Die Expedition ARKTIS XV/3
des Forschungsschiffes „Polarstern“ 1999

The Expedition ARKTIS XV/3
of the Research Vessel „Polarstern“ in 1999

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Zusammenfassung und Fahrtverlauf

Der Fahrtabschnitt ARK XV/3 führte in den nördlichen Teil des Europäischen Nordmeers (Abb. 1). Der Schwerpunkt der Arbeiten lag bei physikalischen und chemischen Untersuchungen im Rahmen der Klimaforschung; dazu kamen Untersuchungen des Ökosystems Meereis und eisbedeckter Ozean, sowie Arbeiten zum Sedimenttransport durch Meereis, zur Physiologie polaren Zooplanktons und zur Verbreitung mariner Pilze in der Arktis. Entlang von 5 Transekten wurden 107 Vertikalprofile von Temperatur und Salzgehalt mit einer CTD-Sonde (Conductivity, Temperature, Depth) gemessen sowie Wasserproben genommen, um Spurenstoffe wie Sauerstoff und Nährsalze zu bestimmen. Auf den Transsekten wurden 23 Netzfänge und 7 Sedimentbohrungen für die biologischen und sedimentologischen Untersuchungen unternommen. 15 ozeanographische Verankerungen wurden aufgenommen und 12 wieder ausgelegt, um kontinuierliche Meßzeitreihen aus dem Untersuchungsgebiet zu erhalten. Auf 6 mehrstündigen Eisstationen wurden biologische Prozesse in und unter dem Eis auf verschiedenen zeitlichen und räumlichen Skalen untersucht und die Sedimente beprobt. Durch 20 Hubschraubereinsätze konnten diese Programme durch weitere Eisbohrungen ergänzt werden.

Das Europäische Nordmeer und das Nordpolarmeer stellen ein System von Becken dar, die miteinander in Austausch stehen; die tiefste Verbindung dafür ist die Framstraße (Abb. 1). Aus dem Atlantik wird warmes, salzreiches Wasser in das Arktische Mittelmeer geführt und dort durch Wärmeabgabe und Eisbildung umgewandelt. Diese Modifikation erfolgt in unterschiedlichen Prozessen. Während in der Grönlandsee tiefreichende konvektive Vermischung im offenen Ozean vorherrscht, dominieren im Nordpolarmeer Prozesse auf den Schelfen. Die umgewandelten Wassermassen werden im Ostgrönlandstrom nach Süden transportiert und leisten einen erheblichen Beitrag zur Erneuerung des Tiefenwassers des Weltmeeres.

Der Wasser- und Eisaustausch durch die Framstraße ist durch großräumige Antriebsbedingungen und durch die lokale Dynamik bestimmt, bei der die komplexe Bodentopographie eine wesentliche Rolle spielt. Da ein großer Teil der Wassermassen, die von Süden in die Framstraße einströmen, dort rezirkuliert, muß der Nettotransport als Differenz zwischen dem erheblichen Ein- und Ausstrom gemessen werden. Da der Süßwasseranteil von besonderer Bedeutung für die Stabilität der Wassersäule ist, wurden auch Zeitreihen der Eisdicke und Eisdrift, sowie des Salzgehalts des Meerwassers in den oberen Schichten gemessen. Die Transporte unterliegen starken Fluktuationen, so daß Zeitreihen über mehrere Jahre gemessen werden müssen, um aussagekräftige Werte zu erhalten. Mit den aufgenommenen Verankerungen liegt der zweite aufeinanderfolgende Datensatz ganzjähriger

Messungen von Strömung, Temperatur und Salzgehalt über den gesamten Querschnitt der Framstraße vor. Die komplizierte räumliche Struktur des Systems erfordert eine hohe räumliche Dichte der Beobachtungen, die nur durch die Verankerungen ergänzende hydrographische Aufnahmen gewährleistet werden kann. Auf dieser Reise wurden zum dritten Mal ein zonaler und ein meridionaler CTD-Schnitt mit hoher horizontaler Auflösung aufgenommen. Die Daten aus den Zeitreihen und den hydrographischen Schnitten werden in Kombination mit regionalen Modellen benutzt, um die Natur längerfristiger Schwankungen des Systems zu verstehen.

Im Sommer und Herbst 1999 lag die Eisgrenze in der Framstraße und nördlich von Svalbard nahe ihrer langjährigen nordwestlichen Extremposition (Abb. 2). Diese günstige Lage erlaubte es, einen Schnitt nördlich von Spitzbergen bis zur Nordspitze des Yermakplateaus zu fahren, um den Einstrom von atlantischem Wasser in das Nordpolarmeer jenseits des Rezirkulationsgebietes in der Framstraße zu erfassen. Sowohl hier als auch in der Framstraße selbst war der atlantische Einstrom bemerkenswert warm: Die obersten 500 m Wassersäule der Framstraße, in der direkte Vergleiche zu den Vorjahren möglich sind, waren im Herbst 1999 über 1K wärmer als in den Vorjahren.

Für die Tiefenwassererneuerung im Nordpolarmeer stellt die Bildung von kaltem Schelfwasser und dessen Abfluß in lokal begrenzten, bodengeführten Schelfwasserfahnen den entscheidenden Mechanismus dar. Diese Schelfwasserfahnen sind für den Wärme- und Salzaustausch wichtig, aber sie transportieren auch partikuläres und gelöstes Material von den Schelfen in die Tiefsee. Ihre zeitlich sehr variablen Eigenschaften wurden beispielhaft durch Langzeitmessungen südlich von Spitzbergen untersucht. In einem mit dieser Reise beginnenden Programm wird geprüft, ob ähnliche Prozesse auch vor Ostgrönland stattfinden.

Die physikalisch/chemischen Arbeiten sind Beiträge zu einem Langzeitprogramm, das international im Rahmen der "Arctic Climate System Study" (ACSYS) des "World Climate Research Programme" (WCRP) eingebunden ist und von der Europäischen Union als Projekt "VEINS" (Variability of Exchanges in Northern Seas) mitfinanziert wird. Die Untersuchungen am Kontinentalabhang von Spitzbergen und Ostgrönland stellen einen Beitrag zum Tiefseeforschung-Projekt des BMBF, „ARKTIEF", dar.

Das mehrjährige Packeis des Nordpolarmeeres bildet ein ausgeprägtes Ökosystem. Die biologischen Untersuchungen des Meereises beinhalteten die qualitative und quantitative Erfassung der gesamten Meereislebensgemeinschaft (Viren bis Metazoen). Besonderes Augenmerk galt den speziellen Anpassungen der Eisorganismen zur Überbrückung des polaren Winters sowie der gesamten Dynamik des Nahrungsnetzes der sympagischen Lebensgemeinschaft. So nutzen herbivore Copepoden, eine in der Arktis dominierende Schlüsselart, offenbar auch einen großen Teil des von Eisalgen produzierten partikulären organischen Materials zur Nahrung. Arbeiten zur Funktion und Diversität von Bakteriengemeinschaften gaben Aufschluß darüber, welche Bakterien spezifisch für das sympagische System sind, welche physiologischen Leistungen und Prozesse für sie charakteristisch sind, ob sich diese auf spezifische Horizonte einengen und ob es endemische Arten gibt. Die Experimente in Neueis, einjährigem und mehrjährigem Packeis belegten, daß trotz der späten Jahreszeit eine sehr hohe biologische Aktivität im Meereis vorhanden ist, insbesondere im erst wenige Zentimeter bis Dezimeter dicken Nilas. Die Auswertung des Probenmaterials sollen quantitative Aussagen über die Nahrungsflüsse innerhalb des mikrobiellen Nahrungsnetzes ermöglichen.

Arktisches Meereis enthält z.T. große Mengen an feinkörnigen Sedimenteinschlüssen aus den nordamerikanischen und sibirischen Schelfmeeren, die dort durch turbulente Prozesse während der Eiskristallbildung in das Meereis eingebunden werden. Das inkorporierte Material wird aus den Schelfmeeren exportiert und trägt somit bedeutend zum Sedimentbudget des Nordpolarmeeres und des Nordatlantiks bei. Arktische Meereissedimente enthalten zum Teil deutlich erhöhte Konzentrationen künstlicher Radionuklide, möglicherweise aus der Kara- und Laptevsee. Sedimentproben in Eis und vom Meeresboden wurden gewonnen, um das Vorhandensein und die Freisetzung von Partikeln aus dem Meereis in den Ablationsgebieten der Barentssee und der östlichen Framstraße zu untersuchen.

In polaren Zooplanktonarten wurden hohe Metallanreicherungen im Verhältnis zu den äußerst niedrigen gelösten Schwermetallkonzentrationen im Meerwasser beobachtet. Da Metalle hauptsächlich als freie Ionen aufgenommen werden, wären die akkumulierten Konzentrationen ohne effektive Entgiftungsmechanismen innerhalb der Zellen akut toxisch. Daher haben Aufnahme- und Entgiftungsmechanismen sowie der gesamte Metallmetabolismus für Organismen mit hohen akkumulierten Metallgehalten eine große Bedeutung. Um die biologischen Eigenschaften der betroffenen Organismen für die Weiterentwicklung eines konzeptionellen Modells zu erfassen, wurden Fänge aus RMT und Bongonetzen einer Kombination von Freilanduntersuchungen und Bioakkumulationsexperimenten an Bord unterzogen. Angestrebt wird die Verifizierung von Modellparametern zur Bioakkumulation.
Mykologische Untersuchungen galten der BMBF-geförderten „Naturstoffforschung“ und fanden innerhalb des Vorhabens „Wirkstoffe aus marinen Pilzen“ statt. Sie dienten dem Nachweis von Diversität und Abundanz mariner Pilze und pilzähnlicher Protisten in der Grönlandsee und der Framstraße im Hinblick auf eine mögliche pharmakologische Anwendung. Der überwiegende Teil aller arktischen Pilzisolate ist - im Unterschied zur Antarktis - identisch mit ubiquitär verbreiteten Arten. Dennoch finden sich auch spezifisch arktische Arten darunter, die vor allem den öko-physiologischen Gruppen der psychrophilen und der wirtsassoziierten Pilze angehören. Bei Proben aus Wasser und Sediment wurden solitär lebende Pilze festgestellt,

während durch Netzfänge assoziierte Formen und in Meereiskernen die Beteiligung von Pilzen an der mikrobiellen Meereisgemeinschaft beobachtet und Species isoliert werden konnten. Eine erste Sichtung läßt eine spezifische Besiedlung der untersuchten Habitate durch einzelne Pilzgruppen vermuten.

