were carried out by liquid extraction in a clean room container on board of "Polarstern". Measurements for Cd, Pb, Cu, Ni, Zn, Co and Fe will be carried out by AAS in the AWI.

In addition to the surface water samples also Zooplankton organisms such as *Calanus hyperboreus* and *Calanus finmarchicus* were collected by bongo net and Multinet (Biology Group) at each station, separated and directly deep frozen for the trace metal analysis in the AWI.

### **6.3 Distribution of Seabirds and Marine Mammals (Jacques Tahon and Chris Jacobson)**

#### Programmes

Under the leadership of Prof. Dr. Claude R. Joiris (V.U.B.), several members of a team of ornithologists obtained knowledge on the distribution and abundance of the seabird species (+/-20) living in the North East Atlantic, in order to assess their ecological role in the different water masses. The main aim of our research on board "Polarstern" ARK VII/2 is to supplement data to those already obtained during similar cruises in 1980 (VI), '85 (VII & VIII), '88 (VI & VII) and '89 (VII) in the Norwegian and Greenland Seas. A second aim is to check and improve the reliability of the watching techniques during critical conditions (ever changing mist density, rough seas, fishing activities,...) in order to fix the limits of "observability" and eventually establish rules allowing us to discard results obtained in sublimit conditions. Special attention is paid to "Polarstern" for "attracting" the different bird species, either when the vessel moves or when she stops for a relatively long time.

#### Collection of Data

Three days before returning to Tromso, 378 standard half hour periods of observations have been performed from the bridge (17 m a.s.l.) in comfortable watching conditions through a 180 degree angle from port to starboard as far as one can see. Furthermore, 68 non-standard periods of about one hour were observed at station stops, where bird counts were made at about 5, 15, 30 and 60 minutes after "Polarstern" stopped while achieving other programmes of scientific teams. These data were collected to increase our understanding of the problem of the "followers", that is, birds that are known to follow vessels during long periods.

## Results

To give here a rough introduction of our results and independently of more fundamental and sophisticated analysis which will be conducted later on, the lists of the observed species are presented in their systematic order in Table 1. A column indicates, for each species, the number of standard half hour periods (SHHP) where at least one contact (observation) was noted amongst the total number of SHHP of observations. Similarly for the marine mammals (whales, seals and polar bears) where there is an additional column for each species for the total number of observed individuals. Comments to Table 1 are in Appendix A.

TABLE 1: OBSERVATIONS OF SPECIES DURING POLARSTERN VII/2 GREENLAND SEA CRUISE

	Number of SHHP with contact	% of Total SHHP
BIRDS		
<i>FULMARIUS GLACIALIS</i> (Dark) (FULMAR Dark)	188	49.2
<i>FULMARIUS GLACIALIS</i> (Light) (FULMAR Light)	315	83.3
<i>SULA BASSANA</i> (GANNET)	1	0.3
<i>SOMATERIA MOLLISSIMA</i> (EIDER)	1	0.3
<i>STERCORARIUS SKUA</i> (GREAT SKUA)	12	3.2
<i>STERCORARIUS PARASITICUS</i> (ARCTIC SKUA)	31	8.1
<i>STERCORARIUS LONGICAUDUS</i> (LONG-TAILED SKUA)	17	4.5
<i>STERCORARIUS POMARINUS</i> (POMARINE SKUA)	15	4.0
<i>PAGOPHILA EBURNEA</i> (IVORY GULL)	29	7.7
<i>LARUS HYPERBOREUS</i> (GLAUCOUS GULL)	20	5.3
<i>LARUS GLAUCCOIDES</i> (ICELAND GULL)	0	0.0
<i>XEMA SABINI</i> (SABINE'S GULL)	6	1.6
<i>RHODOSTETHIA ROSEA</i> (ROSS'S GULL)	0	0.0
<i>RISSA TRIDACTYLA</i> (KITTIWAKE)	160	31.9
<i>STERNA PARADISEA</i> (ARCTIC TERN)	2	0.5
<i>ALCA TORDA</i> (RAZORBILL)	5	1.3
<i>URIA AALGE</i> (COMMON GUILLEMOT)	62	16.2

<i>URIA LOMVIA</i> (BRUNNICH'S GUILLEMOT)	15.4	
<i>ALLE ALLE</i> (LITTLE AUK)	5.9	15.6
<i>CEPPHUS GRYPHUS</i> (BLACK GUILLEMOT)	4	1.1
<i>FRATERCULA ARCTICA</i> (ARCTIC PUFFIN)	3.1	8.1

	Number of SHHP with contact	Number of animals
WHALES		
<i>PHOCOENA PHOCOENA</i> (HARBOUR PORPOISE)	7	3.9
<i>LAGENORHYNCHUS SP.</i> <i>ORCINUS ORCA</i> (KILLER WHALE)	1	1
<i>HYPEROODON AMPULLATUS</i> (NORTHERN BOTTLENOSE WHALE)	2	2
<i>PHYSETER MACROCEPHALUS</i> (SPERM WHALE)	2	3
<i>BALAENOPTERA PHYSALUS</i> (FIN WHALE)	1	1
<i>BALAENOPTERA BOREALIS</i> (SEI WHALE)	3	4
<i>BALAENOPTERA ACUTOROSTRATA</i> (MINKE WHALE)	1	2
<i>BALAENOPTERA SP.</i> NON IDENTIFIED WHALES	2	4
	1	2
	9	7

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SEALS

<i>PHOCA HISPIDA</i> (RINGED SEAL)	4	1.0
<i>PAGOPHILUS GROENLANDICUS</i> (HARP SEAL)	1	3
<i>ERIGNATHUS BARBATUS</i> (BEARDED SEAL)	3	3
<i>CYSTOPHORA CRISTATA</i> (HOODED SEAL)	1.3	1.7
NON IDENTIFIED SEALS	2.5	4.5
<i>URSUS MARITIMUS</i> (POLAR BEAR)	1	1

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## Birds

Most of the seabird species reach sexual maturity at ages between 3 and 6. They belong to the group of "K" strategists where only one egg is laid a year. Breeding and rearing the young at the nest is a very long process keeping the seabirds (30 million pairs around the North-East Atlantic) for months at the cliffs, unless they are feeding themselves at sea. Some go far at sea to feed and collect the food for the young. The little auk (*Alle alle*) feeds at least as far as 200 km from the breeding colony. This was clearly seen along the Spitsbergen coast. In spite of that, most of the encountered birds during July, in the middle of the North-East Atlantic, are probably juveniles, immature or unsuccessful breeding birds. Their number should considerably increase after the breeding season with the income of adults and fledglings from the colonies during mid-August. As a rule oceanic densities of seabirds are low from June to mid-August (+/- 2 birds/sq. km) and reiteration of counts on the whole array should increase the species specific accuracy of the coverage throughout the vast area involved in the different water masses. Sea watching efforts should be enlarged to the other months of the year to provide more complete pictures of the distribution and ecological role of the birds at sea.

## Followers

A first analysis of the results of consecutive "moving" and "stop" periods, clearly indicates that the impact of real followers is weak for normal conditions (striking exceptions for Fulmar, Kittiwakes and Glaucous Gulls during fishing activities). Nevertheless, the short-term attraction of "Polarstern" for sea birds is revealed by the rapidly increasing concentration of birds (mainly Fulmars and Kittiwakes) sitting around the vessel in the quarters following the stop. After one hour the numbers of Fulmars and Kittiwakes recorded stabilize and are apparently correlated and similar to the numbers seen during two hours (the previous and following ones) of "moving" observations. During misty/foggy conditions, "Polarstern" is totally unattractive to birds.

## Mammals

Whales were numerous in warm waters (75 contacts), in comparison with data of previous cruises, for example 12 in July 1988. Distant detection by members of the crew and of the scientific teams in every direction is not a negligible factor to be taken into account for the "species specific correlation factor" of how well they can be detected.

Seal counts have resulted in rather unreliable results due to poor prevailing weather conditions (long stretches of diffuse mist in icy areas). Most of the animals are "Polarstern-shy" and plunge before identification, even probably before detection. Furthermore, most were young individuals for which identification patterns are not well documented. Members of the crew are also very efficient observers.

A very desired polar bear (*Ursus maritimus*) has visited us when the ship was stationary (79° 25'N/01°45'E). Coming from nowhere, yellowish in a white environment, he appeared at a distance of 2 km when we were already stopped since 140 minutes. Very curious of the Polarstern superstructure and maybe sensitive to agreeable smells, he approached slowly until a distance of 250 m. Reluctant to cross a lead, he evaluated the vessel's significance in the ice background and displayed for some minutes to be admired by most of us in his colours and movements. Scavengers totalling 10 Kittiwakes, 6 Fulmars Dark, 8 Fulmars Light and 2 Ivory Gulls were either flying or sitting at rather close range in that otherwise empty ice area. Having paid his visit he left at ease and disappeared behind pressure ridges. The dream had lasted 40 minutes.

### Systematic Position of Pelagic North-East Atlantic Seabirds

Most of the European bird species are hardly linked with water bodies. From 473 European species in 19 orders, 13 orders totalling 311 species have no water bird species at all; 6 orders with globally 162 species include 109 water bird species. So that only 23,0 % of the species are water bird species.

In Pelagic North-East Atlantic water, bird species are all belonging to only 4 of these 6 orders: Procellariiformes (1 species in ARK VII/2), Pelecaniformes (1, idem), Anseriformes (1, idem) and Charadriiformes (17 species), producing a total of 20 water bird species to be seen. That number amounts to only 4,4% of the 473 European bird species.

Among Charadriiformes, an order totalling 10 families, only 4 families include water bird species: Phalaropodidae (3), Stercorariidae (4), Laridae (27) and Alcidae (6). During the Ark VII/2 cruise we encountered 4 Stercorariidae, 5 Laridae (the Icelandic *Larus glaucoides* and the rare *Rhodostethia rosea* were not seen) and 6 Alcidae.

To sum up a total of 18 species were observed. The number of species is of course limited, but one should remember that 30 million pairs of seabirds nest on the coast around the North-East Atlantic.

### North-East Water Polynya

For what concerns the polynya of North-East water in Greenland (north of 79° N and west of 07° W) the data of the 34 standard half hour periods indicate a rather discrete bird presence. Four species only were observed: Fulmar dark (26/34) 76% of the time and Fulmar light (13/34) 38% of the periods of observation, Ivory gull (11/34) 32%, Kittiwake (3/34) 9% and Brunnich's guillemot (1/34) 3% of the time. The Fulmar dark only can be considered well represented. Numbers of individuals were always low. No bird was observed feeding or sitting on the water. Two whales have been spotted: one was probably a Northern Bottlenose whale, the other has not been identified. Seals were absent.

Reasons for weak densities, that are hardly higher than in the pack-ice, are unknown. Of course, ice-linked species (Ivory Gull and Little Auk) can feed everywhere along leads in pack-ice in July. Food (dead seals, birds, marine detritus and dung) for scavengers as Skuas and Gulls, is also to be found only on ice. Alcids (others than Little Auk) request suitable cliffs and waters well provided in small sized fish when birds start nesting.

In spring, the polynya has probably a greater importance for some species of seabirds, because there are at that time no other open waters in the area where to feed, everything being ice or snow covered. In autumn and winter when young ice forms and covers the leads in pack-ice, polynas probably gain a new importance for those very northern species of birds which survive very harsh over-wintering conditions, as Ross's gull, Sabine's gull, Ivory gull etc..

## Helicopter Survey

From an aerial 1 3/4 hour survey from the helicopter far at sea in the North-East Atlantic on August 11 at 75N 09E in an area of 15 x 25 km an aggregation of birds was clearly observed around several floating objects. The first was the moving "Polarstern" who had attracted about 5 Fulmars in a 1 km radius. An other was a very lonely piece of ice (10 m<sup>2</sup>) which had attracted more than 60 birds, mainly Fulmars. Most of them were sitting on the water around it with the rest circling the object. A lot of circling birds were also seen around two stationary non-fishing ships (at least 10 Kittiwakes and 8 Fulmars).

In the stretches between the floating objects (15-20 km) only very few single birds were observed: During the whole flight only 2. Therefore, it was clear that most of the birds in the covered area were concentrated around the objects. Two huge blows by whales were seen. The whales were probably disturbed by the sound of the approaching helicopter, since they dove and were not seen again.

This all proves that bird watching from the helicopter at sea can be a useful tool to give feedback information on the overall distribution of birds in a certain area. This in addition to the standard counting of birds from ships.

Detailed results and analysis of data obtained during this cruise will be published elsewhere and copies transmitted to the Polarstern library.

## Appendix A

<i>Fulmarus glacialis</i> dark	The second most common bird, mainly in ice conditions and to the North, non-follower, barely attracted by the "Polarstern" at move.
<i>Fulmarus glacialis</i> light	The most common bird in all watermasses, non-follower, attracted by the moving "Polarstern" for minutes only.
<i>Sula bassana</i>	Southern bird
<i>Somateria molissima</i>	Along the ice edge as in 1988
<i>Stercorarius skua</i> <i>S. parasiticus</i> <i>S. longicaudus</i> <i>S. pomarinus</i>	All skua species are 3 to 6 times more numerous than in 1988. <i>S. pomarinus</i> was not seen in 1988. Was due to a lack of food (Lemmings) in Scandinavia?
<i>Pagophila eburnea</i>	Restricted to the ice conditions as in 1988.
<i>Larus hyperboreus</i>	Idem.
<i>Larus glaucooides</i>	Was not seen, in 1988 it was seen close to Iceland.
<i>Xema sabini</i>	Rare bird in the pack ice.
<i>Rhodostethia rosea</i>	Was not seen, very rarely to be seen south of 80°N.
<i>Rissa tridactyla</i>	Second species in abundance after Fulmar, appears in all watermasses, but is less common in western icy conditions, can be a follower for hours if sitting on the "Polarstern", easily discarded in some minutes by discrete approach.
<i>Sterna paradisea</i>	A rare, mainly coastal bird
<i>Alca torda</i>	A coastal bird in Atlantic waters
<i>Uria aalge</i>	Mainly in Atlantic waters, along the Norwegian coast and Jan Mayen. In bad weather conditions confusion is possible with <i>Uria lomvia</i> .
<i>Uria lomvia</i>	Mainly in polar waters along Spitsbergen and Bear Island.
<i>Alle alle</i>	Only in Ice conditions, sitting mainly in large leads.
<i>Cephus grylle</i>	A coastal bird, seen along the ice edge, where it sits on floes.
<i>Fratercula arctica</i>	Mainly in Atlantic waters.

