Scientific Cruise Reports of Arctic Expeditions ARK VI/1–4 of RV "Polarstern" in 1989

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with contributions of the participants

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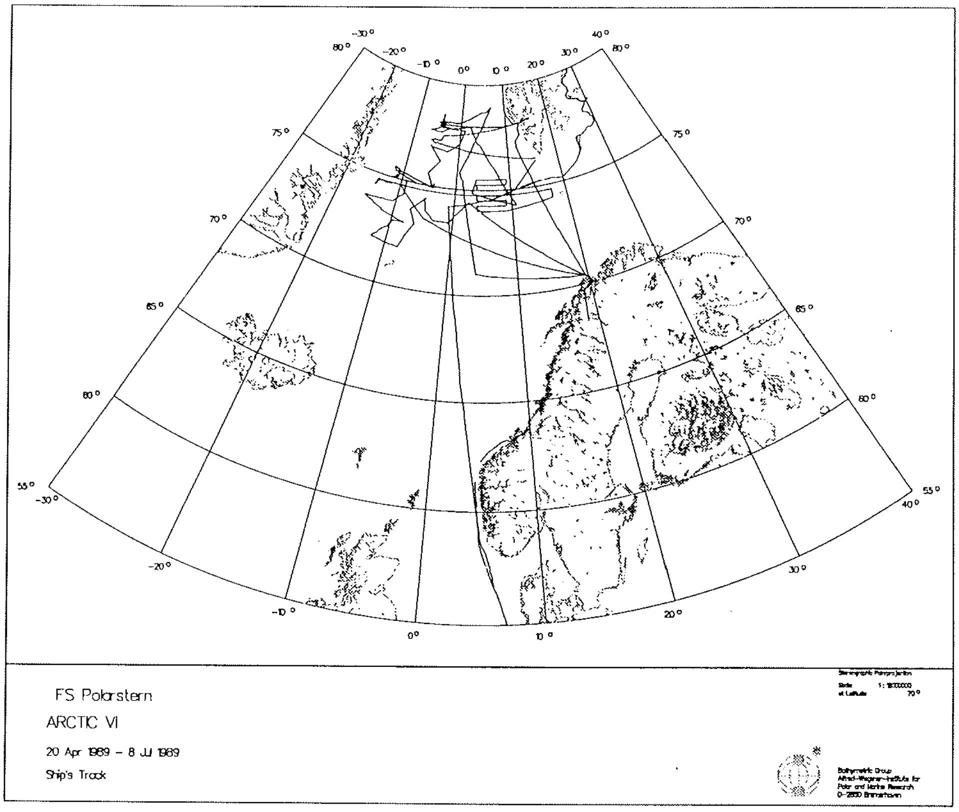
Figure 1



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1. FAHRTABSCHNITT ARK VI/1
BREMERHAVEN - TROMSÖ
20.04. - 15.05.1989

J. Schwarz (Chief Scientist)

1.1 ZUSAMMENFASSUNG UND FAHRTVERLAUF

Der erste Fahrtabschnitt der ARK VI/1 Expedition mit F.S. "POLARSTERN" war hauptsächlich der Erforschung der Eisverhältnisse und der mechanischen und physikalischen Eigenschaften von mehrjährigem Eis und von Eisbergeis in der nördlichen Barents See gewidmet (s. Abb.1.1). Außer diesen eistechnischen Forschungsaufgaben wurden folgende weitere Untersuchungen durchgeführt:

- Sedimenteinschlüsse in verschiedenen Eisarten
- Mikrowelleneigenschaften von Eis, Schnee, Wasser und Luft
- Bestimmung von Strömungsvektoren und Beschreibung der Unterwasser-topographie von Eisbergen
- Vorkommen und Verhalten von Seevögeln in dichtem Packeis
- Lebenszyklen und vertikale Wanderung von herbivoren Copepoden.

An den Untersuchungen waren insgesamt 31 Wissenschaftler aus 5 verschieden Ländern beteiligt.

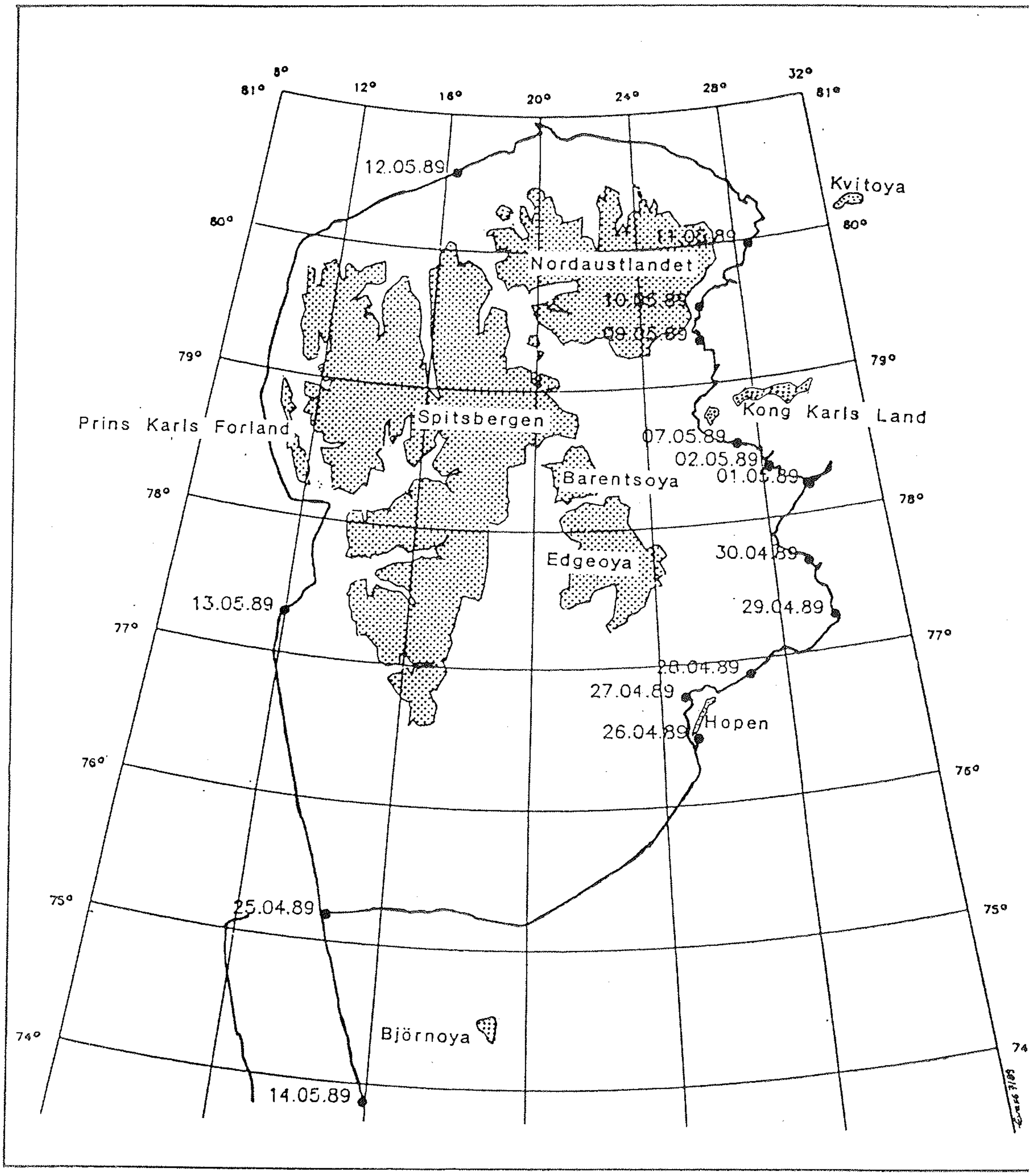
Zur Durchführung der Forschungsaufgaben verließ die "POLARSTERN" am 20.4.1989 um 1:00 Uhr ihren Heimathafen Bremerhaven, zunächst mit Kurs Trondheim in Norwegen, wo am 22.4. vormittags 11 norwegische Wissenschaftler mit ihren Geräten per Hubschrauber an Bord genommen wurden. Aus bisher nicht geklärter Ursache löste sich bei einem der Gerätetransportflüge ein Sonargerät aus der Außenlastschlinge des Hubschraubers, fiel ins Wasser und versank in ca. 300 m Tiefe. Ein Ersatzgerät wurde per Schiff zur "POLARSTERN" gebracht, als diese am 24.4 morgens Tromsö auf ihrem Weg in Richtung Bäreninsel passierte.

Die erste marinebiologische Station wurde am 25.4. morgens bei Pos. 75° 02' N und 11° 45' E (nordöstlich der Bäreninsel) durchgeführt. Am Nachmittag wurde auf der Fahrt in Richtung Hopen die Treibeisgrenze passiert. Bis ca 20 Seemeilen südlich von Hopen erreichte die Eisbedeckung jedoch kaum mehr als 3/10. Auf der Ostseite von Hopen war bei östlichen Winden ein- und mehrjähriges Eis stark aufgepreßt. Eine Durchfahrt wäre hier nur unter großem Zeit- und Energieaufwand möglich gewesen; daher wurde die Insel auf der nahezu eisfreien Westseite passiert. Nordwestlich der Insel Hopen wurden am 26. und 27.4. an drei mehrjährigen Eisschollen Versuche aller wissenschaftlichen Disziplinen durchgeführt. Gleichzeitig wurden Eisproben von einem 2 Seemeilen nördlich von Hopen gestrandeten Eisberg per Hubschrauber geholt.

Am 28.4.1989 morgens wurde die Fahrt in nordöstliche Richtung (Generalkurs 30°) fortgesetzt. Übereinstimmend mit Eisvorhersagekarten des "Atmospheric Environment Service" der York University Toronto (Canada), die per Telefax nahezu täglich auf die "POLARSTERN" gesandt wurden, nahm der Prozentsatz an mehrjährigem Eis kurz nördlich von Hopen deutlich zu (65%). Große mehrjährige Eisfelder (ca. 10 km) mit Eisdicken von 2 bis 4m zwangen das Schiff von der Kursfahrt abzuweichen und einen durch Helikopteraufklärung gewiesenen Weg um die Eisfelder herum in offenen Rinnen und oder durch dünnes einjähriges Eis zu fahren. Auf diese Weise konnten immerhin noch durchschnittlich ca. 6 kn Fahrt gemacht werden.

Am 29.4. wurde bei Pos. 77°15' N und 29°49' E an einer 4,3 m dicken Alteisscholle Station gemacht, wo alle wissenschaftliche Disziplinen ihre Untersuchungen durchführten. Gleichzeitig wurden am Nachmittag bei gutem Wetter von Kapitän und

Figure 1.1



Ship`s Track during ARK VI/1

Fahrtleiter die Eisverhältnisse per Hubschrauber über eine Strecke von 60 Seemeilen in nördliche Richtung erkundet. Dabei wurde übereinstimmend festgestellt, daß zwischen den großen mehrjährigen Eisfeldern weiterhin genügend offene Rinnen und einjähriges Eis vorhanden war, um die Fahrt wie geplant nach Norden fortzusetzen; dabei wurde mit geringerem Fortschritt, aber nicht mit besonderen Schwierigkeiten gerechnet.

Entsprechend diesen Erwartungen wurde am 30.4 und 1.5. dank häufiger Eisaufklärung mit dem Hubschrauber 1 bis 2 Knoten Fahrt gemacht. Ein erneuter Eisaufklärungsflug am 1.5. nachmittags bis Kong Karls Land ergab, daß die Eisverhältnisse günstiger werden, je näher man an die Inselgruppe herankommt; günstiger wegen weniger Alteis und geringerer Eisbedeckung. Nördlich der Inselgruppe war das Meer weithin eisfrei. In der Nähe der Inselgruppe wurden mehrere Eisberge gesichtet; auf zwei von ihnen konnte man mit dem Hubschrauber landen. Die Eisverhältnisse westlich von Kong Karls Land waren deutlich günstiger als östlich; daher wurde geplant, die Inselgruppe im Westen zu passieren.

Auf dem Rückflug von Kong Karls Land zur "POLARSTERN" wurde der Schiffsführung eine vermeintlich gut befahrbare offene Rinne aufgezeigt, in der das Schiff anfangs auch gut vorankam. Gegen Mitternacht (2.5.) wurde es jedoch nebelig, nachdem der Wind auf Süd gedreht hatte; bei sehr schlechter Sicht verlor man die Rinne und machte in schwerem, mehrjährigem Eis kaum Fortschritte. Ab ca. 13 Uhr wurde die Sicht wieder besser; der sich anschließende Eisaufklärungsflug zeigte die schwierige Situation, in der sich die "POLARSTERN" befand: Umgeben von dickem, mehrjährigem Packeis (>65%), in dem kaum noch offene Rinnen vorhanden waren. Der Südwind hatte offenbar das Eis gegen Kong Karls Land gedrückt, wodurch sich die Rinnen dichtgeschoben hatten.

Nach verschiedenen Fehlversuchen, sich hieraus zu befreien, schlug der Kapitän vor umzukehren und um die Südspitze Spitsbergens herum nach Longyearbyen zu fahren, wo am 8.5. der Austausch der Wissenschaftler stattfinden sollte. Nach eingehender Erörterung der Situation im Kreise der Wissenschaftler und mit dem Kapitän entschied man sich, die Fahrt nach Norden fortzusetzen. Maßgebend hierfür war die Information von Satellitenbildern, wonach der Prozentsatz mehrjährigen Eises von Kong Karls Land nach Norden abnahm und die Fahrtstrecken bis zum offenen Wasser nach Norden kürzer als nach Süden waren. Außerdem wäre bei einer Umkehr der wissenschaftliche Wert der Expedition gering gewesen.

Weitere Aufklärungsflüge am 3.5. ergaben, daß sich die extrem schwierige Eislage nur über ca. 12 Seemeilen erstreckte und danach zum Kong Karls Land hin entspannte.Trotz anhaltend südlicher Winde öffneten und schlossen sich im Rhythmus der Tide immer wieder offene Rinnen. Eine Offen-Rinne Situation wurde am 3.5. genutzt, um ca 6. Seemeilen nach Norden zu fahren. Danach mußte in permanentem Rammeisbrechen eine ca. 6 Seemeilen breite Scherzone sehr dicken und z.T. aufgepreßten Eises durchfahren werden. Dies dauerte drei Tage. Damit war klar, daß die "POLARSTERN" verspätet nach Longyearbyen zum Austausch der Wissenschaftler kommen würde. Reederei, Alfred Wegener Institut und alle Angehörigen wurden am 5.5 über die Verspätung informiert.

Seit dem 3.5. herrschte zeitweise dichter Nebel. Da hierbei der Eisbrechfortschritt nicht im Verhältnis zum Brennstoffverbrauch stand, wurde die "POLARSTERN" mehrfach stillgelegt. Diese Situationen wurden von den Wissenschaftlern immer wieder für Messungen auf dem Eis ausgenutzt.

Am 8.5. konnte Svensköya, die westlichste Insel von Kong Karls Land auf der Westseite in flotter Fahrt passiert werden.Unmittelbar nördlich von Kong Karls Land war offenes Wasser. Der Wind hatte inzwischen (am 8.5.) von Südwest auf Nordost gedreht. Erst ca. 15 Seemeilen nördlich von Kong Karls Land begann das Eis, wieder dichter und dicker zu werden.Ein Aufklärungsflug am 8.5. abends über 50 Meilen nach Norden zeigte große mehrjährige Eisschollen im Wechsel mit dünnerem einjährigem Brucheis. Es wurde erwartet, daß durch diese Eisverhältnisse etwa 2-3 kn Fahrt möglich sein würde. Offenbar hatte der Aufklärungsflug während der günstigeren Tidezeit stattgefunden, denn einige Stunden später wurde die Fahrt der "POLARSTERN" durch dickes Packeis erneut gestoppt. Man vermutete, daß die Nordost-Winde die dichtere Packung des Eises verursacht haben könnten. Daher sollte vor einer Weiterfahrt eine Änderung der Windverhältnisse abgewartet werden. Als dies nach 20 Std. nicht eingetreten war (9.5. abends),beschloß man, sich mit Hilfe von Helikopter-Eisaufklärungsflügen weiter nach Norden durchzuboxen. Dies führte dazu, daß die "POLARSTERN" am 12.5. morgens offenes Wasser im Nordosten Spitsbergens erreichte, von wo die Fahrt dann zügig um die Nordküste herum in Richtung Tromsö verlief. Hierhin war der Austausch der Wissenschaftler wegen der Verspätung verlegt worden. Am 13.5. war "POLARSTERN" morgens um 8 Uhr querab vom Isfjord/Spitsbergen, am 14.5. südwestlich der Bäreninsel und am 15.5. morgens in Tromsö.

1.2 SUMMARY AND ITINERARY

The first leg of the ARK VI expedition with R.V."POLARSTERN" was mainly dedicated to investigations of the ice conditions and of the mechanical and physical properties of multi-year- and iceberg ice in the northern part of the Barents Sea (s. Fig.1.1). Besides these ice technological research tasks the following investigations have been carried out:

- Sediments in various types of ice
- Microwave properties of ice, snow, water and air
- Current vectors and underwater topography of icebergs
- Sea birds in the Northern Barents Sea
- Zooplankton investigations.

31 scientists from five countries were engaged in these research activities.

R.V. "POLARSTERN" left its home port Bremerhaven on April 20th,1989 at 1:00 h, first heading for Trondheim, Norway, where eleven scientists and their scientific equipment were lifted on bord by helicopter. On one of the equipment transfer flights a sonar transducer slipped out of the sling load of the helicopter and sank in a water depth of approx. 300 m. The cause of this incident has not yet been revealed. A substitute sonar transducer was transferred to R.V. "POLARSTERN" by ship when the research vessel was passing Tromsö on her way towards the area of Bear Island.

The first marine biological station was carried out in the morning of April 25th, at location 75:02 N and 11:45 E (northeast of Bear Island).The drift ice boundary was passed that afternoon on the voyage towards Hopen Island. Up to 20 nautical miles (nm) south of Hopen the ice coverage reached seldom more than 3/10. On the east side of Hopen first and multi-year ice was heavily ridged. As the passage through this ice would have been very time and energy consuming the island was passed on the nearly icefree westside.

The first ice tests and other research programs were carried out northwest of Hopen Island at three multiyear ice floes on April 26th and 27th. Simultaneously, ice samples of an iceberg grounded two nautical miles north of Hopen were gathered with helicopter assistance.In the morning of April 28th, 1989 the voyage was continued in northeasterly direction (30 degrees).In agreement with ice forecast charts provided almost daily per telefax by the Atmospheric Environment Service of York University, Toronto (Canada), the percentage of multi-year ice increased significantly shortly north of Hopen (65%). Large multi-year ice floes (up to 10 km diameter) of 2 m to 4 m thickness forced the ship to deviate from the main course and to surround the ice floes in open leads or relatively thin first-year ice. These passages were explored by helicopter reconnaissance. By this procedure an average progress of 6 kn was achieved.

On April 29th, a station was performed at location 77:15 N and 29:49 E alongside a 4,3 m thick old ice floe, giving opportunity to all scientific disciplines to execute their investigations. In the afternoon the ice conditions were inspected by ships master and chief scientist over a distance of 60 nm in northerly direction by helicopter. It was unanimously concluded that the ice conditions would permit the further passage of "POLARSTERN" northwards through open leads and first-year ice between giant multi-year ice floes without major difficulties.

On April 30th and May 1st "POLARSTERN" advanced with 1 to 2 knots due to frequent helicopter ice reconnaissance flights. One of these flights was extended as far as Kong Karls Land and showed that the ice conditions would become easier towards these islands; i.e. less old ice and lower ice coverage. North of the islands the sea was free of ice in the visible range. Close to the islands several grounded icebergs were discovered; on two of them helicopter landing was possible. As the ice conditions west of Kong Karls Land were significantly easier to navigate than on the east side, it was planned to pass Kong Karls Land on the west.On the flight back from Kong Karls Land to "POLARSTERN", a navigable channel was found and pointed out to the navigators on the ship.

Along this track the vessel proceeded with good progress. Shortly after midnight it became foggy and the wind changed to southerly direction. Due to the poor visibility the ship lost the track and therefore hardly advanced in heavy multi-year ice. The visibility improved around 13 h of May 2nd and allowed an ice reconnaissance flight which showed that "POLARSTERN" was surrounded by thick multi-year pack ice with only few open leads. The southerly winds had apparently pushed the ice against Kong Karls Land, whereby the open leads had more or less been closed. After several unsuccessful trials to free the ship out of this difficult situation, the ships master suggested to turn around the ship and navigate to Longyearbyen via the southerly tip of Spitsbergen, where the exchange of scientists was scheduled for May 8th.After intensive evaluation of the situation with scientists and ships master it was decided by master and chief scientist to continue the voyage along the northern route (around the north coast of Spitsbergen). This decision was based upon satellite pictures which showed that the north coast of Spitsbergen was free of ice, the percentage of multi-year ice decreased from Kong Karls Land northwards and the distance towards the open water was only 80 nm on the northern against 150 nm on the southern route. Furthermore, the scientific value of the expedition would have been drastically reduced by a return. Ice reconnaissance flights on May 3rd indicated that the extremely difficult ice condition extended only over approx. 12 nm and would ease towards Kong Karls Land. In spite of continuing southerly winds the leads opened and closed according the tidal currents. Taking advantage of an open lead situation on May 3rd "POLARSTERN" advanced 6 nm north. Thereafter a 6 nm wide shear zone of very thick and partly ridged ice had to be passed by continuous ramming; this took three days. It became clear that "POLARSTERN" would be late for the exchange of scientists in Longyearbyen. Hapag Lloyd, Alfred Wegener Institut for Polar and Ocean Research and all relatives were informed of the delay of "POLARSTERN". Since May 3rd the visibility was temporarily reduced by thick fog. As the ships progress was small in relation to the fuel consumption, "POLARSTERN" was repeatedly downed. The scientists took advantage of this situation and carried out ice measurements on multi-year ice floes and icebergs. On May 8th, Svenskøya, the western most island of Kong Karls Land was passed at good speed. Immediatly north of Kong Karls Land the sea was free of ice. The wind had turned on May 8th from southwest to north east. The ice became denser and thicker approx. 15 nm north of Kong Karls Land. A reconnaissance flight in the evening of May 8th reaching as far as 50 nm north showed big multi-year ice floes varying with first-year broken ice. It was expected that "POLARSTERN" would be able to navigate through this ice with 2 to 3 knots. Apparently the ice reconnaissance flight had taken place at a favourable tidal phase, because few hours later "POLARSTERN" was stuck in thick pack ice again. It was assumed that the northeasterly winds had packed the ice more densely. Thus, the voyage should continue after the wind had changed to a more favourable direction. As this did not occur in the following 20 hours (evening of May 9th) it was decided to proceed north with the assistance of ice reconnaissance flights. Due to this procedure "POLARSTERN" reached open water in the north east of Spitsbergen in the morning of May 12th. From here on the voyage continued relatively rapid around the north shore of Spitsbergen heading for Tromsö where the exchange of scientists was rescheduled due to the delay.On May 13th, "POLARSTERN" was off Isfjord (Spitsbergen), passed Bear Island on May 14th and reached Tromsö in the morning of May 15th.1989.

1.3 REPORTS OF THE WORKING GROUPS

1.3.1 SAMPLING OF ICEBERG ICE

H.Jensen, S.Loset,M. Lovas

The objectives of this project were:

a. To sample ice from icebergs encountered along the ship route. Some of the samples were to be tested on board the ship (HSVA), some after the expedition (SINTEF)

b. To obtain temperature profiles of the icebergs.

Achievements

The plan was to start sampling ice cores from an iceberg in position N 75°45' E 23°30', discovered during the R/V LANCE expedition. When reaching this iceberg we experienced that it was surrounded by open water. Hence the other members of the expedition could not work here, and it was decided to skip this iceberg on our way up north, and head for iceberg NE of Hopen.

Iceberg station No. 1 was carried out on a grounded iceberg in position N.76°41' E 25° 48' NE of Hopen. The iceberg was boarded on 27 April and 3 shallow samples from about 50 cm depth were collected by using chain saw. At the same iceberg a temperature profile down to 6 m was obtained with a lowest temperature of about -12.5 degrees Celsius at 6 m depth.

During the R/V LANCE expedition two weeks earlier NHL had deployed an Argos transmitter on this iceberg. The drift track of this iceberg will be recorded via satellite as long as the buoy remains on the iceberg.

Iceberg station No. 2 was carried out on a grounded iceberg in position N 78°40' E 27°15', SE of Svenskøya on May 6. Including ferrying of equipment and personnel the station was carried out in 6 hours. Samples from 3 cores, depth 1.0 m, 2.2 m and 2.6 m respectively, were collected and stored on board the ship. A temperature profile down to 9 m showed a lowest temperature of about -13.5 degrees Celsius at 4 m depth.

Iceberg station No. 3 was carried out on a grounded iceberg in position N 79°00 E 28°10', north of Kongsöya on May 8. The iceberg had a freeboard of about 25 m and was one in a cluster of 6 grounded icebergs close to the edge of the landfast ice. Including ferrying of equipment and personnel the station was carried out within 4.5 hours. On this station 2 cores, 3.2 m and 2.1 m respectively, were sampled and stored on board the expedition ship. A temperature profile down to 11 m showed a lowest temperature of about -15.5 degrees Celcius at 5 m depth.

Both the number of iceberg stations and the time spent on each iceberg suffered from the difficult ice conditions for the ship as well as the problematic flying conditions for the helicopter. Still some 700 kg of iceberg ice will be brought back for later testing and the expedition is from NHL's point of view considered as successful.

1.3.2 RADAR MEASUREMENTS OF ICEBERG THICKNESS

H. Jensen, S. Loset, M. Lovas

The objective was to profile the thickness of selected icebergs by use of a continuous wave (CW) radar. This radar has been used to profile glaciers on Norwegian mainland and Svalbard. In Antarctica it has penetrated more than 1000 m of Antarctic glacier ice.

Two weeks before this expedition the radar was used to profile 3 icebergs at Spitsbergenbanken and Hopen. All these icebergs were flat and tabular, and the radar was operated successfully from a Nansen sled.

During the ARK VI/1 expedition the radar was first tested on a multiyear ice floe in order to check the technical performance. The test was performed with the radar mounted on sled and was executed without encountering any problems.

Later on this expedition the radar has been used on two occations. Both times the radar was installed in the expedition helicopter, a BO 105. When installed in the helicopter, the radar was supplied with electrical power from a generator hanging in a bridle 4 m under the helicopter.

The radar was first used on April 29, when the ship was 62 sm from Stonebreen. In order to be able to fly at normal speed between the ship and the glacier, the radar equipment was loaded into the helicopter and the antennas and the generator in sling load were installed on the sea ice right outside the glacier. The work on the glacier lasted about 2.5 hours. During the operation the generator stopped and the radar could no longer be operated. This stop probably injured parts of the hard disc and damaged the floppy disc drive. After a lot of work and contacts with the programmer we managed to make the radar operational again by recovering and adjusting some older software.

The next profiling was performed at Austfonna on Nordaustlanded May 10. The radar was installed on board "POLARSTERN" about 5 nm from the glacier. Due to low visibility on the glacier the radar was used to profile along the shelf at a distance of 200 - 1000 m from the edge of the glacier. From the quick looks after this profiling it was demonstrated that the helicopter radio and probably the radar altimeter on the helicopter introduce a lot of noise in the radar measurements. After post-processing we still hope that the data from this flight can be interpreted.

After this we were looking for an opportunity to profile either icebergs or a glacier with the radar operated from a sled, but the ship left the area before this could be accomplished. Although the outcome of the radar profiling has been limited during this expedition the radar has proven to be useful for these applications and will most likely be used in future expeditions.

1.3.3 K_{Ic}-DETERMINATION ON ICEBERG ICE SAMPLED IN THE BARENTS SEA

F.U.Häusler

Scope of Work

The principal task of the investigation was to evaluate the plane strain fracture toughness K_{Ic} (critical stress intensity factor for mode I cracks) for ice sampled from icebergs as encountered in late spring in the Barents Sea. In order to validate the K-values determined, the yield strength of the ice investigated was to be evaluated as well (see ASTM E-399-81). For this purpose the bending strength was employed as a measure of the tensile strength. Since iceberg ice appeared to be prone to rather rapid change in its (mechanical) properties after sampling (e.g. due to pressure release), the testing was to be performed as soon as possible after recovery. The crystal structure of the ice was to be documented.

As a side task of the above investigation the fracture toughness of multi-year ice sampled during the expedition was to be studied.

Performance of Research

For the evaluation of the plane strain fracture toughness the compact tension geometry C (T) according to ASTM E 399-81 was employed for the sample shape. The samples were cut as 120 mm thick slabs from cores of 284 mm in diameter sampled by NHL. The cuts were parallel to the longitudinal axis of the cores. By means of an especially designed milling and cutting device the raw slabs were machined to geometrically proper shaped samples. The two cutoffs from each core section were used to produce small scale beams of approximately 340 mm length for the bending tests.

After preparation the samples were loaded on a portable servo-hydraulic testing machine of 10 kn load capacity. For the C (T)-specimen the load was applied through clevises with bolts designed after ASTM E-399-81 for the given sample size. During each test the force and the crack opening displacement (COD) were recorded. The COD-transducer was clamped onto the open end of the notch of the C (T)-sample. The bending specimen were 3-point loaded. Besides the force and the piston stroke, here the beam's deflection was measured at four different positions of the beam simultaneously in order to establish the bending line. The samples were kept at a constant temperature throughout the whole period from sampling until testing. The temperature was set equal to the one found in the layer of the parental ice floe or iceberg that the specimen had been sampled from.

The ice temperature was recorded immediately after a test. In the case of the multi-year ice then parts of the samples were melted, and the salinity of the melt was measured. For later crystallographic investigations thick sections have been cut from the C(T)-samples.

Preliminary Results

From the iceberg cores sampled in the course of the expedition only one was suitable for performing the above tests. This core allowed for the preparation of only two C (T)-specimen with its adjacent bending specimen. The fracture toughness at -12°C was found to be approximately K_{IC}=100 kPA m 0.5 at a bending strength of 1.6 MPa and an elastic modulus of about 10 GPa. The K_{Ic}-value corresponds well with the one known for laboratory grown pure polycrystalline ice.

The K_{Ic} established from the tests on multi-year sea ice samples of about 1...2‰ salinity and -5 to -7° C temperature was found in the same order of magnitude as from the iceberg ice. The bending strength was found to be about 2 MPa and the elastic modulus approximately 7...9 GPa.

1.3.4 PROPERTIES OF MULTI-YEAR SEA ICE OF THE BARENTS SEA

K.U.Evers

Scope of Work

The main objective of the present investigation on multi-year sea ice was the determination of the mechanical properties of this ice. This determination was to be achieved by ice core drilling from various ice floes and subsequent application of the reference strength method (Häusler, 1988), as well as mechanical strength testing in the laboratory.

The reference strength method is a model for sea ice strength which is based on the "basic strength"-concept as described by Weeks and Assur (1968). The reference strengths apply to an imaginary ice possessing sea ice structure but containing no pores being loaded at 0 degree C temperature and 100" s"-1 strain rate. They are available for various load conditions (orientation, uni-axial, multi-axial). Fundamental to the method is the finding that the governing parameter for sea ice strength is the total porosity, except in what concerns the temperature dependence of the pure ice matrix within the sea ice body. Thus knowing the total porosity of a piece of sea ice and it's temperature allows for the computation of it's strength properties. The total porosity can be evaluated by means of the formulae given by Cox and Weeks (1983), which require as input the sea ice temperature, density and salinity. From respective profiles over the full thickness of a sea ice cover it's strength properties with depth can be established.

Since the reference strength method has been validated up to now for columnar grained ice doped with urea and sodium chloride respectively, some cores were sampled for later strength testing in the laboratory. The strength measured on ice are to be used to verify the reference strength method for natural multi-year sea ice.

Performance of Research

In the area between 76 N 24 E and 79 N and 30 E six second-year or multi-year ice floes have been studied. The procedure was as follows:

- augering a core of 105 mm diameter with immediate measurement of ice temperature in equidistant horizons;
- storage of this core for later crystallographic investigation;
- augering of a second 105 mm core in close vicinity to the first one;
- cutting of the second core in to sections of 10 cm length with subsequent density determination;
- melting of the sections in plastic boxes for later salinity evaluation on the melt.

Due to time constraints in the performance of two stations the above procedure was carried out on one single core, skipping the sampling for crystallography. The cores recovered for the petrographic studies were stored in the cold chamber onboard "POLARSTERN". From a part of these cores a sequence of vertical thick sections was prepared over the full core length. In addition horizontal thick sections were prepared from selected depths. The completion of the crystallography shall be done at HSVA.

From two of the ice floes cores of 170 mm diameter were augered. These samples were also stored in the cold chamber onboard at at temperature of -25 degree C. The ice of these cores shall be mechanically tested in HSVA's ice laboratory.

From the temperature, density and salinity profiles measured the profiles of total porosity were established for the ice floes investigated. Also standardized profiles of strength and Young's modulus were computed.

Preliminary Results

The salinity profiles of the ice floes studied exhibited the typical shape for old sea ice (second or multi-year): the upper most layer of 0.3 up to 1.0 m was almost completely desalinated. At lower depths the salinity increased to values of about 2 up to 3 ppt., while at the bottom of the ice cover salinities as high as 5 ppt have been observed. At the bottom end of all cores a skeleton layer of about 1 cm in thickness was found indicating that the ice was still growing. The ice temperatures in the upper layers were found between -2 and -6 degree C. At a depth of about 1 m usually temperatures of -4 degree C have been observed. The subsequent temperature increase up to the melting point was more or less restricted to the 0.5 m from the bottom. The densities measured were in the range of 0.85 up to 0.91 Mg m-3, and showed from their tendency a slight increase with depth. The total porosities computed usually were found between 30 and 80 ppt. In some few cases values up to 175 ppt have been observed.

As far as already finished the thin sections showed the typical texture of columnar grained ice. The grain size in the horizontal direction was in the order of 1 up to 3 cm, while in the long axis direction (vertical i.e. parallel to growth) the grains were twice or three times as large. This finding supports at least at a first glance the applicability of the reference strength.