Die Reise begann am 10. September 1999 in Tromsø (Abb. 1). Südlich von Spitzbergen wurden im Ausstrom aus dem Storfjord eine Verankerung aufgenommen und ein hydrographischer Schnitt durchgeführt. Die Arbeiten wurden auf einem zonalen Schnitt durch die Framstraße bei etwa 79°N fortgesetzt. Dort wurden bei ruhigem Wetter und in weitgehend eisfreiem Wasser 13 Verankerungen aufgenommen und 11 wieder ausgelegt. Wie auf allen Schnitten, wurden in engem Abstand CTD-Profile mit Wasserschöpferproben gefahren, sowie – mit größeren Abstand - Netzfänge ausgeführt und Sedimentkerne gezogen. Erst bei 5°W erreichten wir die Eisgrenze und konnten so im Bereich des Ostgrönlandstroms an drei Positionen ganztägige Eisstationen durchgeführen. Der einsetzende Winter, der durch rasche Neueisbildung teilweise zu einer 100-prozentigen Eisbedeckung führte, erlaubte es nicht, weiter als bis 13,3°W vorzudringen und zwang uns zur Umkehr. Es folgte ein Schnitt auf dem Nullmeridian und dann nach Nordosten auf den Hang des Yermakplateaus, um sowohl die Fortsetzung des atlantischen Randstroms entlang des Hanges als auch seine Rezirkulation in der südlichen Framstraße zu erfassen. Erst nordöstlich von diesem Schnitt trafen wir wieder auf Eis für eine vierte Eisstation. Anschließend nutzten wir die günstigen Eisverhältnisse nördlich von Svalbard und fuhren einen hydrographischen Schnitt von 82,5°N über die Nordspitze des Yermakplateaus, durch den Lenatrog bis zur Schelfkante Spitzbergens. Nach der südlichen Verlängerung des Nullmeridianschnittes bis in das Boreasbecken bei 77,5°N fuhren wir für Eisarbeiten wieder nach Westen in den ostgrönländischen Eisgürtel.

Zum Schluß wurde eine Verankerung am ostgrönlandischen Kontinentalfuß bei 74,5°N ausgelegt, in einem von einem untermeerischen Kanal durchzogenen Gebiet, das auf dem ersten Abschnitt dieser Polarsternreise, ARKXV-1 (Krause, Cruise Report ARKXV/1, Reports on Polar Research, 2000), mit dem ROV (Remote Operating Vehicle) „VICTOR 6000" untersucht worden war. Nach einer letzten eintägigen Eisstation bei 74,5°N schlossen wir am 8. Oktober die Forschungsarbeiten ab. Polarstern kehrte am 13. Oktober nach Bremerhaven zurück.

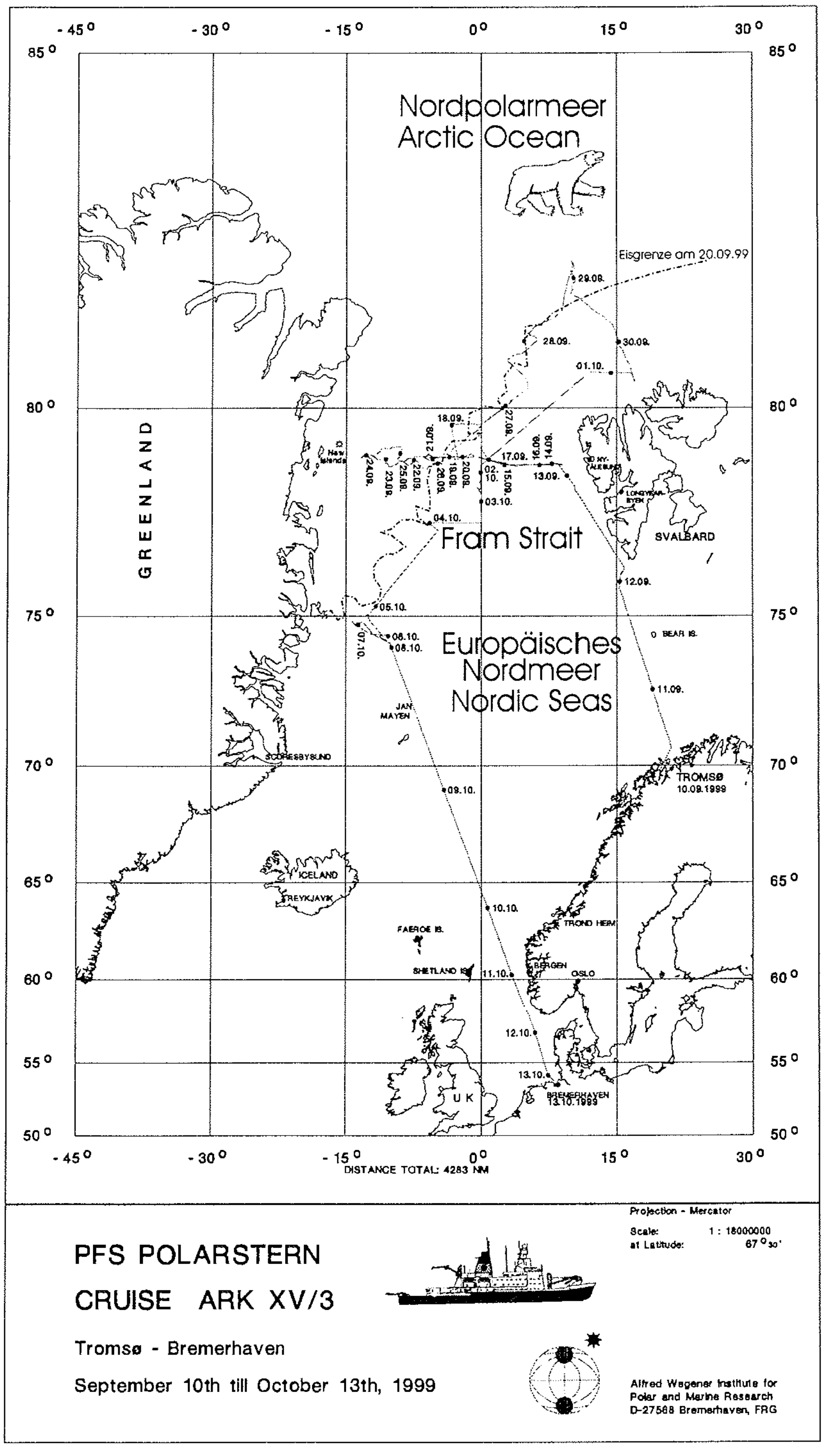

Abb. 1: Fahrtroute während des Fahrtabschnitts ARK XV/3.
Fig. 1: Cruise track during leg ARK XV/3.

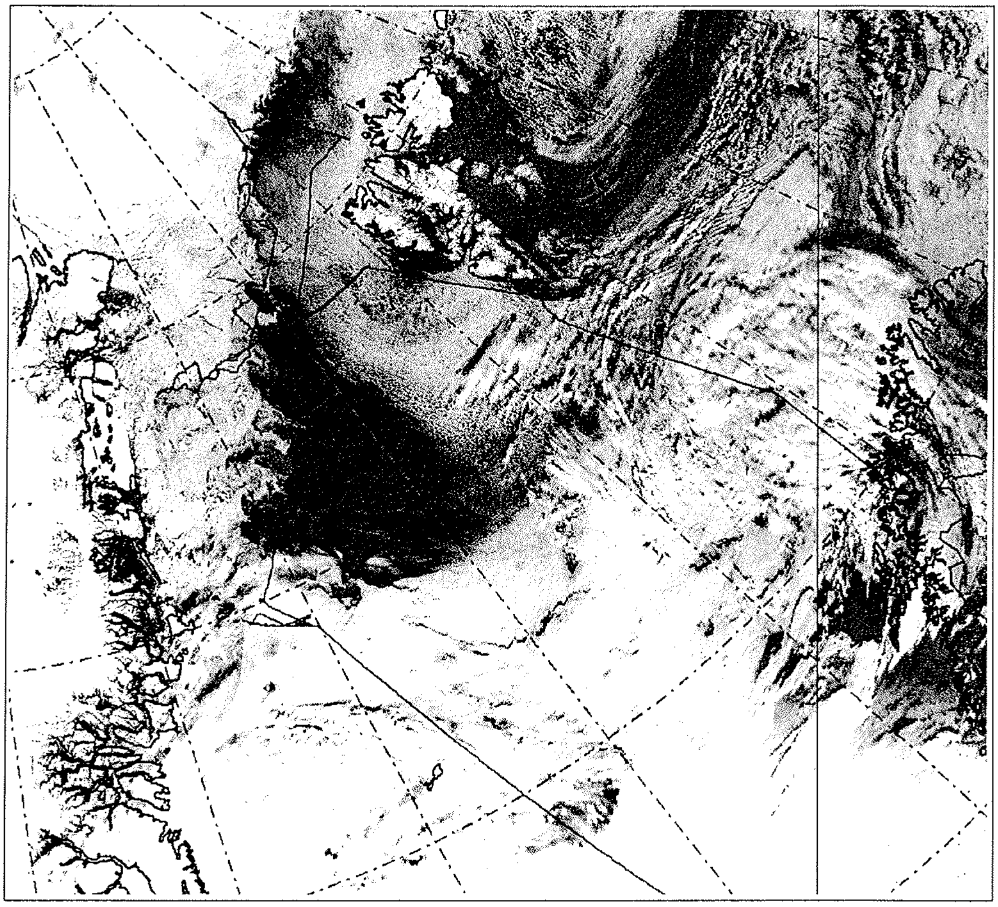

Abb. 2: NOAA-12 AVHRR-Aufnahme mit der Eisbedeckung des Untersuchungsgebietes am 20. September 1999.
Fig. 2: NOAA-12 AVHRR image showing the ice cover of the study area on 20 September 1999.