6.4 Zooplankton Investigations (Doris Berberich, Arne Körtzinger, Ute Meyer, Michael Steinke (AWI), Wilhelm Hagen, Nicolai Mumm)

Zooplankton investigations continued previous studies in the Fram Strait and Nansen Basin. The AWI group concentrated on the spatial distribution, abundance and biomass of *Calanus*, *C. glacialis* and *C. hyperboreus* in relation to hydrography, ice cover and phytoplankton density. Lab experiments were carried out to assess the impact of temperature and food availability on the egg production of *Calanus* females. Additional investigations covered various questions of the distribution and population structure of chaetognaths. Amphipods and ostracods were collected for analyses of their geographical and vertical distribution as compared to ARK VI (Dr. Weigmann-Haass, BAH). Studies of the plankton *in toto* (meso- and macroplankton) by the IPÖ biologists focussed on the distribution, composition and characterization of different plankton communities and their biomass. Biochemical analyses concentrated on lipids and their potential as energy reserves and food chain markers.

Chlorophyll measurements (AWI)

Chlorophyll was measured on two transects across the Greenland Sea (74° 45' N) and Fram Strait (78° N) as well as on three shorter transects in the Northeast Water Polynya (80° - 82° N), where discrete water layers to 200 m depths were sampled by a Bio-Rosette. Data processing was done on board and isolines are shown in Figures 5 and 6. The results are in good accordance with temperature and nutrient data and may also serve for comparison with the fluorescence data of the Bio-CTD.

Distribution of *Calanus* species (AWI)

Zooplankton was collected on 83 stations from the upper 80 m (euphotic zone) by bongo net (335 µm) for abundance and biomass determinations. The three *Calanus* species were clearly associated with different water masses: *C. glacialis* dominated in the Polar Surface Water, *C. hyperboreus* in the Greenland Sea Gyre and *C. finmarchicus* in the Atlantic Water. The Return Atlantic Current near the Polar Front is characterized by the occurrence of *C. finmarchicus*. Thus, the relative abundance of the *Calanus* species was found to be a good indicator of the Greenland Sea hydrography.

Egg production of *Calanus* species (Ute Meyer, AWI)

Secondary production in the Greenland Sea is dominated by herbivorous calanoid copepods. Their biomass is regulated by food availability. Since there is no more growth in females, surplus food is completely utilized for the production of eggs. Therefore, egg production of *C. finmarchicus*, is directly related to food availability and it can therefore be used as an indicator of feeding conditions and as a direct measure of net secondary production. The application of this method requires a detailed knowledge of the reproductive biology of the species considered. Two aspects - effects of temperature and food concentration - have been studied during ARK VII/2. Female *C. finmarchicus* and *C. glacialis* were sorted from the bongo nets and kept separately under various food and temperature conditions. *Calanus* species lay their eggs in batches within a few minutes. Hence, the reproductive activity can be expressed in terms of clutch size and spawning interval. First results show that spawning intervals decrease with increasing temperature in both species (Figure 2.6.4.3), whereas clutch size remains unaffected. The feeding experiments are still in progress and have not yet been evaluated.



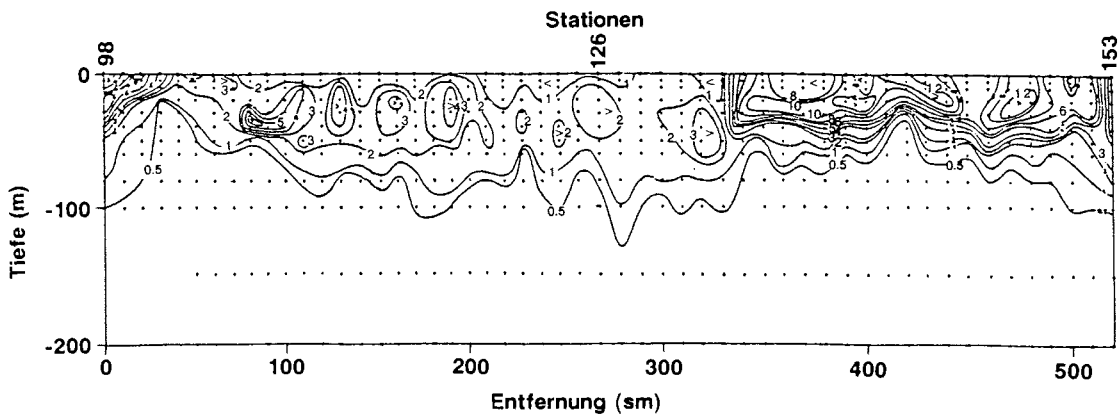


Figure 5: Chlorophyll-Konzentration ( $\text{Chl a} \times 10^{-1} \mu\text{g/l}$ ) in den oberen 200 m auf dem Schnitt durch die Grönlandsee bei  $74^{\circ}45'N$ .  
 Chlorophyll concentrations ( $\text{Chl a} \times 10^{-1} \mu\text{g/l}$ ) in the upper 200 m along Transect 1 ( $74^{\circ}45'N$ , Greenland Sea).

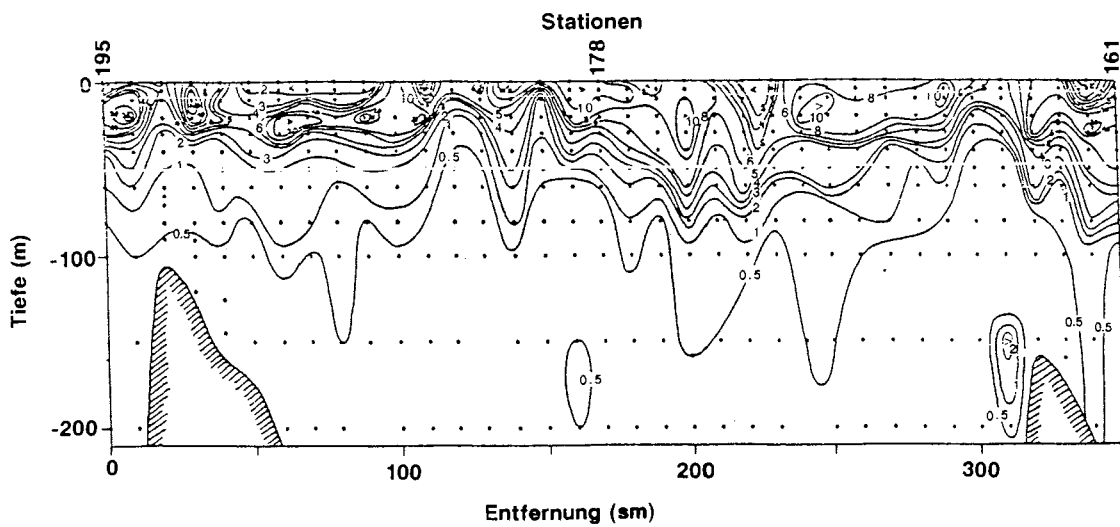


Figure 6: Chlorophyll-Konzentration ( $\text{Chl a} \times 10^{-1} \mu\text{g/l}$ ) in den oberen 200 m auf dem Schnitt durch die Framstraße bei  $78^{\circ}N$ .  
 Chlorophyll concentrations ( $\text{Chl a} \times 10^{-1} \mu\text{g/l}$ ) in the upper 200 m along Transect 2 ( $78^{\circ}N$ , Fram Strait).

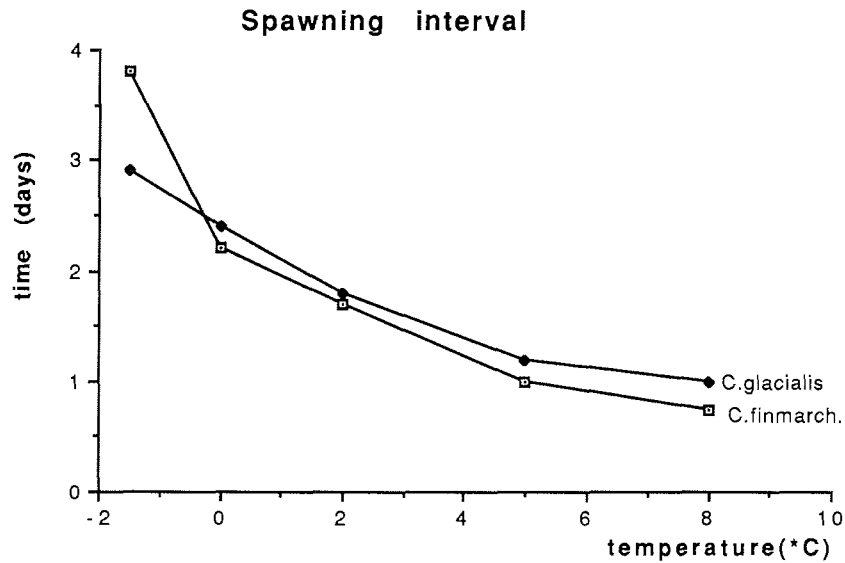


Figure 7: Temperaturabhängigkeit des Brutverhaltens bei *C. finmarchicus* und *C. glacialis*.  
Temperature dependence of spawning intervals in *C. finmarchicus* and *C. glacialis*.

#### Meso- and Macrozooplankton communities

Mesozooplankton sampling was carried out along the transects by stratified vertical Multinet hauls. Maximum hauling depths varied between 125 and 1500 m. Besides the dominant *Calanus* species and *Metridia longa*, copepods of the family Aetideidae were conspicuously abundant along the East Greenland shelf up to 80° N. Further to the North they were greatly exceeded by *Scaphocalanus magnus*. Three species of the carnivorous genus *Pareuchaeta* (*P. barbata*, *P. glacialis*, *P. norvegica*) also occurred in fair numbers on the western side of Fram Strait. Females with ripe ovaries and egg sacs were observed frequently. Besides copepods, ostracods of the genus *Conchoecia* comprised the most abundant component of the mesozooplankton south of 79° N. The population was mostly confined to the water layers below 200 m. A mass occurrence of the larvacean species *Oikopleura vanhoeffeni* was observed on the inner East Greenland shelf at 74° N. High concentrations of meroplanktonic larvae, mainly ophioplutei, echinoplutei and megalopae, suggested recent reproductive activity of the benthic shelf fauna. The northernmost station at 82° N was directly influenced by the Arctic Ocean outflow and especially below 50 m there was hardly any meso- and macrozooplankton present.

For the first time, a large plankton net of 8 m<sup>2</sup> mouth area was used in the Northeast Water polynya. In total, eight oblique RMT 1+8 (Rectangular Midwater Trawl) tows were performed. The maximum hauling depths varied between 100 und 800 m. RMT hauls along the East Greenland shelf break yielded large amounts of gelatinous organisms typical of late summer plankton assemblages. The large ctenophore *Beroë cucumis* (≤ 70 mm) was

especially abundant, chaetognaths comprised another major fraction of the gelatinous zooplankton (see below). The largest species *Sagitta maxima* occurred regularly only in the RMT catches. Highest concentrations were observed north of 80° N. A surprisingly large number of mysids was caught on the outer East Greenland shelf at 78° N. These large specimens ( $\leq 50$  mm) avoided the smaller nets almost completely. The same applies to the euphausiid *Meganycitiphanes norvegica*, which was recorded in fair numbers along the East Greenland shelf break between 78° N and 82° N. The far northward penetration of this subarctic species may indicate the presence of Atlantic water. This assumption was substantiated by similar findings in the benthic fauna (see benthos report). The bathypelagic decapod *Hymenodora glacialis* ( $\leq 60$  mm) was the most evenly distributed large crustacean on the western side of Fram Strait. Due to its sluggish movements this species also appeared in the deeper Multinet samples. In sharp contrast to the rich fauna of the continental rise the shallow shelf areas of the Northeast Water polynya were almost devoid of macrozooplankton organisms.

#### Investigations on chaetognaths

In the Greenland Sea chaetognaths comprise a large amount of the plankton biomass. As predators on other zooplankton and as prey of invertebrates and fish chaetognaths play an important role in the pelagic food web. Investigations on seasonal distribution patterns, population dynamics as well as relationships to hydrographic features continued work of previous cruises in 1988 and 1989. The most abundant species on the Greenland Sea transect was *Eukrohnia hamata*. Juvenile individuals were usually found in the upper water layers, whereas adult specimens occurred mainly between 300 and 500 m. *E. bathypelagica* dominated below 500 m. Some specimens of *Heterokrohnia mirabilis* were found in depths exceeding 1000 m. The two *Sagitta* species occurred in rather low numbers, *S. elegans* mainly on the Spitsbergen shelf, *S. maxima* in deeper waters along the East Greenland shelf break. *Eukrohnia hamata* and *E. bathypelagica* were collected by bongo net or Multinet for biomass determinations. After length measurements individual specimens were immediately frozen at -80° C. In Bremerhaven these samples will be weighed to establish a length/weight relationship and used for C/N analyses.

#### Biochemical investigations

Plankton samples for biochemical, especially lipid analyses, were obtained by bongo net, Multinet and RMT 1+8. The organisms were identified to species level (if possible), sexed and sorted according to developmental stage and body size. Specimens covered the whole range from small copepods to large chaetognaths and other gelatinous zooplankton. The samples were immediately frozen at -80° C or preserved in chloroform/methanol. A total of about 600 samples was collected, including hydromedusae, ctenophores, pteropods, cephalopods, ostracods, copepods, euphausiids, mysids, decapods, amphipods, appendicularians and chaetognaths. The determination of total lipid content, lipid classes and fatty acid/alcohol composition will be carried out in close cooperation of the IPO and AWI in the laboratories in Kiel and Bremerhaven (for lipid investigations on copepods see also the marine chemistry report).

Aquarieninventur vom 13.08.1990 an Bord "Polarstern"

Mollusca

*Colus* sp.  
*Buccinum* sp.  
*Neptunea* sp.  
*Morvillia* sp.  
*Arctinula greenlandica*  
*Astarte crenata*  
*Bathypolypus arcticus*  
*Rossia glaucopsis*

Polychaeta

*Brada* sp.

Pantopoda

*Boreonymphon abyssorum*  
*Chaetonymphon hirtipes*  
*Nymphon* sp.

Crustacea

*Arcturus baffini*  
*Cleippides quadricuspis*  
*Rachotropis aculeata*  
*Stegocephalus inflatus*  
*Epimeria loricata*  
*Sabinea septemcarinata*  
*Spirontocaris galmardi*  
*Sclerocrangon ferox*

Echinodermata

*Ctenodiscus crispatus*  
*Henricia* sp.  
*Solaster papposus*  
*Pteraster* sp.  
*Ophiacantha bidentata*  
*Ophiura robusta*  
*Ophiopleura borealis*  
*Strongylocentrotus pallidus*  
*Cucumaria frondosa*  
*Psolus* sp.

Pisces

*Raja hyperborea*  
*Lycodes reticulatus*  
*Lydodes eudipleurostictus*  
*Gymnelis retrodorsalis*  
*Liparis fabricii*  
*Careproctus reinhardti*  
*Eumicrotremus derjugini*  
*Artediellus atlanticus*  
*Artedielus uncinatus*  
*Icelus bicornis*  
*Cottunculus microps*

**6.5 Benthos and Fish** (Christian v. Dorrien, Michael Schmid, Dieter Piepenburg, Jes Rust, Institut für Polarökologie, Uni Kiel)

The programme of the Institut für Polarökologie in the ice-covered part of Fram Strait comprises both benthic and pelagic studies in order to get a picture of the whole marine ecosystem as complete as possible. The investigations follow a four-stage-approach: 1) faunistic inventory, 2) analysis of distribution and composition of communities, 3) autecological studies on selected "key species", and 4) description of the interrelationships of community structures, autecological adaptations and environmental conditions.