For the temperature conditions found in the ice floes investigated first estimates of the compressive ice strength in plane with the ice cover have been computed. These computations yielded values in the order of 2 MPa for a strain rate of 10^{-3} s^{-1}.

1.3.5 MICROWAVE PROPERTIES OF ICE, SNOW, OCEAN AND ATMOSPHERE

R. O. Ramseier, K. W. Asmus, M. Collin, C. Garrity

Scope

The effort of this cruise was directed primarily to the microwave studies of old, first-year, and new ice. Special attention was given to the overlying snow cover just before and during the initial free water formation. The purpose of this research was to continue the study of the processes in the snow cover which affect the microwave emission from the underlying ice. Strategic and tactical ice reconnaissance support in the form of satellite derived passive microwave ice charts and helicopter reconnaissance was also provided for the ships operation. At the same time, these activities provided a unique data set to validate the Special Sensor Microwave/Imager (SSM/I) on board a polar orbiting satellite.

Once onboard the ship, the unique opportunity presented itself to augment the scope of the experiment by cooperating with our Soviet colleagues from the Arctic and Antarctic Research Institute (AARI) in Leningrad. They made measurements with a 6 GHz passive microwave radiometer.

Experiment set-up and Methodology

A 37 GHz passive microwave radiometer, mounted on top of the bridge at a height of 21 meters above the water surface, provided a nearly continuous data stream at an incidence angle of 53 degrees. During the ten station stops, the microwave data was augmented with sectorial microwave images and incidence angle profiles. At the same time, measurements of snow properties were carried out within the footprint of the radiometer on the three first-year (FY) and seven multi-year (MY)or old ice (OI) floes we occupied. The microwave data was collected with a fully automated data acquisition, processing and storage system dubbed as the Shipboard Based Radiometer (SBR). The SBR consists of an IBM AT computer, a HP data acquisition unit and a 20 Megabyte Bernoulli box. To further reduce the calculated brightness temperatures (TB), a second identical IBM AT with graphics printing capabilities (which also acted as a back up for the primary system) was employed.

The SSM/I data was received five out of seven days from the Institute for Space and Terrestrial Science (ISTS), located at York University in Toronto, Canada. After the SSM/I sensor (1400 km swath) passed over the Barents Sea, the raw data was initially processed in the form of earth located TB's at the U.S. Navy Fleet Numeric Oceanographic Center in Monteray, California. From there, the data was further processed at ISTS using the AES/YORK sea ice algorithm. Finally, completed ice charts depicting total ice (TI) and multi-year (MY) ice fraction contours or data points, were transmitted via INMARSAT directly to the "POLARSTERN" and to the Deutsches Hydrographisches Institute (DHI) in Hamburg. DHI could act as a backup in case we were out of INMARSAT range by sending the data via radio facsimilie. In general the data was less than 24 hours old when received on the ship.

A small sub-project was added to the planned activities which provided 10.25 GHz scatterometer (radar) data. The scatterometer was mounted at a height of 16.1 meters on the port side near the meteorological office. The purpose of these measurements, carried out as function of the incidence angle, was to provide a limited data set for inter-comparison with the SBR incidence and profile data.

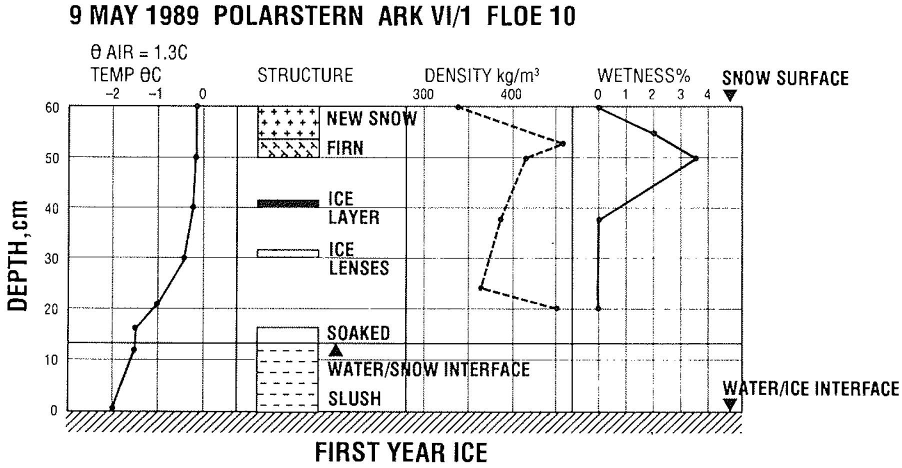
The surface program consisted of digging a snow pit within the footprint of the radiometer, usually at the 53 degree incidence angle location. The size of the footprint is about 6.5 m in length and 3.9 m in width at a distance of 28 m from the ship. Once the pit was dug, one wall was carefully prepared to make the necessary measurements of snow depth, structure of the snow cover (ice layers), temperature, permittivity, density and grain size.

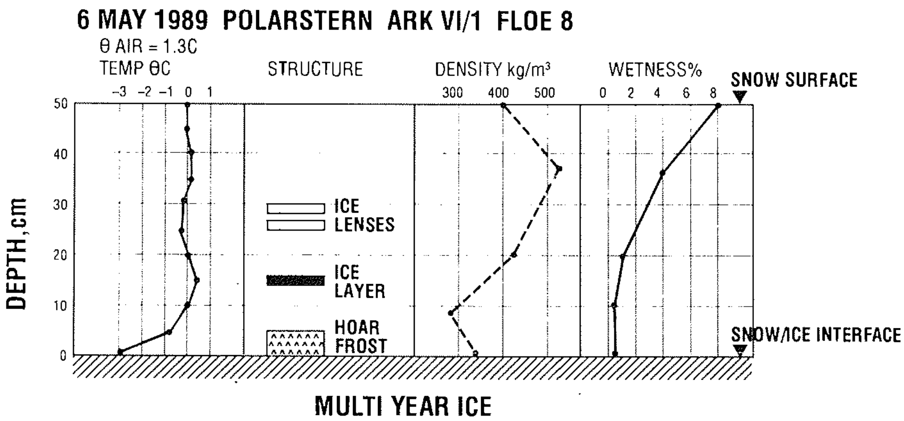
Preliminary Results

Snow Pit Studies

Figure 1.2 A and 1.2B show typical results from a FY (floe 10) and OI (floe 8) snow pit, respectively. Floe 10 is a good example illustrating how a layer of ice within the snow can stop free water from percolating down through the medium. The soaked layer near the snow/ice interface is due to the thick snow cover reducing the freeboard. Snow density is often a complex parameter and does not necessarily increase as the free water in the snow increases. This is especially true for dry snow, where the density can vary from about 100 to 400 kg/m-3. The ice lens at 40 cm can prohibit the incoming radiation during the day from "warming" up the underlying snow. This is shown in the temperature profile in Figure 1.2A.
Due to the warmer air temperature on May 6, the snow wetness for the OI in Figure 1.2B is higher than for the FY ice in the above example. A significant difference between the snow pit on the FY ice compared to the OI pit, is the formation of depth hoar crystals at the snow/ice interface of the OI ice. The freeboard is higher for the OI, thus

Figure 1.2A and 1.2 B





Properties of the surface layer of first year and old ice the formation of slush at the base of the snow cover did not occur. Hoar frost crystals form when the snow experiences changes in temperature. It is a form of metamorphosis of the snow crystals and is prominent during the spring.

In 1987, during cruises ARK IV/I-II (further south), the snow cover on FY ice became stratified at a faster rate than for OI due to the generally thinner snow cover on FY ice. This cruise showed that the snow depth on the ice varies significantly for both ice types. Measured snow depths during ice stations varied from 26-58 cm for FY and for OI from 16-55 cm. The snow metamorphosis is quite advanced for the time of year in changing from the "winter" (cold) snow to "spring" (warm) snow. At the end of April there were surface crusts on the snow for both ice types and the snow wetness increased from 0% to a maximum of 11 % by May 5.

X-Band Scatterometer

Scatterometer data was collected at station stops and while the ship was under way. The stations allowed the opportunity for collecting all four polarizations at incidence angles between 25 and 65 degrees at 5 degree intervals. Eleven data sets were collected in this manner. Due to the depth and wetness of the snow and the relatively low power of the radar, the received power is due to the snow rather than the underlying ice. Since snow wetness measurements were made and snow structure was observed, the backscatter coefficients may be compared to the physical properties of the snow and to prevailing models of backscatter from snow surfaces.

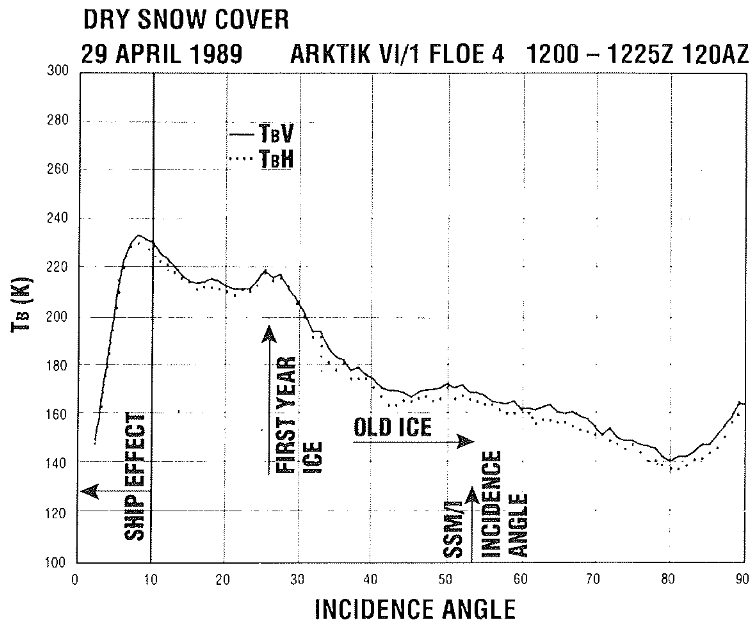
Data was also collected while the ship was in transit. During this phase the surface was sampled at slightly less than once per second and stored in files containing 60 samples. Seventy such files were collected from ice types ranging from grease ice and dark nil as to deformed multi-year floes. The majority of this data was collected in conjunction with the 37GHz passive microwave data and is also supported by coincident segments of video. This data will be used to construct active-passive signature tables of the ice types observed. Since most of the young ice types had no snow cover, the backscatter data will be compared to theories of backscatter from young ice surfaces.

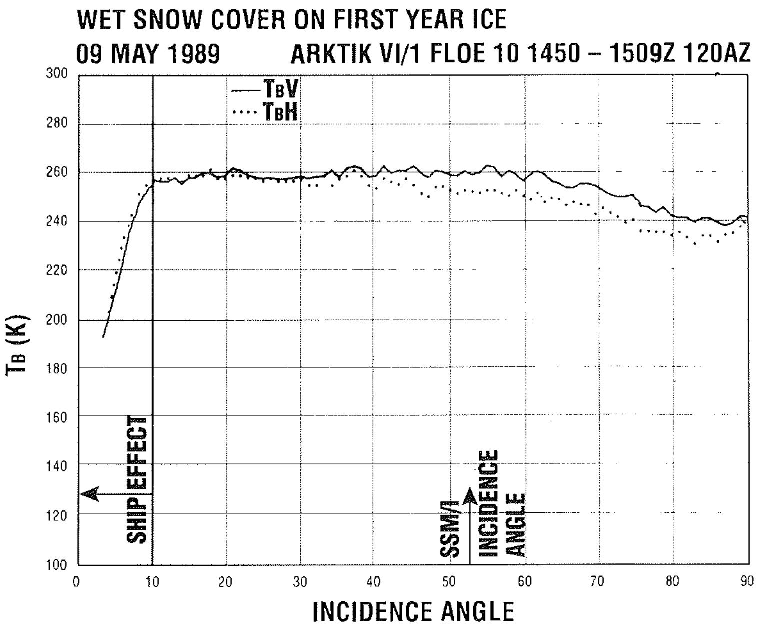
Shipboard Based Radiometer (SBR)

During this extraordinary trip we have collected over 30 Megabytes of profile and station data. The station data, combined with the snow pit measurements, will provide a better understanding of the various processes operating at the same time with the final result that the emission comes from the snow during spring and part of the summer. The formation of ice lenses within the snow cover, the formation and disappearance of surface snow crusts, the presence and absence of hoar frost at the snow-ice interface and the presence or absence of free water, and the migration of free water within the snow cover all have a significant effect on the microwave emission from sea ice. The minimum to maximum fluctuations we have observed in the presence of ice varied between 135 and 270 deg Kelvin at 37 GHz for H polarization and 204 to 270 for V polarization. Water on the other hand has TB's of 123 and 198 for H and V polarization, respectively.

Figure 1.3A and 1.3B show a typical incidence angle curve from dry and wet snow conditions over a MY and FY floe, respectively. Incidence angles from 0 to 10 degrees are influenced by the deck and railing and should be disregarded. Due to the large amount of snow on both floes, the TB's are highly depolarized. The MY ice floe (station 4) has a dry snow cover but the snow layer contains no apparent ice lenses and the surface crust is in the process of forming. In case of the FY ice on floe 10 the free water content is very high as shown in Figure 1.2. At the incidence angle of SSM/I the polarization difference between the two floes amounts to about 86 K. Floe 4 shows some surface characteristics such as a small ridge, while floe 10 is very uniform as a function of incidence angle, which is another manifestation of a snow effect.

Figure 1.3A and 1.3B





Effect of snow cover on incidence angle

Im some cases the ship remained for a number of hours at a floe which gave the opportunity to monitor diurnal, or on one occasion, the effect of snow fall. An example of the effect of a wet snow fall is given in Figure 1.4 for an incidence angle of 53 degrees. In this particular example the TB increased rapidly from 165 to 205 K for the H polarization and from 193 to 206 K for V polarization. The snow fall was observed to start at 120 min (0200 UTC, 27 April 89). The response to the effect of the snow fall is rather quick which is followed by oscillations possibly due to the quarter wavelength effect (coherent emissivity). This would mean that until time 400 the total amount of snowfall was about 3.5 mm according to theoretical calculations, since the wavelength at 37 GHz is 8.1 mm.

The profile data is primarily used to augment the statistics of ice type occurrence. As the ship moves forward, visual observations are made from the bridge just below where the radiometer is mounted to provide a "calibrated" data set. This activity is repeated several times a day. Based on these calibrated data sets, the other data collected during ship transits, where no observations are made, are used to determine the number of specific ice types or ice characteristics encountered during a transit. A typical profile for a 6 minute transit is given in Figure 1.5. "B" signifies brash ice which consists of small fragments of any kind of ice. Brash ice has usually a high TB and is completely depolarized. In the Figure one observes various degrees of depolarization going from B 1 to the B3 type. The degree of depolarization is associated with the amount of slush-like ice. The OI category belongs to old ice and is defined by the lowest TB for OI1. The other four have both varying mixtures of old ice, brash and water in the footprint of the radiometer. In the case of Figure 1.5 the ice types which would be classified on a statistical basis would be old ice type (OI1)and brash ice type (B3).

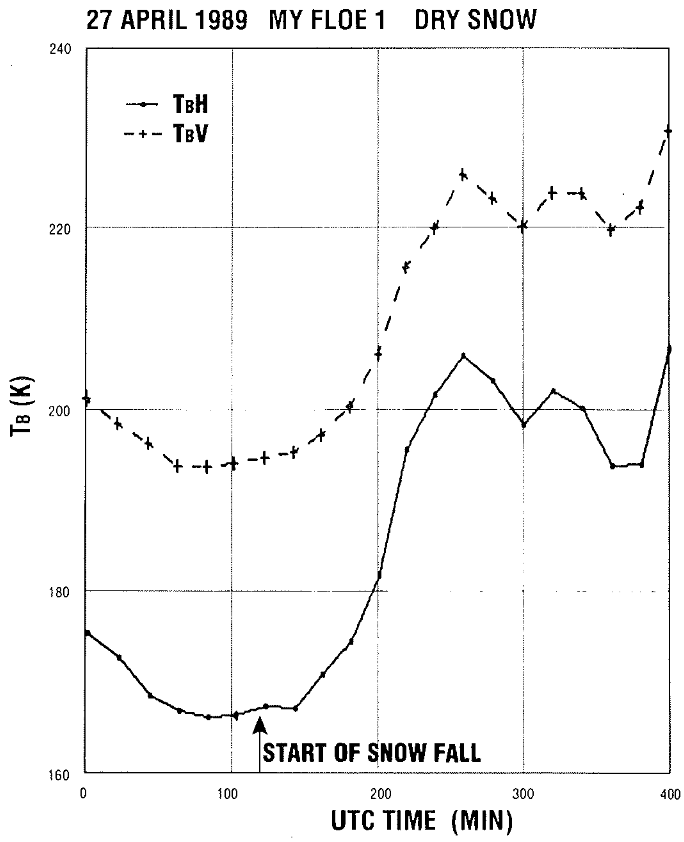
The brightness temperature varied by many tens of degrees during the entire experimental period for a single ice type such as FY or OI. We were exceedingly fortunate to have a warm period after the start of the experiment followed by a cold period. This has given us the opportunity to observe the TB changes and to be able to correlate them with the measurements of the snow properties. We were also able to predict what the satellite data would show. This was particularly interesting since the whole area we were operating in was influenced by the same weather conditions. The effect of these changes with time will be discussed in more detail in the SSM/I section.

AARI and AES/YORK Joint Experiment

The AARI 6 GHz passive microwave radiometer was mounted just aft of the bridge at a height of 18.8 m. They used a 15 degree antenna while the 37 GHz radiometer has a 6.4 degree horn, i.e. the AARI radiometer looks at a much larger footprint. In general the difference in distance between the two radiometers and the different size footprints did not cause any serious problems since in most cases the floes which were studied were rather homogeneous. A total of five floes were done jointly plus one profile at 53 degrees. Figure 1.6 is an interesting example from station 7 for wet snow on top of FY ice. Both the vertical and horizontal TB's are given for an incidence angle going from 40 to 70 degrees. Included in the data set are also the TB's for H and V from the SSM/I footprint covering the ship measurements. The agreement is rather surprising at first hand. We were located in an area south of Kong Karls Land in the Barents Sea within an ice concentration of 100%. The ice cover consisted of FY and OI covered with 30 to 50 cm of snow. The snow was wet containing about 7% of free water within the upper few centimeters. The result is an exceedingly homogeneous surface providing good agreement between a point target and a satellite footprint. The polarization ratio (PR) which is defined as:

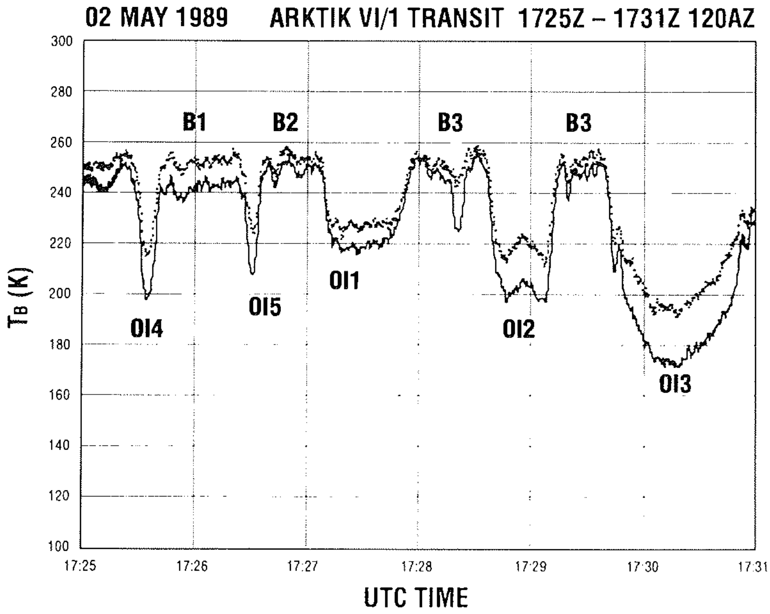
$$PR = (TBV - TBH)/(TBV + TBH)$$

Figure 1.4



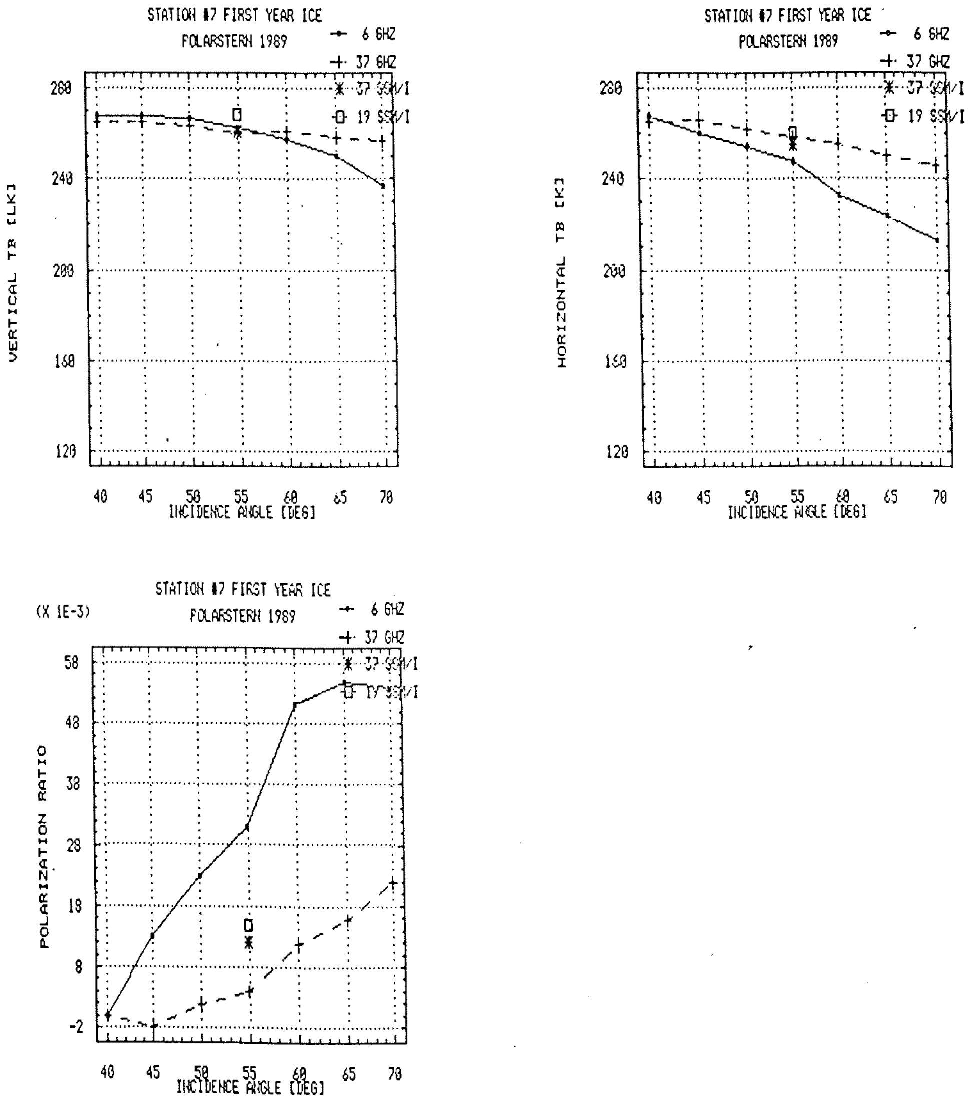
Effect of snow fall on TB

Figure 1.5



Ice characteristics along the ship's track

Figure 1.6



Joint results of 6 and 37 GHz radiometers from Arctic and Antarctic Research Institute and the AES/YORK Microwave Group showing vertical and horizontal polarizations and the polarization ratio. Included are also results for the SSM/I 19 AND 37 frequencies.

differs rather significantly between the 6 and 37 GHz measurements. The cause is the significant amount of depolarization which affects the shorter wavelength more than the longer one at 6 GHz. The PR ratio for the SSM/I data is closer to the shipboard data and is considered to be in good agreement.

Figures 1.7A and B summarize some of the results and a comparison is made with published data by Onstott et al., 1987. Figure 1.7A shows the horizontal emissivity for late spring sea ice conditions for a wet snow cover. At 37 GHz, according to Onstott et al., the FY and MY ice have the same emissivity at the higher frequencies. The difference between the ship data, satellite data and Onstott's general model lies in the fact that the wetness in the current case causes the emissivity to approach a black body. Figure 1.7B shows the data for an OI floe as compared to Onstott's MY model. In this case the difference can again be attributed to the amount of moisture and the stratification in the snow as observed in Figure 1.2.

Special Sensor Microwave/Imager (SSM/I)

Examples of the satellite ice charts are shown in Figures 1.8A to 1.8C to illustrate the effect of a wet snow surface. On April 27,1989 the total ice concentration chart is the sum of FY and OI,while the lower chart shows the contours for OI. Observations on ice conditions made during the transit and from the helicopter have confirmed specifically the total ice concentrations of the SSM/I chart and in a general way the OI fraction. The presence of large amounts of snow, in some cases reaching over a meter of snow accumulated on top of the floes, made it very difficult to identify age categories. The old ice is far smoother on the surface as is experienced in the Beaufort Sea for example.It took us a while to become accustomed to the different characteristics of the Barents Sea ice. Figure 1.8B for May 8 shows that the OI fraction has disappeared. Obviously the old ice is still there but the emission is now primarily from the snow and masks the presence of old ice. During this period the air temperature was above freezing and a significant amount of free water accumulated in the upper parts of the snow cover. On May 10 the old ice fraction is again appearing due to below freezing temperatures.

This example demonstrates an important effect of the snow cover due to wetness. However, the formation of a crust on the surface has similar effects, as well the deposition of a thin, moist snow layer of a few millimeters. In fact it is very likely that from these type of observations some interesting conclusions will emerge concerning some local environmental conditions.

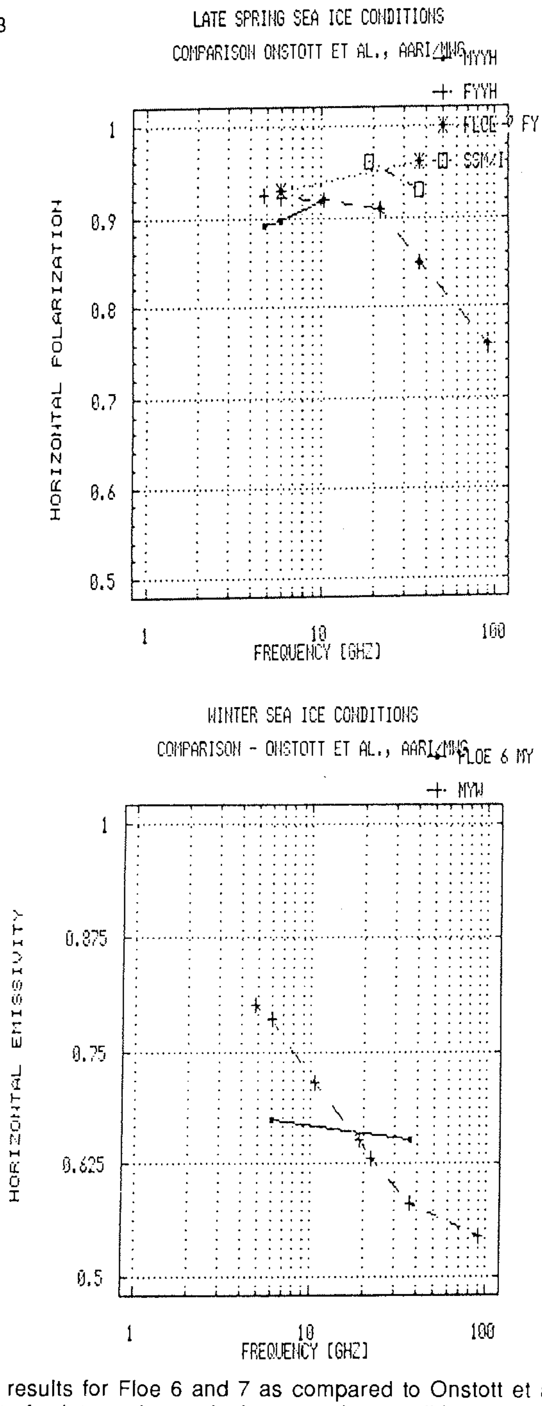
Ice Information and Ships Navigation

Ice observations were made by our group from the bridge (during transits through changing ice conditions at 15 minute intervals) and from the helicopter in support of ship's operation and as part of the SSM/I Validation Project. A total of 13 helicopter ice recco's were flown for a total of 10.7 hours.

We first encountered ice on April 25 at 1137Z at position 75N 1145E while on our eastward track to the Barents Sea north of Bear Island. This first band of sea ice, approximately 140 nm wide, ended at 7519N 2055E. The composition of this band was mainly young and first-year ice (small floes/ice cakes/brash) and occasionally up to 30% old ice cakes. There were large areas of 90-100% new/young ice (pancakes/brash) with large areas of grease/shuga making progress very easy.

Our next encounter with ice was on the northbound leg, east of Bear Island. The compact ice edge was entered on April 26 at 0815Z position 7614N 2504E. The concentration of the ice went from 0% to 100% within a few hundred meters. The ice concentration for the remainder of the northern transit remained between 90-100 %

Figure 1.7A and 1.7B



Horizontal polarization results for Floe 6 and 7 as compared to Onstott et al., 1987 results for late spring and winter sea ice conditions.