Itinerary and summary

The "Polarstern"-cruise ARK XV/3 covered the northern part of the Nordic Seas (Fig. 1). Physical and chemical oceanography investigations carried out as part of climate research formed the backbone of the cruise. In addition, the sea ice ecosystem, the transport of sediment through sea ice, the physiology of zooplankton and the distribution of marine fungi were studied. Along 5 transects, 107 vertical profiles of temperature and salinity were measured with a CTD-system in combination with taking water samples for the determination of oxygen and nutrient contents. To obtain year-long timeseries of various parameters, 15 oceanographic moorings were recovered and 12 were redeployed. Along the transects, nets and box cores were used for biological and sedimentological work. Biological processes in and below the ice were carried out on 6 extended ice stations besides the ship and by the use of 20 helicopter flights.

Exchanges between the North Atlantic and the Arctic Ocean result in the most dramatic water mass conversions in the World Ocean: warm and saline Atlantic waters, flowing through the Nordic Seas into the Arctic Ocean, are modified by cooling, freezing and melting to become shallow fresh waters, ice and saline deep waters. The outflow from the Nordic Seas to the south provides the initial driving of the global thermohaline circulation cell. Measurement of these fluxes is a major prerequisite for the quantification of the rate of overturning within the large circulation cells of the Arctic and the Atlantic Oceans, and is also a basic requirement for understanding the role of these ocean areas in climate variability on interannual to decadal scales.

The Fram Strait represents the only deep connection between the Arctic Ocean and the Nordic Seas. Just as the freshwater transport from the Arctic Ocean is thought to be of major influence on convection in the Nordic Seas and further south, the transport of warm and saline Atlantic water significantly affects the water mass characteristics in the Arctic Ocean and therefore possibly influences also ice and atmosphere. Since 1997, velocity and hydrography measurements were carried out to estimate heat and salt fluxes through the strait as well as fluxes of dissolved substances, and in combination with a regional model, to investigate the nature and origin of the transport fluctuations on seasonal to decadal time scales.

Whereas in the Nordic Seas the ventilation of deeper layers is dominated by open-ocean convection, in the Arctic Ocean the sinking of shelf water plumes is the major ventilation process. Dense water is formed by brine release during freezing and accumulates in appropriate shelf regions. It spreads in plumes along the bottom to the shelf edge and sinks to deeper layers in the basins. En route, the plumes may incorporate sediment and transport material down the slope. As a prototype for Arctic thermohaline shelf plumes, the input of winter water from the

Storfjord to the West Spitsbergen Current was investigated with moorings and hydrographic work since 1997. A related project which aims to find out whether sediment driven plumes occur on the East Greenland continental slope started with this cruise.

The physical/chemical investigations represent a contribution to a long term programme in the framework of the "Arctic Climate System Study" (ACSYS) of the "World Climate Research Programme" (WCRP). The work is partly funded by the European Union project "VEINS" (Variability of Exchanges in Northern Seas). Four of the moorings in Fram Strait are contributed by the Norsk Polarinstitutt. The moorings at the continental slope of Spitsbergen and of East Greenland are a contribution to the deep sea research programme ARKTIEF of the German Ministry of Education, Science and Technology (BMBF).

The multiyear ice of the Arctic Ocean constitutes a very specific ecosystem. The biological investigations addressed the qualitative and quantitative description of the community within and below the sea ice. Some of the key species of Arctic herbivorous copepods are obviously involved in the dynamics of the sea ice related food web which - due to the near absence of large piscivorous fishes in polar oceans has a direct link to sea birds and marine mammals.

In a multidisciplinary approach the organism biomass and abundance in different size classes were studied in relation to physical and chemical conditions. Of particular interest were special adaptations of species to survive the dark polar winter including the formation of resting cells and/or energy storages like lipid droplets within the cells. The layer immediately below the Arctic sea ice and the water column is a particular habitat with special abiotic (e.g. temperature and salinity) and biotic conditions (e.g. algal mats). Its colonization and processes were investigated in different temporal and spatial scales.

Bacteria are the dominating heterotrophic component in the sea ice of polar systems. Sampling of ice and under ice water will give insights into which bacterial species are specific for the sympagic system and which physiological performances and processes are characteristic.

Arctic sea ice widely contains fine grained sediments which are entrained into newly forming ice through turbulent processes like suspension freezing in the Canadian and Siberian shelf seas. The incorporated material is exported from the shelf seas thereby contributing significantly to the sedimentary budget of the Arctic Ocean and the Northern European Atlantic. The occurrence and melt-release of sea ice sediments in the ablation areas of the SW Barents Sea and the E Fram Strait. will be quantified. Thereby, the radionuclide concentration of sea ice- and bottom sediments will be used to identify potential source regions and to trace transport pathways of ice.

Marine amphipods and decapods in polar regions have high metal accumulation which is in contrast to the low soluble metal concentrations normally found in Arctic sea water. Without efficient mechanisms of storage and detoxification, the metal ions taken up by the organisms would be toxic. Experiments with marine amphipods, copepods and decapods will be carried out onboard to study their specific metal metabolism.

In the Greenland Sea and Fram Strait the stable stratified water column in the marginal ice zones and polynias enhances primary production and therefore plankton biomass and vertical particle flux. However, little is known about the function of ice algae and of heterotrophic protozoan grazers for the pelagic system. Biomass build-up, modification, and sedimentation in relation to the physical constraints at the ice edge were studied.

The biodiversity, associations and interactions of marine fungi and fungus-like protists were analysed in sea ice and under ice water and also samples from pelagic and benthic communities.

The cruise started at 10 September in Tromsø (Fig. 1). The first operation was the recovery of an oceanographic mooring on the southern shelf of Spitsbergen which had recorded the outflow of cold water from Storfjord for one year. To determine the cross section of the plume a hydrographic section was taken. We continued with a zonal section across Fram Strait at 79°N. In calm and almost ice-free waters, 13 oceanographic moorings were recovered and 11 redeployed. Like along all sections, CTD measurements with water sampler profiles were taken within tens of kilometers distance as well as net hauls and box cores at a larger distance. At 5°W we reached the ice edge and subsequently had three day-long ice stations and several helicopter flights for ice research. The onset of winter with the rapid formation of new ice led to 100% ice coverage. These conditions prevented us from proceeding west of 13.3°W. We returned to the Greenwich meridian and run a section towards north and then northeast up the slope of the Yermak Plateau in order to cover the recirculation in southern Fram Strait as well as the northward continuation of the West Spitsbergen Current. Only northeast of the section we met the ice again and could do another ice station. Then we made use of the low ice coverage north of Svalbard (Fig. 2) and run a section from the northern tip of the Yermak Plateau at 82.5°N across the Lena Trough up to the shelf off Spitsbergen. After completing the meridional section along 0°E into the Boreas Basin to 77.5°N we headed again towards west for ice research. Finally we deployed a mooring at the foot of the continental slope off East Greenland at 74.5°N. At this location, a submarine channel runs from the upper continental slope to the abyssal sea. The channel was surveyed with the ROV (Remote Operating Vehicle) „VICTOR 6000" during the first leg of the cruise, ARKXV/1 (Krause, Cruise Report ARKXV/1, Reports on Polar Research, 2000). After a final ice station at 74.5°N we concluded the field work on 8 October. Polarstern returned to Bremerhaven on 13 October.

The meteorological conditions

Erdmann (DWD)

RV „Polarstern“ left Tromsø with fresh to strong southwesterly winds. A low near Svalbard caused seas up to 5 m enroute to Bear Island. Approaching Svalbard the wind shifted southerly and decreased. Warm air advection resulted in misty and foggy weather on 11 September. A new low developed southwest of Svalbard passing south of "Polarstern". Therefore the wind changed north to northwest increasing up to Bft 6 for some time. Cold air in the rear of this low affected the operating area and sun came out after more than 60 hours with overcast and misty conditions. Weather conditions remained very good within the next days in the working area near 78.50°N in Fram Strait. First snowfall with temperatures dropping below 0°C were recorded on 15 September.

A strong anticyclone over central Greenland moved eastwards, passing south of "Polarstern"on 17 September. Therefore the wind turned southwest increasing up to Bft 6 and the windchill-temperature dropped below -15°C. First helicopter-flights to the ice edge near 78.50°N and 5°W were carried out without any problems. Clear sky with calm caused the first strong frost below -10 °C over ice at night on 18 September.