The benthic ecology of the high-arctic ice-covered shelf areas at the periphery of the Arctic Ocean is still not well known due to the difficult accessibility of these regions. During the cruise ARK VII/2 of "Polarstern" in summer 1990 the continental margin of Northeast Greenland was the target area for the benthological research programme of the Institut für Polarökologie Kiel. The environment of this region is shaped by the extremely cold East Greenland Current coming from the Arctic Ocean and flowing southerly at the east coast of Greenland. The investigations focussed on a polynya region, the so-called "Northeast Water" (NEW) which opens regularly each spring. The sampling programme of this cruise is thus a northerly continuation of the benthological investigations on the Belgica Bank conducted in 1985 during ARK III/2.

The sampling gears employed were an Agassiz trawl (AGT), a large bottom trawl (GSN) and an underwater camera (FOT). In total, 21 stations off Northeast Greenland (75° to 82° N) were sampled, plus an additional fishery station (station 150) at Bear Island which is not considered in the following. One station (101) was located off Shannon Island, two (195, 199) south of Belgica Bank proper, the other 18 stations in the "Northeast Water" polynya which was situated north of 80° N and has reached approximately the surface area of Denmark during the study period in August 1990. Five stations were arranged along a latitudinal transect at 80° 10' N covering the northernmost part of the Belgica Bank (100 m depth) and the Westwind Trough (app. 300 m depth) which runs perpendicular to the coast and separates the Belgica Bank from the Ob Bank in the north. The other stations covered the transition zone of the southern part of the Ob Bank to the Westwind Trough (100 to 250 m depth) or formed short slope-shelf transects at 81° N and 82° N (100 to 600 m depth). The station plan comprises only depths > 80 m. The shallower area of the Ob Bank proper were not sampled because its bathymetry is still only scarcely known and, therefore, navigation is quite difficult and time-consuming. At 20 stations one trawl (AGT or GSN, towing time 15 min and 30 min resp.) and the underwater camera were employed, at two stations only the camera (Tab.2).

In total, approximately 150 species were identified in the trawl catches, including 23 fish species. The species numbers per station ranged from 12 to 36 for the AGT-catches (Fig. 8) and from 19 to 48 for the GSN-catches (Fig. 9). These values are minimum estimators of the "true" species numbers because they do not include sponges, hydrozoans, actinarians, and bryozoans which will be determined later. Echinoderms were dominant in all catches, occasionally also sponges, molluscs and fish. The composition of the catches is strongly influenced by the species-specific efficiencies of the sampling methods used, e.g. small infaunal species are certainly underestimated.

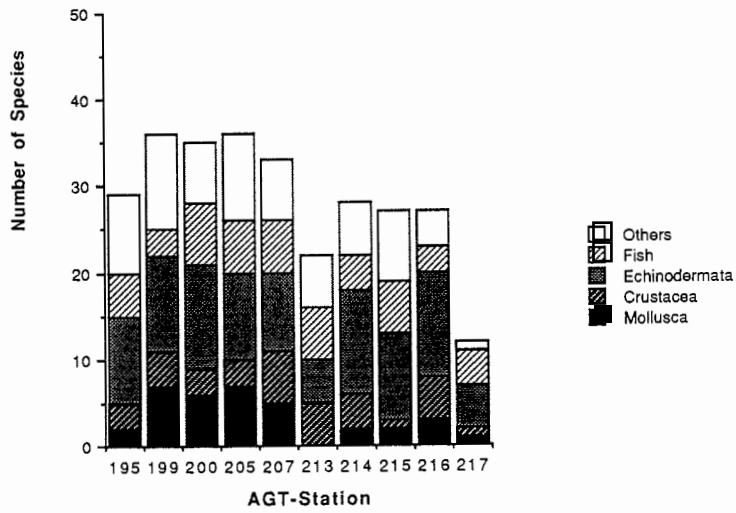


Figure 8: Artenzahl der dominanten Gruppen auf den AGT-Stationen.  
 Number of species of the dominant taxa at the AGT-stations.

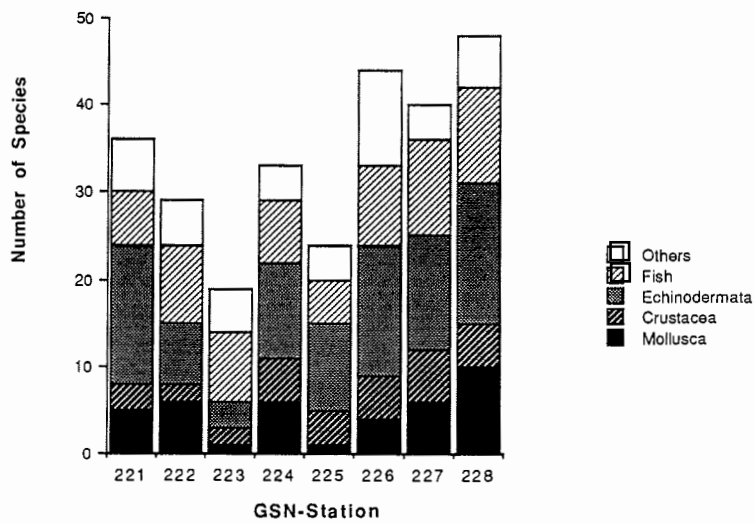


Figure 9: Artenzahl der dominanten Gruppen auf den GSN-Stationen.  
 Number of species of the dominant taxa at the GSN-stations.

First analyses of the catch composition indicate that there are distinct bottom communities at the shelf banks proper, in the shelf troughs and at the deeper slope regions. The area north and east of the Ob Bank is characterized by hard-bottom assemblages whereas soft-bottom communities dominate the fauna of the Belgica Bank, especially of its surrounding shelf troughs. Thus, there is evidence that sediments at the shelf margin between 80° N and 82° N are eroded and/or resuspended by relatively strong bottom currents at the slope whereas sedimentation processes are predominant in the region of Belgica Bank (between 78° N and 80° N). The latter may be caused by a stationary anticyclonic convergent gyre which is induced by the bottom topography and overlays the southerly flowing East Greenland Current in the area considered.

Surprising were the considerable catches of subarctic species like *Pandalus borealis* and *Sebastes marinus* at the Greenland slope even as far north as 82° N. A similar phenomenon is found in the pelagic catches of this cruise (see report of the zooplankton group). These findings show 1) that, in terms of zoogeography, the study area is not completely isolated from subarctic regions, presumably due to the Atlantic Return Current, and 2) that the food supply is obviously sufficient for the species considered, presumably due to relatively high production in the polynya.

Both the Polar Cod *Boreogadus saida* and its near relative, the so-called Arctic Cod or Ice Cod *Arctogadus glacialis*, were caught in the polynya. *A. glacialis* was, in fact, the most abundant fish species in the trawl catches in the northernmost part of the study area where it probably replaces *B. saida*. Its biology is not very well known so far, hence the analyses of our catches will yield much new information.

There is evidence that the study period July/August coincides with the spawning time of many benthic species. Most female amphipods and decapods or male pantopods carried ripe eggs, occasionally also empty egg shells indicating that the brood had hatched very recently. Brood-caring species like e.g. some pantopods and isopods were frequently observed with their offspring. These results are in good accordance with the considerable abundances of meroplanktonic larvae (see report of zooplankton group).

A total of app. 1100 underwater photographs were taken at the 22 stations, i.e. normally 50 per station. The photographs will provide "in-situ"-views of epibenthic habitat structures and allow the determination of absolute abundance values and the identification of small-scale distribution patterns of large epibenthic species like e.g. brittle stars.

The autecological studies on selected "key species" of the investigated benthic ecosystems will include 1) the assessment of parameters of population structures (e.g. size frequencies, age structures, sex ratios, fecundities), 2) the biochemical analyses of body compounds with special emphasis to lipid content and composition, and 3) ecophysiological experiments with live specimens kept in cooled aquaria over long time spans. The "key species" considered range from actinarians to fish, and represent different modes of life, e.g. suspension-feeders, deposit-feeders, predators or sessile and vagile species.

For the population studies all specimens of the species considered (or, when occurring in large numbers, a representative subsample) were sorted out of the catch and preserved for later analyses by frosting at -25° C or in a borax-buffered 4%-formalin-seawater-solution.

For biochemical analyses a total of 112 samples was taken, comprising whole specimens of various species, sexes and sizes or different organs of those specimens, i.e. muscle, gonads, hepatopancreas and liver respectively. The samples were preserved in chloroform-methanol or by frosting at -80° C. The results of these studies will yield new information on the strategy of energy utilization of polar benthic species and on their trophic relationships to the pelagic realm.

The live specimens of app. 40 species (actinarians, gastropods, bivalves, cephalopods, polychaetes, pantopods, isopods, amphipods, decapods, echinoderms, marine rhinogradentians and fish) are kept on board in a lab container cooled to 0° C. They will be transferred to Kiel for several ecophysiological investigations. Their behaviour and metabolism response to the controlled variation of environmental conditions like e.g. temperature and food supply will be studied. This includes the measurement of respiration rates as parameter of metabolic activity which will be partially conducted already on board.

The benthic investigations of this cruise are embedded in a multidisciplinary pilot study for the "International Arctic Polynya Project" (IAPP) in 1993. Based on the results of ARK VII/2 the significance of the polynya for the ecology of the high-arctic seas off Northeast Greenland will be studied in more detail. Regarding the benthic research programme it is planned to employ a box corer as an additional sampling gear to cover also the infauna, i.e. to obtain absolute values of abundance and biomass of this faunal component and to get more information on small-scale sediment structures.



**Tab.2: List of benthological stations during ARK VII/2**

AGT Agassiz trawl  
 FOT underwater camera  
 GSN bottom trawl

#	Stat	Date	Latitude	Longitude	Depth	Gear	Remarks
1	101	15.7.90	74° 59' N	14° 23' W	150 m	GSN FOT	
2	150	22.7.90	74° 54' N	16° 06' E	290 m	AGT GSN	
3	195	31.7.90	77° 59' N	15° 24' W	500 m	FOT	
4	199	31.7.90	78° 20' N	12° 37' W	175 m	AGT FOT	
5	200	1.8.90	80° 09' N	15° 00' W	370 m	AGT FOT	
6	202	1.8.90	80° 09' N	13° 59' W	140 m	AGT FOT	
7	205	2.8.90	80° 10' N	10° 53' W	100 m	FOT	
8	207	2.8.90	80° 11' N	08° 50' W	350 m	AGT FOT	
9	208	2.8.90	80° 09' N	07° 55' W	315 m	AGT FOT	
10	213	3.8.90	81° 01' N	07° 45' W	480 m	FOT	
11	214	3.8.90	81° 00' N	08° 43' W	110 m	AGT FOT	
12	215	3.8.90	81° 00' N	09° 11' W	100 m	AGT FOT	
13	216	4.8.90	81° 41' N	11° 35' W	170 m	AGT FOT	
14	217	4.8.90	81° 50' N	10° 40' W	525 m	AGT FOT	
15	221	5.8.90	81° 48' N	10° 45' W	200 m	AGT GSN	Net damage sponges
16	222	5.8.90	81° 46' N	10° 30' W	350 m	FOT GSN	
17	223	5.8.90	81° 46' N	09° 30' W	545 m	FOT GSN	many sponges
18	224	6.8.90	81° 08' N	08° 36' W	200 m	FOT GSN	
19	225	6.8.90	81° 07' N	08° 20' W	400 m	FOT GSN	Net damage
20	226	7.8.90	80° 37' N	08° 35' W	100 m	FOT GSN	
21	227	7.8.90	80° 36' N	08° 50' W	200 m	FOT GSN	
22	228	7.8.90	80° 34' N	08° 35' W	250 m	FOT GSN	

## 6.6 Particle Flux in High Northern Latitudes (Dierck Hebbeln)

In order to reconstruct paleoenvironments by analysing marine sediments a specific knowledge of sediment forming processes is required. The particle flux to the seafloor with all its seasonal variabilities in quality and quantity can be recorded using time-series provided by sediment traps. In high northern latitudes the largest part of material sinking down to the seafloor is made up either of particulate matter of lithogenic origin derived from melting ice floes or of biogenic origin. A detailed knowledge of these processes enables a better understanding of how marine sediments are formed.

During leg ARK VII/2 three sediment traps were recovered. The first was moored in the central Greenland Sea Basin in 3076 m depth, around 500 m above the seafloor (75°00.5'N, 04°07.1'W). The amount of material in the sequence of 20 sample bottles shows a pronounced seasonal cycle with a major plankton bloom event in spring. Microscopic analyses of smear slides shows a sequence in the composition of the plankton community marked by a relative increase in silico-flagellates in spring. The deployment of another sediment trap at the same position continues this experiment. The second sediment trap was moored off Spitsbergen in the Fram Strait in 1125 m depth, also around 500 m above the seafloor (78°52.6'N, 06°40.5'E). A seasonal cycle is not as obvious as in the Greenland Sea Basin resembling results from earlier sediment trap experiments at this site. Particulate matter is transported from the south into the Fram Strait the whole year round by the West Spitsbergen Current, so seasonal signals are masked. This is also seen in the continual presence of significant quantities of coccolithophorids - small green algae - in the traps, because in the long polar winter night these algae are not common in the Fram Strait. At this longstanding trap site we deployed also another sediment trap for continuation of the experiment. The third sediment trap was recovered in the western Fram Strait off the Greenland shelf in 1011 m depth, again 500 m above the seafloor (78°03.5'N, 04°07.1'W). Unfortunately this trap worked only for three months, collecting the particle flux from September 1989 to the recovery in July 1990 in only one sample bottle. At this site the particle flux beneath a nearly year around ice cover is remarkably low.

To complete the sediment trap experiments we are analysing the distribution of planktonic foraminifera by using net casts. The shells of planktonic foraminifera are the most important microfossils for the reconstruction of marine paleoenvironments. In combination with data from net casts in autumn, winter and spring and with the sediment trap data, the seasonal variabilities in the horizontal and vertical distribution of foraminifera populations are being investigated.

For these investigations a Hydrobios-multinet with a mesh size of 63 µm was used at 16 stations in the different water masses of the Norwegian-Greenland Sea and the Fram Strait. Normally the upper 500 m of the water column were sampled in five depth intervals. Additionally three deep casts were taken at the trap sites for comparison (2500 m at the GS-trap site, and 1500 m at the SP- and the FS-trap site, respectively).