Figure 1.8A

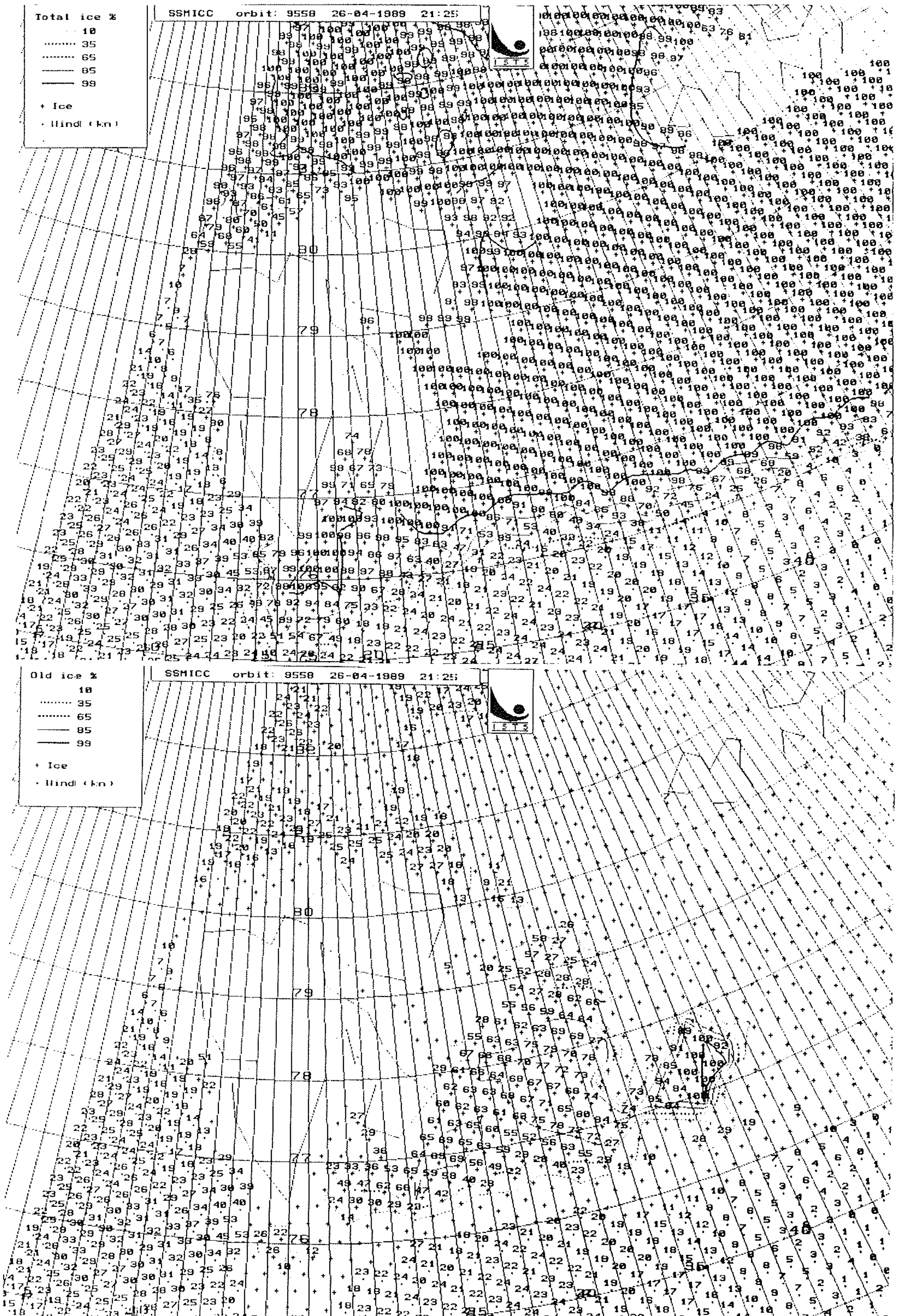
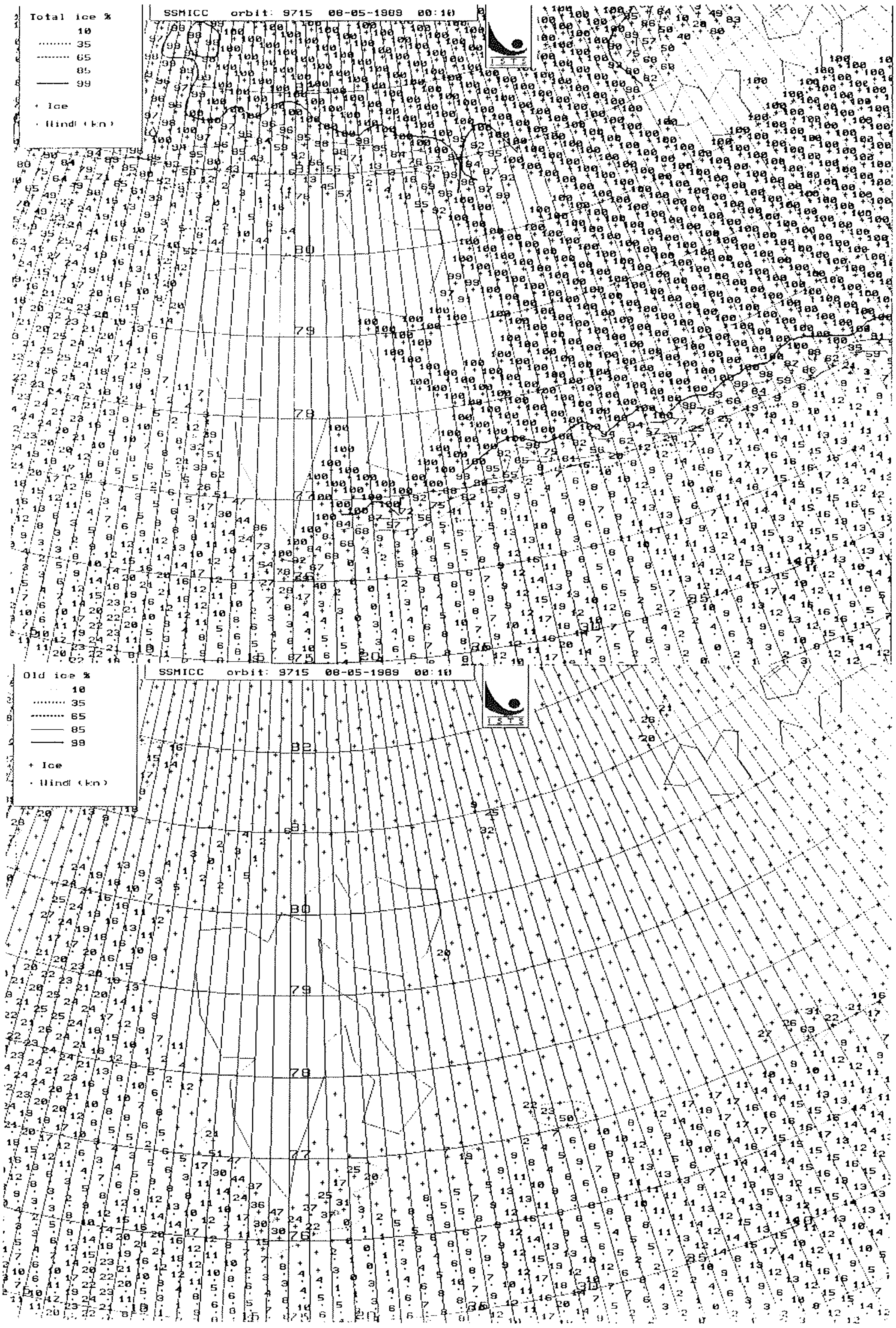
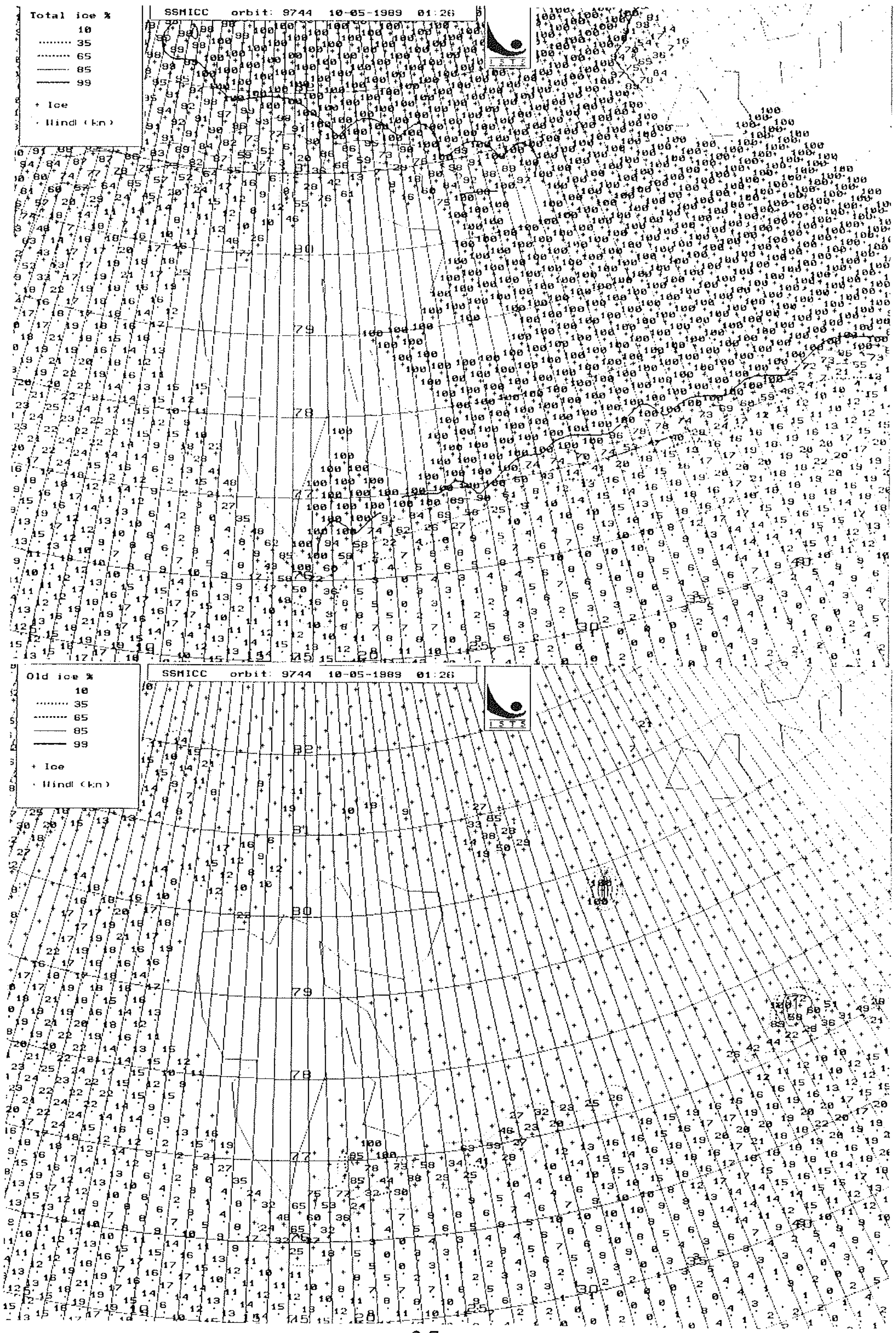

Total ice %
10
35
65
85
99
+ Ice
· Wind (kn)
SSMICC orbit: 9558 26-04-1989 21:25
80
79
78
77
Old ice %
10
35
65
85
99
+ Ice
· Wind (kn)
SSMICC orbit: 9558 26-04-1989 21:25
80
79
78
77
76

Figure 1.8B



Total ice %
10
35
65
85
99
+ Ice
· Wind (kn)
SSMICC orbit: 9715 08-05-1989 00:10
Old ice %
10
35
65
85
99
+ Ice
· Wind (kn)
SSMICC orbit: 9715 08-05-1989 00:10

Figure 1.8C


Total ice %
10
35
65
85
99
+ Ice
Wind (kn)
SSMICC orbit: 9744 10-05-1989 01:26
Old ice %
10
35
65
85
99
+ Ice
Wind (kn)
SSMICC orbit: 9744 10-05-1989 01:26

(with a few areas of 80-90%) north of Kong Karls Land. The heaviest ice conditions were from approximately 7725N to Kong Karls Land. The ice south of 7725N was primarily first-year ice, medium to big floes and north of this point primarily old ice, medium to big floes. A helicopter recco on April 28 identified this boundary of the heavy old ice concentration (this boundary was also shown on the SSM/I ice charts). The ice conditions north of 7725 to Kong Karls Land were extremely difficult and progress by the ship was very slow. Numerous big-vast-giant floes of old ice and occasions when the ice was under pressure (possibly due to wind and or tidal effects) slowed the ships progress to a standstill at times. It was very difficult to easily identify the ice types visually, either from the ship or the helicopter due to heavy snow cover on the ice. The old ice in the area had considerably less features characteristic of old ice found in Canadian waters, and it took some time to recalibrate our visual identification techniques in the Barents Sea.

One of the reasons why transit was so difficult was the fact that the ice concentration in this area was generally 100%, with few leads, making it difficult for the ship to move, as there was no place for the ice to go once broken by the ship. A number of helicopter recco's took place during this period attempting to locate easier ice conditions. The conditions to the west and north west of Kong Karls Land were somewhat easier (8-9/10 concentration) with a higher percentage of first-year floes. The ship made good progress towards the North and North West. As we moved further north, progress again became difficult, but still manageable. The ice conditions were 90% total ice, but under pressure at times. The predominant ice type in this area was heavily ridged/rubbled first-year ice mixed with old ice floes. The floe sizes ranged up to vast and a few giant floes and the snow cover was up to one meter in depth, making identification of the ice types very difficult visually.

We continued to make slow progress northwards, and after crossing 80N, the conditions improved. Ice concentrations varied between 80-90%, but the pressure on the ice was decreased therefore allowing easier progress. On May 12, the boundary between the heavy pack ice and the lighter pack ice was crossed north of Storoy. During the day on the 12th good progress was made in predominately small floe first-year ice with varying concentrations from 30-80%. The ice edge (10% Total Ice) was crossed at 1045Z at position 8042.6N 1757E and the ice free edge was crossed at approximately 1919Z at position 7935.3N 1004.9E.

We again entered an ice field on our southern transit from Longyearbyen on May 13 at approximately 0830Z at position 7746.1N 1237.2E. From this position to 7654.4N 1154.1E, a distance of approximately 48 NM the ice conditions varied from 10% to strips of 90%. The type was mainly first-year and old ice cakes with areas of 30% new ice (pancakes/shuga) and areas of open water (polynias). The ice edge matched very well with the SSM/I ice edge. The remainder of the trip to Tromso was ice free.

Preliminary Conclusions

This was the most successful experiment we have been able to carry out from a ship platform. The ice conditions were difficult but very challenging. The mixture of research, and to be able to immediately apply our findings in assisting the ship to navigate, by providing strategic and tactical ice information was unique and professionally satisfying. Captain Suhrmeyer and his officers, including our Chief Scientist, Dr. Schwarz, have done a superb job in accomplishing a very difficult task, both rewarding from a scientific view point and possibly historical aspect of circumnavigating Svalbard at this time of the year.

References
Onstott, R.G., T.C. Grenfell, C. Matzler, C.A. Luther, and E.A. Svendsen, 1987. Evolution of Microwave Sea Uce Signatures During Early Summer and Midsummer in the Marginal Ice Zone. Journal of Geophysical Research, Vol.92, No.C7,pages 6825-6835.

1.3.6 MICROWAVE INVESTIGATIONS OF SEA ICE

A.N.Darovskich, A.B.Krylov, B.P.Ionov,

Scope

During ARK VI/1 cruise passive microwave emission from first-year and multi-year ice were measured using a 6 GHz dual polarized radiometer. The main purpose of this investigation was to further the understanding of microwave emission from snow covered sea ice. Previous work in the Antarctic instigated such further research.

It was exceptional that the group from the Arctic and Antarctic Research Institute (AARI) had the opportunity to compare measurements made at 6 GHz with the 37 GHz data collected simultaneously by the Canadian colleagues from the Microwave Group (Atmospheric and Environment Services/York University).

Experiment and Methodology

The radiometer was mounted on the port side of the ship, 18.8 m above sea level. The angle of incidence could be changed from 40 to 180 degrees by mechanically rotating the radiometer.

The circular antenna was rotated in intervals of 180 degrees about its axis of rotation in order to find the plane of polarization after which both horizontal and vertical polarizations could be measured simultaneously. The beam width of the antenna is 15 degrees.

Measurements

Passive microwave measurements were made when the ship was stopped for ice stations. The signal is received by a PC computer and the noise level is monitored using a strip chart.

The radiometer was calibrated using the sky as a cold load and a special absorbing material (eccosorb) as a hot load. The emissivity of the hot load was approximately 1.

Preliminary Results

Passive microwave measurements were made for five stations on different days and ice types as indicated in Table 1.

Table 1: Ice Stations during "POLARSTERN" ARK VI/1

Station	Date	Ice Type
3	27.04.89	Multi-year
4	29.04.89	Multi-year
6	23.05.89	Multi-year
7	05.05.89	First-year
9	08.05.89	First-year

An example of the brightness temperature (TB) (vertical, TBV and horizontal, TBH polarization) from multi-year (MY) and first-year (FY) ice as a function of incidence angle is shown in Figures 1.9 and 1.10, respectively. Additionally, the figures show the polarization ratio defined as:

$$PR = (TBV-TBH)/(TBV+TBH) \qquad \{1\}$$

Included in these Figures are the 37 GHz measurements.

Comparing the emission from the two ice types, the TB is lower for MY ice than for FY ice. This is true for both frequencies. The MY ice TB is higher at 6 GHz compared to at 37 GHz, whereas this is the opposite for FY ice.

For MY ice, the polarization ratio is similar for both frequencies. It is noted that the polarization ratio is larger for a colder snow temperature. The polarization ratio for FY ice is significantly different for the two frequencies.

This investigation indicates that the microwave emission from ice is influenced by the snow cover. In future it is needed to have more measurements of different snow covers.

1.3.7 SUBSWEEPER EXPERIMENT - FINAL ACHIEVEMENTS

J. Hjelmstad

The purpose of the experiment was as follows:

- To demonstrate the operation of the subsweeper in ice-covered areas using a bistatic configuration with one transmitting source and one to several receiving units remotely deployed.

- To investigate those properties of acoustic transmission through an ice-covered water mass as relevant to subsweeper operation.

The following experiments have been conducted:

1. Two buoys were deployed at 77.14.49N, 29.45.33E, 30 m separated and located 3km away from the ship. Average depth was 193 m and the ice-cover was 4m thick. A total of 4h 30m recording time was achieved using three different waveforms.

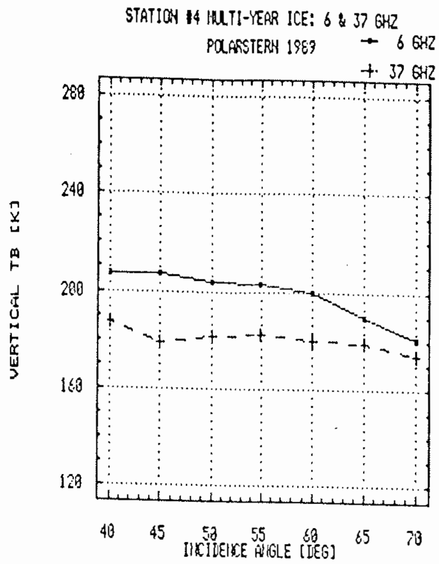
2. Four buoys were deployed at 78.31.25N, 27.47.15E. These were arranged as a down-range/cross-range/depth-range array with 10m grid. Using the three different waveforms 1h 45 m recording was made.

In addition three hours passive recording using this array was made as the icebreaker was heading away.

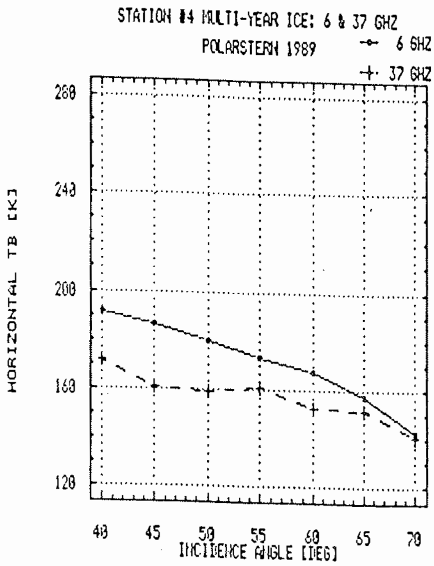
3. One buoy was deployed 5 miles NW of Kvitöya and another two were deployed 10 miles NE of Storöya. Two hours recording was made with pulsed and CW waveforms. Ranges to these buoys were 3.56 and 24 miles. One hour recording was made of ambient noise. Another two hour recording was made as the boat headed away.

The experiment has been very successful and in particular the following has been achieved:

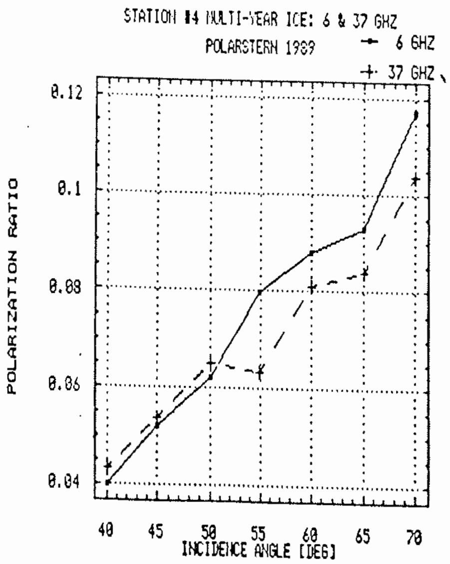
Figure 1.9



a



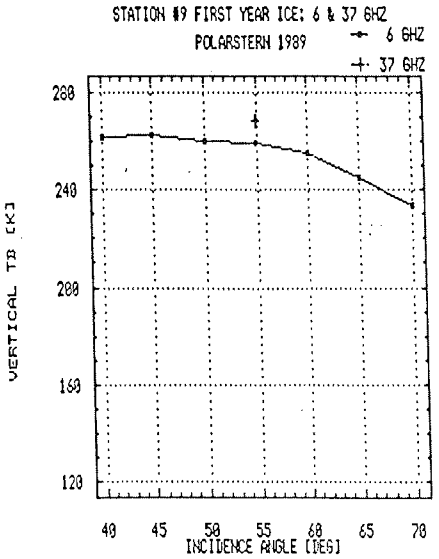
b



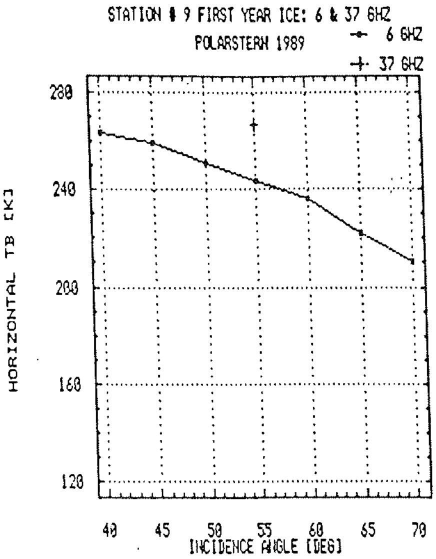
c

Brightness temperatures
as a function of incidence
angle for multi year ice

Figure1.10



a



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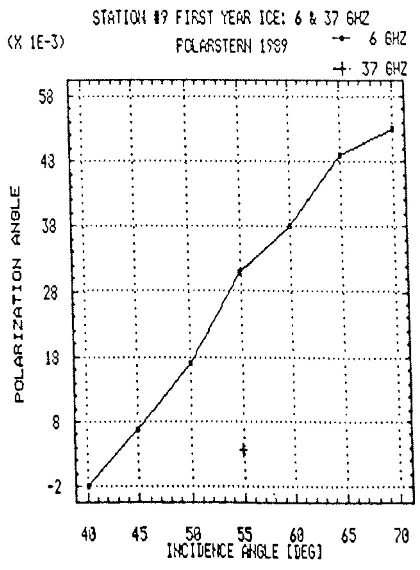


c

Brightness temperatures
as a function of incidence
angle for first year ice

a) Valuable data for an ice-covered acoustic transmission path has been recorded. These are being compared to model developed to study the influence of various assumptions of boundry surface impedence and roughness.

b) The subsweeper has been operated in a number of modes and data has been recorded making it possible to infer its potential in regards to current mapping performance and target detection performance.

1.3.8 SEDIMENT IN BARENTS SEA ICE

S. Pfirman, I. Wollenburg, P. Goldschmidt, J. Bischof, M. Lange

Scope of Work

The main objective of investigations on sediment in Barents Sea ice is to determine the role of sea ice and iceberg rafting in sedimentation in the Barents and adjacent seas. Sea ice samples obtained in 1987 north of Svalbard in the Eurasian Arctic Ocean ("POLARSTERN" ARK IV/3) and in 1988 east of Greenland and in the Fram Strait ("POLARSTERN" ARK VI/2 and 3a) indicate that multi-year sea ice can contain very high particulate loads. Because much of this ice is thought to have undergone several years of surface melting, freezing on the ice underside and extensive deformation, the processes involved in sediment incorporation were difficult to determine from the samples.

By sampling sea ice in early spring in the Barents Sea we hoped to obtain relatively undeformed sediment-laden first or second year ice which would preserve the original ice structure and characteristics, not complicated by summer melting and deformation. In addition, sampling of multi-year floes was carried out for comparison of sediment composition and grain size with that in the Eurasian Basin samples in order to define the regional influence of specific sediment source areas.

The role of sea ice vs. iceberg rafting is important in determining paleoenvironmental conditions, but only indefinite criteria exist to aid in distinguishing between the two. In order to gain better understanding of the type of material transported by icebergs, sediment was obtained from several Barents Sea icebergs. These sediments will be compared with the geology of known source areas of tidewater glaciers to determine the origin of the icebergs and the importance of these source regions for modern-day iceberg rafted material.

Performance of Research

To determine the overall sediment concentration and its vertical and horizontal distribution within specific floes, sea ice sampling was carried out by ice coring both from floes adjacent to the ship and floes reached by helicopter. A total of 54 m of ice from 26 cores was obtained at 16 stations. 15 ice cores contained visible inclusions of particulate material.

As the ship broke through the ice, visual observations of the distribution of particulate material in the sea ice were carried out at 15 minute timespans (longer intervals when the ship's progress was slow). Because of thick (often 20-40 cm) snow cover, these observations were largely limited to notations of sediment content and characteristics of broken ice along the "POLARSTERN"'s hull and in ridges.

Sediment-laden ice from icebergs 2 km east of Hopen (Lat. N. 76 41', Long. E 25 08<') and 1 km north of Kongsöya (Lat. N. 79 00', Long. E 28 02') was sampled by NHL (see 1.3.2) and provided for analysis of the composition and grain size of sediment transported by iceberg rafting. Sediment samples were also obtained from two bergy bits about 10 miles southwest of Isispynten (Lat. 79 35', Long. 26 00') along the Austfonna glacier margin. Further rock sampling was carried out on the island of Hopen and on the shore of Kvitoya. These samples were melted on board and the coarse fraction was analysed under a binocular microscope.

Preliminary Results

Sediment inclusions in sea ice were observed to be widespread but variable in the Barents Sea. Often a band of sediment, a layer of small dark inclusions or of turbid ice occurred about 30-60 cm below the snow-ice interface in multi-(second?) year ice. Above and below this layer, the ice column usually contained no visible sediment inclusions. In one region (from Lat. N 78 22.0', Long. E 28 17.9' to Lat. N 78 23.6', Long 28 11.9'), such a layer extended throughout many ice floes. Other common occurrences were a layer of sediment at the snow-ice interface and multiple bands of sediment throughout the ice. Microscopic analyses of sediment melted from sea ice cores indicate a uniform composition. The sediment is composed of homogenous grey clay with a few silt-sized angular quartz grains.

Although sediment was observed in the first-year ice, it was more common in multi-(second?) year ice. Cross-sectional views of this ice as broken up by "POLARSTERN" indicate that many of these floes consist of rafted ice segments. Because much of the Barents Sea is ice-free in summer, it appears that sediment-laden "old" ice must be transported into this region from other areas. Specific source regions remain to be identified. However, it is clear that, in order for sediment to be included in sea ice, the ice must have formed either close to shore or over shallow water.

Sea ice cores collected on this expedition will be analysed for ice tecture, c-axis orientation, columnar crystal size, salinity ^{18}O, ice chemistry, grain size distribution, mineralogy (especially clay mineralogy), and nutrient and particulate content. By these means we intend to learn the growth history and development of the floes, to understand the processes involved in sediment incorporation, and to determine the source regions of this sediment-laden sea ice.

The Hopen iceberg sediment samples contain largely fine-grained material (>63 µm). They consist of silt-sized quartz grains, biotite, alkali feldspar, garnet, some plagioclase and minor amounts of black minerals; clay was not present. This composition indicated that the bedrock source may have been a garnetmica schist, perhaps from the Hecla Hoek Formation. Because the samples were obtained from the surface of an iceberg which is not thought to have overturned, it is likely that the sediment was transported by win from a nearby region of exposed land. If so, the iceberg probably calved from a tidewater valley glacier or not far from the margin between exposed land and ice of a tidewater ice cap. Taking all this information into account, the iceberg's origin may be: Leighbreen or Austfonna on northern Nordaustlandet: Kvitöya: or one of the tidewater glaciers in Hinlopen Strait. This conclusion is only tentative at this point because the sediments are so fine-grained that shipboard investigations do not allow a more specific determination of the bedrock type.

The sole of a small overturned iceberg sampled 10 miles southwest of Isispynten contained several light red alkali granite rocks of cobble size. These rocks most likely also come from the Hecla Hoek Formation.

At Hopen, variegated sand- and siltstones were collected from a beach conglomerate for comparison with dropstones from the Norwegian-Greenland Sea. At Kvitöya, sampling along the beach yielded 2 different types of crystalline rocks: light red alkali granite and light to medium grey banded plagioclase-quartz-biotite gneiss. Besides these dominant rocks, some plutonic rocks of intermediate composition, probably quartz diorites, were found. Sampling was attempted at Isispynten, but failed because of bad landing conditions. However, a light red granite and a black rock, probably a type of limestone, could be identified from the helicopter.

1.3.9 SEABIRDS IN ICE-FILLED WATERS IN THE NORTHERN BARENTS SEA

F. Mehlum, V. Bakken

Scope of Work

The Northern Barents Sea is inhabited by large populations of seabirds. Previous studies have shown that seabirds are found in abundance in the marginal ice-zone southeast and east of Svalbard during spring and summer. In spring large concentrations of Brünnich's Guillemot (Uria lomvia) have also been observed in open leads far north of the southern sea-ice limit. Analysis of stomach contents of short birds has shown that they prey mainly upon the pelagic amphipod Parathemisto libellula. In order to find out which parts of the ice-covered areas east of Svalbard are utilized by the Brünnich's Guillemots and other seabirds during the spring period, observations from an ice-breaking vessel equipped with helicopter is necessary.

Performance of Research

Transects of seabird observations were made in open water from the area NW of Björnöya to south of Hopen Island. A standard observation method was used and the data was directly entered into a portable field computer (Husky) for further computer analysis. The ship transects were continued in the ice-filled waters between Hopen and Kong Karls Land, and in the Erik Eriksen Stretet. Due to periods with low visibility the censuses hat to be interrupted.
Helicopter was also used to extend the observation areas within the ice-covered waters. Three helicopter transects were conducted, covering a total area of about 38 sq. kms. Two observers were in the helicopter, one in the co-pilot seat, the other one in the back seat on the opposite side. Cruising altitude was 120 - 150 feet.

Preliminary Results

As expected concentrations of seabirds, especially the Brünnich's Guillemot were encountered in leads within the ice-zone. The birds were present in the leads all the way between Hopen and Kong Kars Land and in parts of Erik Eriksen Stretet. However, few birds were seen west of Kong Karls Land. A period of cold weather (the air temperature dropped to about -10°C) caused freezing of the leads and prevented them from use by the birds.

A sudden temperature drop from about 0°C to -10°C occurred during one night (28-29 April). This temperature drop coincided with a massive migration of Brünnich's Guillemots from leads in the northern part of the area and southwards, presumably to the Hopen area and the ice-edge some miles farther north.

1.3.10 ZOOPLANKTON INVESTIGATIONS

H.J.Hirche

Within the project of studying zooplankton life cycles in the Greenland Sea, a further set of multinet samples was obtained in Atlantic water west of Bear Island in the depth layers 2200-1500-1000-750-500-400-300-200-100-0m. The spring phytoplankton bloom at this station had already started and the herbivorous zooplankton has begun its upward migration from overwintering depths to the euphotic zone, although still a large fraction of the populations of the dominant species Calanus finmarchicus and C.hyperboreus were found in deep waters. The samples were preserved for species anlaysis. In addition, certain developmental stages were taken

for determination of organic carbon and nitrogen, lipids, digestive enzymes and nucleic acids. Live female C.finmarchicus are currently being kept in the laboratory to study their fertitility and daily egg production rates in relation to feeding conditions. These experiments will be continued during the next legs.
Bongo net samples were collected at three stations in the Barents Sea east of Spitsbergen. They were dominated by the polar copepod Calanus glacialis. Females of this species are also being kept in the laboratory and their egg production is being studied.

2. FAHRTABSCHNITT ARK VI/2 TROMSÖ- TROMSÖ 16.05.89 - 07.06.89

J. Meincke (Chief Scientist)

2.1 Zusammenfassung und Fahrtverlauf

Der zweite Fahrtabschnitt diente interdisziplinären Arbeiten in der westlichen Grönlandsee. Die Arbeiten der physikalischen Ozeanographie und der Biologie waren dabei Bestandteil des internationalen Grönlandsee-Projektes, in dessen Mittelpunkt die saisonale Erfassung des physikalischen, chemischen und biologischen Zustandes der Grönlandsee steht. Mit dem Fahrtabschnitt der "POLARSTERN" und den zwei Wochen später beginnenden hydrographischen Arbeiten des norwegischen Forschungsschiffes "HAKON MOSBY" wurde die letzte von vier Gesamt-Aufnahmen der Grönlandsee durchgeführt. Insgesamt waren vom Sommer 1988 bis zum Sommer 1989 12 Forschungsschiffe an den saisonalen Schichtungs- und Strömungsmessungen sowie biologischen Sammelprogrammen beteiligt und die nun beginnende Aufarbeitung der Daten sollte eine quantitative Abschätzung der für das Klimageschehen wichtigen Tiefenwasser-Bildungsraten und ihrer chemischen und biologischen Konsequenzen ermöglichen.

Der Fahrtabschnitt begann mit 8-tägiger Verspätung am 16.5. in Tromsö. Aufgrund der Eis- und Atmosphärenbedingungen wurde das Gebiet der Grönlandsee im Uhrzeigersinn abgearbeitet, d.h. die Arbeiten zur Bergung von 13 Strömungsmesserverankerungen, die Neuauslegung von 6 Systemen, die Gewinnung von detaillierten Temperatur-, Salzgehalts- und Sauerstoffprofilen auf 39 geplante Stationen des international vereinbarten Stationsnetzes sowie tiefe Plankton-, Netzfänge und Kastenlot- und Kastengreifereinsatz begannen am 18.5. in der südlichen Grönlandsee. Dank verstärkter Decksbesatzung konnten alle Arbeiten unabhängig von der Tageszeit durchgeführt werden und so wurde schon am 22.5. der eisbedeckte, westliche Teil des Untersuchungsgebietes erreicht und es konnten zusätzlich die Eisbeobachtungen und Eisprobennahmen sowie Eisoberflächenvermessungen im Mikrowellenbereich begonnen werden. Die vorgefundenen Eisbedingungen waren durchweg günstig, allerdings erschwerte die aufgrund der frühen Jahreszeit noch ausgedehnte Schneebedeckung ein Anfahren bzw. Anfliegen von Schollen für gezielte Probennahmen. Mit Hilfe der sehr genauen akustischen Ortung der unter dem Eis liegenden Verankerungen bei 75° Nord gelang deren Bergung auch bei im Mittel 9/10-Eisbedeckung problemlos: Die Verankerungen wurden in dem Moment ausgelöst, in dem das Schiff mit gestoppten Maschinen über sie hinwegdriftete. In den durch das treibende Schiff hervorgerufenen Eislücken tauchten dann auch die Auftriebelemente der Verankerungen auf und dank der guten Deckausstattung des Schiffes konnten die meist auf beiden Seiten des Schiffes befindlichen Teile der Verankerungen mühelos aufgenommen werden.

Bei wechselndem Wetter wurden die auf Schnitten senkrecht zum ost-grönländischen Kontinentallabfall angeordneten hydrographischen Stationen nordwärts fortschreitend abgefahren, immer wieder unterbrochen von Verankerungsaufnahmen/-auslegungen und Netzfängen sowie geologischen Probennahmen. Die Kastengreifer- und Kastenloteinsätze in verschiedenen Tiefenstufen des Kontinentalabfalles und in den zentralen Becken waren aufgrund der stark unterschiedlichen Sedimentkonsistenz und der damit variierenden Probenmenge stets spannend. Aus den Netzfängen ließ sich die biologische Situation der westlichen Grönlandsee eindeutig mit Frühling charakterisieren, indem erste Phaeocystis-Blüten auftraten und die Copepoden aus den Überwinterungstiefen schon wieder in die oberen 100-200 m zurückgekehrt waren.

Die Bergung der nördlichsten Verankerung unter dem Eis gestaltete sich zeitaufwendig, da das Gebiet mit großen Schollen bedeckt war und das Verankerungsseil durch die Schiffsschraube getrennt worden war. Nach insgesamt 36 Stunden waren dann aber zwei Strömungsmesser und eine Sedimentfalle unversehrt an Deck, während zwei weitere Strommesser und ein Eisdicken-Sonar nicht erreichbar unter dem Eis aufgegeben werden mußten. Danach konnte "POLARSTERN" das Eis verlassen, die restlichen Arbeiten wurden bei ruhigem Wetter und hoher Arbeitsgeschwindigkeit so abgewickelt, daß Tromsö am 7. Juni nachmittags erreicht wurde.

Es bleibt zusammenfassend festzustellen, daß die wissenschaftlichen Ziele des Fahrtabschnittes trotz einer Kürzung um 5 Tage erreicht wurden. Dieser Erfolg wurde nur durch einen intensiven Einsatz seitens Besatzung, Maschinentechnik und Eingeschifften sowie dem bei allen Arbeiten in Eisgebieten notwendigen Glück ermöglicht.

2.2 Summary and Itinerary

The second cruise leg comprised interdisciplinary work in the western Greenland Sea. It is a contribution to the international Greenland Sea Project, focussing on the seasonal description of the physical, chemical and biological status of the Greenland Sea. This cruise-leg and the work of the Norwegian RV "Hakon Mosby" following 2 weeks later yielded the last out of four complete coverages of the Greenland Sea, which started in summer 1988 and had a participation of 12 research vessel.