These excellent weather and flight conditions ended abruptly on 19 September, when wind shifted southeast at the western flank of an anticyclone near Svalbard. Warm and moisty air of maritime origin condensed over the cold sea-ice areas and visibility became poor to foggy within 2 hours. West of 7°W the concentration of multiyear-ice increased forcing "Polarstern" to reduce speed.

Freezing fog was observed onboard on 22 September, affecting flight activities. A new low developed in the lee-side of Northeast-Greenland on 23 September with minimum pressure below 1000 hPa. In the rear of this cyclone winds became strong Bft 6 to 7 with heavy snow-gusts over the operating area. The windchill-temperature dropped down to -30°C. Strong northerly winds up to Bft 7 associated with a stationary low over Svalbard persisted within the next 2 days in Fram Strait.

On 27 September, another depression developed south of Svalbard as a result of sharp air temperature differences between Bear Island (6 to 8°C) and the western part of Fram Strait (-8°C) within a belt of strong southerly upper-level winds near 60 kt at 500 hPa. At sea-level, wind increased up to Bft 7 to 8 reaching gales force Bft 9 at times and heavy snowfall. Ice accumulation on board, caused by precipitation and sea spray, affected all working on deck. At position 81.5°N, 5°E the vessel reached the ice edge again. By the time the center of the low,

forming a vortex in 500 hPa, approached our area and the surface pressure fall below 975 hPa on 28 September. The northerly gale decreased rapidly, becoming northwesterly Bft 4.
The northernmost position in the ice was reached on 29 September at 82.5°N, 10°E. Prevailing cold air advection resulted in snow showers and temperatures near -10°C. Decreasing westerly winds, and strong frost occured during the section over the Yermak-Plateau during the last days of September.

In the lee-side of Svalbard a small low developed on 1 October. Because of moderate northerly winds in the lower troposphere towards the mountains weather conditions changed to overcast sky with snowfall. Therefore a flight ashore had to be cancelled.
On our way towards southwest to 78.5°N 0°W, northerly winds increased up to Bft 6 with seas 2 to 2.5m. A wide spread anticyclone over Greenland influenced the operation area from 2 October until 3 October, with moderate to fresh northerly winds and very good visibility due to cold and dry air of Arctic origin. Helicopter flights to ice-stations around the ship could be carried out.

On 4 October, the vessel proceeded southwest to 75°N 12°W, passing the wide-spread ice fields of the Greenland Sea. Light anticyclonic influence and soft winds combined with clear sky caused temperature down to near -12°C.

Within the newly forming frontal zone spreading eastnortheast from the Southern Labrador Sea, another low developed northeast of Cape Farvel, tracking towards Iceland on 5 October, deepening below 1000 hPa by the time. Meanwhile, "Polarstern" steamed to a position southward for the last mooring deployment. On 7 October, this low affected our working area near 74.8°N 14°W with winds slowly increasing up to Bft 5 to 6 from northeast and the sky becoming overcast. During the night hours northerly storm about Bft 9 generated waves of more than 5 m height combined with heavy snowfall. In the early morning of 8 October, the warmfront crossed our working area causing a sharp rise of the temperature from -4°C up to 2°C within 1 hour. The wind shifted northeast dropping off to Bft 6. On late 8 October, "Polarstern" started the voyage home to Bremerhaven. Due to a developing storm depression southwest of Iceland and seas forecasted up to 10 m, spreading northeast, the meteorologist recommended to proceed directly towards the North Sea with maximum speed.

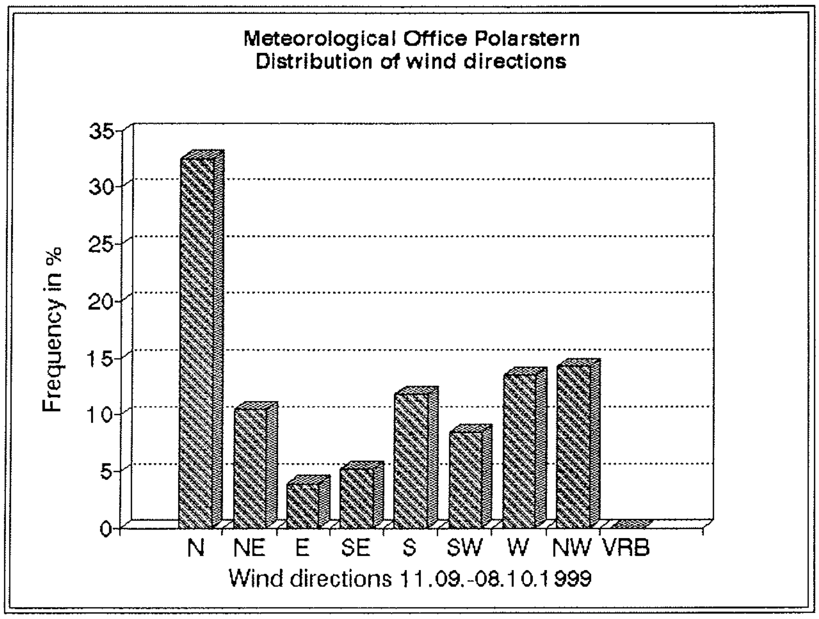

Fig. 3: Histogramm of wind direction

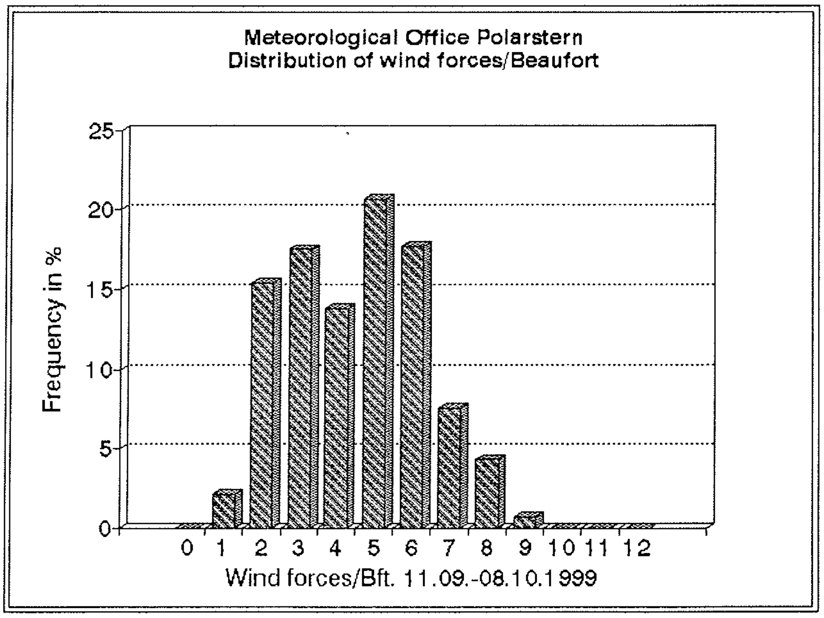

Fig. 4: Histogramm of wind speed

The hydrographic conditions in the northern Nordic Seas in summer 1999

Fossan, Macrander, Monsees, Noack, Pavlov, Roth, Schauer, Schütt, Thoms, Verduin, Wisotzki (AWI, GIB, NPI, UNIS, UBTP, UBUP)

Exchanges between the North Atlantic and the Arctic Ocean result in the most dramatic water mass conversions in the World Ocean: warm and saline Atlantic waters, flowing through the Nordic Seas into the Arctic Ocean, are modified by cooling, freezing and melting to become shallow fresh waters, ice and saline deep waters. The outflow from the Nordic Seas to the south provides the initial driving of the global thermohaline circulation cell. Knowledge of these fluxes and understanding of the modification processes is a major prerequisite for the quantification of the rate of overturning within the large circulation cells of the Arctic and the Atlantic Oceans, and is also a basic requirement for understanding the role of these ocean areas in climate variability on interannual to decadal scales.

- Flow through Fram Strait

The Fram Strait represents the only deep connection between the Arctic Ocean and the Nordic Seas. Just as the freshwater transport from the Arctic Ocean is thought to be of major influence on convection in the Nordic Seas and further south, the transport of warm and saline Atlantic water significantly affects the water mass characteristics in the Arctic Ocean and therefore possibly influences also ice and atmosphere. Since 1997, velocity and hydrography measurements are carried out in Fram Strait in the framework of the European Union project "VEINS" (Variability of Exchanges in Northern Seas) with the aim to estimate heat and salt fluxes through the strait as well as fluxes of dissolved substances. In combination with a regional model, the results will be used to investigate the nature and origin of the transport fluctuations on seasonal to decadal time scales.

The complicated topographic structure of the Fram Strait leads to a splitting of the West Spitsbergen Current carrying Atlantic Water northward into at least three parts. One part follows the shelf edge and enters the Arctic Ocean north of Svalbard. This part has to cross the Yermak Plateau which poses a sill for the flow with a depth of approximately 700 m. A second branch flows northward along the northwestern slope of the Yermak Plateau and the third part recirculates immediately in Fram Strait at about 79°N. Evidently, the size and strength of the different branches largely determine the input of oceanic heat to the inner Arctic Ocean.

- Work at Sea

To measure time series of the current, temperature and salinity field between East Greenland and West Spitsbergen, in summer 1998, 14 moorings have been deployed across Fram Strait at 79°N, in water depths between 200 m and 2600 m (Fig. 5, Appendix 5). These moorings were recovered during ARKXV-3 and the records provide the second set of year-long time series after a first similar array was moored from 1997 to 1998. At 11 locations, moorings were deployed for another year. One of the moorings (V2-2, Appendix 5) could not be recovered completely. The mooring was most likely damaged through commercial fishing activities. The upper part emerged in August 1999 and could be recovered during the preceeding Polarstern leg, ARKXV/2 (Jokat, cruise report ARK XV/2, Reports on Polar Research, 2000).