To investigate the changes in organic matter while settling through the water column we are analysing the stable isotope composition of organic carbon in plankton casts, in sediment trap samples and in surface sediment samples. Additionally to already existing surface sediment data and to the sediment trap samples at 20 stations on the Fram Strait section phytoplankton samples were taken with a 20 µm-plankton net.

6.7 Sediment-Laden Sea Ice in the East Greenland Current (L. Wollenburg, S. Fretzdorf and S. Rumohr)

The sea ice project started in 1987 in the Eastern Arctic Ocean and was continued in 1988 in the Fram Strait, 1989 in the Barents Sea and Greenland Sea.

The investigations during ARK VII/2 in the Fram Strait and Greenland Sea focussed on the recording of the spatial distribution of sediment accumulation in sea ice and on collecting ice cores from various types of sea ice. The Fram Strait is the main outflow area for the Arctic sea ice. From there the East Greenland Current transports the ice further south where it melts completely somewhere south of Greenland. For this reason it is very important to get a data base on the annual variations in distribution and concentration of "dirty" sea ice in this area, which enables us to estimate the flux of sea ice rafted sediment and the importance for sedimentation. Also there is a need to determine the role of Greenland for sediment incorporation and the contribution of sediment-laden Greenland fjord- and shorefast ice to the ice cover in the East Greenland Current.

Data collection during the cruise included

- a) observations and recording of ice cover, ice type, concentration and spatial distribution of sediments on and in the ice,
- b) sampling of surface sediments and ice cores from the ship and by helicopter support, and
- c) video- and photo documentation of the general ice conditions and of dirty floes.

The ice cores were stored in the -27° room aboard "Polarstern" for analysis on ice structure and crystallography, biogenic and lithogenic particle content and chemistry in the lab on shore. Some ice cores were already cut into 20 cm pieces, melted (under room temperature) and then filtered during the cruise. The pre-weighed filters and the surface sediments will be analysed on shore by looking at sedimentological parameters, biogenic material, mineralogy, grain size distribution, surface microtextures etc.

During the expedition 74,65 m of ice cores, from 24 coring stations (16 cores from sea ice and 8 from glacier ice), and 69 surface sediment samples were collected primarily from ice floes with surface sediment accumulations (Table 3). On the first transect into the ice cover at about 75°N and 15°W the ice was relatively clean (Fig. 10). Only small sediment accumulations in patches and on the lee side of pressure ridges could be sampled.

The dredging area in the vicinity of the Molloy-Deep (15°N, 02°E - Fig. 10) was also ice-covered, so one unexpected day in the ice results in some surface samples of pure sediment from the ice surface. Two ice floes contained large (50 x 50 m) patches of a 4 - 5 cm thick layer of pure mud, mixed with wood fragments, clams and pebbles (up to 5 cm).

Due to the good ice conditions this year "Polarstern" reached 82°N. In this area "Polarstern" crossed an area with some tabular icebergs, most probably derived from glaciers in North Greenland, which we were able to sample by helicopter. These samples are important to determine the background of "normal" atmospheric transport in Arctic regions. At 81°N and 05°W "Polarstern" met a very big, multi-year sea ice floe (Fig. 10) with an estimated average thickness of 15 m. This floe was observed for a long time on satellite images and originated probably in the western Arctic Ocean. The ice core we have taken (5,27 m) should allow us to compare, for the first time, sea ice from the Western Arctic Ocean System with sea ice from the Transpolar Drift Stream.

Table 3: Probennahmestationen (Eiskerne, Oberflächenproben) mit zusätzlichen Angaben über Kernlängen und Eistypen (MY = mehrjähriges Eis; SY = zweijähriges Eis).

List of sampling locations (ice cores, surface samples) with additional information on core length and sampled ice type (MY= multi-year sea ice, SY = second-year sea ice).

Station	Ice Core	Length (m)	Surface Sample	Ice Type	Lat.	Lon.
72195	53	2,89	11	MY	75 00,0N	15 00,0W
			21	MY	"	"
			31	MY	"	"
			41	MY	"	"
			51	MY	"	"
			52	MY	"	"
			61	MY	75 00,0N	16 00,0W
			62	MY	"	"
72196	11	3,95	12	SY	74 58,3N	14 01,7W
	14	3,30	13	SY	"	"
			21	SY	"	"
			22	MY	74 59,9N	13 22,6W
			22	MY	"	"
72197	14	4,04	11	MY	74 46,0N	11 27,6W
			12	MY	"	"
			13	MY	"	"
	15	3,72	14	MY	"	"
			15	MY	"	"
	21	3,00	21	SY	74 45,3N	10 49,1W
72206			11	MY	79 42,0N	02 18,8E
			21	MY	"	"
			31	MY	"	"
			41	MY	"	"
			51	MY	"	"
			61	MY	"	"
			71	SY	"	"
			81	MY	"	"
			91	MY	"	"
			101	MY	"	"
			111	MY	"	"
			121	MY	"	"
			131	MY	"	"
			141	MY	"	"
			151	MY	"	"
161	MY	"	"			
171	MY	79 27,0N	01 41,0E			

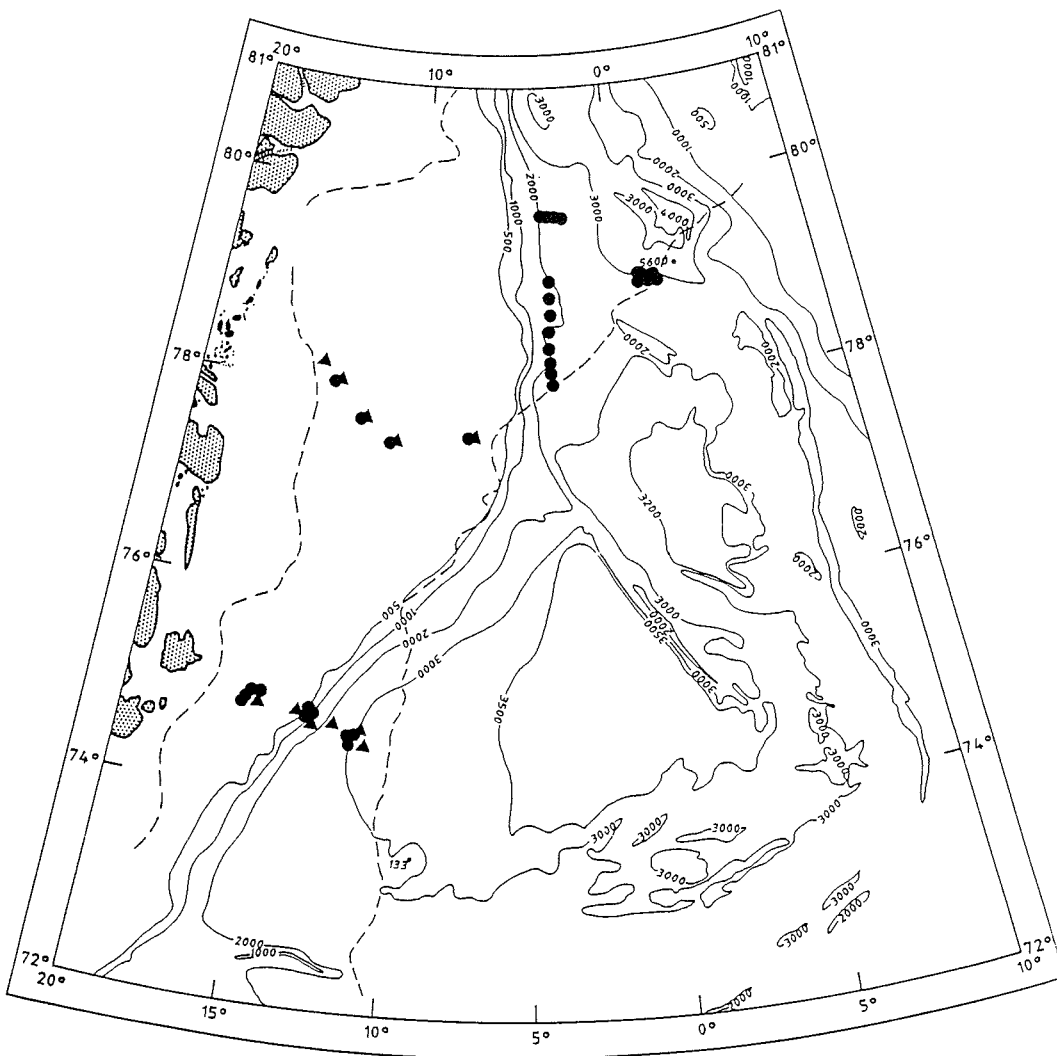
Table 3 (continued)

Station	Ice Core	Length (m)	Surface Sample	Ice Type	Lat.	Lon.
72210	11	4,16		MY	77 59,5N	05 58,3E
			12	MY	"	"
	21	4,55		MY	77 57,2N	08 22,8W
			22	MY	"	"
72211	11	8,48		MY	77 60,0N	11 41,8W
			12	MY	"	"
	21	3,80		MY	77 58,8N	12 23,2W
			22	MY	"	"
72212	11	3,45		MY	78 10,5N	14 04,4W
	12	3,14		MY	"	"
	21	2,75		SY	78 15,0N	13 19,2W
72213			11	MY	79 00,0N	14 00,0W
			21	MY	"	"
			31	MY	"	"
			41	MY	"	"
			51	MY	"	"
			61	MY	"	"
			71	MY	"	"
	81	ca.1,50		Glacier	80 00,0N	16 00,0W
	91	ca.1,10		Glacier	"	"
	101	ca.1,20		Glacier	"	"
72215	11	5,27		MY	81 00,0N	05 26,0W
72216	11	0,69		Iceberg	81 54,0N	10 35,0W
			12	Iceberg	"	"
	13	1,07		Iceberg	"	"
	14	1,15		Iceberg	"	"
	15	0,90		Iceberg	"	"
			21	Iceberg	"	"
	31	1,70		Iceberg	"	"
72219			11	MY	79 35,2N	06 53,0W
			21	MY	"	"
			31	MY	"	"
			41	MY	"	"
			51	MY	79 28,0N	06 07,0W

Table3 (continued)

Station	Ice Core	Length (m)	Surface Sample	Ice Type	Lat.	Lon.
72220			61	MY	79 09,0N	05 06,1W
			71	MY	"	"
			81	MY	"	"
			91	MY	"	"
			101	MY	"	"
			111	MY	"	"
			121	MY	"	"
			131	MY	78 08,6N	05 04,6W

Figure 10



Karte der Probeentnahmestellen. Eiskerne: ▲ Schnee/Sedimentproben: ● .  
Die gestrichelte Linie zeigt die mittlere Lage der Eisgrenze während der Expedition,  
wie sie aus Satelliten-Daten ermittelt wurde.

Map of sample locations. Sea ice cores are marked as ▲ and  
surface snow/sediment samples as ● . Dashed line indicates the average ice edge  
position during the cruise obtained from satellite data.

**6.8 Dredging of the Knipovich Ridge and Molloy Ridge (C.W. Devey, C. Endres and K. Haase)**

Dredge stations were attempted at 7 localities during the cruise, 2 on the northernmost part of the Knipovich Ridge (south of the Spitsbergen Fracture Zone), 4 on the Molloy Ridge north of the Molloy Fracture Zone, and 1 on a more southerly part of the Knipovich Ridge. The locations and water depths of the dredges are given in Table 4, and all except 17/230 are plotted in Figure 11. Figure 12 shows the reconnaissance profiles across the N. Knipovich Ridge.

The northerly Knipovich Ridge dredges were hindered by thick sediment cover (see Fig. 12), and no volcanic rocks were recovered. The dredge was on both occasions filled with deep-sea sediment. The Molloy dredges yielded serpentinites, harzburgites and altered peridotites on three occasions, but no volcanic material. The ultramafic samples were in various stages of alteration, although those from the first dredge (station 17/157) were on the whole particularly fresh. Rock types recovered in 17/157 include harzburgites with orthopyroxenes up to 2 cm across and calcite veining, sheared serpentinites, and some altered peridotite containing Cr-diopside. Station 17/158 recovered only sediment, stations 17/159 and 17/160 yielded mainly altered serpentinite/harzburgite blocks.

Station 17/230, on a more southerly portion of the Knipovich Ridge (at 76°30'N) recovered much sediment and some large dropstones (up to 50 x 50 x 20 cm), together with altered basalts. In at least one case fresh glass was seen on the basalts.

Samples of all igneous rocks were taken for microscopic and chemical analysis in Kiel.

TABLE 4: LOCATION OF DREDGES

Station number	Lat (°N)	Long (°E)	Water Depth
17/154	77°44.77'	7°25.01'	3460 - 3026 m
17/155	78°00.13'	7°09.64'	3052 - 2867 m
17/157	79°19.41'	3°13.60'	2070 - 1939 m
17/158	79°26.65'	3°02.88'	3626 - 3203 m
17/159	79°41.95'	2°19.58'	2567 - 2411 m
17/170	79°25.06'	1°39.62'	2360 - 1918 m
17/230	76°30.12'	7°13.62'	3098 - 2695 m