The cruise leg started in Tromsö on May 16 with a delay of 8 days. The work programme consisted of the recovery of 13 and deployment of 6 current meter moorings, detailed temperature, salinity and oxygen profiles at 39 stations of the internationally agreed station grid, plankton-net hauls and box-grab and box-corer stations in the deep basins and over the Eastgreenland slope and the Greenland Fracture Zone. In addition ice coring snow sampling and ice-surface charting in the microwaveband were to be conducted.

The station work started in the southern Greenland Sea and progressed through the ice-covered western part northward. Ice conditions were good, although mooring recovery had to be achieved at 9/10 ice coverage. This was possible by accurate acoustic ranging of the moorings. It enabled the release at the moment the ship was drifting over the system. The float could thus surface in the wake of the vessel. Only in the case of the northernmost mooring big floes gave problems with recovery. It took 36 hours before half of the system was on deck, the rest had to be left underneath the ice because the connection to it was cut by the ships propeller.

After leaving the ice near 79° N the calm weather allowed to proceed very rapidly with the rest of the programme and to reach Tromsö on June 7.

In summary it can be stated, that the scientific programme could be completed despite a shortening of the cruise leg by 5 days. This was only possible due to an intense effort by crew, scientists and engines plus the bit of luck needed to work in ice covered waters.

2.3 REPORTS OF THE WORKING GROUPS

2.3.1 PHYSICAL OCEANOGRAPHY

K. Aagaard, M.-C. Beaupre, K. Boehnke, C. Darnell, H. Hellmer, J.Marquez-Loyola, M. Matthies, J. Meincke, L. Sellmann, T. Soltau, N. Verch, J. Wells, A. Winguth, H. Wullner

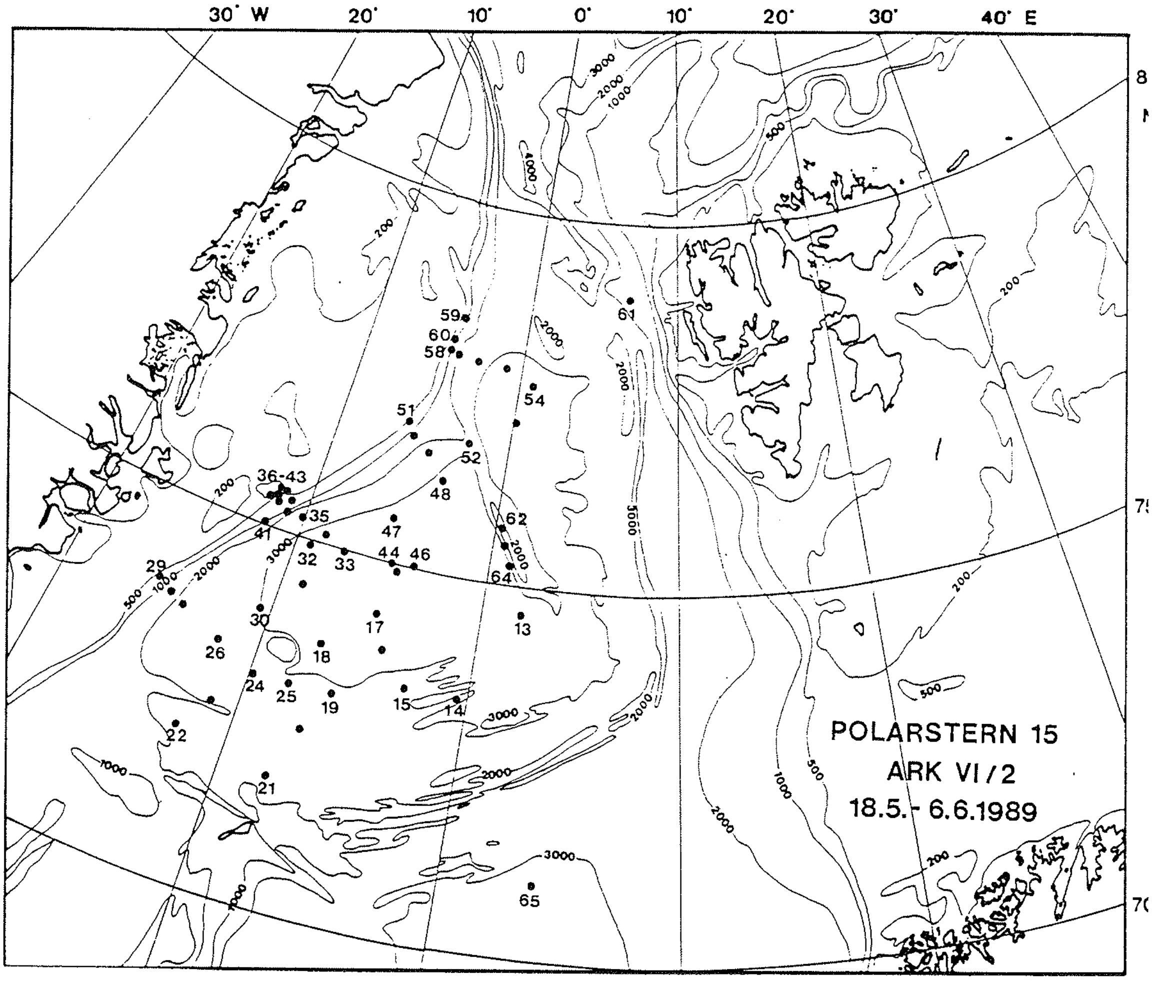
The physical oceanography programme focussed on two components of the international Greenland Sea Project. The first one was the volumetric water mass census. By means of a four-time, seasonal repetition of a station grid covering the Greenland Sea, a direct measure of volume changes of water masses should enable a quantitative estimate of winter convection. This cruise leg, jointly with the work of the Norwegian RV "Hakon Mosby" starting 2 weeks later, was to complete the survey, which started in summer 1988 and had participation of 12 research vessels.

"POLARSTERN" contributed with 33 profiles (see Figure 2.1) of temperature, salinity and oxygen to the total of 74 stations of the international programme. They were run with a Neil Brown MK3 CTD and a 24 bottle-rosette. Since the cruise leg followed about the same route as in summer 1988, a comparison of this years´ sections with the ones 12 months earlier is possible. One aspect of this comparison is illustrated by Figure 2.2, which shows the T, S profiles obtained at a station in the center of the convective gyre during all four seasons. Conditions in summer 1988 and summer 1989 differ quite considerably in the upper 2200 m, in particular the depth range between 1300 m and 2200 m was found warmer and saltier in 1989. There are two explanations: The first one would invoke an eastward shift of the Greenland Sea gyre, enabling Arctic Ocean Deep Water to penetrate from the Greenland continental slope towards the center of the basin. The other one would be just an enhanced admixture of Arctic Ocean Deep Water to the intermediate levels in the gyre.

A second aspect concerns the maximum depth of convection during the past winter. From Figure 2.3 one would read 900 m. However, during the February/March cruise of RV "Valdivia" we had been able to occupy the same station as shown in Figure 2.2 three times within one month. Figure 2.3 shows the changes and gives a clear indication of the convection reaching to at least 1600 m. A close inspection of the summer 1988-profiles suggests, that convection in the gyre has indeed reached 1800 m over a wider area. Figure 2.2 and Figure 2.3 both point to a problem we have to face with evaluating the volumetric water mass differences between the seasonal surveys: Advective changes and non-synopticity especially of the winter surveys will have to be considered.
Furthermore a comparison of average temperature, salinities and oxygen-values for all samples below 2000 m in the Greenland Sea gyre has been carried out for the years 89, 88, 87, 84, and 82. Temperatures and salinites for 89 were found highest, oxygen lowest. This is in agreement with the observations of limited convection and means, that there has been no renewal of Greenland Sea Deep Water below 2000 m since 8 years.

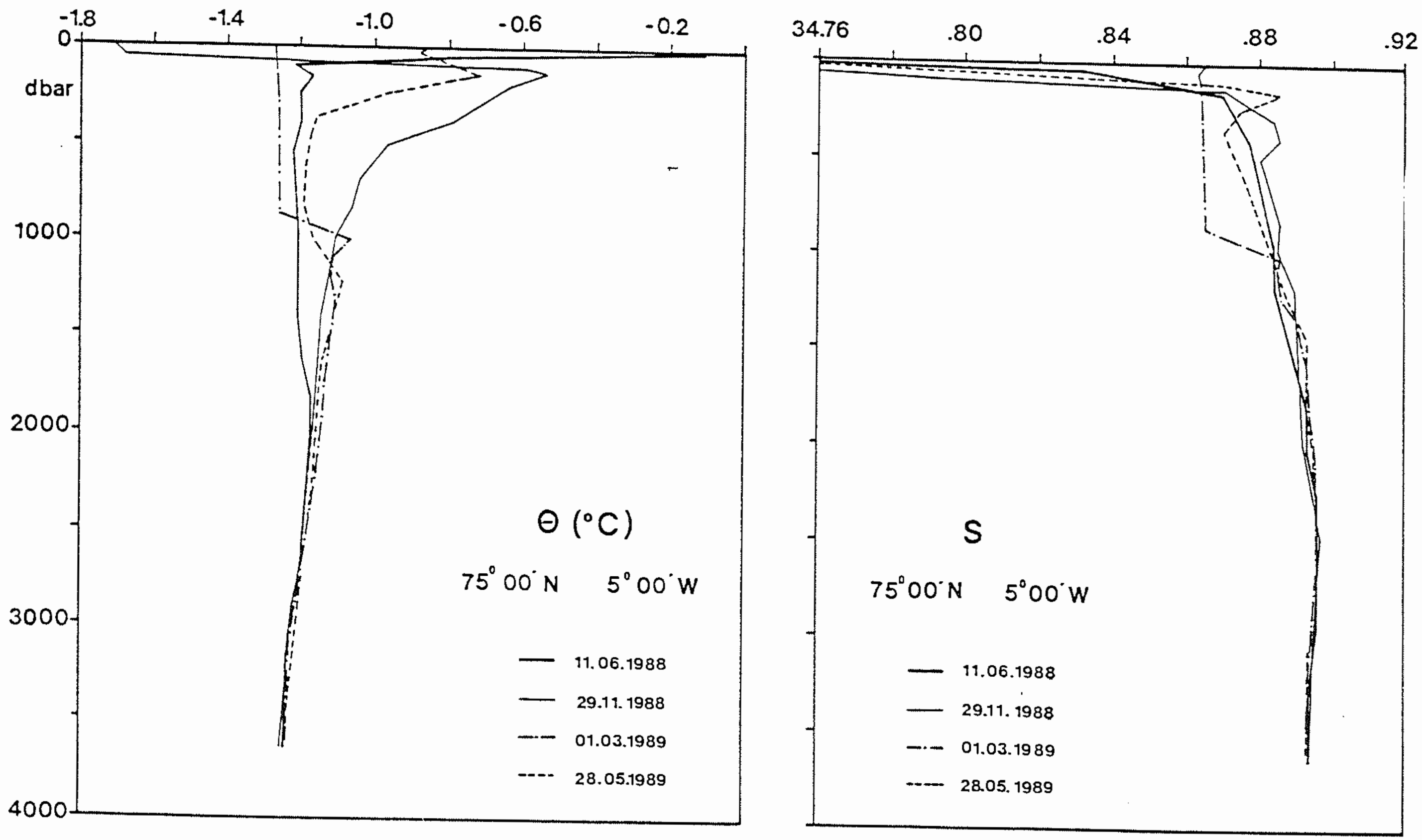
The second component of the Greenland Sea Project was the recovery of 13 and the deployment of 6 one-year arrays of moored current meters (Table 2.1) designed to obtain a direct measure of the circulation. The recovery of the mooring under ice was quite a challenge (see Summary and Itineray), but except 2 current meters and one upward looking sonar all gear was recovered. A technical problem became evident after reading the memories of the new vector-averaging Aanderaa current meters: All instruments stopped recording meaningful data after 8 months, because of exhausted batteries. The instruments have already been returned to the manufacturer and changes in the electronics and the sampling-scheme have reduced the current consumption. This loss of 30 % of data from 50 % of instruments deployed is another example of the user running the "real" tests of instruments out of a new production line.

Figure 2.1



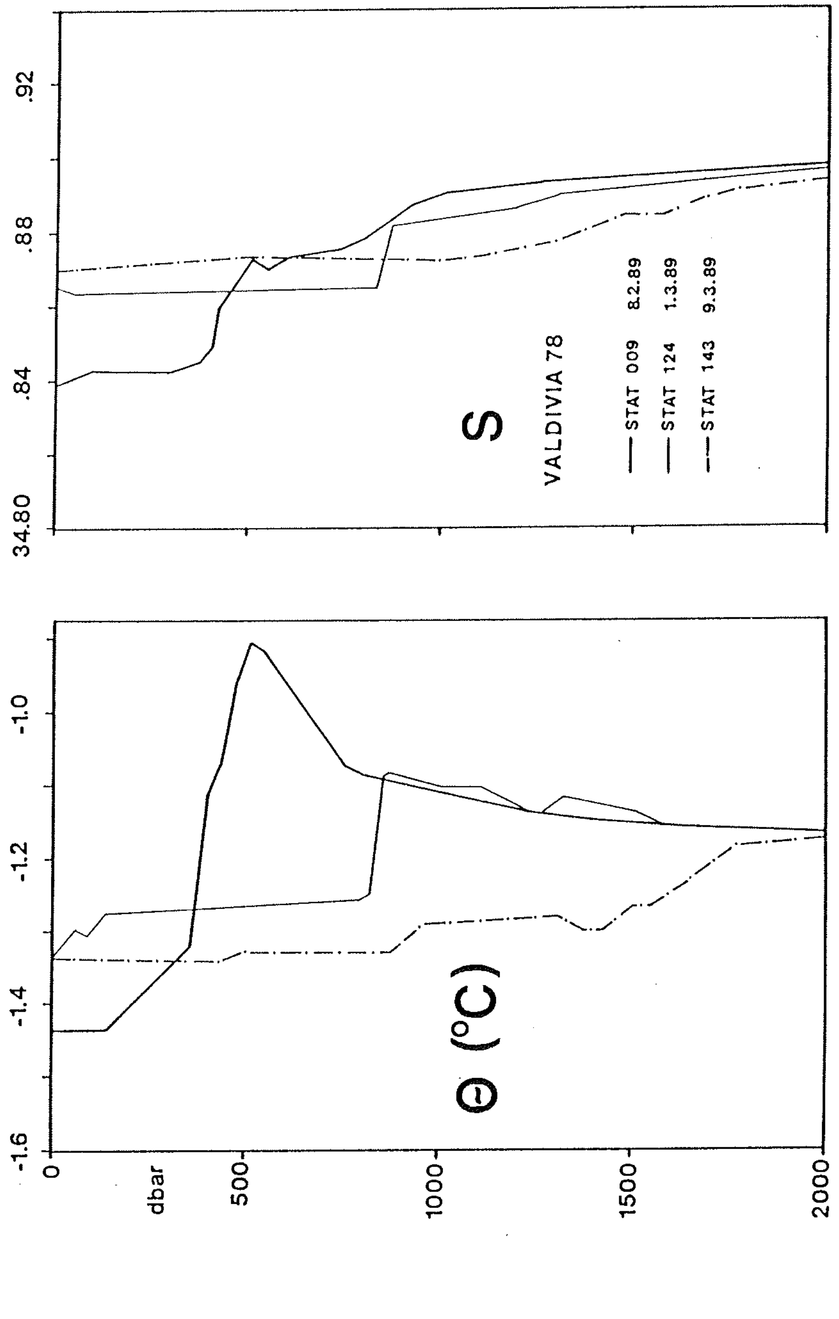
Position of Stations

Figure 2.2



Profiles of potential temperature Θ- and salinity S obtained in summer 89 ("Polarstern"), fall 88 ("Meteor"), winter 89 ("Valdivia") and summer 89 ("Polarstern") in the center of the convective Greenland Sea gyre.

Figure 2.3



Consecutive profiles of Θ and S, showing the development of stratification during the period February 8 to March 9 at 75°N, 05°W (position as in Figure 2.2)

Table 2.1

Moorings deployed for period 89 /90

Institute	Ident.	Position	Depth(m) indic.	Depth(m) corr.	No./Type of instr.	Date deployed
AWI	403-3	75°00.347'N 09°14.071'W	3300	3250	5 A-RMC8	24.05.89
IfMH +GuB	0162*	78°52.58'N 06°40.50'E	1706	1670	4 A-RMC4/5 1 SED-Trap	04.06.89
IfMH +IfMK +GuB	0270*	75°00.15'N 04°04.01'W	3636	3583	1 A-Therm.Ch. 1 ADCP 4 A-RCM4/5 1 SED-Trap	25.05.89
NOAA/ PMEL	GSP-3B	73°49.72'N 04°50.02'W	3624	3571	4 A-RCM4/5	19.05.89
	GS-3B	73°04.0'N 08°02.5'W	2670	2626	4 A-RCM4/5	22.05.89
NPI IfMH NOAA GuB	0261	78°03.46'N 04°47.55'W	1540	1506	1 ULS 1 A-RCM 4 1 SED-Trap	02.06.89
AWI	405-1	74°30.9'N 05°27.9'E	2535		4 A-RCM4/5	03.07.89

This report on the last cruise for the German groups participating in the first phase of the Greenland Sea Project is the occasion to thank the crew of "POLARSTERN" for their engaged and skillful participation in the large number of deep CTD-casts (168 altogether during the two GSP-cruises in 1988 and 1989 and the pre GSP-cruise in summer 1987) and the deployments (30) and recoveries (24) of deep sea moorings, lots of them under ice and for most of them with the engines shut down.

2.3.2 SEDIMENT TRANSPORT BY SEA ICE IN THE EAST GREENLAND CURRENT

I. Wollenburg, S. Pfirman

Scope of work

Sea ice drift is characterized by two major drift systems. The Beaufort Gyre transports sea ice in a clockwise direction through the Western Arctic Basis (American Basin). The second main drift stream, the Transpolar Drift, carries sea ice from the Siberian Shelves northward, over the Arctic Ocean, into the Fram Strait, where the East Greenland Current transports it further south. Drift trajectories of satellite tracked buoys show that most of the sea ice in the Transpolar Drift exits the Arctic Ocean through Fram Strait. Only a small part of the ice drifts east of Svalbard through the Barents Sea (See cruise report ARK VI/1 - the Barents Sea).

Analysis of "dirty" sea ice sampled during the ARK VI/3-expedition (1987) in the central Eastern Arctic Ocean (Eurasian Basin) and during the ARK V/2- and V/§a-expeditions (1988) in Fram Strait and Greenland Sea indicate very high concentrations of fine grained sediments on and in the ice. Especially multi-year ice contained high surface sediment concentrations of up to 560 g sediment/kg ice.

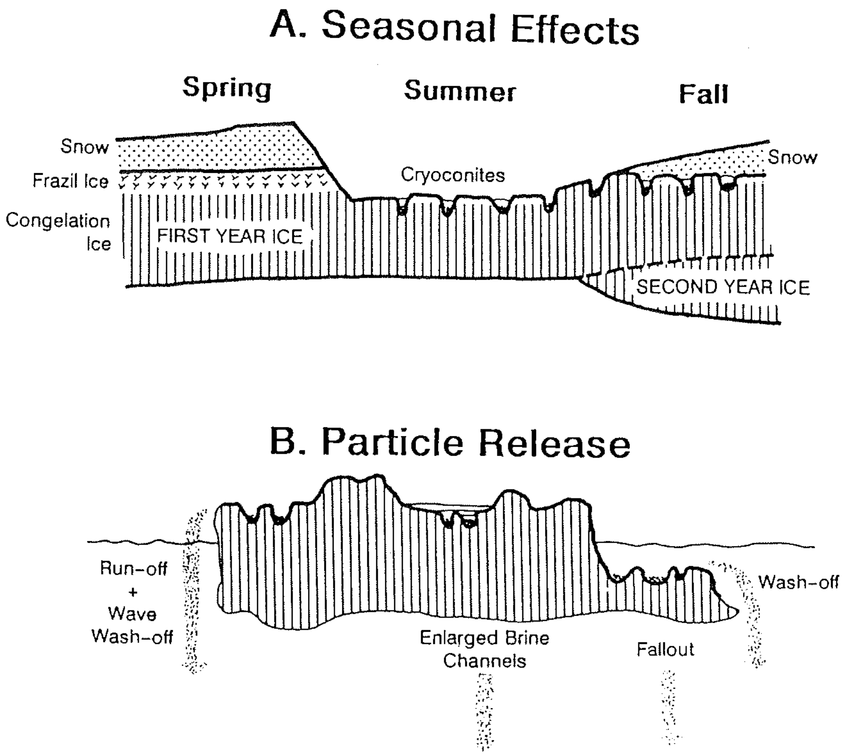
Goals

The incorporation of sediment is thought to happen during ice formation in shallow sea areas. For the sea ice in the Transpolar Drift this are most likely the Siberian Shelf regions. After several years of surface melting in summer the enclosed material is concentrated at the ice surface (fig. 2.4). Much of the ice exits the Arctic Basin via Fram Strait, depositing its sediment load along the axis of the East Greenland Current. Sea ice sampling and ice observation during ARK VI/2 should provide new data of dirty ice export through Fram Strait in the East Greenland Current. In comparison with data from 1987 and 1988 we will evaluate the annual variations of sediment-laden sea ice in the East Greenland Current.

Large volume samples of sea ice sediments ("bulk samples" for detailed sedimentological, mineralogical and biological analysis; detailed sampling (ice cores, surface samples) and detailed measurements of size, the thickness, ridging, freeboard and melt water system of characteristic floes; in connection with observations on the distribution of dirty ice in the East Greenland Current, will help to estimate the annual amount of sediments transported by sea ice and to determine the contribution of sediment-laden sea ice to ocean bottom sediment deposition (particle flux from sea ice).

Variations in sediment distribution on and in the ice, variations in grain size composition, concentration, dissolving and sedimentation processes will be analysed and will help, in relation to ice texture, to determine the origin and incorporation processes of the ice rafted sediments and the history of the ice floes.

Figure 2.4

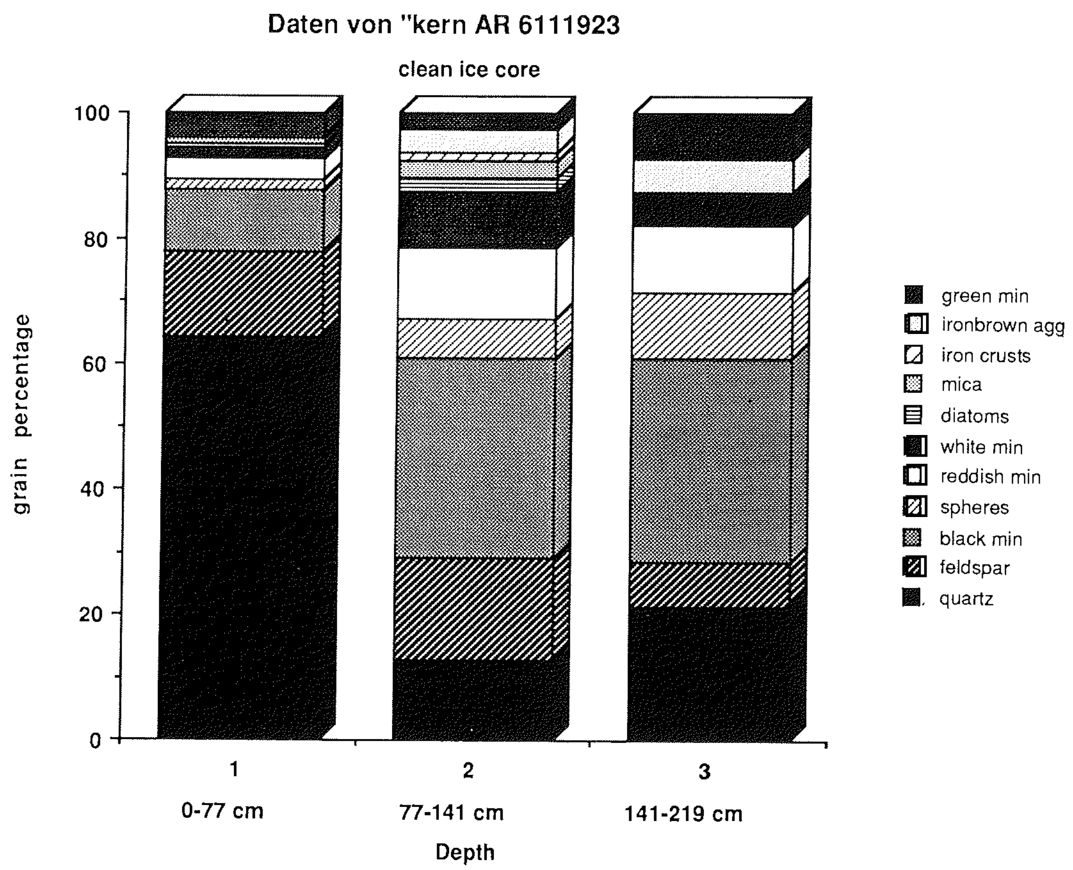


Schematic drawings of

A. the effect of seasonal melting on the distribution of sediments in the ice column. Because of summer surface melting the material will concentrate on the surface and because of solar absorption cryoconites may form.

B. the sedimentation processes during ice drift. The estimatation of sediment loss due to this processes is very important for determination of sediment flux from sea ice.

Figure 2.5



Mineralogical composition of a "clean" ice core, which means the sample showed no visible particle content before filtering. The core was broken in three pieces during coring and was not subdivided to prevent contamination. After melting the water was filtered and the particles in the filtrate were microscopically counted. Mainly the particles are siltsized. The core contain only little clay (20 %) and only 5 % of sandsized material. The mineralogy is dominated by quartz and feldspar. Interesting is the high content of heavy minerals.

Preliminary results

Sea ice observations of the ice characteristics (total ice cover, percentage of dirty ice, snow cover and others) were carried out in 15-minutes intervalls. They yielded a high percentage of "dirty" ice in the East Greenland Current this year. Often very high sediment concentrations distributed in the upper ice column were observed, to describe this ice darkened by sediment a new term was created: "chocolate ice".

Because of the early season the ice was covered by up to 100 cm thick old- and new snow, which complicated the locating and sampling of dirty ice. New and surprising was the occurrence of high sediment accumulations in first year ice. Often a clean surface layer (30 - 50 cm thick) without visible particle content overlies a 30 - 40 cm thick layer of dirty ice with a sharp boundary. The lower part of the ice column, underneath the sediment rich layer, consists of clean ice. The lower contact of the "dirty" layer had often a smeared appearance. In some cases two smaller "dirty" layers were observed.

Fortunately we succeeded in sampling some big pieces of this dirty layer by helicopter. So detailed analyses of sea ice cristallography, in connection with geological analyses, can be carried out to analyse the origin and formation of this new ice type.

In general the sea ice sediment was very fine grained, mainly clay- and silt-sized material. The mineralogy was dominated by quartz and feldspar. Minor components are heavy minerals, mica and coal fragments. The clay fraction, which seems to be the most powerful tool for determining the sediment source region, will be analysed on shore by x-ray diffraction.

On board some ice cores were melted and filtered to get preliminary data on particle content and mineralogy. Figure 2.5 is an example for the particle content of a clean ice core. The core was melted in three, natural broken sections to prevent contamination on board.

2.3.3 MICROWAVE PROPERTIES OF ICE, SNOW, OCEAN AND ATMOSPHERE

R. Ramseier, C. Garrity, D. J. Lapp, W. Grady

Scope

The effort of this part of the cruise was directed primarily to the microwave studies of old, first-year, and new ice. Special attention was given to the overlying snow cover that affects the microwave emission from the underlying ice. Strategic and tactical ice reconnaissance support in the form of satellite-derived passive microwave ice charts was also provided for the ship´s operation. At the same time, these activities provided a unique data set to validate the Special Sensor Microwave/Imager (SSM/I) on board a polar-orbiting satellite.

Experiment set-up and Metholody

A dual polarized 37 GHz passive microwave radiometer, mounted on top of the bridge at a height of 21 metres above the water surface, provided a nearly continuous data stream at an incidence angle of 53 degrees. During the two station stops, the microwave data was augmented with sectorial microwave images and incidence angle profiles. At the same time, measurements of snow properties were carried out within the footprint of the radiometer on two multi-year (MY) floes and one first-year (FY)

floe we occupied. The microwave data was collected with a fully automated data acquisition, processing and storage system dubbed the Shipboard Based Radiometer (SBR). The SBR
consists of an IBM AT computer, an HP data acquisition unit and a 20-megabyte Bernoulli box. To further reduce the calculated brightness temperatures (TB), a second identical IBM AT with graphics printing capabilities (which also acted as a back-up for the primary system) was employed.

The SSM/I data was received five out of seven days from the Institute for Space and Terrestrial Science (ISTS), located at York University in Toronto, Canada. After the SSM/I sensor (1400 km swath) passed over the Greenland Sea, the raw data was intitially processed in the form of earth-located TBs at the U.S. Navy Fleet Numeric Oceanographic Center in Monterey, California. From there, the data was further processed at ISTS using the AES/YORK sea-ice algorithm. In addition, we received on three occasions wind-speed maps of the ice-free Greenland Sea, which compared very favorably with the meteorological charts prepared on board by Mr. H. Malewski, our meteorologist. Finally, completed ice charts depicting total ice (TI) and MY ice fraction contours or data points were transmitted via INMARSAT directly to the "POLARSTERN" and to the Deutsches Hydrographisches Institute (DHI) in Hamburg. DHI could act as a back-up in case we were out of INMARSAT range by sending the data via radio facsimile. In general, the data was less than 10 hours old when received on the ship.

The surface program consisted of digging a snow pit within the footprint of the radiometer, usually at the 53 degree incidence angle location. The size of the footprint was about 6.5 m in length and 3.9 m in width at a distance of 28 m from the ship. Once the pit was dug, one wall was carefully prepared to make the necessary measurements of snow depth, structure of the snow cover (ice layers), temperature, permittivity, density and grain size. Due to the nature of ARKVI/2 cruise, it was not possible to occupy many floes within sight of the radiometer. Instead, our group joined up with the GEOMAR group and took advantage of the daily helicopter flights to visit 21 floes within a 10-km radius of the ship, where detailed snow pit measurements were carried out on 5 FY, 4 SY and 12 MY floes.

While in the ice a total of 199.5 hours, ice observations were collected in support of the objectives mentioned above. This data is now in the process of being reduced and preliminary results will be available during the next cruise. Generally, the snow during ARKVI/1 had more ice lenses and was better with a maximum wetness of 11%, compared to 5% during ARKVI/2. These differences will affect the radiometric measurements.

Preliminary Results

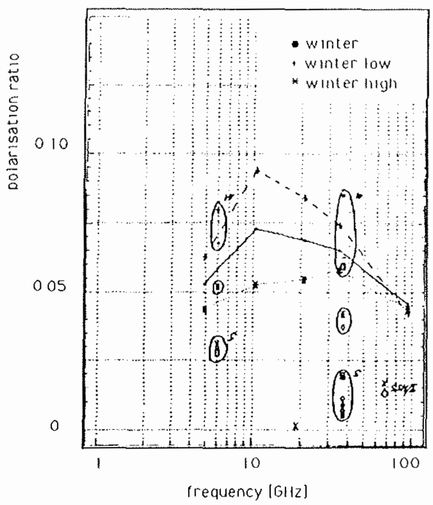
Some results are now available from ARKVI/1 in which a similar program was carried out. Figure 2.6 represents the summary of all the floe measurements, combined with the passive microwave measurements carried out at 57 GHz bz the York Microwave Group and the 6 GHz measurements carried out bz the Arctic and Antarctic Research Institute (Leningrad), The passive microwave data is given in the form of a polarization ratio (PR) which is defined as the difference between the vertical and horizontal polarizations divided by the sum of both polarizations for each frequency. For purposes of comparison, the data by Matzler (1987) have also been included, but divided into a winter and summer regime. Matzler's data is an average of several years' work on the microwave properties of snow at the Avalanche Research Institute of the Weissfluhjoch, Switzerland. The snow is usually much deeper, but undergoes changes similar to the relatively deep snow found during ARKVI/1, particularly if there is any wet snow present. Generally speaking, the data fall within the limits indicated by Matzler for both the dry conditions (winter) and wet conditions (summer), and are considered to be in good agreement. Included are also measurements from the SSM/I during wet conditions at 19 and 37 GHz. This was possible because the temporary warm period we experienced affected the entire Barents Sea.

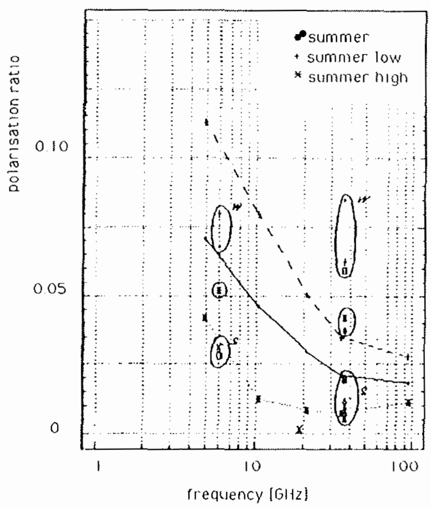
According to the figure, the ARKVI/1 data can be divided into two distinctive groups, which fall into the winter and summer regime respectively, while a third group at 37 GHz falls in between, somewhat closer to the summer data set. The decrease in polarization gario follows in general an increase in the amount of free water with the exception of floe 2. Floe 2 had a well-defined 2 cm wet surface snow layer, while the 40 cm amount of snow remains below freezing temperatures. The cause of this anormalty may be explained by the layering effect which results in a higher PR.

References

Matzler, C. (1987), Applications of the interaction of microwave with the natural snow cover. Remote Sensing Reviews, Vol. 2, pp 259-387.