For a sufficient vertical resolution, each mooring carried 3 to 7 instruments like current meters from Aanderaa and FSI, Seacats and Microcats from Seabird, Upward Looking Sonars from APL and CMR. Temperatures and salinities were measured together with the currents, to allow derivation of the heat and salt transports.

Hydrographic sections were conducted to supply temperature and salinity at a much higher spatial resolution than given through the moorings (Fig. 6). The CTD-measurements were complemented by water samples to measure nutrients and oxygen to identify trends in the variability in the properties of the advected water masses. One hydrographic section crossed Fram Strait from the Svalbard shelf to the East Greenland shelf parallel to the mooring line, but extended onto the broad shelf off East Greenland (section II, Fig. 7). A second section, running from the Yermak Plateau quasi-meridional through the center of the strait into the Boreas Basin allows to trace the northward continuation of the flow along the Yermak Plateau and the recirculation of Atlantic Water within Fram Strait itself (section III, Fig. 8.). The favourable ice conditions in this summer allowed to run in addition a section from the northern tip of the Yermak Plateau to the shelf edge north of Svalbard (section IV, Fig. 9) covering the inner branch of the boundary current.

The CTD (Conductivity, Temperature, Depth) system used during the cruise was a Seabird Electronics SBE9*plus* probe, *SN 09P16392-0485*, in combination with a SBE32 Carousel Water Sampler, *SN 3217673-0202*, which operated 24 12-liter Ocean-Test-Equipment bottles. The CTD was equipped with standard conductivity, temperature and pressure sensors, *SN 03p2417* for temperature and *SN 042055* for conductivity, and in addition a Wetlabs light transmissiometer, *SN CST-267 DR*. For determining the distance to the bottom a Benthos

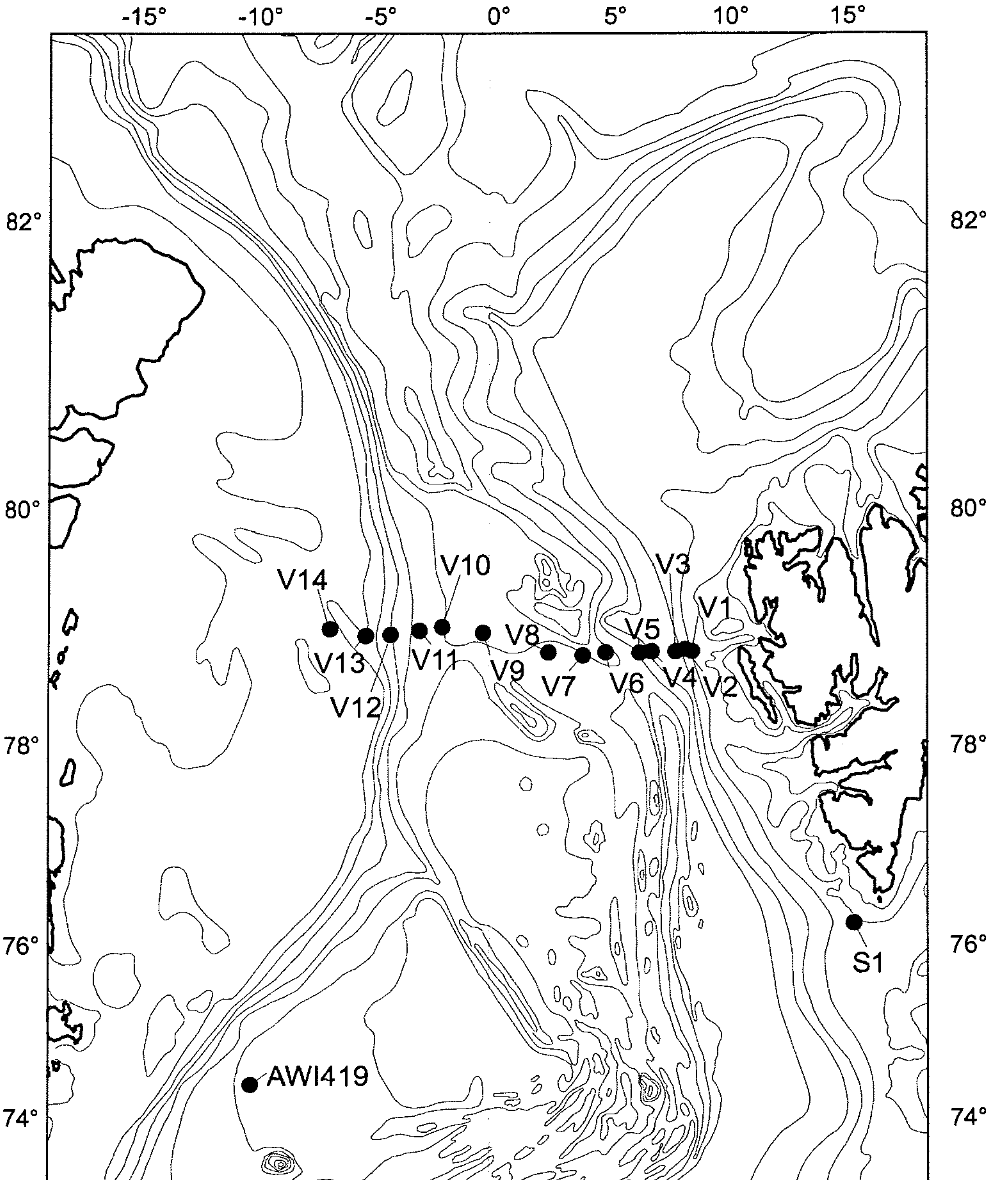

Fig. 5: Locations of the moorings (see Appendix 5). S1 and V7 to V9 were recovered only, AWI419 was only deployed.

Altimeter, Model 2110-2, *SN 189*, was used and also a mechanical bottom contact with a weight tied to an eight meter long rope.

The temperature and conductivity sensors were calibrated by the manufacturer immediately before and after the cruise. The transmissiometer was calibrated in fresh water on July 23 1999. According to the manufacturer, the sensor accuracy is about 1dbar for the pressure sensor, 0.001°C for the temperature sensor and 0.003mS/cm for the conductivity sensor. In addition, salinity values derived from the CTD measurements were calibrated with the aid of water samples. During the cruise a total number of 548 samples were analysed with a Guildline Autosal 8400A salinometer, and IAPSO standard seawater Batch number P135, K15=0.99992. Although it was difficult to achieve stable temperature conditions for the salinometer, preliminary comparisons between sensor and bottle data indicated that the conductivity sensor measured 0.002-0.003 mS/cm too low values. For a more precise estimation of this error, 70 salinity samples were brought back to AWI for analysis there. As a check that the bottles were fired at the right depths, SIS Kiel electronic thermometers and pressure meters were mounted on seven of the bottles, and their readings were recorded after each cast.

- Preliminary results of the CTD survey in the Fram Strait

With sections II and III the third high-resolution survey in a year to year sequence was performed. The most striking results are that the surface layer was more saline and that the Atlantic layer was warmer than in the two preceeding years. The increase of salinity in the upper 30 m was more than 1 psu mostly in the western Fram Strait (Fig. 10) indicating that the outflow of Arctic surface water became saltier. The temperature increase in the layer 50-500 m by more than 1 K extended from the warm core at the shelf edge off Spitsbergen along the recirculation branch to the East Greenland continental slope (Fig. 11). The very warm flow continued also northward along the Yermak Plateau (Fig. 8) and possibly even to the northeastern tip of the latter since the temperature is higher there than above the Yermak Plateau further south (Fig. 9). The core of the boundary current at the shelf edge north of Spitsbergen covers only a small cross section area according to its temperature. But the maximum temperature was also higher this year than in 1997 (Rudels et al., 2000. Water Mass Distribution in Fram Strait and over Yermak Plateau in summer 1997, Annales Geophysicae, submitted).