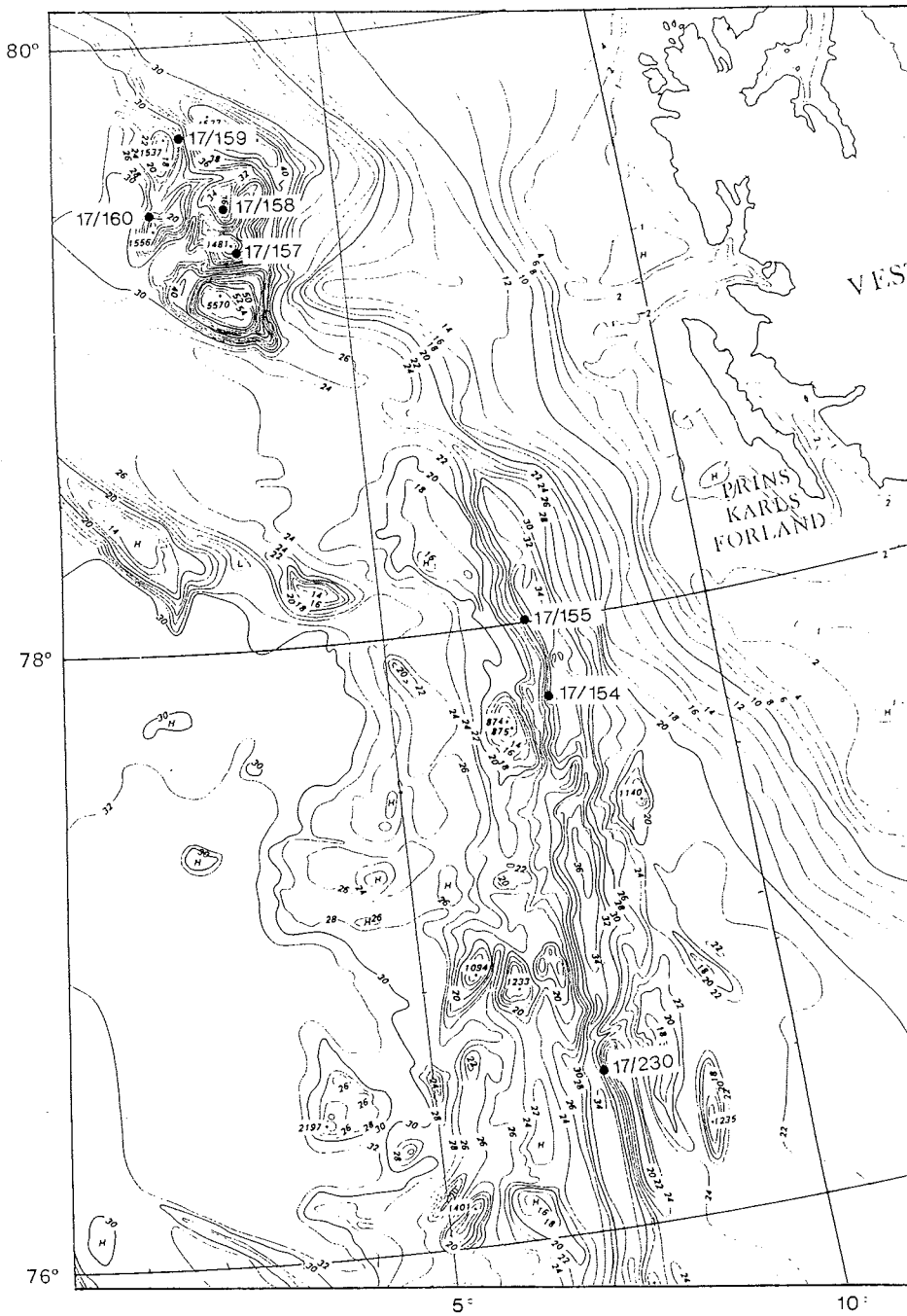
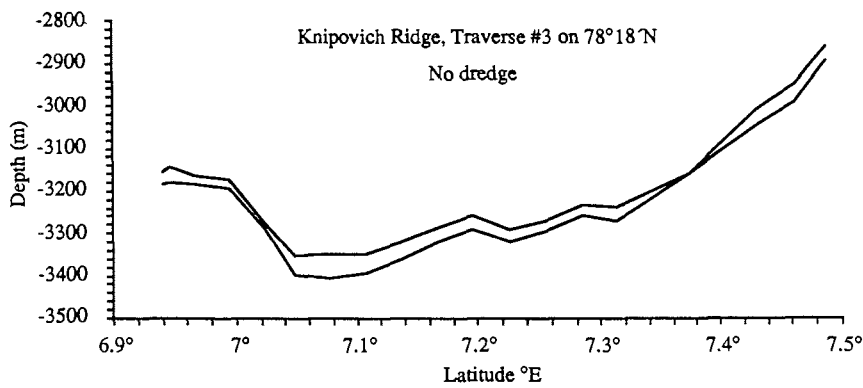
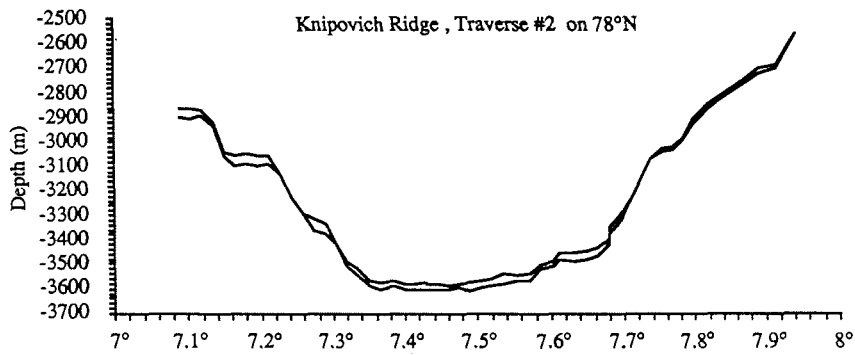
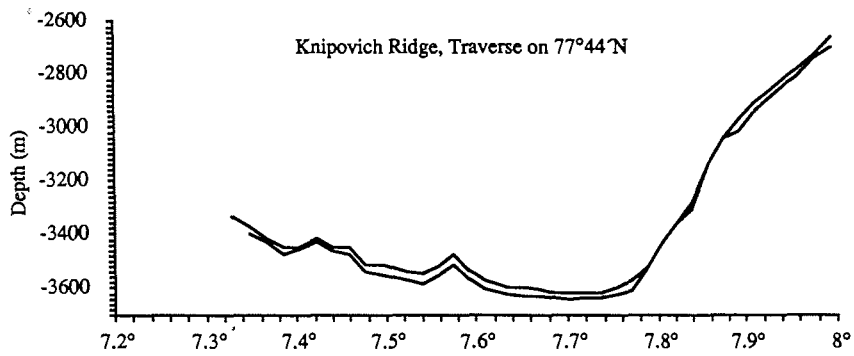


Figure 11: Lage der Probenentnahmestellen mit der Gesteinsdredge  
Dredge positions.

Figure 12: Bodenprofile (obere Linie) und maximal aufgezeichnete Sedimentdicke (untere Linie) auf dem Knipovich-Rücken.

Bottom profiles (upper line) and maximum sediment thickness penetrated (lower line)



6.9 Remote Sensing of the Sea in Solid and Liquid Form (C. Garrity, S. El Naggari, A. Bochert, K.W. Asmus, V.R. Neralla and R.O. Ramseier)

Introduction

The natural emission of energy from the sea surface in both liquid and solid form was measured using an Aerojet Electrosystems 37 GHz dual polarized radiometer operated by the Microwave Group and a line scan camera operated by members of the Alfred-Wegener-Institut für Polar- und Meeresforschung. Even though the two instruments have different wavelengths, they are both able to detect features on an ice surface that are characteristic of "summer" ice as well as the amount of foam on the ice free ocean which is related to windspeed. The radiometer operates at a wavelength of 8 mm and the line scan camera from 400 nm to 1200 nm. Both the microwave emission and albedo of an ice surface are affected by the amount of melt accumulation in pools on the ice surface named "puddles" as well as holes through the ice caused by excessive melt known as "thaw-holes". It is important to quantify the effect of these melt features on ice concentrations calculated from using satellite passive microwave data from the Special Sensor Microwave Imager (SSM/I).

Ice maps giving total ice and old ice concentration are produced at the Institute for Space and Terrestrial Science (ISTS) in Toronto, Canada by Sharon Trojan using an algorithm developed by Irene Rubinstein who are members of the Microwave Group. Both 19 GHz and 37 GHz frequencies are used from the SSM/I to obtain ice information using the AES/ISTS algorithm. It is our objective to determine the correction required for ice concentrations as calculated by the algorithm as a result of melt features. The line scan camera quantifies the concentration of puddles, thaw-holes, ice and open water based on helicopter flights for a 25x25 km footprint of the satellite, whereas the shipborne radiometer furthers our understanding of passive microwave emission of summer ice, as well as the line scan camera.

The amount of foam on the open ocean will affect the microwave emission and albedo measured by a radiometer and line scan camera, respectively. The percentage of foam in a footprint of the satellite can be correlated with windspeed. In 1987, it was observed that the sea surface temperature may have an effect on the passive microwave emission at 37 GHz. For sea surface temperatures less than 279 K there is an increase in microwave emission from the sea surface.

During this cruise, we were fortunate to get calm seas while passing over the cold ocean with Arctic and Polar fronts. Therefore, the only major effect on the microwave emission would be sea surface temperature. Consequently a correction may be required to the satellite algorithm for determining wind speed over the ocean for different sea surface temperatures. With the help of the line scan camera, the amount of foam for different wind speeds may be quantified for a variety of sea surface temperatures and then correlated with the wind speeds (brightness temperatures) determined by the AES/ISTS algorithm.

The AES/ISTS algorithm applies a correction for the atmosphere. It will be interesting to see if the dense fog which was present during most of the cruise had an effect on the calculation of wind speed over the open ocean as well as ice concentration using the satellite data. The atmospheric correction may have to be modified due to the dense fog. With the help of the radiosonde, the thickness of the fog can be quantified, and then related to the microwave emission measured using the shipborne radiometer. This will give a good indication of the effect fog has on the microwave emission at 37 GHz.

## Floating ice

There were four main programs occurring while in the ice: 1) passive microwave measurements of an ice floe during an ice station, 2) line scan camera and passive microwave measurements as the ship moved through the ice, 3) line scan camera measurements from the helicopter and 4) a comparison of ice concentration with satellite ice maps produced using the AES/ISTS algorithm.

## Ice Stations

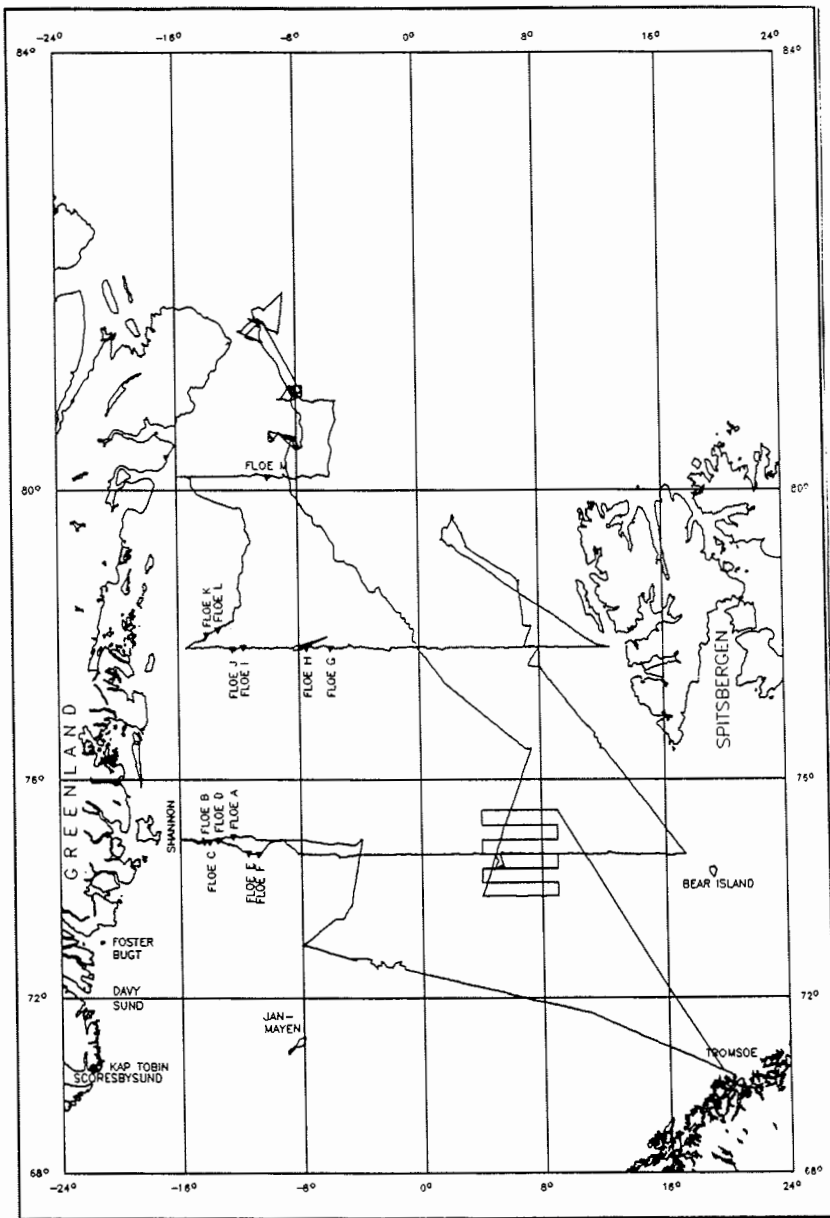
Electrical and physical properties of the snow and ice as well as puddle characterization furthered the understanding of passive microwave measurements of summer ice. A total of 13 ice stations on old ice were completed from July 14 to August 2 at the locations shown in Figure 13. The air temperatures varied between 0°C and 4.2°C. The snow was surprisingly not as wet as expected for "summer" snow. The free water content in the snow ranged from 0% to 6% by volume. Often the snow free water content was less than 1% despite the warm air and snow temperatures. This can be explained by the large snow grains, usually centimetres in size, which made it possible for the free water to drain out of the snow. The snow grains had undergone significant metamorphism creating either large needles or large rounded grains. The ice surface was often moist except in small drainage channels which lead to puddles, thaw-holes, or low lying levels on the ice surface causing the surface to be wet. Therefore, microwave emission from the thin (1-3 cm) snow cover common for summer ice, often did not affect the microwave signature of the ice. This is not the case in the spring where the snow has a significant effect on the emission from ice which can cause a misclassification of ice type.

A total of 13 floes, A to M (Figure 13) were surveyed and the data on physical characteristics of puddles such as depth, thickness of the frozen ice on the surface (if present) and temperature of the puddle were gathered. It was noticed that most of the puddles were unfrozen on the surface with the temperature of the puddle water varying between 0.3°C to 1.0°C. The sizes of the puddles surveyed were of the order of 1.5 sqm to 440 sqm although there were several much larger puddles on some of the floes. The depth of the puddles varied from 4 cm to 45 cm. The salinity of water in all puddles was found to be zero, that is, there are no discernible salts present in the puddle water. This is expected since the ice stations were on old ice.

To augment the snow and ice measurements, a total of 36 floes were visited by helicopter. Only general observations of the floe were made due to time limitations. Seven of the floes may have been first year ice since it was difficult to classify the rotting ice at this time of year with out an ice core. The snow was looser with a more advanced stage of snow metamorphism on the first year ice as compared to the old ice types in July, but in August the snow was the same for both ice types. During the spring, in the East Greenland Sea, the snow on first year ice was also at a more advanced stage of metamorphism compared to snow on old ice (Garrity, ARK IV/1,2 1987). Most of the first year ice was very rotten with about 30% and 50% of the floes covered by thaw-holes during the last 2 weeks in July and first week in August, respectively.

Due to the large amount of surface sediment on the ice, there could be an effect on the microwave emission from dirty ice since the permittivity for dirt (2.84) is smaller than for dry old ice (3.15). We were fortuitous to be able to measure the emission from a tabular

Figure 13: Lage der Eisschollen-Stationen  
Positions of ice floe stations



iceberg at 81° 54'N/10° 47'W on August 4. There was a high concentration of surface sediment on the iceberg. The permittivity of the ice surface was measured and was found to be low(1.56) due to the snow ice (ice formed from snow which has a large amount of air pockets). Thus, the high emission from the ice could be due to the surface sediments.