Figure 2.6 Summary of passive microwave measurements





2.3.4 ALUMINIUM IN THE GREENLAND SEA

C. Measures

Aluminium determinations were performed on 389 samples collected from 19 profiles on three sections in the Fram Strait, central and southern Greenland Sea. Preliminary results from the shipboard analyses showed the following features. Extremely depleted values in the East Greenland Current (less than 2 nM/kg) rise to values of approximately 14 -15 nM in the central Greenland Sea. The role of advective processes in establishing the observed distributions was particularly evident in samples collected at the northern entrance to the Greenland Sea. At these stations the multiple interleaving of the upper polar water with recirculated Atlantic water, as shown by the temperature and salinity, was also clearly visible in the Al data. Three clean snow samples and one bearing evidence of wind blown material were collected from ice floes during a helicopter sampling trip. Also one sample of rafted sea ice was collected. The results of Al determinations on these sample indicated elevated values in the samples containing eolian material and values in the sea ice that were considerably above those of the surface waters in these regions. The final intercalibration station in the Norwegian Sea yielded elevated Al values ca. 35-40 nM. Since the inflowing waters that make up the Norwegian Sea contain only some 15nM each another local process must be responsible for the observed enrichments
A more detailed interpretation of the data set will be made when the final correction and calibrations have been made.

2.3.5 MARINE GEOLOGY

U. Pagels, A. Freiwald, D. Nürnberg, I. Wollenburg, J. Bischof, H. Bohrmann

The development of the Arctic and Norwegian-Greenland Basins has a key function in the circulation of the global ocean and global climate evolution. For the understanding of this development a better knowledge of the paleo-oceanographic history of the East Greenland Current in relation to the Arctic Ocean and the North Atlantic is necessary.

The geological objectives during the "POLARSTERN"-expedition ARK VI/2 are:

- the recording of the paleo-oceanographic history of the East Greenland Current and the adjacent gyres,
- the study of the macrofaunistic composition of perennial ice covered sediments.

During ARK VI/2 we continued the work from ARK IV/3 and ARK V/3a and carried out the sampling from the continental slope east of Greenland, the Greenland Basin, the Boreas Basin and the Greenland Fracture Zone. The goal is to obtain long, large volume sediment cores with high stratigraphic resolution to reconstruct the Late Quaternary paleo-oceanographic development of deep sea basins from high latitudes.

Three box cores (KAL), station 15/017 southeastern Greenland Basin, 15/054 northern Boreas Basin and 15/063 Greenland Fracture Zone, results in a sediment core with a total length of 18,63 m. The 12 giant box cores (GKG) from the continental slope profiles C and D, east of Greenland, as well as from the basins reveal mainly good results with a total core length of 3,72 m.

The surface sediments are yellowish-brown and consist of sandy-silty sediments with occasional dropstones. Carbonate contents of the surface sediment, measured on board with the "Karbonat-Bombe" show values of less than 5 wt.%, except cores from the central Greenland Basin, GKG 15/017 with a carbonate content of 22.2% and GKG 15/046 with 7,1 % $CaCO_3$. GKG from the continental slope are commonly marked by dropstone-"pavements" with Fe-Mn coatings. This accumulation of dropstones is presumably a secondary effect due to strong bottom currents. The surface sediments show a high number of agglutinated benthic foraminifers. Slope upwards the sediments increase in grain size, frequency of terrigenous material and decrease continuously in number of planktonic foraminifers. The sediments are frequently bioturbated up to 20 cm in depth. In the lower part, GKG 15/050, show a gravel layer with occasional mud clasts up to 5 cm in diameter, maybe an indicator for ice rafted material. GKG 15/037, east Greenland shelf, is characterized by a layer of bivalves covered by a 20 cm thick turbidit layer. Carbonate contents downcores are in general less than 5 wt.% $CaC0_3$, except GKG 15/014 with values of 12,5 wt.% in a foraminifera sandlayer at 10 cm depth and 8,7 % $CaC0_3$ in 15 cm depth.

The KAL are characterized by changing yellowish-brown sediments with green-brown and gray layers. The sediments consist of sandy-silty layers with occasional dropstones. Bioturbation has been observed in all cores. KAL 15/063 from the Greenland Fracture Zone is characterized in contrast to the other cores by fine grained, clayey sediments. The carbonate and organic carbon measurements of KAL 15/054 (Figure 2.7), carried out in Kiel, show values up to 27 wt.% $CaC0_3$ in the upper 25 cm of the core. With increasing depth in core the average carbonate content decrease continuously and show values of 2 - 12 wt.%. All cores from the Greenland Basin are indicated by high sand contents and sandy layers due to strong turbidite influence.

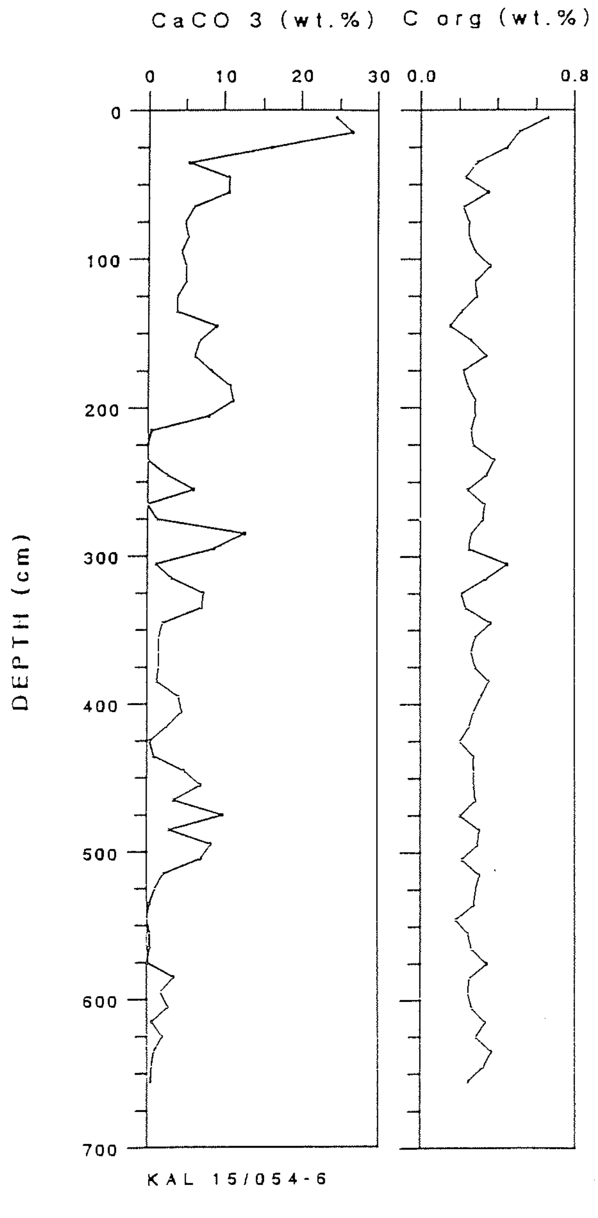
Macrofaunistic observations show that dropstones control the occurrence of the hardground fauna in the Greenland Sea. Typical dropstone populations are coelenterates, porifers, bryozoa, serpulids and benthic foraminifers. In the 1100 - 1200 m depth area dropstones are sparsely populated by porifers. The soft bottom fauna living burried in the sediments consist mainly of mullusks (lamellibranchiata, scaphopoda) as well as gastropoda found on the sediment surface. All of the bivalves are atlantic species and edemism are not observed. Worth mentioning is the finding of Rhizocrinus lofotensis (echinoderm, crinoidea) whose northernmost occurrence is assumed till now near Island. The finding of a 10 mm tardigrada is also of special interest.

2.3.6 SEDIMENT TRAP-EXPERIMENTS AND AKTUOPALEONTOLOGY

J. Carstens, D. Hebbeln

In order to reconstruct paleoenvironments in the geologic history by analysing marine sediments a specific knowledge of the sediment forming processes is required. The particle flux to the seafloor with all its seasonal variabilities in quality and quantity was recorded using time-series sediment traps. The largest part of material sinking to the seafloor is made up of particular matter of biogenic origin or of lithogenic origin

Figure 2.7



Carbonate- and organic carbon from KAL 15/054 (northern Boreas Basin) derived from melting ice floes. A detailed knowledge of these processes enables a better understanding of how marine sediments are formed.

During leg ARK VI/2 two sediment traps were recovered and three were moored for another year. In addition to the existing mooring positions on the western and the eastern slopes of the Fram Strait, a third sediment trap was moored in the Central Greenland Sea Basin. We only used HED-sediment traps (Kiel Sediment Trap), which were each incorporated in oceanographic moorings of IFM Hamburg.

The sediment trap FS 4 from the western slope of the Fram Strait was the first trap to be moored under year-round ice cover. Because the particle flux is very low, seasonal variabilities cannot be observed by eye. Remarkable is the great number of 1 - 2 cm large amphipods in single sample cups. In contrast, the sediment trap SP 2 from the eastern slope of the Fram Strait shows a clear seasonal signal both in quantity as well as in the composition of the trapped material. This sediment trap, which was only at times covered by ice collected considerably more material than the FS 4 trap, which was constantly under ice cover.

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

For these experiments a Hydrobios-multi-net with a mesh-size of 63µ was used at 18 stations, of which 9 were in ice covered waters. In standard procedure the depth-intervals 500 m - 300 m, 300 m - 200 m, 200 m - 100 m, 100 m - 50 m, and 50 m - 0 m were sampled. In addition, a multi-net cast was taken down to 3000 m water depth at one station.

The concentrations of planctonic foraminifera are around 15 ind./m^3, integrated over the uppermost 500 m of the watercolumn, with maximal values up to 60 ind./m^3. The largest proportion of the foraminifera population lives in the uppermost 200 m of the water column. Compared with the winter months the shell size of the foraminifera had clearly increased. The first appearance of the shell characteristics "kummerkammer" and "calcite crust" indicates the beginning reproduction period. Only less than 3 % of all individuals showed these characteristics, the percentage of dead individuals was also very low. The fauna in the Greenland Basin in this season was dominated by Neogloboquadrina pachyderma. Globigerina quinqueloba was only of little importance and the Globigerinita-species were almost totally absent.

2.3.7 Sarcodine Biology

<u>N. Swanberg</u>, L. Eide

Our objective for participation in Ark VI-2 was to collect plankton samples for analysis of the abundance and species composition of the radiolarian fauna in the Greenland Sea. We are analysing the distribution of species of radiolaria in the plankton in order to allow us to relate their patterns of occurrence in the water column with general patterns in production. As we are primarily interested in the sense of the long term change in the radiolarian assemblage in response to the bloom, we will do this by using mathematical methods from ecology which seek gradients in the distribution of a multi-species assemblage and which are particularly sensitive to gradients. As there are both N-S and E-W components to the production signal, the program of the "POLARSTERN" cruises fits in particularly well with our plans. Our plans were to run vertical plankton hauls with our own equipment. Several days of ship time were lost on Ark VI-2 before departure.

In one effort to conserve time in the attentuated "POLARSTERN" Ark VI-2, our group agreed, on request of the chief scientist, to share plankton samples for radiolaria with Jörn Carstens' group rather than duplicate the same samples. This represented no loss for us as Carstens' equipment was better than ours (the multinet allows for rapid collection of stratified vertical samples), his sampling grid and his goals were very similar to ours. After Carstens has removed his foraminifera we will either take a <500 µm filtered sample of the wet material, returning the undisturbed remainder of the zooplankton, or use the remainder of his low-temperature ashed samples. In either case we will be sent our samples after Carstens returns to the Alfred-Wegener Institute. The plankton samples which we will analyse were collected by Carsten's group from 19 stations.

This plan left us with considerable time to tend to other things, so we directed our attention to some of our alternate cruise goals. In August, 1988 we had sampled the Tintinnida on the R/V *Endeavor* working near the ice edge in the Barents Sea and the vicinity of Svalbard. The preliminary results were promising, and as we found that very little is published on the distribution of this group in the arctic, we decided to proceed with the sampling program, by sampling the euphotic zone of most of the CTD casts for the abundance of Tintinnida. Because of "POLARSTERN's" ice breaking ability, this gave us an opportunity to get samples from under the ice pack. After the CTD was sampled for water chemistry, the remainder of the water, up to 4-l, was filtered through a 10 µm mesh net and preserved. We collected and filtered 73 such shallow samples from 27 CTD casts for tintinnids, concentrating on B, C, and D lines, with some samples in the A and I series. These samples will probably also be analyzed for copepod fecal pellets.

We also took 10-l samples through the ship's clean seawater pump system at most stations for surface particle distribution. These samples were filtered through 0.45 µm Millipore filters and will be analyzed with polarized light microsocopy and the SEM for the coccolithophoran flora. If appropriate we may also analyse them for terrigenous particle load and diatoms. Surface sediment samples were taken from the box core stations for coccolithophore fauna.

Table 2.2

ARK VI/2 Station List

Stat. No	Date	Time (GMT) Start End	Position		Depth (m)	Gear
15/013	18.05.88	08.15-11.13	74°24.4'N	02°27.9'E	3642	GSP-1 rec
15/014	18.05.88	18.05-23.24	73°21.5'N	00°48.2'W	3056	0250 rec, CTD, Mu
			73°22.9'N	00°49.9'W	3198	
15/015	19.05.88	04.02-06.56	73°23.0N	03°14.9'W	3056	CTD
			73°23.8'N	03°15.8'W	3046	
15/016	19.05.88	10.44-16.10	73°47.8'N	04°49.6'W	3568	GSP-3 rec, Mu(2x)
			73°50.6'N	04°50.04'W	3629	GSP-3B depl.
15/017	19.05.88	19.59-02.36	74°19.7'N	05°10.9'W	3516	KG, CTD, KAL
			74°20.9'N	05°11.9'W	3502	
15/018	20.05.88	08.00-11.05	73°45.5'N	07°18.9'W	3353	CTD, Mu
			73°45.5'N	07°21.1'W	3352	
15/019	20.05.88	16.03-17.56	73°04.9'N	06°14.7'W	2660	CTD
			73°05.1'N	06°13.7'W	2656	
15/020	20.05.88	22.15-23.54	72°30.1'N	07°14.3'W	2562	CTD
			72°30.9'N	07°13.6'W		
15/021	21.05.88	06.00-07.56	71°50.1'N	08°00.7'W	2544	CTD
			71°50.3'N	07°56.3'W	2523	
15/022	21.05.88	15.08-16.54	72°03.8'N	12°18.8'W	2424	CTD
			72°03.8'N	12°19.2'W	2426	
15/023	21.05.88	20.44-23.18	72°29.1'N	11°06.7'W	2279	CTD, Mu(2x),
			72°28.4'N	11°06.3'W	2124	
15/024	22.05.88	03.50-05.57	73°02.1'N	09°40.4'W	2939	CTD
			73°02.4'N	09°41.1'W	2945	
15/025	22.05.88	9.59-11.21	73°04.4'N	08°04.6'W	2693	GSP-3b depl
			73°03.52'N	08°03.12'W	2673	
15/026	22.05.88	19.13-21.52	73°22.2'N	11°59.8'W	2786	CTD, Mu
			73°23.1'N	11°56.9'W	2800	
15/027	23.05.88	03.23-05.18	73°40.2'N	14°00.7'W	2410	CTD
			73°40.5'N	14°02.3'W	2412	
15/028	23.05.88	07.50-10.53	73°45.2'N	14°50.9'W	1814	CTD, KG
			73°44.5'N	14°52.5'W	1752	

15/029	23.05.88	12.26-14.10	73°50.1'N 73°50.1'N	15°20.4'W 15°20.9'W	1129 1116	CTD, ICEFLOE
15/030	24.05.88	03.17-05.30	73°54.8'N 73°54.6'N	10°30.3'W 10°32.3'W	3050 3050	CTD
15/031	24.05.88	10.39-12.48	74°27.1'N 74°26.5'N	09°00.2'W 08°59.4'W	3294 3295	CTD
15/032	24.05.88	15.53-22.30	74°59.6'N 75°01.0'N	09°06.1'W 09°14.5'W	3317 3300	403-2rec, Mu, 403-3depl
15/033	25.05.88	01.51-04.44	75°00.8'N 75°01.9'N	07°30.1'W 07°33.1'W	3422 3420	CTD, Mu
15/034	25.05.88	07.09-10.06	75°08.1'N 75°07.9'N	08°49.5'W 08°55.9'W	3297 3268	CTD, Mu
15/035	25.05.88	12.13-14.40	75°14.7'N 75°13.8'N	10°00.6'W 10°07.9'W	2885 2887	CTD, Mu
15/036	25.05.88	19.32-22.02	75°22.1'N 75°20.3'N	11°30.9'W 11°33.9'W	1034 1082	CTD, Mu (2x), KG
15/037	26.05.88	00.37-01.20	75°28.6'N 75°28.0'N	11°40.7'W 11°41.7'W	483 481	Mu, KG
15/038	26.05.88	02.40-02.56	75°30.4'N 75°30.2'N	11°46.0'W 11°46.3'W	333 337	KG
15/039	26.05.88	04.28-05.09	75°27.5'N 75°26.3'N	11°50.0'W 11°50.6'W	329 325	ICEFLOE
15/040	26.06.88	12.26-14.54	75°32.92'N 75°32.3'N	11°39.20'W 11°39.52'W	341 367	401-2rec
15/041	27.05.88	00.00-02.55	75°01.36'N 74°59.7'N	11°52.75'W 12°01.4'W	1821 1734	404-2rec
15/042	27.05.88	07.20-10.56	75°19.9'N 75°17.7'N	10°54.5'W 11°03.4'W	2086 2033	CTD, Mu, KG
15/043	27.05.88	12.55-16.34	75°26.2'N 75°24.8'N	10°50.37'W 10°52.4'W	1793 1847	402-2rec
15/044	28.05.88	00.54-03.42	75°00.0'N 74°59.8'N	05°00.2'W 05°00.7'W	3593 3593	CTD, Mu
15/045	28.05.88	05.56-08.36	74°57.4'N 74°57.6'N	04°59.8'W 04°58.3'W	3598 3333	V-319rec
15/046	28.05.88	11.00-00.40	75°01.9'N 74°54.7'N	04°00.3'W 04°10.6'W	3637 3631	027depl, Mu(4x), Bo, KG, KAL
15/047	29.05.88	08.02-10.18	75°35.2'N 75°34.8'N	05°30.5'W 05°30.7'W	3482 3479	CTD

15/048	29.05.88	14.26-16.37	76°15.0'N 70°14.4'N	03°29.9'W 03°32.7'W	3617 3607	CTD
15/049	29.05.88	19.24-21.09	76°32.9'N 76°32.0'N	04°39.2'W 04°36.9'W	2581 2594	CTD
15/050	29.05.88	23.24-01.41	76°47.4'N 76°46.0'N	05°30.7'W 05°35.1'W	1653 1695	CTD, KG
15/051	30.05.88	03.40-05.18	76°55.5'N 76°55.3'N	06°00.5'W 06°00.5'W	1031 1063	KG, CTD
15/052	30.05.88	10.20-11.50	76°42.4'N 76°42.3'N	02°24.0'W 02°24.2'W		0171rec
15/053	30.05.88	15.54-17.52	77°08.2'N 77°08.4'N	00°01.4'E 00°00.3'W	3236 3236	CTD
15/054	30.05.88	21.22-10.54	77°45.0'N 77°46.6'N	01°00.1'E 00°55.3'E	3118 3052	CTD, BO, Mu(3x), KG(2x), KL
15/055	31.05.88	13.15-15.45	77°49.1'N 77°48.4'N	01°00.5'W 01°01.7'W	3079 3082	CTD, Mu
15/056	31.05.88	20.44-23.20	77°52.1'N 77°51.1'N	02°50.7'W 02°44.1'W	2904 2915	CTD, Mu
15/057	01.06.88	05.15-07.42	77°54.2'N 77°51.9'	04°06.4'W 04°02.8'W	2599 2648	CTD, Mu
15/058	01.06.88	11.50-11.58	77°55.9'N 77°55.9'N	04°47.4'W 04°43.7'W	1796 1858	ICEFLOE, CTD, Mu, KG
15/059a	02.06.88	03.05-12.20	78°26.55'N 78°15.92'N	04°04.40'W 04°15.65'W	1693 1868	0260rec
15/059b	03.06.88	14.50-18.30	77°56.2'N 77°53.2'N	04°00.3'W 03°55.8'W	2601 2664	0260rec
15/060	02.06.88	22.04-01.39	78°03.9'N 77°59.4'N	04°47.0'W 04°32.6'W	1535 2113	0261 depl, Mu(2x), KG
15/061	04.06.88	10.55-14.44	78°53.8'N 78°52.89'N	06°39.7'E 06°40.59'E	1671 1706	0161rec, Mu, 0162depl
15/062	05.06.88	05.23-06.38	75°46.32'N 75°46.3'N	00°24.26'E 00°28.9'E	2360 2360	GSP-6rec
15/063	05.06.88	07.54-11.06	75°31.4'N 75°30.9'N	00°49.5'E 00°53.4'E	1730 1757	KG, KL(2x)
15/064	05.06.88	12.54-14.08	75°17.05'N 75°17.6'N	01°11.85'E 01°11.2'E	2565 2372	GSP-5rec
15/065	06.06.88	08.24-10.29	70°59.9'N 71°01.1'N	04°00.0'E 03°58.3'E	3179 3181	CTD

3. FAHRTABSCHNITT ARK VI/3 + 4
TROMSÖ-LONGYEARBYEN - HAMBURG
08.06.1989 - 08.07.1989

G. Krause (Chief Scientist)

3.1 ALLGEMEINER FAHRTBERICHT

Dieser Fahrtabschnitt diente der Weiterführung der bisherigen Beiträge zu den Programmen des Internationalen Grönlandsee-Projekts. Die Untersuchungen beinhalteten die ozeanographische, biologische und chemische Erforschung der drei hydrographischen Regionen der Grönlandsee mit Schwerpunkt im Bereich der Arktik- und Polarfront.
Der Fahrtabschnitt konzentrierte sich auf 5 Hauptthemen:

- Wie groß ist die jahreszeitliche Veränderung der Lage und Struktur der Artik-Front?
- Wird Salz als eine der möglichen Anregungsquellen für tiefreichende Konvektion über die Arktik-Front in den Grönlandsee-Wirbel transportiert?
- Ist hohe biologische Produktivität das Ergebnis eines Eisrand-Effektes oder wird sie durch die Frontenzirkulation bewirkt?
- Welcher Anteil der biologische Produktion wird innerhalb der euphotischen Zone umgesetzt, und wie hoch ist der Anteil, der exportierten Produktion, der für den Transport von CO_2 von der Atmosphäre in den Ozean relevant ist?
- Besteht die Möglichkeit, Wassermassen durch Fluoreszenz Spektren zu kennzeichnen, um sie mit Hilfe eines LIDAR Systems zu identifizieren?

Einige Projekte des Fahrtabschnitts 1 und 2 mußten zudem weitergeführt werden, insbesondere die Erforschung von Mikrowellen-Eigenschaften des Eises und der Lebenszyklen und saisonalen Vertikalwanderung der herbivoren Copepoden. Vergleiche zwischen Mega-Benthos des Ostgrönland Shelfs und des Spitzbergen Shelfs wurden ebenfalls ins Programm aufgenommen.

In der zur Verfügung stehenden Schiffszeit wurden 2 Profile auf den Breitengraden 74°30'N und 78°N mit einem Stationsabstand von 10nm durchgeführt. Jedes Profil begann am Ostgrönland-Shelf im polaren Wasser, verlief durch die Polarfront, den Grönlandsee-Wirbel, die Arktische Front und endete im Atlantischen Regime im Bereich der Bäreninsel bzw. vor Spitzbergen

Außerdem wurde symmetrisch zu 74°45'N ein größeres XBT-Meßprogramm auf einem Stationsnetz zwischen 4°E und 9°E mit einem Abstand von jeweils 3,5 nm durchgeführt, das mit 7 Schnitten die Frontalzone der Arktischen Front abdeckte.

Nur durch die Beschränkung auf die folgenden Instrumente war es möglich, diese aufwendigen Stationsarbeiten zu Ende zu führen:
CTD + Rosette bis 200 m Tiefe, Planktonnetz ("Bongo") bis 80 m Tiefe, getrennte CTD ohne Wasserschöpfer (mit Ausnahme von verschiedenen Kalibrierungsüberprüfungen), die jeweils abwechselnd bis zum Grund oder einer Tiefe von 2000 m eingesetzt wurden. Dieses CTD-Gerät (eine Bathysonde von Salzgitter Elektronik) konnte mit einer Geschwindigkeit von 3m/s gehievt werden. Durch die dadurch erreichte Zeitersparnis waren Messungen auf 89 Stationen mit diesem Gerät möglich. Einmal am Tag wurde zusätzlich an einer Station Primärproduktions-messungen vorgenommen. Hubschrauber-Flüge mit einem Radiometer wurden zur Erkundung der Arktischen Front entlang der geplanten Schiffsroute eingesetzt, außerdem auch zur Aufzeichnung der Temperaturverteilung im umliegenden Gebiet der Stationen innerhalb der Frontalzone.

Im hydrographischen Schacht des Schiffes wurden Sensoren eingebaut, um folgende Werte zu bestimmen:

- Temperatur und Salzgehalt
- Fluoreszenz von Chlorophyll und Gelbstoff
- Mie-Rückstreuung
- Messung vertikaler Stromprofile mit einem akustischem Doppler-Strommesser (ADCP)

Neben diesen Messungen wurde fortlaufend die Partikel- und Nährstoffverteilung mit Hilfe der bordeigenen Seewasserleitungen mit einem Wassereinlaß in 7 m Tiefe ermittelt.

Weitere Programme im Eisgebiet beinhalteteten die Bestimmung von Mikrowelleneigenschaften von Eis und Schnee und den erfolgreichen Einsatz einer weiterentwickelten Line-Scan-Kamera, die vom Flugzeug oder Hubschrauber aus eingesetzt werden kann.

Am 8. Juni, nur 20 Minuten nach Eintreffen der Wissenschaftler an Bord, verließ "POLARSTERN" Tromsö in Richtung Grönlandsee Shelf. Die Eisbedingungen waren relativ günstig. Auf der kalten Seite der Arktischen Front gab es viel Nebel, während in der Atlantischen Region klare Wetterverhältnisse vorherrschten. Es gab nur einen kurzen Sturmvon Bft 9, 4 vollkommen sonnige Tage, aber insgesamt war es eine typische graue, aber angenehme Sommerfahrt in der Grönlandsee.

Am 29. Juni wurde ein Drittel der wissenschaftlichen Besatzung in Longyearbyen ausgetauscht. Unter der Fahrtleitung von Prof. G. Hempel lief "POLARSTERN" Richtung Westen zum Ostgrönlandshelf und danach zurück zum südlichen Spitzbergenshelf, um jeweils Bodentierproben für die Untersuchung von Megabenthos zu sammeln. Daneben wurde auf den Shelfgebieten sowie im tiefen Wasser (4000 m) ein neuer Vielfachbodengreifer mit Video-Kamera erfolgreich getestet. Außerdem wurde eine Strommesserverankerung in der Arktischen Front ausgelegt.

Am 8. Juli lief "POLARSTERN" wie geplant Hamburg an. Im Rahmen der Feierlichkeiten aus Anlaß des 800. Hafengeburtstages wurde das Schiff der Öffentlichkeit mit einem "Tag der offenen Tür" vorgestellt. Schließlich kehrte "POLARSTERN" am frühen Morgen des 9. Juli in den Heimathafen Bremerhaven zurück.

3.2 GENERAL CRUISE REPORT

This cruise leg continued former contributions to the international Greenland Sea Project. They comprise oceanographical, biological and chemical investigations into the three hydrographical regimes of the Greenland Sea, and particularly into the frontal zones of the Arctic and the Polar Front.
Five main objectives determined the cruise plan:

- What is the seasonal variation of position and structure of the Arctic Front?
- Is salt as an agent for deep convection being mixed across the Arctic Front into the Greenland Sea Gyre?
- Is high biological productivity an effect of the marginal ice zone or a result of frontal circulation?
- What proportion of the biological production is recycled within the euphotic zone and how much is exported and thus relevant for the removal of CO_2 from the atmosphere?
- Is it possible to characterize watermasses by fluorescence spectra in order to make them detectable by a Lidar system?

In addition some projects of leg 1 and 2 had to be continued, particularly the studies on ice properties in relation to remote sensing by passive microwaves and the studies on life cycles and seasonal vertical migration of herbivorous copepods. Furthermore some comparisons between the mega-benthos of the East-Greenland Shelf and Spitsbergen Shelf were planned.

To compromise on the available ship time, two sections along the latitudes 74°30'N and 78°N were occupied with a station spacing of 10 nautical miles. Each began on the East Greenland Shelf in Polar Water, crossed the Polar Front, the Greenland Sea Gyre, the Arctic Front and ended up in the Atlantic regime on the shelves of Bear Island and Svalbard, respectively.

Additionally a larger XBT survey was carried out on a grid between 4°E and 9°E covering the Arctic frontal zone with 7 sections, each 3.5 nm apart and centered at 74°45'N. XBT casts were done every 3.5 nm, too.

This rather extensive station work could only be completed by concentrating on few instruments: CTD+rosette sampler down to 200m, plankton net ("Bongo") down to 80m, separate CTD without bottles (with the exception of several calibration checks) alternating down to bottom or 2000m depth. This CTD (a Salzgitter Elektronic Bathysonde) could be hoisted with a speed of 3m/s. This saved so much time that we completed 89 stations of this type. Once per day one station was additionally occupied for primary production measurements. Several helicopter flights with a radiometer were performed to detect the Arctic Front along the planned ship's track and to map the temperature distribution in the vicinity of stations in the frontal zone.
In the hydrographic well of the ship sensors were mounted to record

- temperature and salinity
- fluorescence of chlorophyll and yellow substances
- Mie backscattering
- velocity profiles with an ADCP

and, using the scientific water supply system of the ship with its intake in 7m depth, continuous measurements of particle size distributions and several nutrients were performed.
Two other programmes were carried out while the ship was within ice cover: the investigations of microwave properties of ice and snow and the successful test of a newly developed line-scan camera to be carried by helicopter or aircraft.

"POLARSTERN" left Tromsö on the 8th June, only 20 minutes after the arrival of the scientific party on board and headed for the East Greenland Sea Shelf. No severe ice conditions were encountered. The cold side of the Arctic Front was foggy while clear conditions prevailed in the Atlantic regime. There was a short storm of Bft.9, 4 sunny days, but otherwise it was just a typical grey but pleasant summer cruise in the Greenland Sea
On June 29, a third of the scientific crew was exchanged in Longyearbyen. With Prof. G. Hempel as chief scientist "POLARSTERN" headed west to the East Greenland Shelf where bottom samples were taken for the study of megabenthos. The same was done after returning to the southern Spitsbergen Shelf. Additionally a new multibox corer with video camera was successfully tested on the shelf and in deep water (4000 m), and a current meter mooring was deployed in the area of the Arctic Front.

As planned "POLARSTERN"called at the port of Hamburg on July 8 and participated in the programme on the occasion of the 800th anniversary of the port. For one day the ship was open to the public. Finally, "POLARSTERN" was back in her home port in the morning of July 9.

3.3 REPORTS OF THE WORKING GROUPS

3.3.1 PHYSICAL OCEANOGRAPHY

G. Budéus, T. Oishi, W. Schneider, C. Kougias, R. Plugge, K. Meyer

The general aim of this cruise was another investigation of the close interrelations between physical oceanographic processes and biological production in the Greenland Sea with emphasis on the frontal zones of the Arctic and East Greenland Polar fronts. This cruise leg was also part of a larger plan to study the variability of the frontal structures, general flow patterns and hydrographical conditions as a function of the seasons and from year to year.

Of specific interest are the variability of the front's position, inclination of the frontal interface, horizontal gradients and along front inhomogenities as well as the exchange across the front whether due to separation of eddies or mixing. The inclination of the interface effects e.g. the vertical stability and therefore the environmental conditions for biological production. Separated eddies of warm Atlantic waters may also result in favourable living conditions. These cells of high saline water may contribute to the deep reaching convection, if winter cooling is sufficient. Investigations of the frontal dynamics, which are important for the drift of immotile organisms, with respect to the wave lengths of pertubations and frontal jet streams are another essential part of the programme.

The physical working group performed the following investigations:

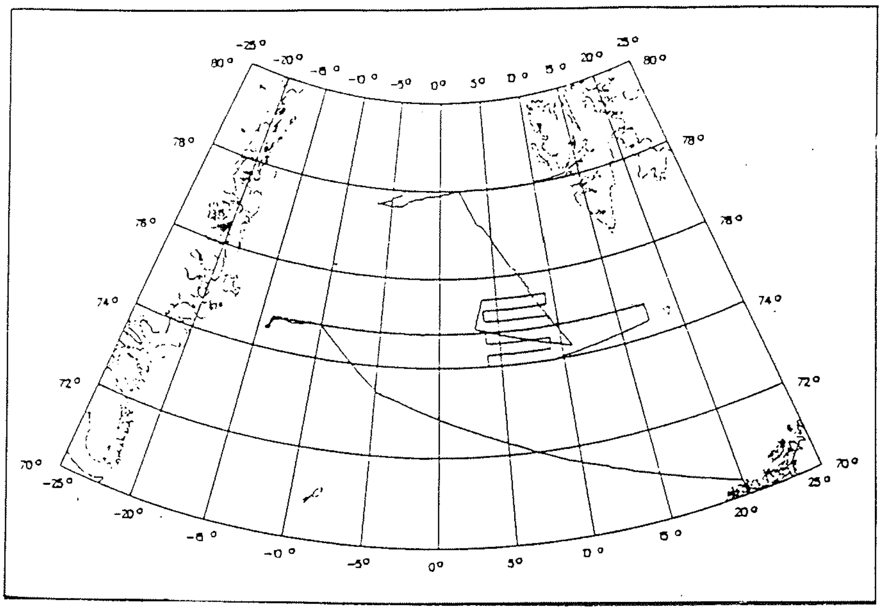
- CTD casts along two zonal transects from the western to the eastern shelf of the Greenland Sea and on a transect across the Arctic Front
- XBT drops in a closely spaced grid centered around the Arctic Front (Figure 3.1)
- continuous Acoustic Doppler Current Profiler measurements in open waters
- continuous measurements of salinity, temperature, light extinction coefficient, chlorophyll fluorescence, Mie backscattering and yellow substance fluorescence on the ship's tracks (instruments installed in the moonpool)

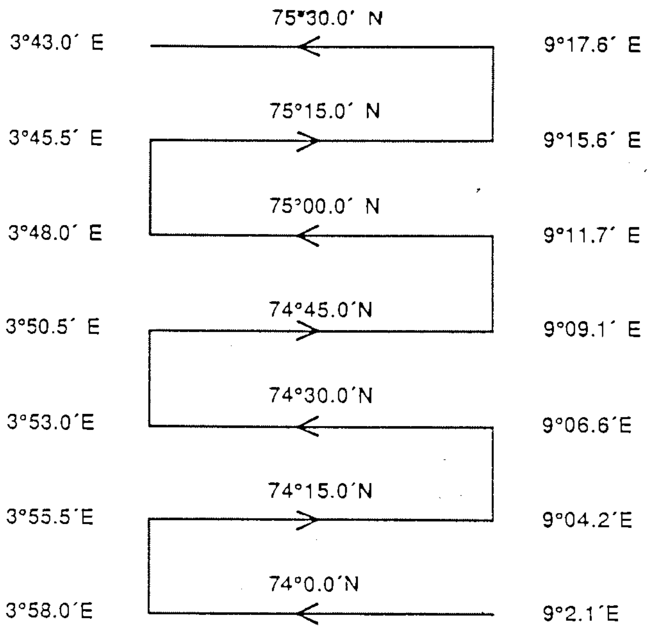
The first zonal transect - with 10 nautical miles between stations - located at 74°45'N, started at 14°26.8' W on the East Greenland shelf and ended at 17°24.4'E near Bjørnøya. The first part of the transect - across the Polar Front - was ice covered and the front and its surface outcrop could be well identified. Subsequently the Greenland Sea Gyre and the Arctic Front were crossed with the same spacing. The CTD together with the ADCP measurements allow detailed estimations of the dynamical processes during the time of investigation. The deep reaching CTD casts will be used for calculating geostrophic velocities. The ADCP velocity measurements will be related to this and give additional information about the horizontal velocity field. Frontal structures with convergencies and jets are expected to be better resolved, as well as eddies to be identified by the continuous measurements of current profiles by the ADCP.