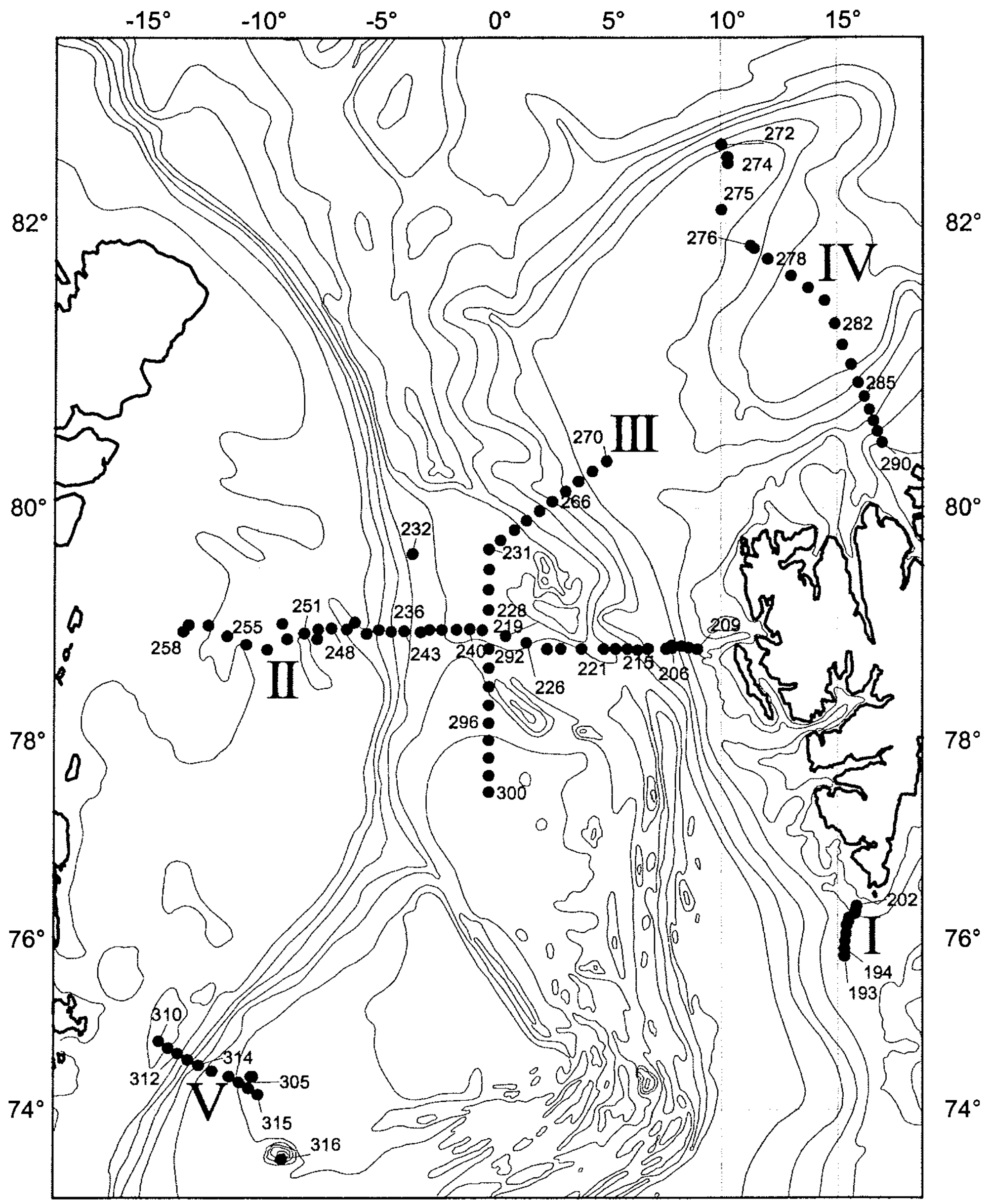

Fig. 6: Locations of the CTD stations. Sections are numbered I to V.

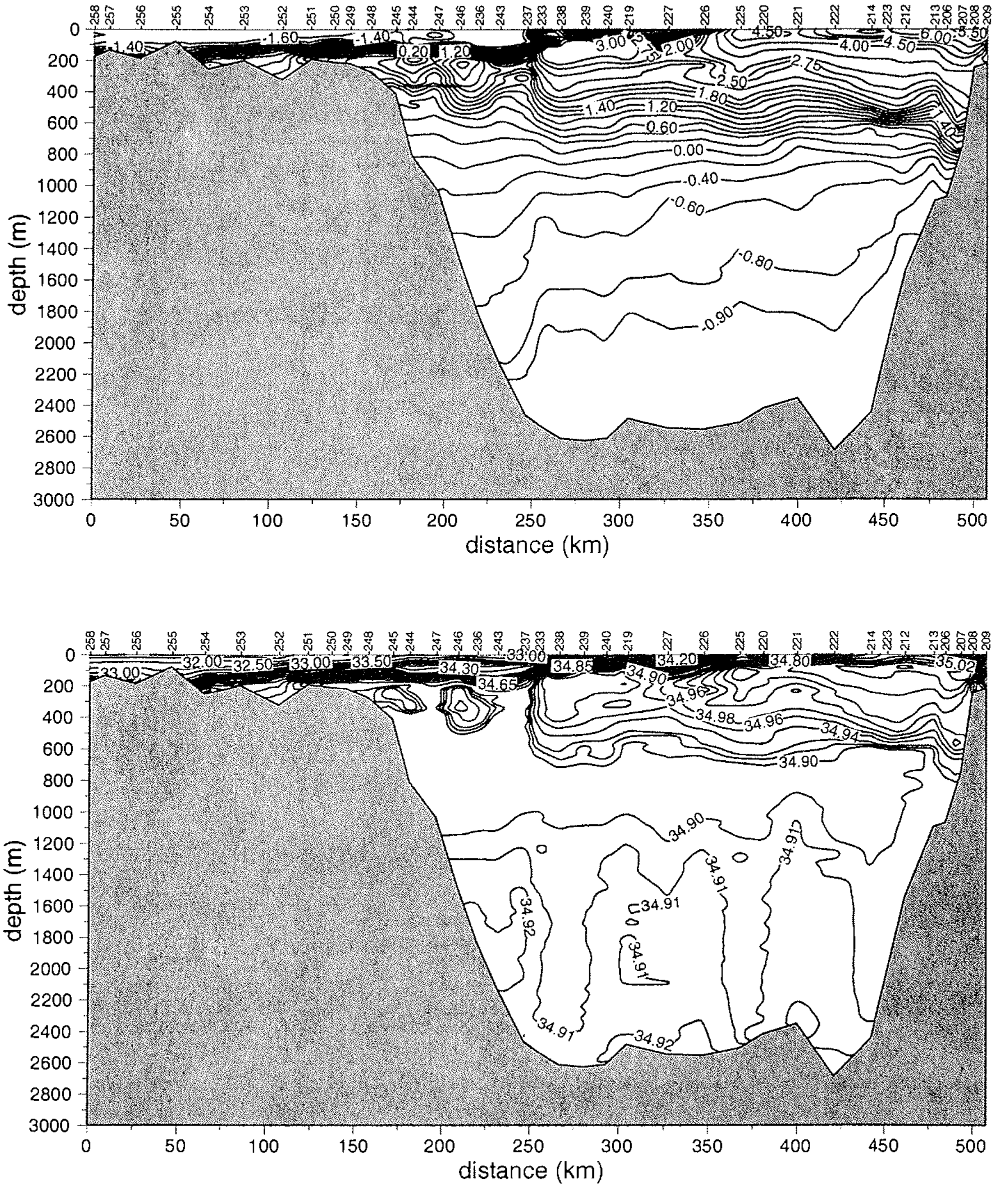

Fig. 7: Distribution of potential temperature and salinity at section II.

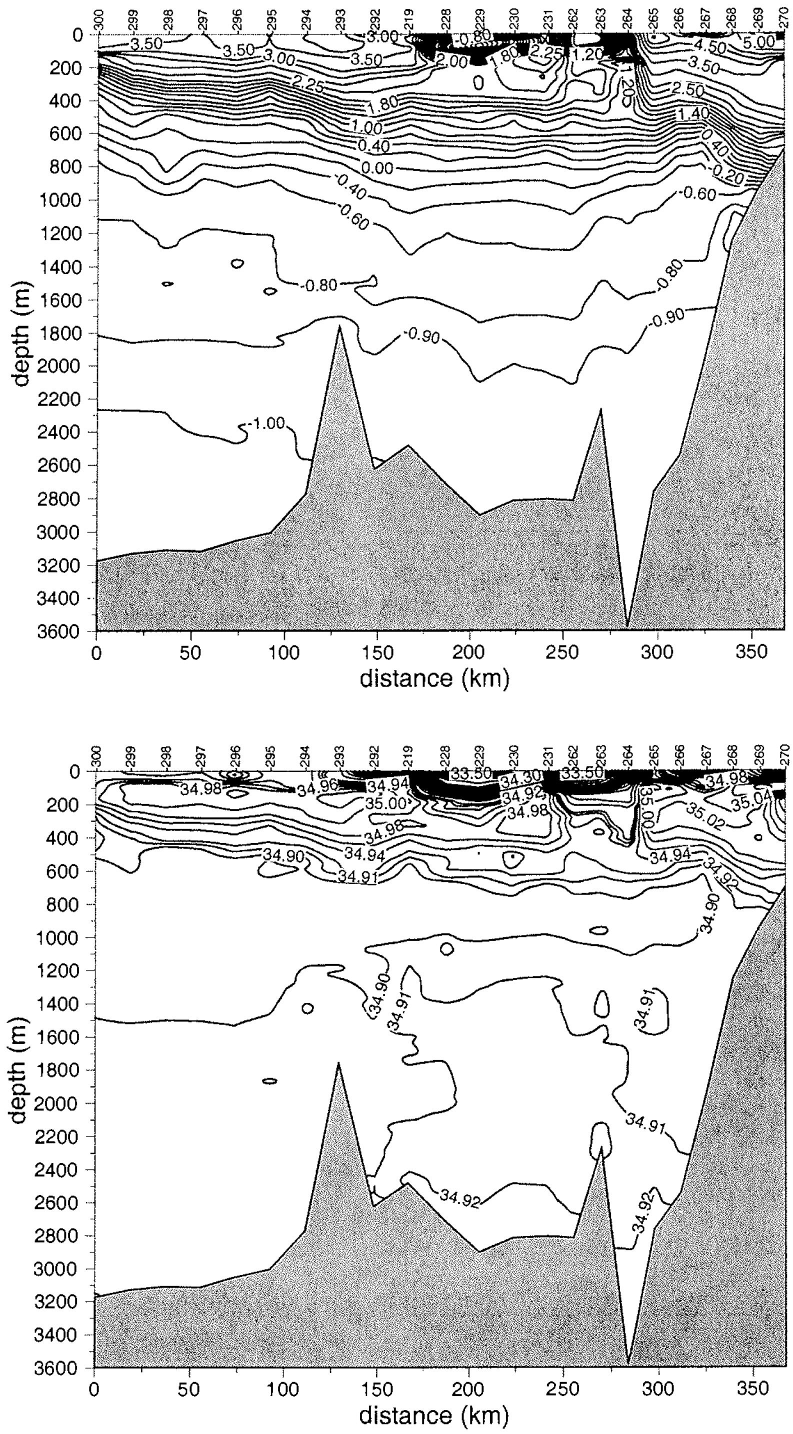

Fig. 8: Distribution of potential temperature and salinity at section III.