The permittivity of old sea ice was generally high ranging from 8.30 to 18.32 due to a moist ice surface. Thus, the dirt on sea ice during the summer may be detectable from the microwave emission due to the contrast between the permittivity of the moist ice surface and the dirt. Further analysis of the dirty ice signatures will confirm the possibility of detecting dirty sea ice in the summer using the passive microwave sensor. This is of interest due to our joint work with Ingo Wollenburg from GEOMAR Forschungszentrum für Marine Geowissenschaften, F.R.G., who is interested in the location and origin of dirty ice.

#### Radiometric and Line Scan Measurements

Some puddles had a thin layer of ice on the surface which would cause the emission to be high. When there was no surface ice, the puddles would give a microwave signature of water which is much lower than for ice. Surprisingly, the puddles often gave a high depolarized signature (that is the vertical and horizontal polarizations were similar). This may be because the ice on the puddles was rough in the microwave range either due to a small amount of slush or due to the roughness of individual ice crystals which were sometimes observed by the eye. Ten minute averages of the emission from ice containing puddles will be compared to the ten minute averages of the line scan camera data as the ship moved through the ice. Averaged data may better indicate the effect of puddles on the microwave emission.

A line scan camera system was mounted on the bridge and oriented to the same spot as the radiometer field of view. The incidence angle of the camera brings the width of the field of view to 30 m. Ten minute averages were calculated automatically at a 10 Hz scan rate. The signals from the water, ice and puddles on the ice were very well identified, as seen in Figure 14. The data will give us new information about the surface properties which will be compared to the radiometric data.

#### Airborne Line Scan Camera Measurements

A line scan camera system was mounted on the helicopter to measure the ice and puddle concentrations. The system consisted of a line scan camera with 2048 silicon photo diodes whose spectral response lies between 400 and 1200 nm. The scan rate was 20 Hz and the camera optics provided a line width equal to the flight height which was perpendicular to the flight direction. The flight height was determined by the cloud level and had to be within the minimum and maximum heights allowed by the system of 100 m to 1000 m before useful data could be collected. This gives a resolution between 5 and 50 cm in width. The flight ground speed varied between 40 and 60 knots. This will give a resolution between 1m and 1.5m m in the flight direction.

Figure 14: Gemittelte Daten der Line-Scan-Kamera: Beispiel für 19 % Wasser, 14 % Schmelztümpel und 67 % Eis. Grönlandsee 79°25'N, 06°00'W, 07.08.90

Line-scan average data: Example with 19 % water, 14 % puddles and 67 % ice. Greenland Sea 79°25'N 06°00'W, August 07/ 90.

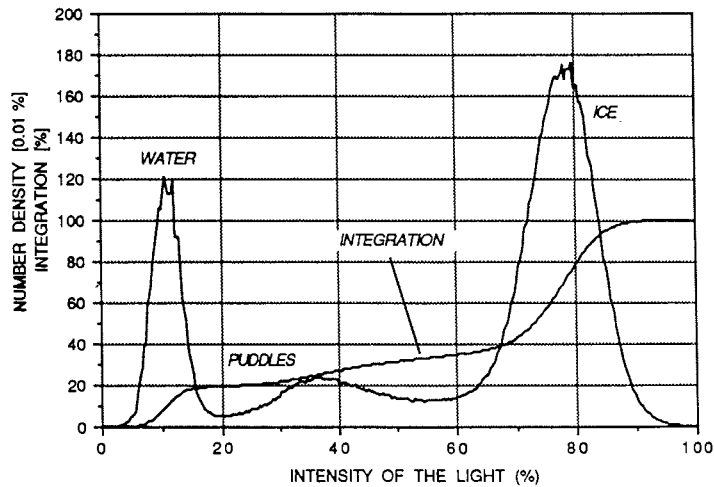
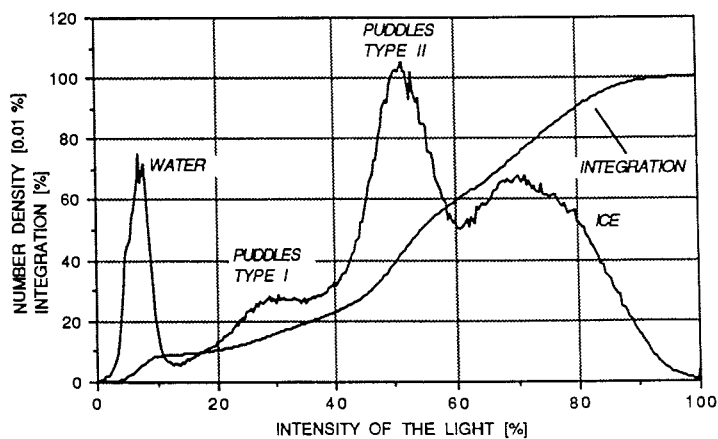


Figure 15: Gemittelte Daten der Line-Scan-Kamera: Dieses Bild zeigt 2 Typen von Eistümpeln, 8 % Wasser, 52 % Schmelztümpel (beide Typen), 40 % Eis. Grönlandsee 79°09'N, 05°04'W, 08.08.90.

Line-scan average data: This example includes 2 types of puddles. 8 % water, 52 % puddles (2 types), 40 % ice. Greenland Sea 79°09'N, 05°04'W, August 08/90.



Four flights were completed at different locations and times which are summarized in Table 5. The puddle concentration varied from 16% to 23%. A comparison to the SSM/I satellite data will be obtained later.

TABLE 5: RATIO OF PUDDLES/ICE INDICATING PUDDLE CONCENTRATION

Date	Latitude	Longitude	Ratio %
14.07.90	75 03.4N	12.0 20.6W	16
06.08.90	81 07.4N	08.0 39.0W	23
07.08.90	80 37.5N	08.5 05.6W	16
07.08.90	79 25.0N	06.0 0.00W	23

The signals from the water, puddles, frozen puddles and ice were well resolved and the errors were less than 1%. An example is shown in Figure 15.

#### SSM/I Produced Ice Charts

The old ice was identified by using 19 GHz and 37 GHz satellite data. Based on the shipborne 37 GHz measurements of ice, it is not possible to classify ice by type due to the high dielectric constant of the moist ice surface for both first year and old ice. The longer wavelength at 19 GHz is required to attempt to classify ice by type in the summer.

The ice concentration using the AES/ISTS algorithm often overestimates the ice concentrations by about 10% based on visual observations. This was also the case in the Weddell Sea during September and October, 1989 (Garrity, ANT VIII/2 1989). Before corrections are applied to the algorithm the line scan camera data needs to be analyzed.

Ice observations were made from six helicopter flights and from the bridge of the ship while in the ice. The ice edge and ice concentration boundaries on the SSM/I maps agreed very well with the visual observations. Captain Jonas, who has made use of the SSM/I maps both in the Greenland and Weddell Seas, stated a few times that these maps are the best ice information he has used (personal communication; 1989, 1990).

The SSM/I charts were received from Toronto on a regular basis, even as far north as 82°N, via INMARSAT. These charts were used by the Captain for navigation purposes and by the Chief Scientist for planning purposes. We also relayed ice information to the Norwegian ship "Lance" and to the German ship "Meteor". Both the Captains of the "Polarstern" and "Meteor" were very grateful for the detailed information, and its usefulness in planning strategic operations.

#### Emission from the unfrozen ocean

There is a well established relationship of wind speed over the ice free ocean and microwave emission. The microwave emission increases linearly with wind speeds greater than 7 m/s near the ocean surface. There is also a relationship of the reflectance from the ocean measured by the line scan camera for greater than 7 m/s wind speeds. This was observed



during this cruise. The results found during this cruise have confirmed that there appears to be a sea surface temperature dependency on the emission. What is not well understood is the wind speed dependence as influenced by cold water and or capillary waves.

High wind speeds over the open ocean provided a good opportunity to fly the line scan camera in order to determine the percent of white caps. This can be compared to the wind speed determined for a satellite footprint using the AES/ISTS algorithm.

#### Arctic and Polar Fronts

During this cruise a relationship, similar as in 1987, between the microwave emission of the open ocean for different sea surface temperatures was found (Figure16). For sea surface temperatures less than 279 K, an increase in emission occurs. We were fortunate to get calm seas during these measurements, thus there was no influence from foam produced by white caps on the microwave emission. Capillary waves in the millimetre range will cause the microwave emission to increase. This is the main reason for the scatter in the data. We hope to screen the data based on capillary wave effects, which should reduce the scatter in Figure 16, as well as include many more data points.

The reason for the increase in emission for colder sea surface temperatures cannot be explained at the present. In the future, a comparison of the biological material in the waters for the Arctic and Polar fronts will be made with the microwave emission to see if this may be one of the causes.

#### Line Scan Camera Measurements of White Caps

The airborne line scan camera system was used in open sea to measure the white cap concentration. There were five flights for different wind speeds as indicated in Table 6. There are some difficulties in distinguishing between water and white caps caused by the overlap of both signals due to the variable illuminations caused by fog and clouds. However, careful analysis should be able to minimize the errors. A preliminary analysis of a few data sets show a correlation between wind speed and white caps. To get a definite relationship we need more data. A special program is needed to be prepared for this purpose.

TABLE 6: PERCENT OF WHITE CAPS ON THE OPEN OCEAN DUE TO WIND

Date	Latitude	Longitude	Wind speed (M/S)	White caps (%) ± 2%
24.07.90	78 45.0N	06 42.0E	10.0	5
04.08.90	81 55.1N	10 13.1W	07.5	3
06.08.90	81 07.4N	08 31.0W	12.5	8
07.08.90	80 37.5N	08 55.6W	11.0	6
10.08.90	74 30.0n	04 00.0E	11.0	6

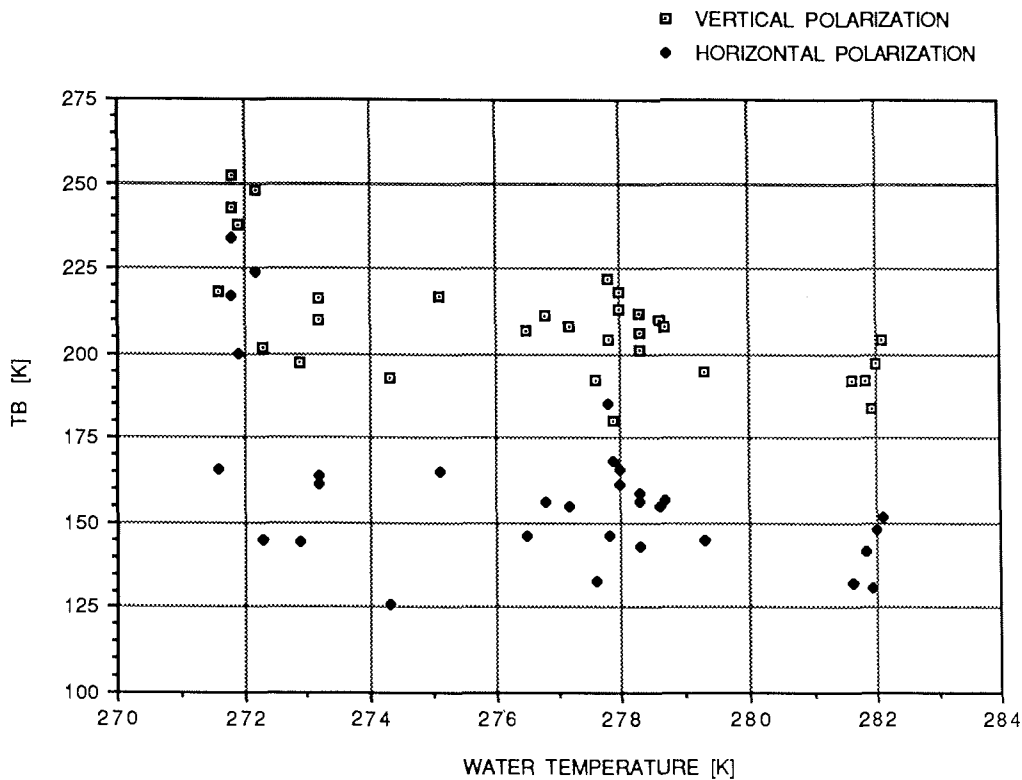


Figure 16: Passive Mikrowellenmessungen in der Grönlandsee: Helligkeitstemperatur als Funktion der Wassertemperatur in der Grönlandsee.

Passive microwave measurements of the sea surface: Brightness temperature in the Greenland Sea.

#### Comparison of Shipborne Wind Speeds with the AES/ISTS Winds

A logarithmic velocity profile has been used to reduce the ship ("Polarstern") winds to 1 m, 5 m and 10 m levels. Winds, as derived from the SSM/I data, were compared during the period of the expedition, with the "Polarstern" winds. It is to be noted that comparisons could be made only when the ship was in open waters. A qualitative comparison indicates that the SSM/I winds are overestimating at all three levels. A detailed examination with a larger data set could identify the required atmospheric and sea surface temperature corrections.

### Passive microwave emission from the atmosphere

One of the main atmospheric corrections required to the SSM/I satellite derived data is due to dense fog. We had dense fog present during most of our cruise. Measurements of the atmosphere using the shipborne radiometer were made every day.

### Radiosonde and Radiometric Measurements

As stated earlier, fog dominated this expedition. The radiosonde became operational on July 26. The daily synoptic charts and the limited amount of radiosonde data through tephigrams, clearly indicate a layer of shallow fog extending from the surface to about 500 m most of the time. We observed an increase in atmospheric microwave emission in the presence of fog. This is due to the presence of water vapour in the atmosphere. The water vapour content can be quantified from the radiosonde data and will be correlated with the measured microwave emission from both the onboard microwave radiometer and the SSM/I.

### Infrared Thermometer Flights

A Barnes Precision Radiation Thermometer (PRT-5) was mounted on the ship's helicopter. This is an infrared radiometer operating in the 8 to 14 micron region. A Gridcase Laptop computer was also mounted in the helicopter for data collection and storage. A number of missions were flown to (a) map the sea surface temperature (skin temperature) and to (b) locate the Arctic Front. The data collected could be graphed soon after landing. We were able to easily detect the surface front in most cases (Figure 17).

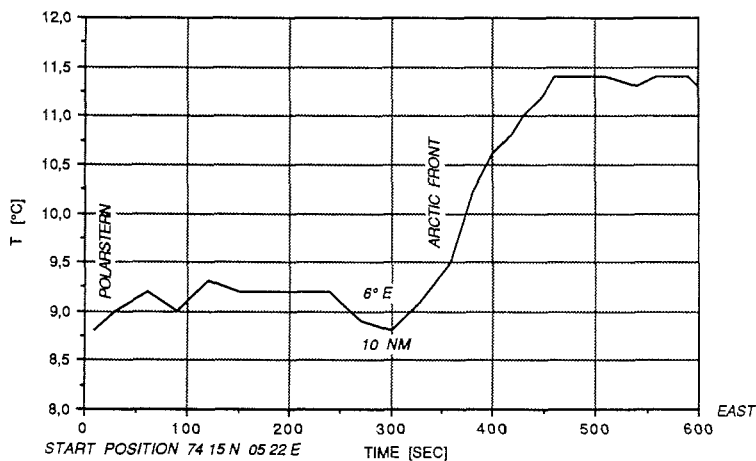


Figure 17: Infrarotmessungen der Wasseroberfläche: Vom Hubschrauber aus gemessene Oberflächentemperatur entlang 74°15'N. 10.08.90, 12.27 h.