Information about surface gradients across the frontal interfaces is supplied by the data output of the instruments installed in the moonpool. Enhanced biological activity at the fronts and inherent patchiness of a waterbody are observed.

The XBT-survey was performed with the intention to gain a more detailed knowledge of the frontal structure of the Arctic Front in smaller space scales. The working box with 84 nautical miles long east-west transects - 15 geographical minutes apart - extended from 74°00' to 75°30'N. The distance between XBT drops was chosen to be 3 nautical miles in order to receive a high cross frontal resolution. The survey was completed within two days to approach a synoptic picture of the front. The eddy structure found was taken as a criterion for the location of the next CTD transect across this front. The along front variability is illustrated by the data of this second transect.

Figure 3.1 Cruise track and XBT-survey





Length of section:	83 nm
Total range of profile:	671 nm
Distance between stations:	3 nm on sections 1.5 nm in the range of strong temperature gradients
Number of stations:	222 (+7)

Another east-west transect from shelf to shelf further up in the north at 78°00'N allows an estimation of transports at different latitudes of the Greenland Sea Gyre. As the aims are comparable, the sample strategy was the same as for the southern transect.

In addition, an in-situ partical counter developed by the AWI was tested in the surface layer at several stations. The along track measurements have been continued on the way back home.

Calibration of probes, post-processing and checking of consistency and quality of the data (especially the ones received by the ADCP) are the next steps towards a presentation of results.

3.3.2 OPTICAL PROPERTIES OF SEA-WATER

T. Hengstermann, K.D. Loquay, B. Nieke, R. Theis, R. Willkomm

Introduction

Our investigations focussed on the measurement of inherent optical parameters of the water masses in the frontal regions. We are interested in the following topics:

- quantity and optical signatures of dissolved organic matter (DOM)
- correlation of fluorescence and beam attenuation of DOM
- covariance of these data with other hydrographic (T/S), chemical (nutrients) and biological (phytoplankton) parameters
- potential of describing water masses and fronts using optical methods in Northern polar regions.

For this purpose water samples from different depths are analyzed fluorometrically and with respect to turbidity. Two laboratory instruments are utilized:

a) a Perkin Elmer LS 50 spectrometer for registration of continuous emission spectra with excitation at UV-VIS wavelength, yielding data on fluorescent compounds of DOM and on in-vivo chlorophyll a;
b) a beam attenuation meter having an optical path length of 1 m. From the analysis of filtered samples (by 0.2 µm cellulose nitrate filters) and taking purified water as a reference medium, specific spectra of beam attenuation co-efficients of DOM are derived in the wave length range 300 to 700 nm.

In particular, these investigations will allow to further define the specifications of a shipboard lidar which will be developed in the near future. With this instrument, depth profiles of turbidity and of DOM fluorescence will be obtained from the moving ship. A depth penetration of more than 50 m is estimated in the open ocean under clear water conditions with a vertical resolution of 20 cm, yielding a continuous measurement of hydrographic structures in the upper water column.

Description of our measurement programme

a) Fluorescence of DOM (yellow substances) and Chlorophyll a

With the LS 50 we are able to use an excitation range from 200-700 nm and an emission range from 200-800 nm. The fluorescence of yellow substances is distributed on the range of 400-600 nm.
For chlorophyll a the fluorescence range amounts to 680 - 690 nm. To get a selective quantity of yellow substance and chlorophyll a it is necessary to excite the water samples in the UV and VIS.

For our investigation we used the following wavelength ranges:

excitation (nm)	emission (nm)
254	260-700
275	285-530
308	320-600
355	370-700
488	500-750

Measured water samples:
- leg 3:

all samples were taken from the bio-rosette.

station 67-155	5 m/surface
	20 m
	80 m

in addition to these depths following samples were measured at stations 133-155:

30 m
40 m
60 m

- leg 4

samples were taken by the bio-rosette and from the seawatermains (positions are appended in table 3.1) in cooperation with the members of the working groups of H.J. Hirche and G. Kattner.

b) Attenuation of DOM

Dom absorbs the light in the UV and blue range of the spectrum. We investigated the attenuation of yellow substances in the range of 300-700 nm.
The fact that we needed at least one hour per measurement made it impossible to measure more than a surface water sample per station.
For leg 3 we started at station 69 and investigated all stations till 155.
The stations of leg 4 which were measured at leg 4 are mentioned in table 3.1.

Table 3.1

Chapter 3: stations and kinds of measurement of leg 4

date	time[utc]	latitude	longitude	sample no.	fluoresc.	attenuat.
30.06.89	08:56	77:28.7'N	02:58.9'W	300	*	
30.06.89	10:38	77:27.0'N	03:37.5'W	stn15/156v	*	
30.06.89	11:12	77:26.7'N	03:38.2'W	stn15/156	*	*
30.06.89	17:19	77:14.0'N	05:24.7'W	stn15/157	*	*
30.06.89	23:22	77:11.4'N	06:02.5'W	301	*	*
01.07.89	01:12	77:04.7'N	05:27.4'W	302	*	*
01.07.89	03:22	77:06.6'N	04:51.8'W	303	*	*
01.07.89	05:21	77:03.0'N	03:59.8'W	304	*	*
01.07.89	08:16	77:00.2'N	02:30.3'W	305	*	*
01.07.89	09:12	76:59.2'N	01:59.8'W	stn15/159	*	*
01.07.89	11:45	76:55.8'N	00:09.3'W	306	*	*
01.07.89	12:45	76:52.6'N	00:53.9'E	307	*	
01.07.89	13:41	76:50.0'N	01:52.5'E	308	*	*
01.07.89	14:50	76:47.4'N	03:05.3'E	309	*	
01.07.89	15:34	76:45.5'N	03:52.7'E	310	*	*
01.07.89	17:28	76:40.8'N	05:27.4'E	311	*	
01.07.89	20:34	76:33.8'N	09:07.5'E	312	*	*
01.07.89	22:28	76:28.8'N	11:05.3'E	313	*	*
02.07.89	00:24	76:24.6'N	13:03.8'E	314	*	*
02.07.89	05:48	76:20.7'N	15:39.0'E	315	*	*
02.07.89	06:54	76:24.0'N	16:08.7'E	316	*	*
02.07.89	10:20	76:19.3'N	15:42.2'E	317	*	*
02.07.89	12:25	75:57.2'N	14:18.1'E	318	*	*
02.07.89	15:26	75:25.5'N	12:22.3'E	319	*	*
02.07.89	18:11	75:00.2'N	10:51.2'E	stn15/162	*	*
02.07.89	21:32	74:57.2'N	10:42.5'E	320	*	*
02.07.89	22:32	74:52.3'N	09:48.4'E	321	*	
03.07.89	23:37	74:46.9'N	08:51.1'E	322	*	*
03.07.89	01:31	74:37.8'N	07:15.4'E	323	*	*
03.07.89	04:45	74:30.5'N	05:28.5'E	stn15/163	*	
03.07.89	05:33	74:31.1'N	05:25.8'E	324	*	
03.07.89	07:31	74:24.6'N	03:46.2'E	325	*	*
03.07.89	09:19	74:18.1'N	02:13.2'E	326	*	*
03.07.89	10:28	74:14.7'N	01:13.0'E	327	*	
03.07.89	13:20	74:08.0'N	00:59.8'W	stn15/164	*	*
03.07.89	18:10	73:48.7'N	00:47.8'W	328	*	*
03.07.89	21:39	73:05.9'N	00:26.2'W	329	*	
04.07.89	23:46	72:40.3'N	00:14.7'W	330	*	*
04.07.89	02:50	72:03.9'N	00:03.1'E	331	*	
04.07.89	06:50	71:14.8'N	00:25.3'E	332	*	*
04.07.89	08:15	70:57.4'N	00:34.3'E	333	*	
04.07.89	09:06	70:47.1'N	00:38.2'E	334	*	
04.07.89	12:25	70:05.9'N	00:54.9'E	335	*	*
04.07.89	12:48	70:01.0'N	00:57.6'E	336	*	
04.07.89	16:45	69:51.5'N	00:56.8'E	337	*	
04.07.89	17:49	69:30.3'N	01:07.4'E	338	*	*
04.07.89	20:55	68:52.6'N	01:07.4'E	339	*	
05.07.89	00:00	68:13.6'N	01:43.8'E	340	*	*
05.07.89	02:53	67:35.7'N	01:57.2'E	341	*	
05.07.89	05:44	66:57.9'N	02:12.3'E	342	*	*
05.07.89	08:59	66:16.9'N	02:25.5'E	343	*	
05.07.89	11.02	65:51.8'N	02:30.8'E	344	*	*

Table 3.1 continued

date	time	latitude	longitude	sample no.	fluoresc.	attenuat.
05.07.89	14:56	65:03.3'N	02:52.8'E	345	*	
05.07.89	16:01	64:49.8'N	02:59.9'E	346	*	
05.07.89	17:04	64:36.7'N	03:04.7'E	347	*	
05.07.89	17:43	64:30.7'N	03:06.8'E	348		*
05.07.89	17:50	64:27.3'N	03:07.7'E	349	*	
05.07.89	19:20	64:08.9'N	03:12.4'E	350	*	
05.07.89	20:54	63:49.5'N	03:18.7'E	351	*	*
05.07.89	23:57	63:10.9'N	03:32.9'E	352	*	*
06.07.89	01:59	62:46.1'N	03:39.8'E	353	*	
06.07.89	02:59	63:33.4'N	03:43.9'E	354	*	
06.07.89	06:09	61:53.3'N	03:56.3'E	355	*	*
06.07.89	08:55	61:20.3'N	04:07.3'E	356	*	
06.07.89	11:59	60:44.2'N	04:15.9'E	357	*	*
06.07.89	14:00	60:20.3'N	04:23.3'E	358	*	
06.07.89	15:02	60:09.4'N	04:26.3'E	359	*	*
06.07.89	16:07	59:55.3'N	04:30.8'E	360	*	
06.07.89	17:43	64:30.7'N	03:06.8'E	361	*	*
06.07.89	20:06	59:02.5'N	04:48.0'E	362	*	
06.07.89	22:04	58:38.3'N	04:54.6'E	363	*	*
07.07.89	00:37	58:14.6'N	05:15.8'E	364	*	*
07.07.89	02:03	57:50.9'N	05:30.7'E	365	*	

The ranges of fluorescence and attenuation spectra are the same

3.3.3 MICROWAVE PROPERTIES OF ICE, SNOW, OCEAN AND ATMOSPHERE

R.O. Ramseier, K. Asmus, C. Garrity

Scope

The effort of this part of the cruise was directed primarily to the microwave studies of old and first year ice. Special attention was given to the overlying snow cover during the initial free water formation and the appearance of melt ponds. The purpose of this experiment was to continue the study of the processes in the snow cover which affect the microwave emission from the underlying ice. Strategic and tactical ice reconnaissance support in the form of satellite derived passive microwave ice charts was also provided for the ship's operation. At the same time, these activities provided a unique data set to validate the Special Sensor Microwave/Imager (SSM/I) on board polar orbiting satellite. A unique opportunity arose in support of the RV "METEOR'S" mission, by providing directly to the ship SSM/I ice charts. In addition, a close cooperative effort between Dr. Krause's instrumentation group (AWI) and ours came into effect, by the use of a precision radiation thermometer (PRT-5) as a helicopter sensor to better map the temperature regime of fronts.

Experiment Set-up and Methodology

A dual polarized 37 GHz passive microwave radiometer, mounted on top of the bridge at a height of 21 meters above the water surface, provided a nearly continuous data stream at an incidence angle of 53 degrees. A precision radiation thermometer (PRT-5) complemented the microwave radiometer. During the four station stops, the microwave data was augmented with sectorial microwave images and incidence angle profiles. At the same time, measurements of snow properties were carried out within the footprint of the radiometer on three multi year (MY) floes and one first year (FY) floe we occupied. The microwave data was collected with a fully automated data acquisition, processing and storage system dubbed as the Shipboard Based Radiometer (SBR). The SBR consists of an IBM AT computer, an HP data acquisition unit and a 20 Megabyte Bernoulli box. To further reduce the calculated brightness temperatures (B'TB), a second identical IBM AT with graphics printing capabilities (which also acted as a back-up for the primary system) was employed. Unfortunately the microwave radiometer ceased to function for the last three ice days of this cruise. The overall impact on the data set is negligible.

The SSM/I data was received five out of seven days from the Institute for Space and Terrestrial Science (ISTS), located at York University in Toronto, Canada. After the SSM/I sensor (1400 km swath) passed over the Greenland Sea, the raw data was initially processed in the form of earth-located TB's at the U.S. Navy Fleet Numeric Oceanographic Center in Monterey, California. From there, the data was further processed at ISTS using the AES/York sea ice algorithm. In addition, we received many wind speed maps of the ice-free Greenland Sea which compared very favorably with the meteorological charts prepared on board by Mr. H. Malewski, our meteorologist. Finally, completed ice charts depicting total ice (TI) and multi year (MY) ice fraction contours or data points, were transmitted via INMARSAT directly to the "POLARSTERN" and to the Deutsches Hydrographisches Institute (DHI) in Hamburg. In addition, the German RV "METEOR", operating in the southern Greenland Sea, did also receive the ice charts in support of navigation. DHI could act as a back-up in case we were out of INMARSAT range by sending the data via radio facsimile. In general, the data was less than 10 hours old when received on the ships.

The surface program consisted of digging a snow pit within the footprint of the radiometer, usually at the 53 degree incidence angle location. The size of the footprint was about 6.5 m in length and 3.9 m in width at a distance of 28 m from the ship. Once the pit was dug, one wall was carefully prepared to make the necessary measurements of snow depth, structure of the snow cover (ice layers), temperature, permittivity, density and grain size. Based on the experience gained during the ARK VI/2 cruise, using the helicopter for floe studies, a similar procedure was used for this cruise where 18 floes along the ship track were visited. Daily helicopter flights while in the ice gave the opportunity to conduct detailed snow pit measurements on 11 FY, 1 SY and 6 MY floes.

While in the ice a total of 38.1 hrs of ice observation data were collected in support of the objectives mentioned above. This data is now in the process of being reduced. Due to the heavy workload and new projects no preliminary results were available. Generally, the snow during ARK VI/1 had more ice lenses and was better with a maximum wetness of 11% compared to 5 % during ARK VI/2. During this cruise the melt water had percolated through the snow to the snow ice interface where it formed water puddles. At the end of this cruise numerous melt ponds had already formed.

A precision radiation thermometer (PRT-5) was installed in the helicopter. The head was mounted on a bracket below the helicopter while the readout was located in the rear seat. The data was put manually into a lap-type computer. After landing the data could easily be processed on a personal computer.

Preliminary Results

We made a number of flights for a total of 8.6 hours to measure the sea surface temperature. Before and after each flight the radiometer was checked against an ice bath. No changes in calibration were observed. Figure 3.2 gives an example of a flight line containing an arctic front. As the ship was underway continuous measurements were made with the shipboard radiometer. Based on the experience gained during this cruise increased helicopter use in remote sensing missions is expected.

The use of SSM/I ice charts by the RV "METEOR" lead to the successful retrieval of a buoy.

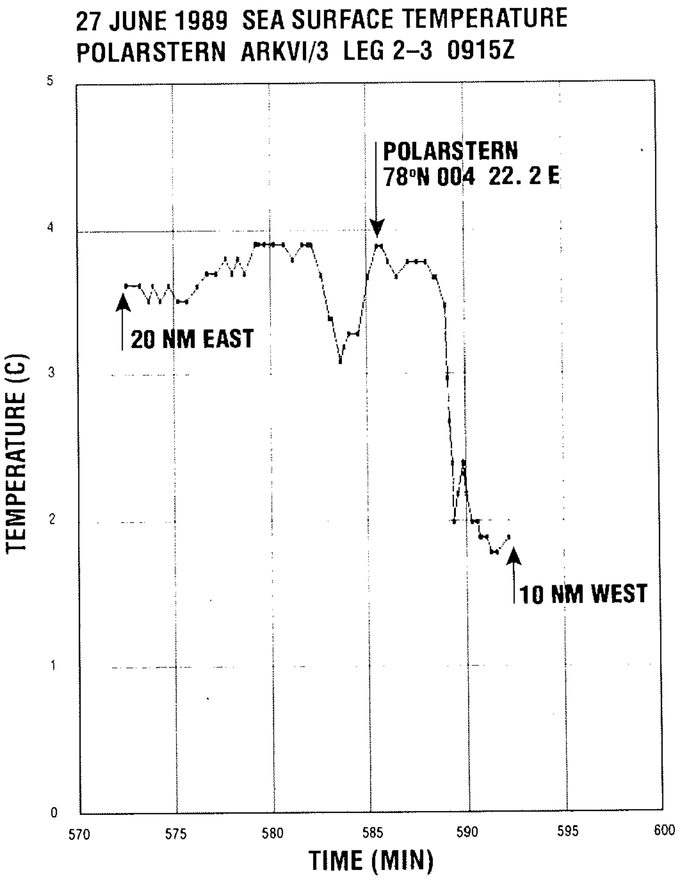


Figure 3.2

3.3.4 MARINE CHEMISTRY

G.Kattner, H. Becker, M.Graeve, , K. Pfeifer, M.Stuercken

The determination of nutrients and total nitrogen are closely connected with the biological and physical studies. When light intensities are sufficient in the upper layers of the water column, the euphotic zone, are well stratified phytoplankton blooms can occur. These conditions are found often in frontal areas and at marginal ice zones. The phytoplankton blooms can be limited by the depletion of nutrients. On the other hand, e.g. ammonium is released by zooplankton and bacteria due to remineralisation processes.

Furthermore nutrients may serve as an additional tracer for the water mass identification. Thus, the major gradients of nutrients are often 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.

To balance the amount of nitrogen containing substances total and dissolved nitrogen were determined. Besides the nitrogenous nutrients and the particulate nitrogen a considerable proportion of dissolved organic nitrogen exists; its molecular structure is mostly unknown. To what extent the phytoplankton is dependant on the dissolved organic nitrogen pool can hardly be estimated.

During the cruise the upper 200 m of the water column were extensively studied. On the transects samples were taken with the CTD sampler system generally at depths of 0, 5, 10, 20, 30, 40, 50, 60, 70, 80, 100, 150, 200 m in 10 nm intervals. Phosphate, silicate, nitrate, nitrite, ammonium, urea and total dissolved free amino acids were determined with an autoanalyzer system. At every second station total and dissolved nitrogen were measured with the persulfate oxidation method at 5 depths. At the other stations dissolved organic nitrogen was enriched by using Sep Pak cartridges at 2 different depths. The cartridges will be extracted and investigated later in the laboratory.

Along the transects nitrate was measured continuously at 7 m depth to determine in detail small scale changes, e.g. in frontal areas.

Detailed studies in the euphotic zone were performed together with the Canadian group of L. Legendre. Nutrients were analysed from 20 samples which were taken according to light intensities. The results will be interpreted with the biological data, e.g. for calculation of fluxes.

The first interpretation of the results shows that very different regimes were investigated. Thus, in the Atlantic water concentrations of nutrients were high, whereas in the Polar frontal areas nutrients were nearly depleted, especially nitrate. The continuous measurements of nitrate show that considerable changes in concentration can occur within less than 1 nm. The Polar water in the Fram Strait area was characterized by high silicate concentration, which are probably regenerated on the Canadian shelf.
The data will be interpreted in more detail with the biological and physical investigations.

3.3.5 TRANSPORT OF TRACE METALS BY WATER AND ZOOPLANKTON ORGANISMS

C. Pohl

This project aims at the investigation of the biogeochemical cycle of trace metals in the various water masses of the North Atlantic Ocean including the Greenland Sea. It is intended to find out how trace metals are transported in the water column and by plankton organisms. Therefore samples were taken from the surface by an all teflon Mercos sampler via the bow beam in front of the ship, by teflon coated Niskin bottles and zooplankton from the Bongo net.
On the two main transects each station was occupied, and thus samples were obtained from Polar Water, the Greenland Sea Gyre, the water of the West Spitsbergen Current and the frontal zones of the Arctic and Polar front.

Water sampling

All water were collected in acid cleaned teflon bottles. If necessary the filtration of samples (pressure filtering with nitrogen) through precleaned 0,4 um nuclepore filters followed before they were acidified by addition of subboiled nitric acid to the final pH of around 1.7. These procedures have been taken in a clean-bench class 100. Measurements will be carried out after liquid-extraction by atomic absorption spectroskopie in the clean laboratory of the AWI.

Zooplankton organisms

Zooplankton organisms (Calanus hyperboreus, C. finmarchicus, C.orcheta) were taken with the bongo net in team work with H.J. Hirche. The individuals were sorted out alive under the binocular microscope, checked for contamination and deep frozen. Following freeze drying and acid digestion, analysis will be carried out for Dc, Pb, Cu and Zn by AAS in the laboratory.

3.3.6 CONTINUOUS MEASUREMENTS OF TEMPERATURE AND PARTICLE SIZE DISTRIBUTION

M. Kahru, S. Nommann, J. Sildam, and A. Sirk

Introduction

Frontal regions in the ocean are known to as areas of locally increased biological productivity and/or biomass as well as of high spatial and temporal variability. Due to the low spatial and temporal resolution of conventional sampling methods compared to the scales of real variability, the ecological aspects of oceanic fronts are difficult to study. During the "POLARSTERN" cruise ARK 6/3 the mesoscale spatial distribution of plankton in frontal regions of the Greenland Sea was studied by "on-line" measurements of particle concentrations in various size fractions along with measurements of chlorophyll in vivo fluorescence and temperature. The spatial variability of plankton distribution has been traditionally studied using in vivo fluorescence of chlorophyll a as an index of phytoplankton abundance. Chlorophyll is an integral parameter clumping together all phytoplankton without regard to the species or size structure. Crucial aspects of trophic interactions depend on the size structure of the planktonic communities. Therefore, it is important to meaningfully differentiate the chlorophyll signal into functionally different size classes. "On-line" particle counting in different size fractions provides a means of high-resolution measurements of plankton distribution in relation to hydrography on various scales (gyre, meso- and small-scale), including the effects of frontal and ice edge regions, different water masses, etc.

Methods and Materials

Underway shipboard measurements of particle concentrations and chlorophyll a in vivo fluorescence were made in the along-track sampling mode from the water that was continuously pumped into the lab by a membrane pump from the inlet near the ship's bow at the depth of 9 m. The "flow-through" system contained a reservoir tank to maintain a relatively constant flow rate necessary to obtain the particle concentrations from an on-line Hiac-Royco PC- 320 particle size analyzer. The counter included two sensors (CMH-60 and E-1000) that enabled to register particles with the equivalent spherical diameter from 1 to 1000 um in 12 size classes.

In contrast to the well-known Coulter counter, the Hiac- Royco sensors measure the projection area of each particle. The channel settings of the counter were held constant throughout the study and the concentrations in the respective size fractions will be designated as Ch1 to Ch12 (Table 3.2).

The usual way of representing particle data is to express them as volume concentrations (ppm), but as the particles can be seldom considered spherical, the conversion of the projection area actually measured by the counter to volume has not been pursued. Moreover, the activity of marine organisms is roughly proportional to their surface area and not to the volume (see Platt and Denman 1978). Hence, as a measure of the integral particle concentration, the total particle surface area in the range 1-1000 µm was used. At the same chlorophyll level planktonic communities may differ drastically in the size structure, and, hence, in the physiology and trophic status. As a measure of the relative dominance of different size fractions, the ratio of a size fraction's surface area to the total particle surface area (in per cent) is used.

In vivo fluorescence of the chlorophyll pigments was measured with a Turner Designs 10-005R flow-through fluorometer. The fluorescence values were transformed to chlorophyll a concentration using a bivariate regression against extracted chlorophyll a values from aliquots of the flow-through water. As the chlorophyll a analyses from this cruise were not available before the end of the cruise, a previously established regression equation was used. After the calibration with the data of this cruise the calculated chlorophyll values will probably be slightly different.

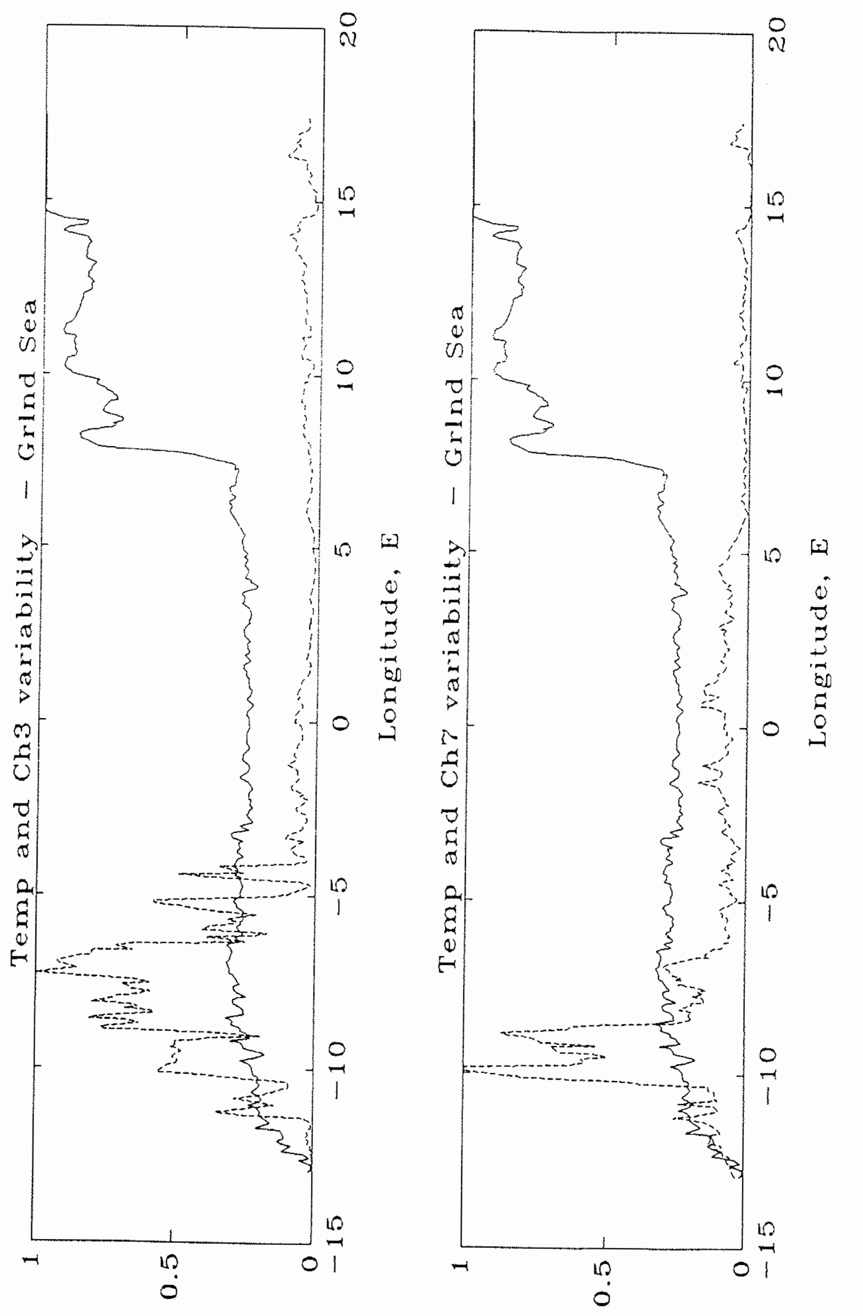
The time interval between the registration of integrated particle counts as well as fluorescence was set at 1 or 2 min. The actual counting time for the both particle sensors was either 10 or 20 s. Depending on the ship's speed the spatial sampling interval varied from zero to about 800 m. The corresponding data of the water temperature from 2-m depth as well as the position of the ship were retrieved from the Indas files.

In general, measurements were not made in dense ice due to the contamination of the seawater by snow and ice particles. Some short, spike-like pulses may still influence the data. The collected data were stored in 114 files. Figure 3.3 presents an overview on the nature of the data.

PRELIMINARY RESULTS

Only the long transect across the Greenland Sea is shown on figures (similar plots for all the other transects will be made later). The variable mentioned first in the heading is always depicted with continuous line, the second variable with dashed line and the third one (if present) with the dotted line. The "variability" plots contain normalized variables (changing from 0 to 1). The "% area" plots show the relative surface area of the particular size fraction of the total particulate surface area in the equivalent spherical diameter range of 1-1000 um. The scatter plots "Chl vs. ChX" show the channels that are correlated with the chlorophyll content, and thus being the major sources of chlorophyll variability.

Figure 3.3



Temperature and particle distributions along 75°N in the Greenland Sea

Table 3.2

Channel settings for the Hiac-Royco Model PC 320 particle counter in equivalent spherical diameters

Sensor	Channel	Diameter range (μm)
CMH-60	1	1 - 2
	2	2 - 4
	3	4 - 6
	4	6 - 10
	5	10-20
	6	20-60
E-1000	7	28-42
	8	42-73
	9	73-105
	10	105-163
	11	163-305
	12	305-1000

3.3.7 NEW PHYTOPLANKTON PRODUCTION

L. Legendre, G. Rosenberg, M. Gosselin, G. Bergeron and M.-J. Martineau

Objectives

(1) Prieur & Legendre (1988) have derived equations that provide numerical criteria for the timing and depth of new phytoplankton production at sea. Their computations are based on measurements that are easily (and often routinely) performed during oceanographic cruises (i.e., surface solar irradiance, vertical light attenuation, concentration of the limiting nutrient at depth, and density structure of the water column). The first objective of the project was to test, in waters and fronts of the Greenland Sea, the numerical criteria proposed by Prieur & Legendre (1988) and to derive the parameters necessary to use these criteria on future cruises in the same area.

(2) Legendre & Le Fèvre (1989) have recently proposed that production export is mainly controlled by cell size. The second objective of the project was to compare the production by large (> 5 um) and small (< 5 um) phytoplankters to the more usual measurements of new and regenerated production (uptake of ^{15}N-labelled compounds; Dugdale & Goering 1967).

Methods

Between 11 and 27 June 1989, 16 stations were occupied for the primary production measurements (Table 3.3). The sequence of operations at the stations was as follows: (1) measurement of the photosynthetically available radiation (PAR) at 20 photic depths, using a quantum irradiance meter mounted on the bio-rosette, (2) sampling at these 20 depths using the Niskin bottles on the rosette.

Objective 1. In order to compute the criteria of Prieur & Legendre (1988), the following information is required: (1) average irradiance at the sea surface (PAR), (2) vertical attenuation coefficient of PAR, (3) rate of dissipation of turbulent kinetic energy (values from the literature, e.g., Denman & Gargett 1983), (4) vertical density profile, (5) nitrate concentration at depth, (6) general relationship between nitrate and water density in the sampling area. Results of the computations are vertical profiles of mean doubling rates of phytoplankton, which may be converted into productivity rates (production per unit chlorophyll *a*) through multiplication by (7) the carbon:chlorophyll *a* ratio. results of the calculations will be compared with detailed vertical profiles (20 depths) of (8) measured phytoplankton productivity.

In order to achieve objective 1, the following measurements were performed at each station (numbers are the same as those in the above paragraph): (1) irradiance above the sea surface, (2) underwater irradiance at 20 photic depths, (4) CTD, and collection of water samples at 20 photic depths (bio-rosette) for the determination of (5-6) nutrients, (7) CHN and chlorophyll *a* , and (8) primary production. The 20 photic depths corresponded to irradiances available in a linear laboratory incubator, used for simulated *in situ* measurements of primary production under artificial illumination (^{14}C incorporation, simulated *in situ* approach of Herman & Platt 1986). In addition, water samples have been preserved with acidic Lugol for phytoplankton identification and enumeration under the inverted microscope.

Objective 2. Legendre & Le Fèvre (1989) have proposed that production export is mainly due to large phytoplankters. This idea will be tested by comparing the productivity of the large and small cells with the uptake of nitrate (new production) versus that of ammonia and urea (regenerated production).

In view of achieving objective 2, samples for chlorophyll *a*, phytoplankton production and cell counts (epifluorescence microscopy) have been size-fractionated (> 5 um et < 5 um) on Poretics™ filters. At each station, incorporation of ^{15}N-labelled nitrate, ammonia and urea was measured on phytoplankton from 2 depths.

At the end of the cruise, the following data are already available: underwater irradiance, chlorophyll *a* and phaeopigments, primary production and productivity (the biological measurements are for the total biomass and also for the two size classes), and preliminary values for temperature, salinity and nutrients. Samples for CHN, ^{15}N uptake and cell counts (light and epifluorescence microscopy) remain to be analyzed.