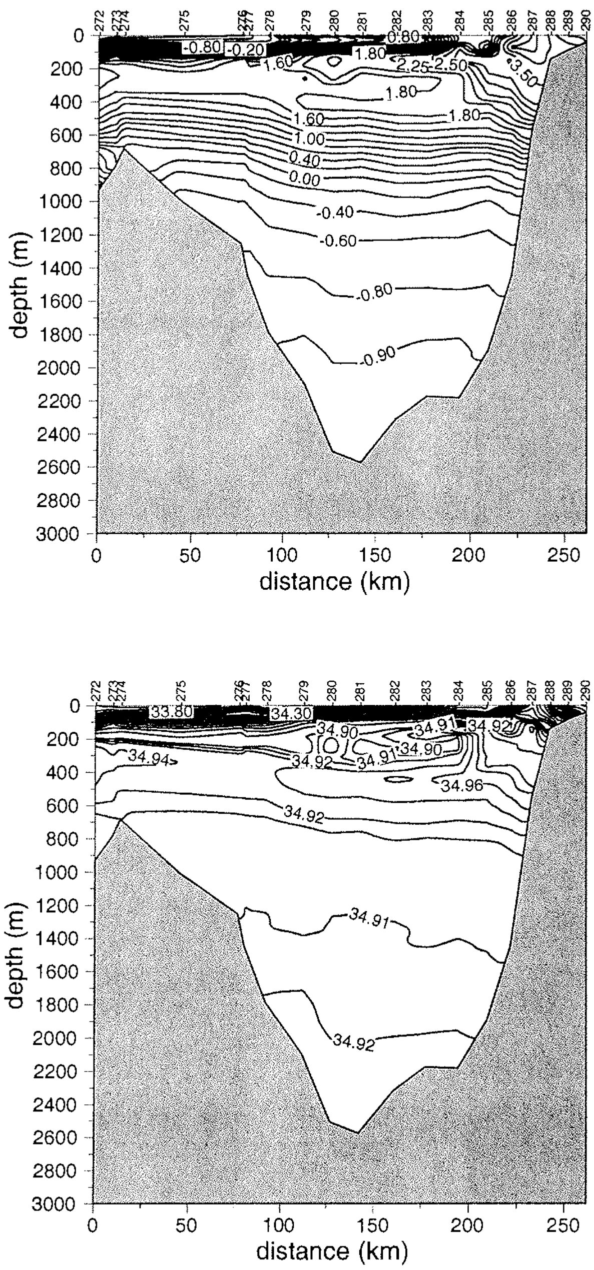

Fig. 9: Distribution of potential temperature and salinity at section IV.

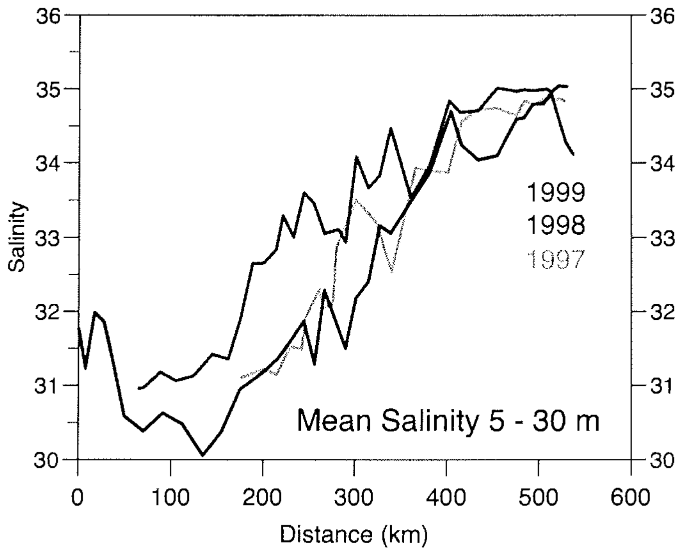

Fig. 10: Mean salinity in the layer 5 –30 m in Fram Strait (Section II) in the summers 1997, 1998 and 1999. Distance is measured from position 79°N, 16°18'W

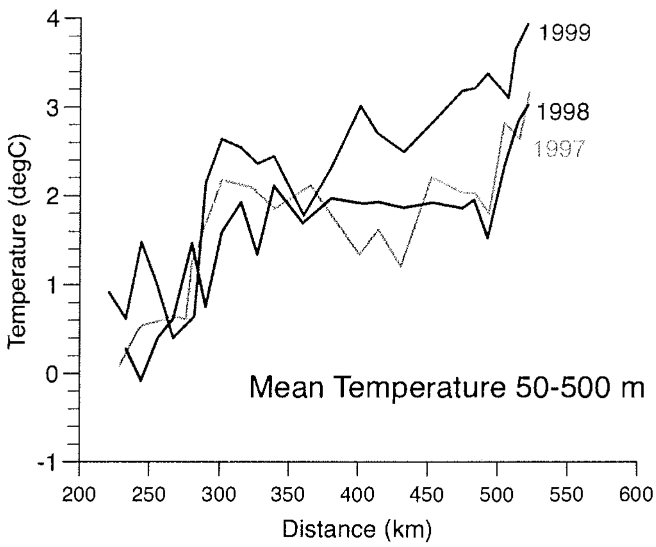

Fig. 11: Mean temperature in the layer 50-500 m in Fram Strait (Section II) in the summers 1997, 1998 and 1999. Distance is measured from position 79°N, 16°18'W

• Preliminary results of the time series

We had only two Aanderaa current meters in upper Arctic water layer (moorings V12 and V14, depth 62 and 66 m) in the western part of the Fram Strait. According to the records of these instruments, south-westerly flow predominated in this region (Fig. 12). Only in September 1999a, northwesterly direction of the monthly mean current was observed. Velocities, temperatures and salinities in the upper layer have a significant seasonal variability. The maximal values, >15 cm/s and >–1.5°C for current velocity and temperature respectively, occured in summer and autumn (Fig. 12). Minima of the temperature (<-1.7°C) and current speed (<5 cm/s) were observed in winter. Salinity was highest (>34.0) in summer and lowest (<33.5 psu) in September-October (Fig. 12)

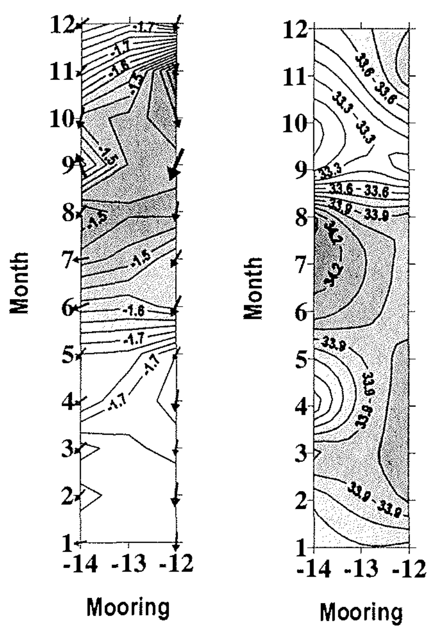

*Fig. 12: Monthly mean values of current and temperature **(A)** and salinity **(B)** in the upper Arctic water (about 60 m depth) in the western Fram Strait. Note that month 1 is Jan 1999 and month 12 is Dec 1998.*

The instruments in about 250 m depth, representing the Atlantic Water layer, show positive temperatures everywhere during all the year. Maximum values >3.5° C were reached in December and in summer. The maximum in August 1999 is due to a general increase of the temperature of the Atlantic layer in 1999 as compared to 1998 (not shown here, but see Fig. 11 for comparison of CTD-surveys). The circulation in the Atlantic Water layer has a stable structure in the period of the observations (September 1998 to September 1999) (Fig. 13).

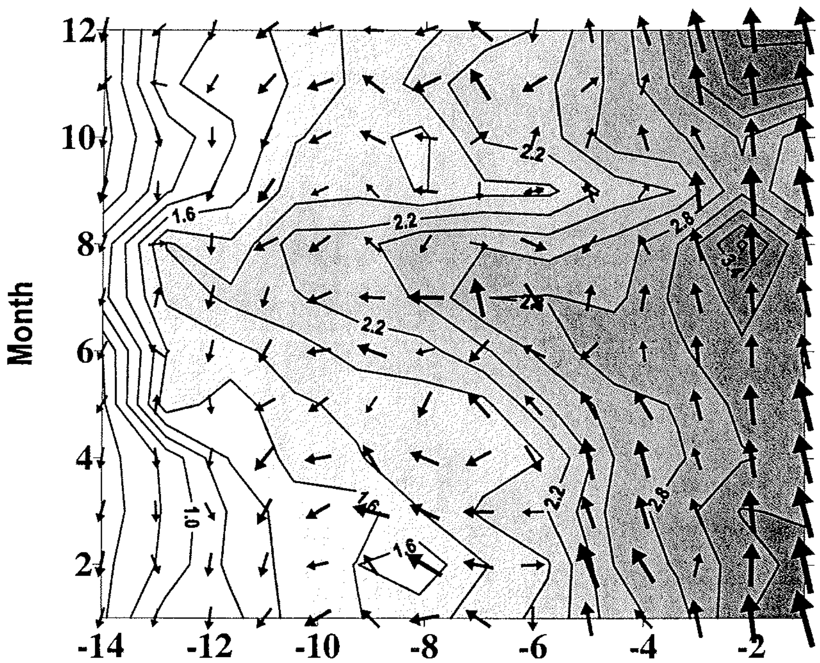

Fig. 13: Monthly mean values of current and temperature in the Atlantic Water layer (instruments at about 250 m depth). Note that month 1 is Jan 1999 and month 12 is Dec 1998.