Airborne infrared measurements over the Arctic Front along 74°15'N.  
10.08.90, 12.27 h.

6.10

**Film-Project: "Anthology of the Water"**

Partial Production during the ARCTIC-Expedition VII (W. Morell)

The scheduled scheme for shooting of ice had to be entirely re-evaluated and a new concept to be adopted. For once that was due to the unacquainted situation of being in the ice, to the tremendous variety of motives created by it, but also due to the so far unfamiliar conditions on the ship.

Strong vibrations, unknown positions for motives, unsteady sites for the camera tripod on the ship's deck and last, but not least the weather conditions were unfavourable factors for shooting. Therefore the periods following icebound days were used to develop a concept which not only was adjusted to the above mentioned situations, but which among others included additional segments of the film which had not been scheduled before, such as the filming of fishing and of the vessel itself. After completion of shooting about 80 minutes of film were exposed corresponding to approximately 900 m of film material with about 250 different camera set-ups or motives respectively.

During the final version of the film the segment of ice will be allocated approximately 10 minutes, thus, based on a shooting relation of 1 : 7, creating ideal preconditions to produce excellent results.

7. Fahrtteilnehmer/Participants		ARK VI/2
Name/Name	Institut/Institute	
1. Abelmann, Horst	AWI	
2. Asmus, Ken	AES	
3. Berberich, Doris	AWI	
4. Bochert, Axel	AWI	
5. Brunßen, Jutta	AWI	
6. Budéus, Gereon	AWI	
7. Catewicz, Sigmund	AWI	
8. Darnall, Clark	PMEL	
9. Devey, Colin	GPI	
10. Dimmler, Werner	AWI	
11. Dorrien, Christian	IPÖ	
12. Drübbisch, Ulrich	IfM HH	
13. El Naggar, Saad	AWI	
14. Endres, Christoph	GPI	
15. Fretzdorff, Susanne	GEOMAR	
16. Garrity, Caren	AES	
17. Graeve, Martin	AWI	
18. Haase, Karsten	GPI	
19. Hagen, Wilhelm	IPÖ	
20. Hebbeln, Dierk	GeoB	
21. Hoeppe, Götz	AWI	
22. Holloway, Peter	AWI	
23. Jacobson, Chris	Uni Brussel	
24. Kattner, Gerhardt	AWI	
25. Knack, Christian	DWD	
26. Körtzinger, Arne	AWI	
27. Krause, Gunther	AWI	
28. <i>Lahmann, Uwe</i>	<i>Heli</i>	
29. Meyer, Ute	AWI	
30. Michel, Andreas	AWI	
31. <i>Moehrke, Holger</i>	<i>Heli</i>	
32. Morell, Wolfgang	Zentralfilm	
33. Mumm, Nicolai	IPÖ	
34. Murken, Andrea	AWI	
35. Naralla, V. R.	AES	
36. Papenbrock, Thomas	Uni Bochum	
37. Piepenburg, Dieter	IPÖ	
38. Plugge, Rainer	AWI	
39. Pohl, Christa	AWI	
40. Ramseier, René	AES	
41. Rumohr, Sven	GEOMAR	
42. Rust, Jes	IPÖ	
43. Schäfer, Bettina	Uni FF	
44. Schmid, Michael	IPÖ	
45. Sonnabend, Hartmut	DWD	
46. Staubes, Regina	Uni FF	
47. Steinke, Michael	AWI	
48. Stürken, Martha	AWI	
49. Tahon, Jacques	Uni Brüssel	
50. Tandetzki, Jörg	AWI	
51. Tillmann, Urban	AWI	
52. Weidemann, Hartwig	AWI	
53. Wollenburg, Ingo	GEOMAR	

## 8. Beteiligte Institute/ Participating Institutes

Bundesrepublik Deutschland

AWI Alfred-Wegener Institut  
für Polar- und Meeresforschung  
Columbusstraße  
2850 Bremerhaven

GeoB Universität Bremen  
Fachbereich Geowissenschaften  
Postfach 33 04 40  
2800 Bremen 33

Uni Bochum  
Ruhr-Universität Bochum  
Fakultät für Chemie  
Universitätsstraße 150  
Gebäude NC 5/72  
Postfach 10 21 48  
4630 Bochum 1

GPI Geologisch-Paläontologisches  
Institut und Museum  
Universität Kiel  
Olshausenstr. 40-60  
2300 Kiel

IPÖ Institut für Polarökologie der  
Universität Kiel  
Olshausenstr. 40  
2300 Kiel

GEOMAR  
Wischhofstr. 1 - 3  
Gebäude 4  
2300 Kiel

Uni FF  
Johann Wolfgang Goethe-Universität  
Frankfurt am Main  
Institut für Meteorologie und Geophysik  
FB Geowissenschaften  
Feldbergstr. 47  
6000 Frankfurt am Main 1

IfM Institut für Meereskunde  
der Universität Hamburg  
Troplowitzstraße 7  
2000 Hamburg 54

Kanada

AES Atmospheric Environmental Service  
AES/CRESS Microwave Group  
Petrie 214 - York University  
4700 Keele Street  
North York, Ontario  
Canada M3J 1P3

Vereinigste Staaten von Amerika

PMEL  
NOA Pacific Marine  
Environmental Laboratory

Norwegen

NPI Norsk Polarinstitut  
Postboks 158  
N-1330 Oslo /Norge

Belgien

Uni Brû  
Vrije Universiteit Brussel  
Faculteit Wetenschappen  
Pleinlaan 2  
B-1050 Brussel

## 9. Schiffspersonal/Ship's Crew

Jonas, Heinz, G.W.	Kapitän
Goetting, Hans	1. Offizier
Schiel, Helmut	Naut. Offizier
Rodewald, Martin	Naut. Offizier
Blersch, Bruno	Arzt
Geiger, Horst	Funkoffizier
Wanger, Karl-Heinz	Funkoffizier
Briedenhahn, Claus	Ltd. Ingenieur
Knoop, Detlef	1. Ingenieur
Fengler, Rolf Ruediger	2. Ingenieur
Erreth Monostory, Gy	2. Ingenieur
Hoops, Klaus-Jürgen	Elektroniker
Muhle, Heiko	Elektroniker
Lembke, Udo	Elektroniker
Muhle, Helmuth	Elektroniker
Kampen, Michael	Elektroniker
Schuster, Georg	Elektroniker
Schwarz, Reinhold	Bootsmann
Hopp, Wolfgang	Bootsmann
Marowski, Klaus	Zimmermann
Soage Curra, Jose	Matrose
Abreu Dios, Jose	Matrose
Novo Loveira, Jose	Matrose
Pousada Martinez, Sat	Matrose
Gil Iglesias, Luis	Matrose
Oujo Oujo, Domingo	Matrose
Proi Otero, Antonio	Matrose
Reitz, Marcel	Matrose
Schierl, Franz	Lagerhalter
Husung, Udo	Maschinenwart
Wittforth, Willi	Maschinenwart
Schade, Achim	Maschinenwart
Werner, Kurt	Koch
Bruemmer, Johann	Kochsmaat
Stroehlein, Bernd	Kochsmaat
Scheel, Gerhard	1. Steward
Lee, Wen Hsiung	2. Steward
Ambo-Masse, Sjafei	2. Steward
Hopp, Agnes	Stewardess
Lieboner, Roswitha	Stewardess/Krankenschwester
Reitz, Monika	Stewardess
Yu, Chung-Leung	Wäscher
Yang, Chien-Chang	Wäscher



## Stationsliste

### List of Stations

Abkürzungen:  
Abbreviations:

ME	Mercos Water Sampler
BS	Bathysonde, a CTD-device
BRO	"Bio-Rosette", 12 Niskin Bottles + CTD unit
PLA	Plankton net
BO	Bongo net
MJ	Multinet

Station No.	Date 1990	Time UTC	Latitude N	Longitude W	Depth (m)	ME	BS	BRO	PLA	BO	MU	Sonstiges
092	11.07.	16.01 16.10	71°57' 71°57'	07°26' 07°27'	2782 2782			X	X			
093	12.07.	13.51 15.08	73°04' 73°04'	08°02' 08°02'	2684 2681							Aufnahme Verankerung GS-3B
094	12.07	16.20 18.28	73°04' 73°04'	08°03' 08°01'	2667 2683		X					Auslegen Verankerung GS-3C
095	13.07	00.15 01.47	73°50' 73°49'	04°50' 04°49'	- 3289							Aufnahme Verankerung GSP-3B
096	13.07	07.25 18.18	75°00' 75°01'	04°04' 04°07'	3636 3633	X						Aufnahme Verankerung 0270 als 0271 wieder ausgelegt
097	14.07	03.43 04.20	75°00'	09°14'	3300							abgebrochen wegen schlechter Sicht und starker Eisbedeckung
098	14.07	21.53 24.00	75°00' 75°01'	16°00' 16°00'	250 244	X	X	X	X	X	X	
099	15.07	00.06 00.17	75°01' 75°01'	16°00' 16°00'	243 243		X					
100	15.07	01.58 03.40	75°00' 75°01'	15°23' 51°21'	144 139	X	X	X	X	X	X	
	15.07	05.18 07.00	74°57' 74°58'	14°42' 14°38'	170 160	X	X	X				

Station No.	Date 1990	Time UTC	Latitude N	Longitude W	Depth (m)	ME	BS	BRO	PLA	BO	MU	Sonstiges
101	15.07	08.11 14.08	75°02' 75°00'	14°31' 14°22'	145				X	X		FOT, GSN, RMT, AGT, RTR
102	15.07	15.44 17.20	74°58' 74°58'	14°01' 14°02'	181 176		X	X		X		
103	15.07	19.00 20.07	75°00' 75°00'	13°27' 13°27'	211 211	X	X	X		X		
104	15.07	23.10 23.57	74°56' 74°56'	12°48' 12°49'	806 819	X	X		X	X		
	16.07	00.02 01.20	74°56' 74°55'	12°49' 12°50'	815 815			X		X	X	
105	16.07	05.35 08.00	74°53' 74°52'	12°08' 12°10'	1978 1951	X	X	X				
106	16.07	10.24 12.23	74°47' 74°46'	11°28' 11°28'	1821 2826		X	X				
107	16.07.	13.58 16.48	74°45' 74°45'	10°48' 10°49'	3100 3098	X	X	X		X		
108	16.07.	19.49	74°57'	10°09'	3192	X	X	X	X	X		
109	16.07 17.07	23.20 00.41	75°00' 75°00'	09°30' 09°30'	3259 3191	X X	X X					

Station No.	Date 1990	Time UTC	Latitude N	Longitude W	Depth (m)	ME	BS	BRO	PLA	BO	MU	Sonstiges
109 A	17.07.	02.45 05.00	75°00 75°005	09°14' 09°14'	3300 3300							
110	17.07.	06.20 08.55	74°55' 74°55'	08°51' 08°50'	3345 3345	X	X	X		X		
111	17.07.	10.45 13.16	74°45' 74°46'	08°13' 08°16'	3377 3371	X	X	X	X	X		
112	17.07.	14.39 16.47	74°45' 74°45'	07°34' 07°35'	3427 3427	X	X	X	X	X		
113	17.07	17.54 20.24	74°45' 74°75'	06°54' 06°53'	3468 3469	X	X	X	X	X		
114	17.07.	21.28 23.56	74°45' 74°45'	06°15' 06°14'	3506 3508	X	X	X	X	X	X	
114	18.07.	00.30 00.44	74°45' 74°45'	06°13' 06°13'	3510 3510						X	
115	18.07.	02.42 05.51	74°42' 74°42'	05°31' 05°34'	3548 3545	X	X	X	X			
116	18.07.	07.00 09.38	74°44' 74°43'	04°56' 04°55'	3587 3590	X	X	X	X			
117	18.07.	10.42 13.13	74°45' 74°45'	04°19' 04°15'	3619 3620			X	X	X	X	

Aufnahme Verankerung  
AWI 403-3

Station No.	Date 1990	Time UTC	Latitude N	Longitude W / E	Depth (m)	ME	BS	BFO	PLA	BO	MU	Sonstiges
118	18.07.	14.30	74°45'	03°39'	3648	X	X	X	X			
		16.14	74°45'	03°39'	3650							
119	18.07.	17.28	74°45'	03°00'	3670	X	X	X	X			
		19.16	74°45'	03°00'	3670							
120	18.07.	20.17	74°45'	02°23'	3682	X	X	X	X	X	X	
		19.07.	00.02	74°45'	02°26'							
121	19.07.	01.16	74°45'	01°45'	3670	X	X	X				
		03.01	74°45'	01°46'	3671							
122	19.07.	04.05	74°45'	01°08'	3643	X	X	X				
		06.05	74°46'	01°08'	3669							
123	19.07.	07.07	74°45'	00°30'	3464	X	X	X		X		
		09.10	74°45'	00°27'	3508							
124	19.07.	10.11	74°50'	00°09'E	3732	X	X	X	X			
		11.45	74°50'	00°11'E	3660							
125	19.07.	12.57	74°45'	00°46'E	3772	X	X	X				
		14.45	74°45'	00°47'E	3773							
126	19.07.	15.53	74°45'	01°25'E	3769	X	X	X		X		
		17.38	74°45'	01°26'E	3770							

Station No.	Date 1990	Time UTC	Latitude N	Longitude E	Depth (m)	ME	BS	BFO	PLA	BO	MU	Sonstiges
127	19.07.	18.36	74°45'	02°02'	3768	X	X	X	X		X	
		20.56	74°46'	02°04'	3769							
128	19.07.	21.58	74°45'	02°41'	3770	X	X	X				
		23.37	74°45'	02°41'	3769							
129	20.07	00.51	74°45'	03°19'	2422	X	X	X	X	X	X	
		04.14	74°46'	03°24'	2565							
130	20.07.	05.11	74°45'	03°57'	3646	X	X	X				
		06.56	74°46'	03°57'	3644							
131	20.07.	07.58	74°45'	04°34'	3335	X	X	X				
		09.30	74°45'	04°35'	3350							
133	20.07.	11.32	74°31'	05°28'	2623							Aufnahme AWI 405-1
		12.47	74°32'	05°28'	2610							
132	20.07.	14.19	74°45'	05°13'	3369	X	X	X	X	X	X	
		17.11	74°47'	05°18'	3316							
134	20.07.	18.08	74°45'	05°50'	2788	X	X	X	X	X		BO-H
		20.14	74°46'	05°52'	2734							
135	20.07.	21.20	74°45'	06°28'	2268	X	X	X	X	X		
		22.55	74°46'	06°30'	2288							
136	21.07.	00.00	74°45'	07°07'	2036	X	X	X	X	X		
		01.19	74°46'	07°10'	2052							