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Table 3.3. Primary production stations, and approximate depths of the 1% irradiance level.

Latitude	Longitude	Date	Time (start)	Approx depth 1% (m)
74°29.7 N	14°22.0 W	11 June	11h25	43
74°46.1 N	11°05.4 W	12 June	09h30	29
74°44.7 N	06°37.6 W	13 June	10h25	38
74°44.3 N	02°50.2 W	14 June	11h55	48
74°45.4 N	01°02.6 E	15 June	08h55	56
74°44.7 N	05°23.6 E	16 June	09h05	50
74°45.7 N	09°47.4 E	17 June	08h20	32
74°45.0 N	14°53.5 E	18 June	09h30	80
74°45.0 N	09°02.2 E	20 June	15h10	38
75°29.9 N	09°17.3 E	21 June	09h00	39
74°39.4 N	05°25.4 E	22 June	09h25	33
74°20.7 N	09°37.4 E	23 June	07h45	34
77°59.8 N	01°59.6 E	24 June	10h25	20
77°59.9 N	03°39.5 W	25 June	10h30	43
77°41.9 N	06°00.2 W	25 June	21h10	39
78°00.9 N	03°31.7 W	27 June	07h40	29

3.3.8 ACOUSTIC INVESTIGATIONS OF PATCHINESS AND SCHOOLING BEHAVIOUR OF ZOOPLANKTON AND NEKTON IN FRONTAL ZONES

I. Sprong

Analyses of patchiness, the inhomogeneous distribution of marine organisms in the horizontal and vertical planes (Haury et al, 1978), from echogram data can provide valuable information for ecological and biogeographical studies (Dunlap, 1971; Haigh, 1971; Backus & Craddock,1977; Holliday & Pieper, 1987; Schalk, 1988). Recent investigations with echo-sounders in the North Sea and Banda Sea showed distinct differences in the acoustic characteristics between watermasses, which could be related to biological differences (Sprong et al, submitted; Schalk et al, 1988).
The Arctic waters sampled during the ARKTIS-VI expedition have a highly variable and complex hydrographic structure with many sharp boundaries for temperature and salinity, and strong vertical mixing in the upper waterlayers (Helland-Hansen & Nansen, 1912; Coachman & Aagard, 1974; Paquette et al, 1985). The occurrence of different watermasses and the circulation in the frontal zones, and the extreme environmental conditions ruling in this area, cause the marine organisms to concentrate strongly (Hansen & Dunbar, 1971; Zahuranec & Pugh, 1971; Haury & Pieper, 1988), making this an ideal area for studying patchiness and related boundary zones.
During legs 3 & 4, echo-recordings were made with an ELAC 30 kHz echo-sounder with the purpose of studying distributions and schooling-behaviour of zooplankton and nekton from meso- to small scale, in particular school-size and shape. The echodata will be compared with biological and a-biological data collected during the cruise.
The echo-signal was registered standard in two ways:

a) Received echo-signals were recorded on paper (Table 3.4). Five types of echopatterns were defined (Table 3.5). Depth distributions of echo-patches and sound scatterings layers (SSL) were described along the transects between 0-500 metres. Horizontal and vertical dimensions, and shapes were measured for each echo-patch or layer per 10 minutes.

Table 3.4: echogram registration form ARK VI/3 DD. 08-06-1989 until 07-07-1989.

Roll-number	Date (start/finish)	Time (start/finish)	Position (start/finish)
89001	08-06-1989	20.00 hours	70°05'N 020°14'W
	10-06-1989	17.07 hours	74°21'N 008°29'W
89002	10-06-1989	17.14 hours	74°23'N 008°35'W
	13-06-1989	08.48 hours	74°45'N 007°19'W
89003	13-06-1989	09.07 hours	74°45'N 007°17'W
	16-06-1989	07.58 hours	74°44'N 005°23'E
89004	16-06-1989	08.05 hours	74°44'N 005°23'E
	18-06-1989	13.10 hours	74°45'N 015°32'E
89005	18-06-1989	13.16 hours	74°45'N 015°32'E
	22-06-1989	10.01 hours	74°39'N 005°25'E
89006	22-06-1989	11.07 hours	74°39'N 005°22'E
	27-06-1989	09.10 hours	78°00'N 003°53'E
89007	27-06-1989	09.17 hours	78°00'N 004°00'E
	07-07-1989	06.00 hours	53°33'N 010°00'E.

Table 3.5: Types of echo-patterns: A-E.

Type	Layers number of	Layers name	Depth of occurrence (in meters)	Description
A1	3	SSL I:	surface-30 (40)	layer grape-bunch shaped, density* dense/vague.
		SSL i:	70-110 (north) to 200-400 (south)	layer of v-shaped fish-schools.
		SSL II:	270-500	layer with cloudy structure density dense/vague.
A2	2	SSL I:	surface - 20 (30)	see A_1.
		SSL i:	present	see A_1,connected with SSL II.
		SSL II:	270-500	see A_1.
A3	2	SSL I:	surface - 30 (40)	see A_1.
		SSL i:	absent	
		SSL II:	290-400 (460), north to 200-440 (south)	see A_1.
A4	2	SSL I:	surface - 15 (20)	see A_1, discontinuous.
		SSL i:	absent	
		SSL II:	350 (270) - 400	see A_1.

* Density is expressed in four degrees of blackness on the echograms: 'dense' presents maximum blackness, 'dense/vague' presents ± 0.5 x maximum density, 'vague' ± 0.25 x maximum density, 'very vague' ± 0.125 x maximum density.

Type	Layers number of	Layers name	Depth of occurrence (in meters)	Description
A_5	1	SSL I:	surface - 20 (40)	see A_1, continuous layer density vague
		SSL i:	absent	
		SSL II:	absent.	
B	2	SSL I:	surface - 140 (180)	lumps of 10 mtrs high zigzag-type layers, density dense/vague.
		SSL i:	absent	
		SSL II:	300 - 400	approx. 50 mtrs. high, migrating between 300 400 mtrs.
C	2	SSL I:	surf - 20 (30) x surface - 140 (180)	grape-bunch shaped combined with lumps of 10 mtrs high zigzag layers
		SSL i:	absent	
		SSL II:	380 - 440 (north) to 300 -500 (south)	layers of approx. 50 mtrs high, migrating between 380 -440 (300-500 mtrs).
D_1	1	SSL I:	surface - 40 (50)	patchy layer, approx. 10 mtrs high, migrating vertically over 20 - 30 mtrs distance between surf - 40 (50) mtrs.
		SSL i:	absent	
		SSL II:	predominantly absent	very vague.
D_2	1	SSL I:	usually absent	very vague.
		SSL i:	absent	
		SSL II:	absent	
E_1	1	SSL I:	surface - 20 (25)	homogeneous layer, density dense/vague.
		SSL i:	absent	
		SSL II:	absent	
E_2	1	SSL I:	surface - 20 (25) x surface - 100 (140)	see E_1, combined with lumps of 10 mtrs high zigzag type layers.
		SSL i:	absent	
		SSL II:	absent.	

b) The transmitted and received echo-signals were stored on video-tape with a PANASONIC NV F70 HQ Stereo Videorecorder (Table 3.6), for ARK-VI leg 3. After A/D-conversion of the audio-signals the acoustic data will be processed (integration with high horizontal and vertical resolutions) by computer. An analysis of

Table 3.6: video recordings ARKTIS VI/3, 08-06-1989 until 28-06-89.

Tape no.	Date (start)	Date (finish)	Time (start)	Time (finish)	Position (start)	Position (finish)	Period (Day/Night)	Signal R/M
I	09-06	10-06	23.00.00	05.08.53	72°29` N 003°03` E	72°59`N 008°12`E	N	R
II	10-06	10-06	09.45.00	15.50.00	73°22`N 004°30`E	74°10`N 007°47`W	D	R
III	10-06	11-06	21.00.00	03.08.48	74°45`N 010°30`W	74°44`N 013°22`W	N	R
IV	11-06	11-06	09.01.00	15.10.02	74°27`N 014°26`W	74°40`N 013°54`W	D	R
V	11-06	12-06	21.00.00	03.09.04	74°42`N 012°49`W	74°45`N 011°41`W	N	R
VI	12-06	12-06	09.01.15	16.10.11	74°46`N 011°04`W	74°45`N 009°47`W	D	R
VII	12-06	13-06	21.05.00	03.13.55	74°45`N 009°10`W	74°45`N 008°10`W	N	R
VIII	13-06	13-06	09.10.10	15.18.56	74°45`N 007°17`W	74°45`N 006°06`W	D	R
IX*	14.06	14.06	09.04.00	15.12.09	74°44`N 002°49`W	74°44`N 002°13`W	D	R
X	14-06	15-06	21.22.00	03.31.15	74°45`N 000°54`E	74°44`N 000°21`E	N	R
XI	15-06	15-06	09.00.00	15.08.44	74°44`N 004°96`E	74°45`N 001°47`E	D	R
XII	15-06	16-06	21.12.00	03.21.14	74°44`N 003°12`E	74°44`N 004°17`E	N	R
XIII	16-06	16-06	09.10.00	15.09.49	74°44`N 005°23`E	74°45`N 006°40`E	D	R
XIV	16-06	17-06	21.07.00	03.15.54	74°45`N 007°55`E	74°45`N 009°11`E	N	R
XV	17-06	17-06	09.00.00	15.08.51	74°45`N 009°47`E	74°45`N 011°05`E	D	R
XVI	17-06	18-06	21.04.00	03.13.08	74°45`N 011°47`E	74°45`N 013°02`E	N	R
XVII*	18-06	18-06	10.53.00	17.02.14	74°45`N 014°52`E	74°44`N 017°03`E	D	R

* No registration during the night.

Table 3.6 continued

Tape no.	Date (start)	Date (finish)	Time (start)	Time (finish)	Position (start)	Position (finish)	Period (Day/Night)	Signal R/M
XVIII	18-06	19-06	21.11.00	03.20.18	74°19`N 016°42`E	74°18`N 012°14`E	N	R
XIX	19-06	19-06	08.56.50	15.05.35	73°59`N 005°02`E	73°10`N 006°32`E	D	R
XX	19-06	20-06	20.45.00	02.54.00	74°14`N 006°32`E	74°30`N 007°27`E	N	R
XXI	20-06	20-06	08.56.00	15.04.62	74°45`N 004°11`E	74°45`N 009°11`E	D	R
XXII	20-06	21-06	21.23.00	03.22.10	74°60`N 005°49`E	75°15`N 005°42`E	N	R
XXIII	21-06	21-06	09.56.00	06.05.10	75°29`N 009°11`E	75°30`N 004°03`E	D	R
XXIV	21-06	22-06	21.00.00	03.08.57	74°50`N 003°00`E	74°44`N 004°12`E	N	R
XXV	22-06	22-06	10.01.00	16.10.49	74°39`N 005°23`E	74°33`N 006°38`E	D	R
XXVI	22-06	23-06	21.07.30	03.16.21	74°28`N 007°42`E	74°22`N 009°22`E	N	R
XXVII	23-06	23-06	10.16.10	16.24.41	74°16`N 010°13`E	74°42`N 009°48`E	D	R
XXVIII	27-06	27-06	10.04.02	16.13.03	78°00`N 004°23`E	78°00`N 005°59`E	D	R
XXIX	27-06	28-06	21.30.30	03.39.19	78°00`N 007°33`E	78°00`N 009°48`E	N	R

D = Day-time recording

N = Night-time recording

R = Raw signal

the volume backscattering strength-distributions, an indication for density and abundancy-distributions of zooplankton and nekton, will be made, with special attention to the small scale distribution (patchiness) in the upper 50 meters.

Additionally, during experiments, the echo-intensity distribution was recorded from one channel of the Acoustic Doppler Current Profiler (ADCP), operating at a frequency of 150 kHz, for comparison with the 30 kHz data. An attempt will be made to process the ADCP-data analogical to the method described in b).

Preliminary results

From the echogram-analysis of ARK-VI leg 3, five types of acoustic patterns A-E were distinguished, which could be divided in several sub-classes (Table 3.5, fig. 3). Type A-C patterns are characterized by a shallow, non-migrating grape-bunch shaped (patchy) layer in the upper 40-50 meters. (Sound Scattering Layer I) or derivatives of this layer, the divisions in sub-classes being based on the presence or absence of an intermediate layer (SSL i), a deep non-migrating layer (SSL II), or both. Types D-E are characterized by the presence only of SSL I: type D consists of one patchy, ±10 mtrs. high zigzag-like SSL I, with no other layers present (D_1), or absence of all layers (D_2), whereas type E has a homogeneous SSL I (surface**-20 mtrs) and no other layers present.
Based on the distribution of the patterns, the investigated area is preliminary divided as depicted in figure 3.4a. Regions with distinctly differing patterns (types A, D and E), and regions where intermediate patterns were found (presented by types B,C and E) were recognized. Figure 3.4b presents in detail the distributions of echo-patterns between approximately 74°15'N and 75°45'N, and 3°-10°E.
Distinct differences between day and night were not observed except for a slightly more shallow occurrence of the SSL I during the night. Diurnal vertical migration over a distance of hundreds of meters was only observed rarely.
No conclusions on relations between echo-pattern distributions and biological and a-biological structures can be given yet, as the hydrographical and biological data are still not available. However, given the strong relation found between the distribution of watermasses, faunal provinces and echo-patterns in previous data, combined with hydrographic structures in this area, known from literature, the following suggestions are made:
Type A is proposed to be characteristic of waters of Atlantic origin (i.e. the West-Spitsbergen Current, recirculation within the East Greenland Current). Type D is found mainly between 1°W-8°E, 74°N-75°20'N (Figures 3.4a,b), thus most likely presenting the waters of the Greenland Gyre. Type E is suggested to be a reflection of the influence of Arctic waters. In the marginal ice-zone, and under the pack-ice mainly be type C distributions are found, in the arctic front area (Figure 3.4b) types A, B, C and D. The types B and C probably indicate areas of mixing, being intermediates between types A and D.
Figures 3.5a,b,c show the changes in the distributions of echo-patterns on repeated sections in the area between approximately 74°45'N and 4°-9°E. The changes occurred within a one week period (15-6, 20-6 and 22/23-6-1989). Figure 3.5a (15-6) shows a sharp distinction between two types of echopatterns, A_1 and D_1, contrary to Figures 3.5b and c, where type D_1 has completely disappeared, being replaced by type C and B patterns.
Taking the above statements into consideration, it is assumed that the changes in echopatterns between 15-06 and 22/23-06-1989, are caused by an intrusion of warm Atlantic waters into the Greenland Gyre.

** surface = surface of the transducer.

It is very likely that after comparison with the distribution of the watermasses and the composition of the fauna associated with these waters, the echodata are accurately and distinctly reflecting the location of the watermasses and areas of mixing, maybe even

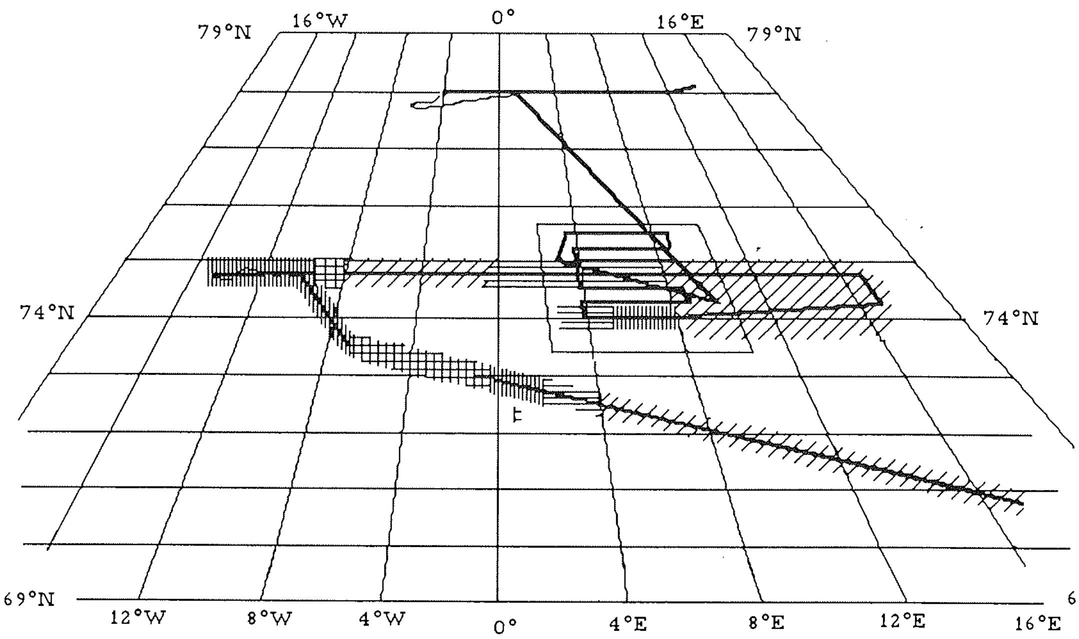
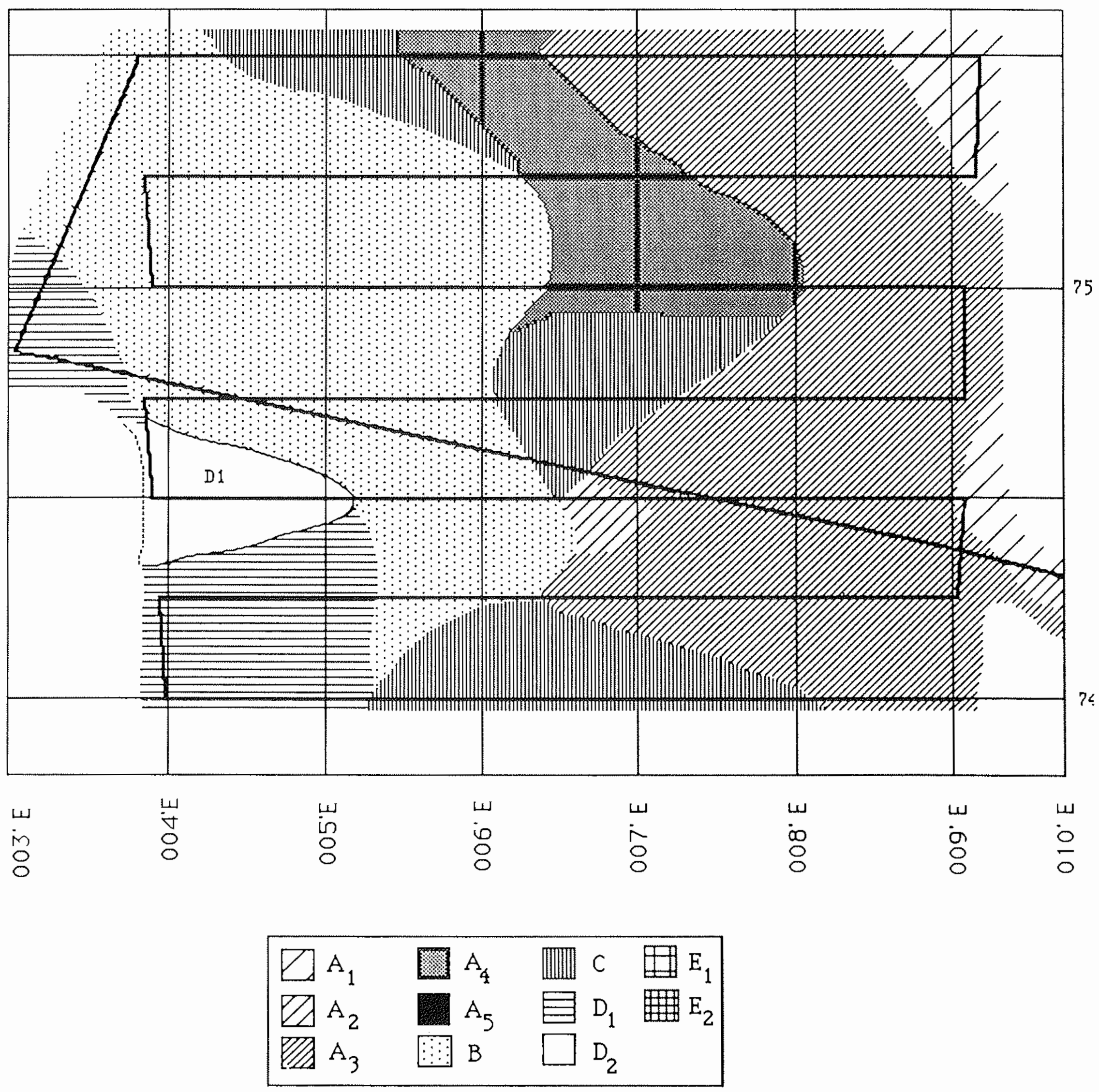


Figure 3.4a: **General division of the investigated area (for legenda see fig. 3.4b) in types A-E, between 08-06 and 18-06-1989. North of ± 76°N 007°E sufficient data are not available yet, due to irregular malfunctioning of the sounder-unit.**

Figure 3.4 B



Detailed distribution of echo-patterns A-E in Arctic front area, between 18-06 and 21-06-1989.

Figure 3.5 A

: ARKTIS VI-3: I
(15-06-1989)

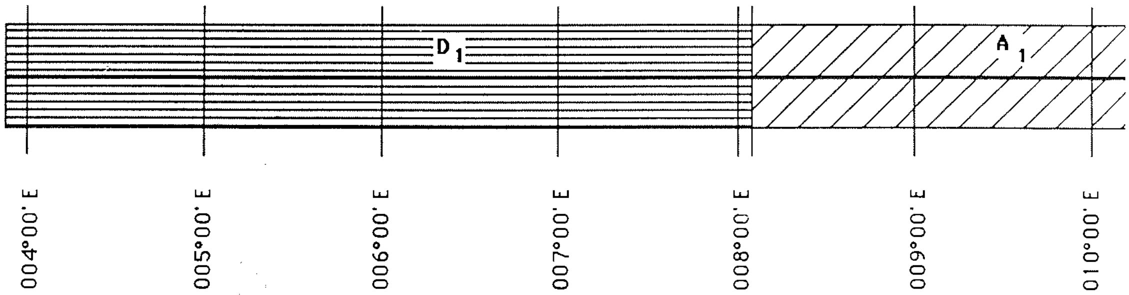


Figure 3.5 B

: ARKTIS VI-3: II
(20-06-1989)

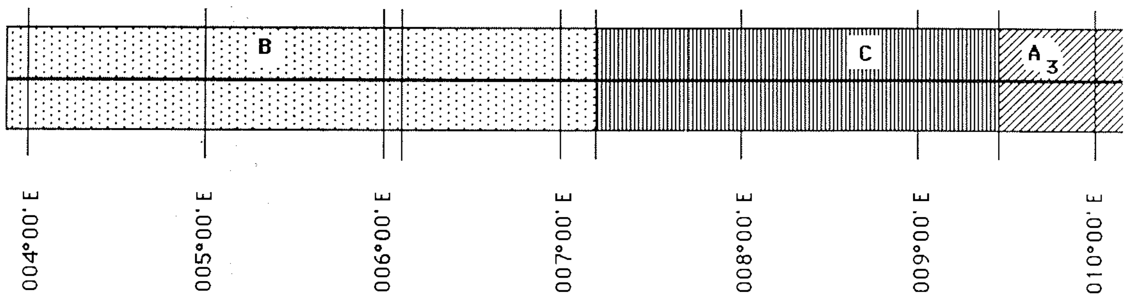
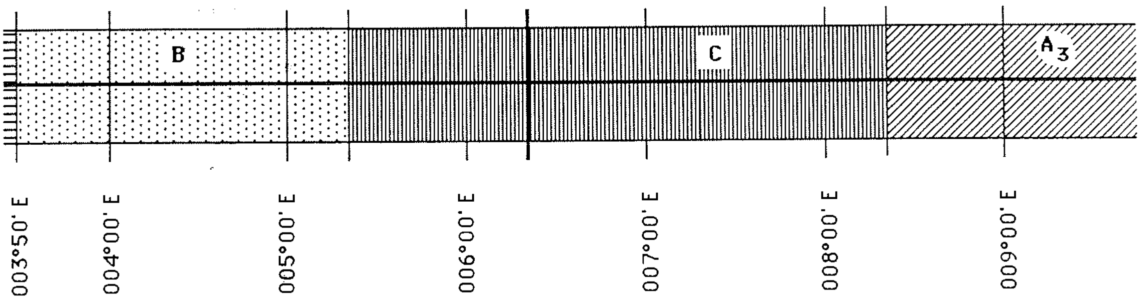


Figure 3.5 C

: ARKTIS VI-3: III
(22/23-06-1989)



Figures 3.5 A,B,C : **Changes in distributions of echopatterns in a period of one week, at approximately 74°45'N, between 4°-9°E.**

more so than physical and biological measurements could, as the echo-registrations are continuous and have a high horizontal and vertical resolution.
The variations in echopatterns, caused by an inhomogeneous distribution of sound scattering organisms, can be taken as indicative for both hydrographical and biological differences in the area studied. The acoustic data obtained during this cruise will be of great value for evaluation and interpretation of further cruise-data.

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3.3.9 ZOOPLANKTON INVESTIGATIONS - MOULTING PHYSIOLOGY OF COPEPODS

A. Warpakowski

For growing and metamorphosis crustaceans have to shed their old exoskeleton after building a new one under the old, called moulting or ecdysis. The repeated moulting with its physiological and morphologial processes has a large effect on the life and development of the crustaceans.

The moult cycle, this is the time between two moultings, follows a common pattern in all crustaceans and is well devided into three stages, characterized by the successive development of the new setae and spines (setogenesis), the epidermis and the new cuticula: premoult, postmoult and intermoult.

There are only little information about the moult cycle of copepods and only of preserved animals.

The distribution of the moult stages of postlarval copepods provides information about the age composition and the physiological condition of copepod populations. This is of special interest for the investigation of experimental animals and the investigation of the life history of slowly growing species with overwintering stages like the arctic species Calanus hyperboreus.

For the determination of growth and developmental times various copepodits of C. hyperboreus were sorted out from the zooplankton samples, cultivated at 0°C and fed regularly.

For the description of the moult cycle living individuals were examined under the microscope and the different moult stages were documented by photographs. After that the copepods were preserved in 4%-formalin-seawater-solution to compare the morphology of the moult stages of living and preserved animals and to determine the changes by preservation.

The rearing experiments and the further investigation of preserved copepods (especially the zooplankton samples from the Greenland Sea November 1988 to September 1989) will be continued at the Alfred-Wegener-Institute.

3.3.10 BENTHOLOGICAL INVESTIGATIONS

D. Piepenburg, A. Freiwald, A. Körtzinger

Our knowledge on distribution and composition of the benthic communities of the Fram Strait is still relatively scarce, particularly with regard to the western part off East Greenland characterized by high-arctic conditions (very low water temperatures and permanent ice cover). First investigations carried out in the area of the Belgica Bank (78° - 80°N) in summer 1985 showed a relatively rich bottom fauna on the shelf in depths < 100 m but a very poor one at the continental slope with depths > 300 m. The eastern part of the Fram Strait, particularly the shelf off Spitsbergen, is influenced by warmer Atlantic water masses and belongs to the sub-arctic faunal province. There are benthic communities which are dominated by carbonate accumulating species providing habitats for a diverse hard-substrate epifauna. The recent and fossil composition and the processes of evolution and destruction of these "shallow-water carbonate facies" will be studied in more detail within a geological DFG-project.

During the "POLARSTERN" expedition ARK VI/4 1989 benthological and geological samples were taken by means of an Agassiz trawl (AGT) and an underwater photo camera (UWP). The AGT was used at four stations, two at the shelf break off Northeast Greenland (st. 157 and St. 158) and two on the Svalbard-Shelf off Sörkapp (st. 160 and St. 161), the UWP only at the latter two stations (see Table 3.7 and Figure 3.6). Organisms and dropstones were sorted out of the AGT catches in order to describe the composition of the bottom fauna and carbonate sediments. Living animals of several species ranging from actinians to fish were kept in cooled aquaria and transferred to Kiel in order to study their metabolic adaptations to the severe arctic environment under controlled lab conditions. For several species, tissue samples were taken and preserved in chloroform/methanol and by deep-frosting at -80°C respectively. They will be analysed with regard to their lipid content and composition. The results will provide information on the strategy of energy utilization and may shed light on trophic relationships.

There are first results regarding the faunal composition at the four stations: The catch at St. 157 (East Greenland continental slope, >800m) was very poor, consisting mainly of sponges, zoantharians (Epizoanthus spec.), brittle stars (Ophiopleura borealis, Gorgonocephalus arcticus) and fish (Lycodes spec., Cottunculus microps, Careproctus reinhardti). The sediments in the net consisted mainly of sandy silt, and there were a lot of dropstones of a size range from 1-40 cm in diameter and some snail shells (Colus, Buccinum). The fauna at St. 158 (East Greenland shelf break, 300 m) was considerably richer, both in species numbers and abundances. Brittle stars were dominant faunal elements, indicating a soft-bottom community. The sediment consisted of salty sand but there were more dropstones than at St. 157. These stones provide settling grounds for several epibenthic organisms (e.g. bryozoans and serpulid polychaetes).

The composition of the catches on the Svalbard-Shelf will be described below.

Table 3.7: List of benthological stations during "POLARSTERN" expedition ARK VI/4

Used sampling methods: AGT Agassiz trawl
UWP Underwater photography

Station	Date	Latitude	Longitude	Depth	Gears
15/157	30.06.89	77°14'N	5°25'W	900-800	AGT
15/158	30.06.89	77°12'N	6°00'W	295-275	AGT
15/160	02.07.89	76°20'N	15°24'E	200-210	UWP
		76°21'N	15°24'E	185-200	AGT
15/161	02.07.89	76°22'N	16°00'E	30-25	UWP
		76°23'N	15°57'E	85-75	AGT

Some geological and biological remarks on the development of the shallow-water carbonate facies on the southern part of the western Svalbard-Shelf

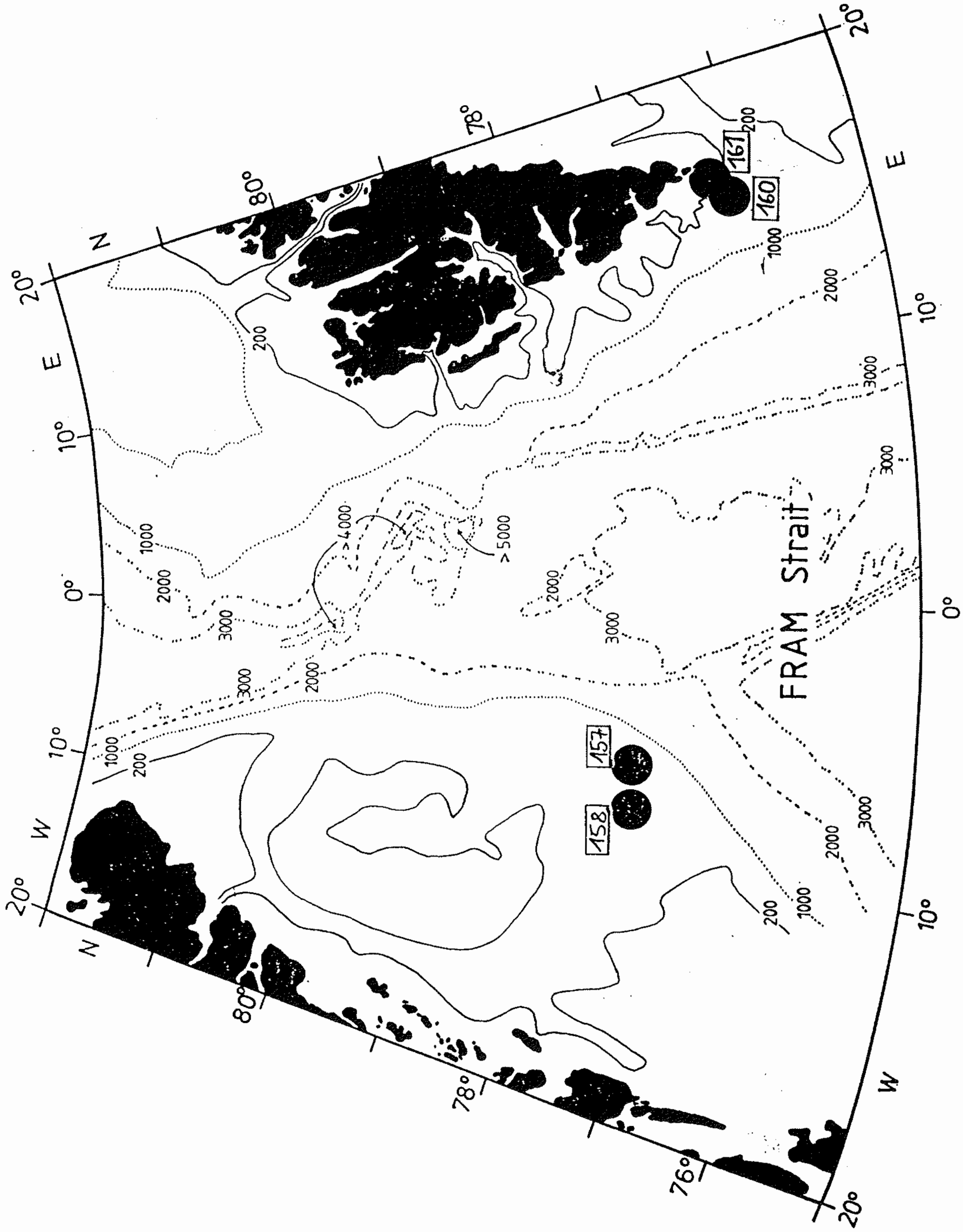
The distribution of carbonate sediments in time and space is used to suggest paleoenvironmental conditions. Usually thought to be only associated with low-latitude deposits they do also occur regularly on high-latitude shelves. One scientific aim of the leg ARK VI/4 was the detection of shallow-water or "cold-water" carbonates on the western Svalbard-Shelf. The two stations (St. 160 and St. 161) are situated near the southernmost end of the western Svalbard-Shelf adjacent to the Sörkapp. A short distance further to the south of the Storfjord-Trough separates the Svalbard-Shelf from the Spitsbergenbank which is part of the Barents-Shelf. The investigated area is free of ice from June to October (MIDTUN 6 LOENG 1986).

On the first station at a depth of 200 m (AGT 15/160) the net was filled with lots of ice-rafted debris ranging in diameter from 1 cm to 50 cm. All of the ice-rafted material is coated by a thin Fe-/Mn-crust indicating low rates of deposition. The dropstones are colonized by encrusting and dendroid bryozoans, brachiopods (*Macandrevia cranium*), and several undetermined actinians and hydrozoans. The presence of some brittle stars (*Ophiopleura boralis, Ophiopholis aculeata*) indicate the existence of soft-bottom substract between the dropstones. A few corroded valves of the infaunal pelecypods *Mya truncata* and *Hiatella arctica* and of the epifaunal clam *Chlamys islandica* were found.

The following AGT-attempt at a depth of 27m failed due to wavy sea conditions but there are some hints that the bottom is covered with huge boulders (echosounder).

At station 161 at a depth range from 73 to 83 m we detected the expected shallow- or "cold"-water carbonates. The sediment consists of shelled invertebrates and few dropstones. However, we do not know anything about the fraction less than 10 mm due

Figure 3.6


FRAM Strait
157
158
160
161
N
E
W
80°
78°
76°
20°
10°
0°
200
1000
2000
3000
>4000
>5000

to the big mesh-size of the AGT-net. But the low abundance of brittle stars and the occurence of *Onyphis conchylega*, an errant polychaet living in a quiver of coarse sediment particles, and the presence of a further polychaet also living in a quiver but using finer sediment suggests that the sediment fraction less than 10 mm is medium to coarse sand.

The carbonate producers are:

Chlamys islandica	(subfossil - recent; very abundant)
Mya truncata	(subfossil; common)
Hiatella arctica	(subfossil; common)
Astarte borealis	(subfossil; rare)
Modiolus sp.	(subfossil; very rare)
Spirorbis borealis	(recent; common)
Balanus balanus	(recent; rare)
Cellepora ventricosa	(subfossil - recent; common)
Leieschara coarctata	(recent; common)
encrusting bryozoans genera indet.	(recent: abundant)
Hemithyris psittacea	(recent; rare)

All infaunal pelecypods (*M. truncata, H. arctica, A. borealis)* are highly corroded by bioerosion (e.g. by funi, endolithic algae, grasping echinoderms and gastropods). Regarding to the different grade of bioerosion the valves can be grouped into "recent" and "subfossil" ones.

A geological interpretation of the postglacial history of the shallow- or "cold"-water carbonates on the western Svalbard-Shelf based only on two AGT-stations is doubtful. Further investigations should include side-scan-sonar observations to map the extension of these carbonates and box-corer sampling to get information on the sediment fraction > 10 mm.

Nevertheless, on the adjacent Spitsbergenbank on the Barents-Shelf BICKERT (1988 unpubl.)made some investigations on "cold"-water carbonates which covered wide areals on the bank from 30 to 200 m. He distinguished tree facies-zonations:

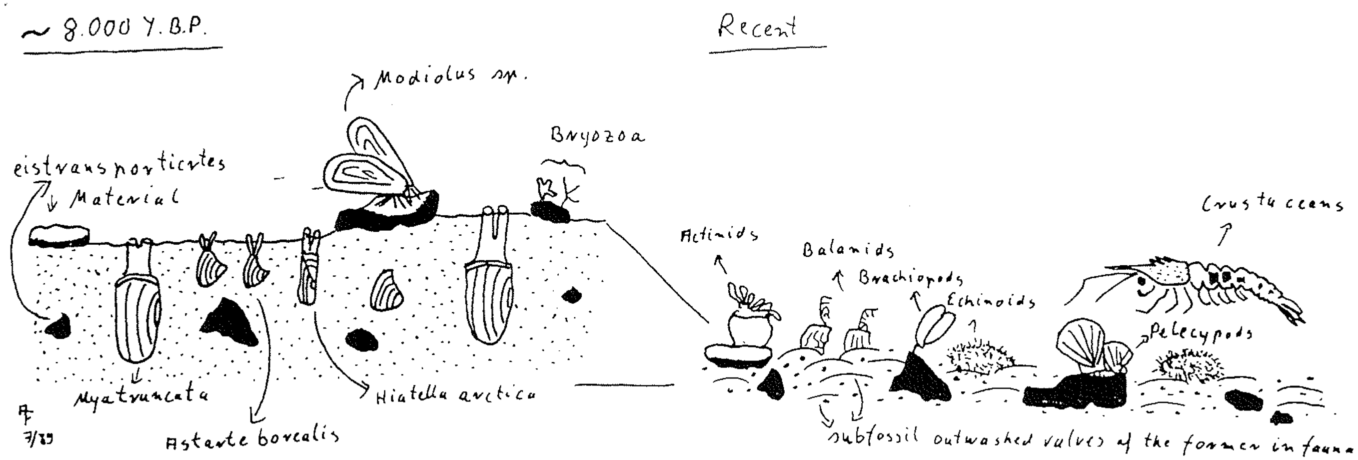
Balanus crenatus-Facies	28 to 43 m
Balanus balanus-Facies	40 to 73 m
Caquina-V´Facies	64 to 200 m

Assuming the carbonate accumulation mechanisms proposed by BICKERT (1988) are also effective on the Svalbard Shelf the geological development of the carbonates can be outlines as follows (note the absolute datings are taken from BICKERT (1988):

About 13,000 to 8,000 years B.P. the ice cover retreated from the Svalbard Shelf. The sea bottom consisted of unconsolidated glacio-marine sediments with scattered ice-rafted material. The glacio-marine deposits were colonized by pelecypods (mostly infauna, see list above) and bryozoans (8,000 - ?). Due to the isostatic uplift of Svalbard, the upper parts of the shelf entered regions with increased bottom-currents. The fine sediments were outwashed and the once buried infauna came to the sediment surface (8,000? to recent). Thus, there was a change from soft-bottom to hard-bottom conditions (see Figure 3.7). The carbonate hardsubstrate was colonized by epifaunal sessile and vagile invertebrates, leading to the present situation.

The recent fauna is dominated by the clam *Chlamys islandica*, the character species of the community which shapes the biotope physically and provides settling substrates for several epibenthic species. Other abundant species in the catch at St. 161 were the sea urchin *Strongylocentrotus* spec., the epifaunal balanid *Balanus balanus*, the

Figure 3.7



Glacio-marine soft-bottom sediments with scattered dropstones. The sediment was colonised mostly by infaunal and rare epifaunal pelecypods.

Outwash of the fine sediment fraction led to the relictic enrichment of the former infaunal valves. This sediment consists of high percentages of pure carbonate and is now oversettled by an hardgrond-epifauna.

sea spider *Hyas coarctatus*, the shrimp *Sclerocrangon boreas*, the sea stars *Solaster papposus* and *Leptasterias spec.*, and at least two species of actinians.

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3.3.11 A LINE SCAN CAMERA SYSTEM TO DETECT THE DIFFERENT ICE TYPES AND TO MEASURE THE ICE COVERING RATIO

S.El-Naggar, A. Bochert

The ice cover of the sea in the polar regions influences the interaction between the ocean and atmosphere. As examples: Ice growth and decay, radiation energy balance, surface roughness etc.
Therefore the determination of the ice covering ratio plays a central role in studying and modelling the ocean and the atmosphere. For this purpose a line-scan-camera was developed in the Alfred-Wegener-Institute which can be used from ship, airplane or helicopter to measure the ice covering ratio and to obtain information about different ice types and the distribution of ice floes various in size.

This system has been tested during the "POLARSTERN"-cruise ARK VI/3 and 4.

System Configuration

The systems consists of an electronic camera with a one-dimensional photo diode array. This array is 26 mm long and 26 µm wide and consists of 2048 diodes. Their spectral response ranges from 400 nm and 900 nm with a maximum of 800 nm. A personal computer connected to the camera by a special interface controls timing, data transfer and data storage.
The camera operates with a fixed scanning frequency of 100 Hz. The image data can be transferred with a scanning rate between 30 Hz and 1 Hz. The diode illumination could be controlled manually by a remote controlled diaphragm.

Principal of operation (Operation Procedure)

The camera optics (aperture 56 degrees) projects a two dimensional picture o the photo diode array. This can be scanned electronically in one dimension. To receive the second dimension, the camera should be moved (ship, airplane, helicopter etc.) perpendicularly to the array direction. The analog signals produced by each diode, depending on illumination and integration time, are digitized online using an analog to digital flash converter (35 MHz) with 2 bit-resolution. A high speed shift register (2048 bytes deep) is holding the image data until the PC transfers it to the disk. The data of each scan contains all image information in digital form which can be easily processed.

Results

The system has been tested on the following features:

a) Principal operation of all components
b) Signal quality of its dependency on different parameters
c) Software suitability (compatibility?) for operator and data acquisiton

To a):
The results of the test show that all components of the system operate correctly, therefore enabling us to obtain a precise image information. It was noted, though, that the helicopter vibrations increase the access time to the winchester disk caused by read/write operation errors. These errors were then minimized by damping the vibrations with a suitable foundation.

To b):
The signal quality depends on different parameters like illumination, diaphram, albedo or object reflectivity, height etc. Under constant conditions the signal varies only within the natural noise of the photo diodes. A correction of signal amplitude with regard to the geometrics is necessary.
With this system we are in a position to determine not only different types of ice like old ice, new ice, melt ponds, but also the sea foam covering ration (white caps) in the open ocean can be measured.
Ice charts from visual observation were made for each flight to (compare?calculate) the correlations between signal and ice types. That work had been carried out by the Canadian group (R. Ramseier et.al.).

To c):
The software has been (frequently) modified (updated) on board to satisfy all operation conditions, especially the data collection programme and the data acquisition.
The system is now supported by a powerful programme, which offers a variety of useful utilities for the operator. Data correction and filtering are done automatically .
The data acquisition programme offers a preliminary evaluation yielding a visual image and additionally the total and particular ice covering ratios.

3.3.12 TEST OF MULTIBOX-CORER WITH UNDERWATER VIDEO SYSTEM

D. Gerdes, H. Klindt, B.Weiser,

The objective of this working group was to test a UW-video system developed for applications with the multibox-corer. The equipment allows the on-line transfer of simultaneous video- and telemetric signals over cable paths up to 10.000 m length. Due to limitations in the transmission of video signals over long cable paths intense effort had to be spent in optimizing the transceiver characteristics in both the underwater and surface unit. The complete system was successfully deployed on two stations. The system was shown to provide high quality pictures from the sea-bed down to more than 3.000 m water depth.

3.3.13 Stationsliste

Station No	Date 1989	Time UTC	Latitude N	Longitude W	Depth (m)	ME	BS	BRO	BO	QM	BS/RO	MU
087	14.06.	16.50	74°45'	01°34'	3665	X					X	
		18.54	74°44'	01°35'	3663							
088	14.06.	20.06	74°45'	00°56'	3253	X			X		X	
		22.03	74°45'	00°54'	3600							
089	14.06.	23.10	74°45'	00°18'	3770	X					X	
	15.06.	01.09	74°45'	00°16'	3771							

Station No	Date 1989	Time UTC	Latitude N	Longitude E	Depth (m)	ME	BS	BRO	BO	QM	BS/RO	MU
090	15.06.	02.20	74°51'	00°21'	3766						X	
		04.04	74°45'	00°22'	3766							
091	15.06.	05.16	74°45'	00°59'	3770	X		X	X	X	X	X
		12.13	74°45'	01°09'	3768							
092	15.06.	13.05	74°45'	01°36'	3770	X	X	X				
		14.49	74°45'	01°38'	3770							
093	15.06.	15.55	74°45'	02°14'	3771	X	X	X	X			
		17.46	74°45'	02°15'	3771							
094	15.06.	18.59	74°45'	02°53'	3772		X	X				
		20.40	74°44'	02°50'	3773							
095	15.06.	21.50	74°45'	03°30'	3159	X	X	X	X			
	16.06.	00.03	74°45'	03°31'	3310							

Station No	Date 1989	Time UTC	Latitude N	Longitude W	Depth (m)	ME	BS	BRO	BO	QM	BS/RO	MU
066	11.06.	08.27	74°28'	14°27'	271	X	X	X	X	X		
		12.16	74°30'	14°29'	245							
067	11.06.	13.23	74°35	14°03	437		X	X	X			
		14.25	74°35'	14°04'	355							
068	11.06.	15.50	74°42'	13°36'	518	X	X	X	X			
		16.51	74°42'	13°37'	517							
069	11.06.	18.37	74°45'	12°60'	740	X	X	X	X			
		20.13	74°43'	12°58'	792							
070	11.06./	22.16	74°45'	12°20'	2091	X	X	X				
	12.06.	00.57	74°45'	12°21'	2112							
071	12.06.	02.36	74°45'	11°42'	2669		X	X	X			
		05.22	74°45'	11°40'	2706							
072	12.06.	06.49	74°45'	11°04'	3060		X	X	X	X		
		10.40	74°47'	11°04'	3047							
073	12.06.	12.02	74°45'	10°26'	3187	X	X	X	X			
		14.23	74°45'	10°24'	3192							
074	12.06.	15.53	74°45'	09°48'	3269	X	X	X	X			
		18.01	74°46'	09°45'	3273							
075	12.06.	21.15	74°46'	09°11'	3306		X					
		22.53	74°46'	09°09'	3308							
076	13.06.	00.21	74°45'	08°32'	3346	X			X		X	
		02.30	74°45'	08°32'	3345							

Station No	Date 1989	Time UTC	Latitude N	Longitude W	Depth (m)	ME	BS	BRO	BO	QM	BS/RO	MU
077	13.06.	03.46	74°45'	07°54'	3406						X	
		05.40	74°46'	07°54'	3284							
078	13.06.	06.53	74°45'	07°17'	3447	X			X		X	
		09.15	74°45'	07°17'	3450							
079	13.06.	10.26	74°45'	06°38'	3486	X		X		X	X	
		13.58	74°45'	06°37'	3487							
080	13.06.	15.14	74°45'	06°00'	3524	X			X		X	
		17.37	74°45'	05°59'	3523							
081	13.06.	18.42	74°45'	05°22'	3576	X					X	
		20.52	74°44'	05°22'	3576							
082	13.06.	22.00	74°45'	04°44'	3599	X			X		X	
	14.06.	00.14	74°46'	04°41'	3600							
083	14.06.	01.20	74°45'	04°06'	3630	X					X	
		03.35	74°45'	04°04'	3631							
084	14.06.	04.50	74°45'	03°28'	3651				X		X	
		07.07	74°45'	03°27'	3658							
085	14.06.	08.18	74°45'	02°51'	3675	X		X		X	X	
		11.59	74°44'	02°50'	3675							
086	14.06.	13.15	74°45'	02°12'	3680	X			X		X	
		15.40	74°45'	02°14'	3681							

Station No	Date 1989	Time UTC	Latitude N	Longitude E	Depth (m)	ME	BS	BRO	BO	QM	BS/RO	MU
096	16.06.	01.14	74°45'	04°08'	3148	X	X	X				
		03.09	74°45'	04°08'	3144							
097	16.06.	04.24	74°45'	04°46'	3533		X	X	X			
		06.33	74°45'	04°46'	3444							
098	16.06.	07.43	74°45'	05°23'	3080	X	X	X		X	X	
		10.30	74°45'	05°22'	3231							
099	16.06.	11.43	74°45'	06°02'	3243	X	X	X	X			
		13.50	74°45'	06°04'	2732							
100	16.06	14.58	74°45'	06°40'	2301	X	X	X	X			
		16.52	74°45'	06°45'	2210							
101	16.06.	17.53	74°45'	07°19'	2144		X	X	X			
		19.34	74°44'	07°15'	2122							
102	16.06.	20.53	74°45'	07°56'	2524	X	X	X	X			
		22.40	74°46'	07°54'	2333							
103	17.06.	00.07	74°45'	08°34'	3217	X	X	X	X			
		02.07	74°45'	08°33'	3262							
104	17.06.	03.24	74°45'	09°12'	2577		X	X	X			
		05.18	74°45'	09°11'	2587							
105	17.06.	06.33	74°45'	09°50'	2582	X	X	X	X	X		
		09.33	74°46'	09°47'	2587							

Station No	Date 1989	Time UTC	Latitude N	Longitude E	Depth (m)	ME	BS	BRO	BO	QM	BS/RO	MU
106	17.06.	10.44	74°45'	10°28'	2515	X	X	X	X			
		12.39	74°45'	10°29'	2514							
107	17.06.	13.51	74°45'	11°06'	2489	X	X	X	X			
		15.37	74°46'	11°05'	2489							
108	17.06.	16.50	74°45'	11°45'	2448		X	X	X			X
		22.50	74°46'	11°48'	2446							
109	17.06.	23.55	74°45'	12°23'	2258	X					X	
	18.06.	01.13	74°45'	12°24'	2371							
110	18.06.	02.18	74°45'	13°00'	2255				X		X	
		03.40	74°45'	13°02'	2245							
111	18.06.	04.45	74°45'	13°38'	2132	X					X	
		05.50	74°45'	13°38'	2125							
112	18.06.	06.50	74°45'	14°15'	1952	X			X		X	
		08.15	74°46'	14°14'	1942							
113	18.06.	09.30	74°45'	14°54'	1484	X		X		X	X	
		11.22	74°45'	14°53'	1501							
114	18.06.	12.37	74°45'	15°32'	821	X			X		X	
		13.27	74°45'	15°33'	802							
115	18.06.	14.38	74°45'	16°11'	293	X					X	
		14.43	74°45'	16°11'	294							

Station No	Date 1989	Time UTC	Latitude N	Longitude E	Depth (m)	ME	BS	BRO	BO	OM	BS/RO	MU
116	18.06.	16.05	74°45'	16°48'	187	X			X		X	
		16.37	74°44	16°46'	184							
117	18.06.	17.51	74°45'	17°24'	259						X	
		18.14	74°45'	17°24'	252							
118	19.06.	09.06.	74°00'	09°02'	2704		XBT-survey					
	21.06.	16.33	75°30'	03°43'	2999							
119	21.06.	20.07	74°51'	03°01'	3191		X	X	X			
		21.52	74°51'	03°00'	3090							
120	21.06.	23.13	74°47'	03°37'	3712		X	X	X			
	22.06.	01.03	74°48'	03°35'	3704							
121	22.06.	02.21	74°45'	04°13'	3232		X	X	X			
		04.05	74°45'	04°12'	3205							
122	22.06.	05.27	74°42'	04°49'	3520		X	X	X			
		07.02	74°42'	04°48'	3528							
123	22.06.	08.23	74°39'	05°26'	3044		X	X	X	X		
		11.02	74°40'	05°22'	2863							
124	22.06.	12.34	74°36'	06°03'	2206		X	X	X			
		14.12	74°37'	06°01'	2728							
125	22.06.	15.39	74°34'	06°38'	3013		X	X	X			
		17.06	74°34'	06°37'	3007							
126	22.06.	15.39	74°34'	07°13'	1934		X	X	X			
		20.00	74°31'	07°12'	1937							

Station No	Date 1989	Time UTC	Latitude N	Longitude E	Depth (m)	ME	BS	BRO	BO	QM	BS/RO	MU
127	22.06.	21.30	74°28'	07°50'	2605		X	X	X			
		22.58	74°28'	07°49'	2607							
128	23.06.	00.25	74°26'	08°27'	3038		X	X	X			
		01.54	74°26'	08°27'	3048							
129	23.06.	03.13	74°22'	09°02'	2700		X	X	X			
		04.38	74°23'	09°02'	2692							
130	23.06.	06.02	74°21'	09°38'	2445		X	X	X	X		
		08.30	74°21'	09°38'	2419							
131	23.06.	09.56	74°17'	10°13'	2448		X	X	X			
		11.24	74°17'	10°13'	2450							
132	23.06.	12.46	74°14'	10°49'	2385		X	X	X			
		14.10	74°15'	10°50'	2388							
133	24.06.	10.30	78°00'	01°59'	3122	X	X	X	X	X		
		13.28	78°00'	01°54'	3123							
134	24.06.	14.36	78°00'	01°12'	3108	X	X	X	X			
		16.33	78°00'	01°11'	3108							
135	24.06.	17.44	78°00'	00°24'	3098	X	X	X	X			
		20.12	78°00'	00°25'	3103							
Station No	Date 1989	Time UTC	Latitude N	Longitude W	Depth (m)	ME	BS	BRO	BO	QM	BS/RO	MU
136	24.06.	21.30	78°00'	00°26'	3100	X	X	X	X			
		23.27	78°00'	00°30'	3093							

Station No	Date 1989	Time UTC	Latitude N	Longitude W	Depth (m)	ME	BS	BRO	BO	QM	BS/RO	MU
137	25.06.	0041	78°00'	01°13'	3029	X	X	X	X			
		02.29	78°00'	01°15'	3030							
138	25.06.	03.46	78°00'	02°01'	2976		X	X	X			
		05.09	78°00'	02°01'	2976							
139	25.06.	06.36	78°00'	02°49'	2862		X	X	X			
		08.12	77°59'	02°55'	2848							
140	25.06.	09.32	78°00'	03°37'	2714	X	X	X	X	X		
		11.55	77°59'	03°42'	2711							
141	25.06.	14.23	77°52'	04°26'	2296		X	X	X			
		16.08	77°50'	04°31'	2170							
142	25.06.	18.15	77°45'	05°13'	615	X	X	X	X			
		19.26	77°45'	05°09'	594							
143	25.06.	20.48	77°42'	06°01'	348	X	X	X	X			
		22.37	77°42'	05°58'	350							
144	26.06.	00.12	77°41'	06°33'	258	X	X	X	X			
		00.55	77°41'	06°33'	254							

Station No	Date 1989	Time UTC	Latitude N	Longitude E	Depth (m)	ME	BS	BRO	BO	QM	BS/RO	MU
145	26.06.	19.40	78°00'	02°00'	3125		X	X	X			X
		23.53	77°59'	01°59'	3124							

Station No	Date 1989	Time UTC	Latitude N	Longitude E	Depth (m)	ME	BS	BRO	BO	QM	BS/RO	MU
146	27.06.	01.35	78°00'	02°48'	2997	X	X	X	X			X
		04.48	78°01'	02°46'	3081							
147	27.06.	06.04	78°00'	03°36'	3134		X	X	X	X		
		08.34	78°00'	03°32'	3134							
148	27.06.	09.55	78°00'	04°24'	2774	X	X	X	X			
		12.07	78°00'	04°49'	2670							
149	27.06.	12.34	78°00'	05°12'	2625	X	X	X	X			
		14.42	78°00'	05°36'	2530							
150	27.06.	15.16	78°00'	06°00'	2344	X	X	X	X			
		17.05	78°00'	06°25'	2040							
151	27.06.	17.46	78°00'	06°49'	2381		X	X	X			
		19.05	78°00'	06°41'	2381							
152	27.06.	20.15	78°00'	07°34'	3500	X	X	X	X			
		22.32	78°00'	08°01'	2455							
153	27.06.	23.08	78°00'	08°25'	1896	X	X	X	X			
	28.06.	01.06	78°00'	08°48'	1436							
154	28.06.	01.46	78°00'	09°12'	933	X	X	X	X			
		03.22	78°00'	09°37'	218							
155	28.06.	04.01	78°00'	10°02'	161	X	X	X	X			
		04.42	78°02'	10°00'	160							

Station No	Date 1989	Time UTC	Latitude N	Longitude W	Depth (m)	ME	BS	BRO	BO	QM	BS/RO	MU
156	30.06.	10.04	77°27'	03°37'	2990			X	X			X
		11.29	77°27'	03°38'	2993							

4. Appendix

4.1 Participants

ARK VI/1

Name Name	Institut Institute
Asmus, K.	AES
Bakken, V.	NPI
Bendixen, B.	Norw.Def.Research Est.
Bischof, J.	Uni Kiel
Burmeister, K.-H.	NDR
Cameron, G.A.	AES
Collins, M.	AES
Crissoulidis, D.	NTNF
Daranskich, A.N.	AARI
Evers, K.U.	HSVA
Garrity, C.	AES
Gerchow, P.	AWI
Goldschmidt, P.	GEOMAR
Harms, U.	TUHH
Häusler, F.U.	HSVA
Hjelmstad, J.	NTNF
Holsten, K.G.	NDR
Ionov, V.P.	AARI
Jensen, H.	NHL
Kirndörfer, J.G:	NDR
Krylov, A.V.	AARI
Lahrmann, U.	HSW
Löraas, S.M.	NHL
Löset, S.	NHL
Mehlum, F.	NPI
Mohr, H.	HSVA
Moore, C.	GL
Neper, W.	HSVA
Pfirman, S.	GEOMAR
Ramseier, R.	AES
Ringstad, B.	MOBIL
Schmidt, O.	HSW
Schreiber, R.	EPR
Schwarz, J.	HSVA
Schwarz, I.	HSVA
Steen, E.	Uni Kiel
Wollenburg, I.	GEOMAR

ARK VI/2

Name Name	Institut Institute
Aagaard, K.	PMEL
Bader, B.	GEOMAR
Beaupre, M.	SIO
Bieser, J.	GEOMAR
Bischof, J.	UNI K
Bohrmann, H.	UNI K
Cameron, M.A.	AES
Carstens, J.	GEOB
Cussion, M.	AES
Darnell, D.	PMEL
Eide, L.K.	IMB
Freiwald, A.	GEOMAR
Garrity, C.	AES
Goldschmidt, P.	GEOMAR
Hebbeln, D.	GEOB
Hellmer, H.	AWI
Hillebrandt, O.	HSW
Lapp, D.	AES
Mahler, G.	HSW
Marquez, J.	IFM
Matthies, M.	IFM
Measures, C.	MIT
Meincke, J.	IFMH
Nürnberg, D.	GEOMAR
Oehmig, R.	GEOMAR
Pagels, U.	GEOMAR
Patrick, R.	SIO
Precht, H.	IFM
Sellmann, L.	AWI
Soltau, T.	IFMH
Swanberg, R.	IMB
Swift, J.	SIO
Verch, N.	IFMH
Warpakowski, A.	AWI
Wollenburg, I.	GEOMAR
Wüllner, H.	IFMH

ARK VI/3

Name Name	Institut Institute
Asmus, K.	AES
Babst, U.	AWI
Becker, H.	AWI
Bergeron, G.	GIROQ
Bochert, A.	AWI
Budéus, G.	AWI
Cameron, M.A.	AES
El-Naggar, S.	AWI
Garrity, C.	AES
Gosselin. M.	GIROQ
Graeve, M.	AWI
Hengstermann, T.	CL
Hillebrandt, O.	HSW
Hirche, H.J.	AWI
Kahru, M.	ITE
Kattner, G.	AWI
Körtzinger, A.	IPÖ
Kougias, Ch.	AWI
Krause, G.	AWI
Legendre, L.	GIROQ
Loquay, K.D.	CL
Mahler, G.	HSW
Malewski	DWD/SWA
Martineau, M.J.	GIROQ
Meyer, K.	AWI
Meyer, U.	AWI
Nieke, B.	CL
Nommann, S	ITE.
Ochsenhirt	DWD/SWA
Oishi, T.	AWI
Pfeifer, K.	AWI
Plugge, R.	AWI
Pohl, C.	AWI
Ramseier, R.	AES
Rosenberg, G.	GIROQ
Schneider, W.	AWI
Seifert, P.	AWI
Sildam, J.	ITE
Sirk, A.	ITE
Stürcken, M.	AWI
Theis, R.	CL
Thierbach	Journalist
van der Zanden-Sprong, I.	ITZ
Warpakowski, A.	AWI
Willkomm, R.	CL

ARK VI/4

Name Name	Institut Institute
Babst, U.	AWI
Becker, H.	AWI
BKA	
Bochert, A.	AWI
Budéus, G.	AWI
El-Naggar, S.	AWI
Gerdes, D.	AWI
Graeve, M.	AWI
Hempel, G.	AWI
Hempel, I.	AWI
Hengstermann, T.	αL
Joiris, C.	Uni Brüssel
Klindt, H.	AWI
Körtzinger, A.	IPÖ
Kougias, Ch.	AWI
Krause, G.	AWI
Loquay, K.D.	αL
Mack	
Malewski	DWD/SWA
Meyer, K.	AWI
Meyer, U.	AWI
Nieke, B.	αL
NN (Funkerin)	
Ochsenhirt	DWD/SWA
Oishi, T.	AWI
Pfeifer, K.	AWI
Piepenburg, D.	IPÖ
Plugge, R.	AWI
Pohl, C.	AWI
Schmidt, H.	
Schmidt, L.	
Schneider, W.	AWI
Seifert, P.	AWI
Theis, R.	αL
Thierbach, D.	Journalist
Warpakowski, A.	AWI
Weiser	Ing.Büro München
Willkomm, R.	αL

4.2. Participating Institutes

Address

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

Bundesrepublik Deutschland

AWI	Alfred-Wegener-Institut für Polar- und Meeresforschung Columbusstraße 2850 Bremerhaven
GEOB	Fachbereich 5 - Geowissenschaften - Universität Bremen Postfach 33 04 40 2800 Bremen 33
GEOMAR	GEOMAR Wischhofstr. 1-3 D-2300 Kiel
GIK	Geologisch-Paläontologisches Institut und Museum Universität Kiel Olshausenstr. 40-60 2300 Kiel
GL	Germanischer Lloyd AG Vorsetzen 32 D-2000 Hamburg 11
HSVA	Hamburgische Schiffbau- Versuchsanstalt GmbH Bramfelder Str. 164 Postfach 60 09 29 D-2000 Hamburg 60
HSW	Helicopter Service Wasserthal GmbH Kätnerweg 43 2000 Hamburg 65
IFMH	Institut für Meereskunde Universität Hamburg Troplowitzstr. 7 2000 Hamburg 54
IPÖ	Institut für Polarökologie der Universität Kiel Olshausenstr. 40 2300 Kiel

TUHH	Technische Universität Hamburg-Harburg Elbchaussee 35 D-2000 Hamburg 50
OL	Universität Oldenburg - Fachbereich Physik - Ammerländer Heerstraße 2900 Oldenburg
SWA	Seewetteramt Hamburg Deutscher Wetterdienst Bernhard-Nocht-Str. 76 Postfach 180 2000 Hamburg 4

Kanada

AES	Atmospheric Environmental Service AES/CRESS Microwave Group Petrie 214 - York University 4700 Keele Street North York, Ontario Canada M3J 1P3
GIROQ	Université Laval Centre des Sciences et de Genie Department de biologie Cite Universitaire Québec, Canada G1K 7P4

Niederlande

ITZ	University of Amsterdam Institute for Taxonomic Zoology Department: Marine Invertebrates P.O. Box 4766 1009 AT Amsterdam

Norwegen

IMB	Institut for Marin Biologi Univ.i. Bergen N-5065 Blomsterdalen
NHL	(SINTEF) Norwegian Hydrotechnical Laboratory Klabuveien 153 N-7034 Trondheim
NTNF	Norwegian Council for Scientific and Industrial Research P.O. BOx 70 Tasin N-0801 Oslo 8

NPI Norwegian Polar Research Institute
Postboks 158
N-1330 Oslo Lufthavn

Sovietunion

AARI Arctic and Antarctic Research
Institute
Bering Str. 38
199226 Leningrad

ITE Institute of Thermophysics and
Electrophysics
Department of the Baltic Sea
Paldiski Rd. 1
20031 Talinn, Estonia

Vereinigte Staaten von Amerika

MIT Massachusetts Institute
of Technology
Dept. of Oceanography
Cambridge, MA 02139

PMEL NOA Pacific Marine
Environmental Laboratory

SIO Scripps Institution of Oceanography
University of California
La Jolla, CA 92093

TCES Tiburon Center for Environmental Studies
P.O. Box 855
Tiburon, Ca. 94920

4.3 Ship's Crew

	ARK VI/1	ARK VI/2	ARK VI/3+4
Kapitän	Suhrmeyer	Suhrmeyer	Suhrmeyer
1. Offizier	Allers	Allers	Allers
Naut.Offizier	Stehr	Stehr	Stehr
Naut.Offizier	Fahje	Fahje	Varding
Arzt	Dr. Gießler	Dr. Gießler	Dr. Gießler
Ltd.Ing.	Dietrich	Briedenhahn	Briedenhahn
1. Ing.	Knoop	Knoop	Knoop
2. Ing.	Delff	Delff	Delff
2. Ing.	Simon	Simon	Simon
Elektriker	Erdmann	Erdmann	Erdmann
Elektroniker	Nitsche	Nitsche	Nitsche
Elektroniker	Mutter	Mutter	Mutter
Elektroniker	Husmann	Husmann	Husmann
Elektroniker	Both	Thonhauser	Thonhauser
Funkoffizier	Butz	Geiger	Geiger
Funkoffizier	Müller	Wanger	Wanger
Koch	Tanger	Tanger	Tanger
Kochsmaat/B	Kubicka	Kubicka	Kubicka
Kochsmaat/K	Bender	Bender	Bender
1. Steward	Scheel	Scheel	Scheel
Krankenschw./ Stewardess	Pötzsch	Pötzsch	Pötzsch
Stewardess	Friedrich	Friedrich	Friedrich
"	NN	NN	NN
"	NN	NN	NN
2. Steward	Chang	Chang	Chang
2. Steward	Chau	Chau	Chau
Wäscher	Shyu	Shyu	Shyu
Bootsmann	Woltin	Woltin	Woltin
Zimmermann	Marowsky	Marowsky	Marowsky
Matrose	Iglesias Bermudez	Iglesias Bermudez	I. Bermudez
Matrose	Suarez Paisal	Suarez Paisal	Suarez Paisal
Matrose	Soage Curra	Soage Curra	Soage Curra
Matrose	Gil Iglesias	Gil Iglesias	Gil Iglesias
Matrose	Abreu Dios	Abreu Dios	Abreu Dios
Matrose	Pousada Martinez	Pousada Martinez	P. Martinez
Lagerhalter	Schierl	Schierl	Schierl
Masch.Wart	Wittfoht	Wittfoht	Wittfoht
Masch.Wart	Dufner	Dufner	Dufner
Masch.Wart	Carstens	Carstens	Carstens
Masch.Wart	Husung	Husung	Husung
Masch.Wart	Ulbricht	Ulbricht	Ulbricht