Station No.	Date 1990	Time UTC	Latitude N	Longitude E	Depth (m)	ME	BS	BFO	PLA	BO	MU	Sonstiges
137	21.07.	02.22 03.50	74°45' 74°46'	07°46' 07°48'	2450 2345	X	X	X		X		
138	21.07.	04.48 07.00	74°45' 74°45'	08°23' 08°25'	3097 3298	X	X	X		X	X	
139	21.07.	07.58 09.33	74°45' 74°45'	09°01' 09°10'	2598 2598	X	X	X		X	X	
140	21.07.	10.38 12.11	74°45' 74°46'	09°39' 09°41'	2589 2593	X	X	X	X	X		
141	21.07.	13.15 14.14	74°45' 74°45'	10°17' 10°20'	2530 2520	X	X	X		X		
142	21.07.	14.46 17.00	74°45' 74°44'	10°55' 10°57'	2491 2486	X	X	X				
143	21.07.	18.01 19.56	74°45' 74°44'	11°32' 11°32'	2471 2471	X	X	X	X			
144	21.07. 22.07.	21.07 01.09	74°45' 74°47'	12°10' 12°11'	2409 2396	X	X	X		X	X	
145	22.07.	02.22 05.06	74°45' 74°46'	12°50' 12°51'	2290 2278	X	X	X			X	

Station No.	Date 1990	Time UTC	Latitude N	Longitude E	Depth (m)	ME	BS	BRO	PLA	BO	MU	Sonstiges
146	22.07.	06.04	74°45'	13°27'	2147	X	X	X				
		07.57	74°49'	13°29'	2144							
147	22.07.	08.57	74°45'	14°05'	2009	X	X	X	X	X	X	
		10.42	74°45'	14°05'	2011							
148	22.07.	11.55	74°45'	14°43'	1630	X	X	X	X			
		12.45	74°45'	14°44'	1612							
149	22.07.	13.58	74°45'	15°21'	1038	X	X	X	X			
		14.48	74°46'	15°22'	1515							
151	22.07.	15.56	74°45'	15°58'	282	X	X	X	X	X		
		16.08	74°45'	15°58'	285							
150	22.07.	17.00	74°45'	16°00'	283							GSN, FOT, RMT
		20.57	74°44'	16°32'	189							
152	22.07.	21.15	74°45'	16°36'	238	X	X	X				
		21.58	74°45'	16°35'	247							
153	22.07.	23.04	74°45'	17°17'	237	X	X	X	X	X		
		23.58	74°46'	17°15'	265							
154	23.07.	19.18	74°45'	07°25'	3449							Gesteinsdredge
		23.40	77°46'	07°17'	2956							
155	24.07.	03.30	78°00'	07°10'	3054							Gesteinsdredge
		06.15	78°00'	07°01'	2725							



Station No.	Date 1990	Time UTC	Latitude N	Longitude E	Depth (m)	ME	BS	BFO	PLA	BO	MU	Sonstiges
156	24.07.	11.15 17.37	78°32' 78°55'	06°39' 06°33'	1749 1750					X	X	Aufnahme Verankerung 0162 Auslegen 0162/1
157	24.07. 25.07.	22.25 00.53	79°20' 79°20'	03°14' 03°14'	2042 2045							Gesteinsdredge
158	25.07.	03.30 06.29	79°27' 79°26'	03°03' 03°02'	3575 3116							Gesteinsdredge
159	25.07.	09.22 11.30	74°42' 79°42'	02°19' 02°19'	2455 2476							Gesteinsdredge
160	25.07.	16.23 18.23	79°25' 79°25'	01°37' 01°44'	2640 1803							Gesteinsdredge
161	26.07.	08.12 09.05	78°00' 78°00'	12°30' 12°31'	232 232	X	X	X		X		
162	26.07.	10.23 11.15	78°00' 78°00'	11°42' 11°42'	217 217	X	X	X	X	X		
162 A	26.07.	12.22 13.10	78°00' 78°00'	10°53' 10°54'	186 183	X	X	X	X	X		
163	26.07.	14.24 15.11	78°00' 78°00'	10°00' 10°00'	159 156		X	X	X	X		
164	26.07.	16.15 19.53	78°00' 78°00'	09°13' 08°58'	920 1265	X	X	X	X	X		RMT, RTR

Station No.	Date 1990	Time UTC	Latitude N	Longitude E	Depth (m)	ME	BS	BRO	PLA	BD	MU	Sonstiges
165	26.07.	20.40 23.33	78°00' 78°01'	08°25' 08°27'	1884 1835		X	X	X	X	X	
166	27.07.	00.47 03.15	78°00' 78°01'	07°37' 07°43'	3445 3363	X	X	X	X	X	X	
167	27.07.	04.29 05.53	78°00' 78°00'	06°48' 06°49'	2384 2383	X	X	X				
168	27.07.	06.55 08.17	78°00' 78°00'	06°00' 06°00'	2352 2355	X	X	X		X		
169	27.07.	09.25 11.30	78°00' 77°59'	05°11' 05°07'	2554 2475		X	X	X		X	
170	27.07.	12.28 14.34	78°00' 78°03'	04°23' 04°21'	2786 2852	X	X	X	X	X	X	
171	27.07.	15.37 17.19	78°00' 78°01'	03°35' 03°33'	3140 3130	X	X	X	X			
172	27.07.	18.20 20.09	78°00' 78°00'	02°78' 02°49'	3000 2999	X	X	X	X	X		
173	27.07.	21.15 23.07	78°00' 77°59'	01°59' 01°58'	3122 3124		X	X	X	X		

Station No.	Date 1990	Time UTC	Latitude N	Longitude E / W	Depth (m)	ME	BS	BRO	PLA	BO	MU	Sonstiges
174	28.07.	00.58	78°00'	01°11'	3106	X	X	X	X	X	X	
		03.35	77°59'	01°11'	3109							
175	28.07.	05.02	78°00'	00°23'	3102	X	X	X		X		
		06.46	78°01'	00°24'	3101							
176	28.07.	08.06	78°00'	00°24'W	3101	X	X	X	X	X		
		09.59	78°01'	00°24'W	3090							
177	28.07.	11.08	78°00'	01°13'W	3029	X	X	X	X	X		
		12.41	78°00'	01°10'W	3034							
178	28.07.	14.10	78°00'	02°01'W	2979	X	X	X	X	X		RMT
		17.26	77°57'	02°00'W	2984							
179	28.07.	18.57	78°00'	02°49'W	2870	X	X	X	X	X		
		20.40	77°59'	02°52'W	2857							
180	28.07.	21.56	78°00'	03°37'W	2716	X	X	X	X	X	X	
		29.07.	00.12	78°18'	03°39'W							
181	29.07.	01.46	78°00'	04°25'W	2260	X	X	X		X	X	
		03.50	78°00'	04°25'W	2252							
181A	29.07.	05.38	78°03'	04°48'W	1545						X	Aufnahme Verankerung 0261 Auslegen 0261/1
		10.12	78°01'	04°46'W	1672							
182	29.07.	11.06	78°00'	05°14'W	579		X	X	X	X		XBT
		12.12	77°59'	05°13'W	634							

Station No.	Date 1990	Time UTC	Latitude N	Longitude W	Depth (m)	ME	BS	BFO	PLA	BD	MU	Sonstiges
183	29.07.	13.50	78°00'	05°59'W	318	X	X	X	X	X		
		15.08.	77°59'	05°57'W	320							
184	29.07.	16.48	78°00'	06°51'	345	X	X	X	X	X		
		17.44	78°00'	06°50'	340							
185	29.07.	20.00	78°00'	07°34'	250	X	X	X	X	X		
		20.57	78°00'	07°32'	259							
186	29.07.	23.57	78°00'	08°26'	219	X	X	X		X	X	
		30.07.	01.38	78°00'	08°27'	222						
187	30.07.	02.40	78°00'	09°14'	215	X	X	X		X		
		04.09	78°00'	09°17'	211							
188	30.07.	05.12	78°00'	10°01'	208	X	X	X		X		
		06.18	78°01'	10°03'	206							
189	30.07.	07.40	78°00'	10°50'	226	X	X	X		X		
		09.01	78°00'	10°51'	225							
190	30.07.	10.30	78°01'	10°38'	183		X	X	X	X		
		11.51	78°00'	11°37'	183							
191	30.07.	15.00	77°59'	12°23'	158		X	X	X	X		
		15.46	77°88'	12°23'	152							
192	30.07.	18.24	78°01'	13°16'	127		X	X		X		
		19.15	78°01'	13°15'	137							
193	30.07.	20.58	78°00'	14°02'	109		X	X		X		
		22.33	78°01'	14°00'	107							

Station No.	Date 1990	Time UTC	Latitude N	Longitude W	Depth (m)	ME	BS	BRO	PLA	BO	MU	Sonstiges
194	30.07.	23.57	78°00'	14°50'	413		X	X	X	X		
	31.07.	01.30	78°00'	14°47'	418							
195	31.07.	02.32	78°00'	15°20'	476		X	X		X	X	FOT,AGT,RMT
	31.07.	07.43	78°00'	15°22'	481							
196	31.07.	09.00	78°05'	14°47'	173		X	X				
		09.32	78°05'	14°46'	171							
197	31.07.	14.18	78°11'	14°04'	177		X	X	X	X		
		15.10	78°11'	14°04'	178							
198	31.07.	17.08	78°15'	13°19'	131		X	X				
		17.28	78°15'	13°20'	127							
199	31.07.	19.33	78°20'	12°37'	179		X	X		X		AGT, FOT, BO-H
		22.14	78°20'	12°37'	175							
200	01.08	14.49	80°08'	15°11'	403		X	X		X		FOT,AGT, RMT
		18.54	80°09'	15°02'	372							
201	01.08.	20.06	80°10'	16°01'	245		X	X	X	X		
		20.59	80°10'	16°01'	323							
202	01.08.	23.15	80°10'	14°00'	141		X	X		X		FOT
		02.09.	00.44	80°10'	13°59'	143						
203	02.08.	01.48	80°10'	13°01'	74		X	X	X	X		
		02.30	80°10'	13°00'	74							

Station No.	Date 1990	Time UTC	Latitude N	Longitude W	Depth (m)	ME	BS	BFO	PLA	BO	MU	Sonstiges
204	02.08.	03.37	80°10'	11°59'	156		X	X				
		04.11	80°10'	11°59'	154							
205	02.08.	05.44	80°10'	11°00'	103		X	X		X		FOT,AGT
		07.44	80°11'	10°50'	123							
206	02.08.	08.46	80°10'	10°00'	269		X	X	X	X		
		09.37	80°09'	09°58'	271							
207	02.08.	11.40	80°10'	08°53'	331		X	X				FOT,AGT,RMT
		15.25	80°10'	08°48'	342							
208	02.08.	17.25	80°10'	07°56'	342		X	X		X		FOT
		18.49	80°09'	07°56'	319							
209	02.08.	20.13	80°10'	06°59'	315		X	X				
		21.15	80°10'	07°00'	323							
210	02.08.	22.41	80°10'	05°59'	367		X	X	X	X		
		24.00	80°10'	05°56'	373							
211	03.08.	06.00	81°00'	05°31'	2283		X	X			X	
		09.52	81°00'	05°26'	2290							
212	03.08.	11.20	81°00'	06°34'	1152		X	X	X	X		RMT
		14.14	81°00'	06°52'	1480							
213	03.08.	15.23	81°00'	07°38'	558		X	X			X	AGT,FOT
		19.17	81°02'	07°50'	456							

Station No.	Date 1990	Time UTC	Latitude N	Longitude W	Depth (m)	ME	BS	BRO	PLA	BD	MU	Sonstiges
214	03.08.	20.11	81°00'	08°43'	115		X	X	X	X		FOT,AGT
		22.16	81°01'	08°45'	121							
215	03.08.	23.00	81°01'	09°14'	101		X	X		X		AGT, FOT
		04.08. 01.00	81°00'	09°05'	111							
216	04.08.	06.07	81°42'	11°46'	167		X	X		X		AGT, FOT
		08.22	81°42'	11°34'	169							
217	04.08.	09.51	81°50'	10°36'	540		X	X	X			AGT, FOT
		12.53	81°51'	10°42'	494							
218	04.08.	14.39	81°56'	10°22'	2400		X	X	X	X	X	RMT
		18.58	81°54'	10°00'	2424							
219	04.08.	20.05	82°01'	09°10'	2802		X	X				
		21.23	82°01'	09°11'	2808							
220	04.08.	22.00	82°04'	08°48'	2808		X	X	X	X	X	
		23.43	82°04'	08°50'	2922							
221	05.08.	08.06	81°48'	10°53'	187			X				GSN, FOT
		10.55	81°47'	10°33'	261							
222	05.08.	11.01	81°48'	10°34'	251							GSN, FOT
		13.22	81°45'	10°26'	239							

Station No.	Date 1990	Time UTC	Latitude N	Longitude W/E	Depth (m)	ME	BS	BRO	PLA	BO	MU	Sonstiges
223	05.08.	13.51 17.18	81°48' 81°45'	10°28' 09°59'	550 545							GSN, FOT
224	06.08.	07.56 10.38	81°10' 81°07'	08°39' 08°32'	192 196		X					GSN, FOT
225	06.08.	11.07 13.25	81°09' 81°08'	08°24' 08°21'	377 402							GSN, FOT
226	07.08.	08.00 10.11	80°36' 80°38'	08°19' 09°02'	171 109							FOT
227	07.08.	10.51 12.40	80°35' 80°37'	08°38' 09°00'	247 201							GSN, FOT
228	07.08.	12.57 15.02	80°36' 80°34'	08°52' 08°21'	245 247							GSN, FOT
229	08.08.	18.59 19.17	77°30' 77°30'	01°40'E 01°40'E	3222 3221			X			X	
230	09.08.	02.00 06.48	76°30' 76°31'	07°00'E 07°22'E	2900 2711							Gesteinsdredge
231	09.08.	18.00 20.09	74°00' 74°01'	03°59'E 04°00'E	3382 3248		X				X	
232	09.08. 10.08.	21.34 05.10	74°00' 74°00'	04°01'E 08°59'E	3402 2777							Beginn der XBT-Vermessung



Station No.	Date 1990	Time UTC	Latitude N	Longitude E	Depth (m)	ME	BS	BRO	PLA	BO	MU	Sonstiges
232	10.08.	05.10	74°00'	08°59'	2777							XBT-Vermessung
		23.50	74°30'	09°00'	2645							
232	11.08.	01.43	74°45'	09°00'	2594							XBT-Vermessung
		18.14	75°15'	09°00'	2452							
232	12.08.	00.55	75°15'	04°00'	3226							Ende der XBT-Vermessung
		09.04	75°30'	09°00'	3044							