Maximum daily mean velocities up to 30 cm/s occurred in the West Spitsbergen Current. The currents had about northern direction and their month to month changes were not significant. In the western part of Fram Strait, currents had opposite direction and velocities of up to 5 cm/s. The westward flow in the central part of the strait documents the recirculation of Atlantic Water. The negative, but high (R= 0.61) correlation between the daily mean northward component of the flow in the eastern and western part of the Fram Strait (Fig.14) indicates that recirculation takes place as a coherent flow over at least 200 km.

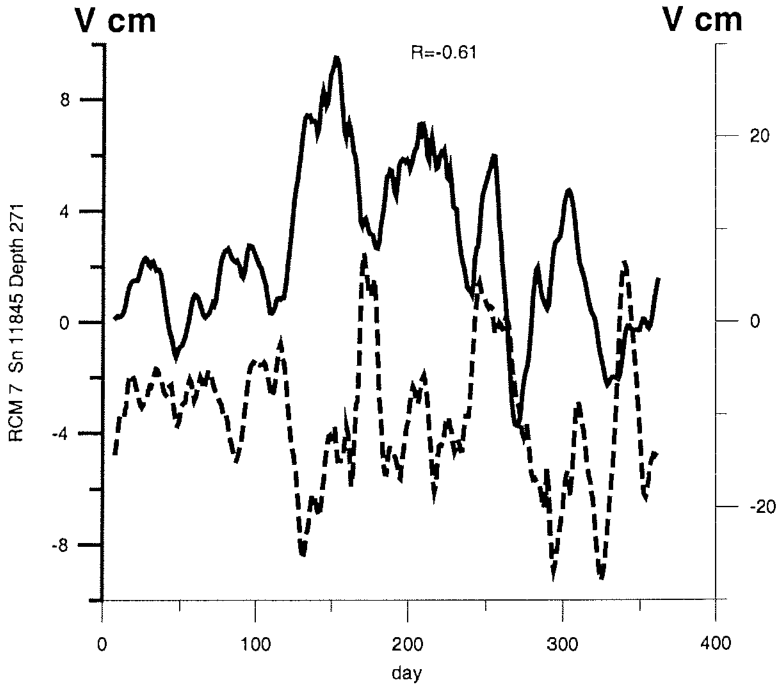

Fig. 14: Running average over 11 days of the daily mean northward component of the flow in the Atlantic layer for the eastern part (solid line) and the western part (dashed line) of the Fram Strait.

Similar as in the Atlantic layer, at the depth of about 1500 m the flow is southward in the east and northward in the west (Fig. 15). However, in the central part of the strait, there is no longer a coherent recirculation and the currents have unstable directions. The gradient of the temperature in this layer is opposite to the temperature gradient at the upper levels (Fig. 15), i.e. it is warmer in the eastern part and colder in the western part throughout the year which agrees with the synoptic survey of the CTD-section (Fig. 7). Contrary to the upper layers there is almost no seasonal variation of the temperature at 1500 m.

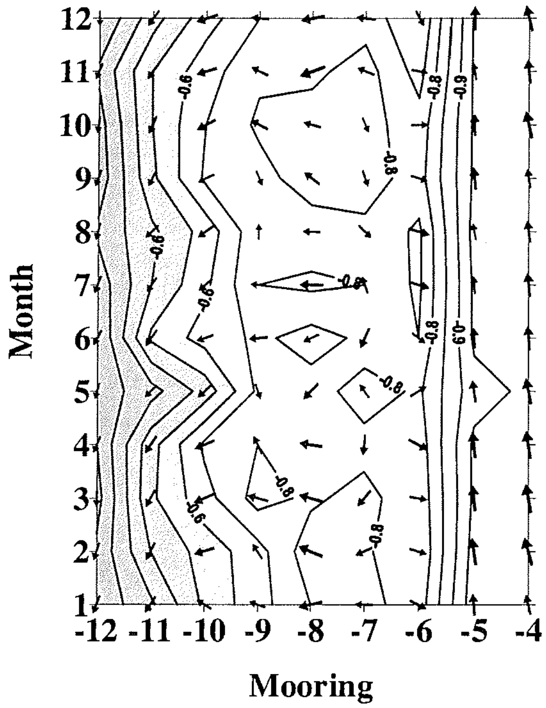

Fig. 15: Monthly mean values of current and temperature at about 1500 m. Note that month 1 is Jan 1999 and month 12 is Dec 1998.

The structure of the currents in the bottom layer (Fig. 16) is almost like that at 1500 m. There are stable currents with opposite directions in the western and eastern parts of the strait. In the central part of the strait, the flow has variing directions and is sometimes divergent possibly caused through the local topography. The temperature in the bottom layer has almost no variability throughout the year, even at the shallower depths of the continental slopes off Spitsbergen and Greenland.

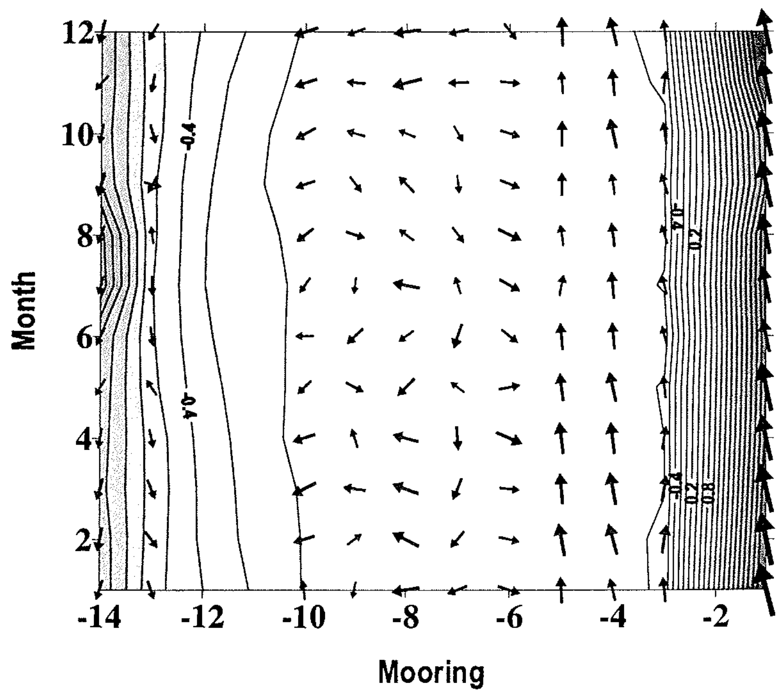

Fig. 16: Monthly mean values of current and temperature in the bottom layer. Note that month 1 is Jan 1999 and month 12 is Dec 1998.

- Shelf-slope interactions in the western and eastern Greenland Sea
  Schauer, Schütt, Verduin, Wisotzki (AWI)

Whereas in the Nordic Seas the ventilation of deeper layers is dominated by open-ocean convection, in the Arctic Ocean, the sinking of shelf water plumes is the major ventilation process. Dense water is formed by brine release during freezing and accumulates in appropriate shelf regions. It spreads in plumes along the bottom to the shelf edge and sinks to deeper layers in the basins. En route, the plumes may incorporate sediment and transport material down the slope. As a prototype for Arctic thermohaline shelf plumes, the flow of winter water from the Storfjord to the West Spitsbergen Current was investigated with moorings and hydrographic work since 1997 (Fig. 6, section I). A related project which aims to find out whether sediment driven plumes occur on the East Greenland continental slope started with this cruise (Fig. 6, section V). Both projects are part of the BMBF funded programs "ARKTIEF I" and "ARKTIEF II".

One mooring (S1, Appendix 5) was recovered at the Barents Sea shelf edge which was instrumented to monitor the current velocity, temperature and salinity of the Storfjord dense water plume when it approaches the shelf edge. To study the spatial structure, a hydrographic section was carried out parallel to the shelf edge (Fig. 17). At some selected stations water samples were taken for the determination of the suspended sediment carried by the bottom water plume. The samples were filtered onboard and the filtrate will be analysed at home for its content of seston, particulate organic carbon (POC), particulate organic nitrogen (PON) and biomarkers.
As in previous years, a clear signal of dense winter water carrying suspended matter was present at the shelf bottom. The densest bottom water was about as cold and saline in 1999 as in 1998. Since that late in summer the plume flow occur intermittant rather than continuously it cannot be decided from hydrographic observations alone whether the change reflects interannual variation or whether it is caused by short term fluctuations.

At the opposite site of the Greenland Sea basin (Fig. 5), a mooring (AWI419) was deployed for a pilot study to monitor intermittantly occurring strong bottom currents which were observed in that area earlyer. The mooring was positioned in a submarine channel which runs from the upper continental slope to the abyssal sea. The channel was surveyed with the ROV (Remote Operating Vehicle) „VICTOR 6000", during the first leg of the cruise, ARKXV-1 (Krause, Cruise Report ARKXV/1, Reports on Polar Research, 2000). Such channels might be related to or even maintained by strong bottom currents. The mooring contains sediment traps in order to study the possible role of particle delivery from upper layers to trigger the process. Close to the mooring site, a CTD section was carried out (Fig. 18).

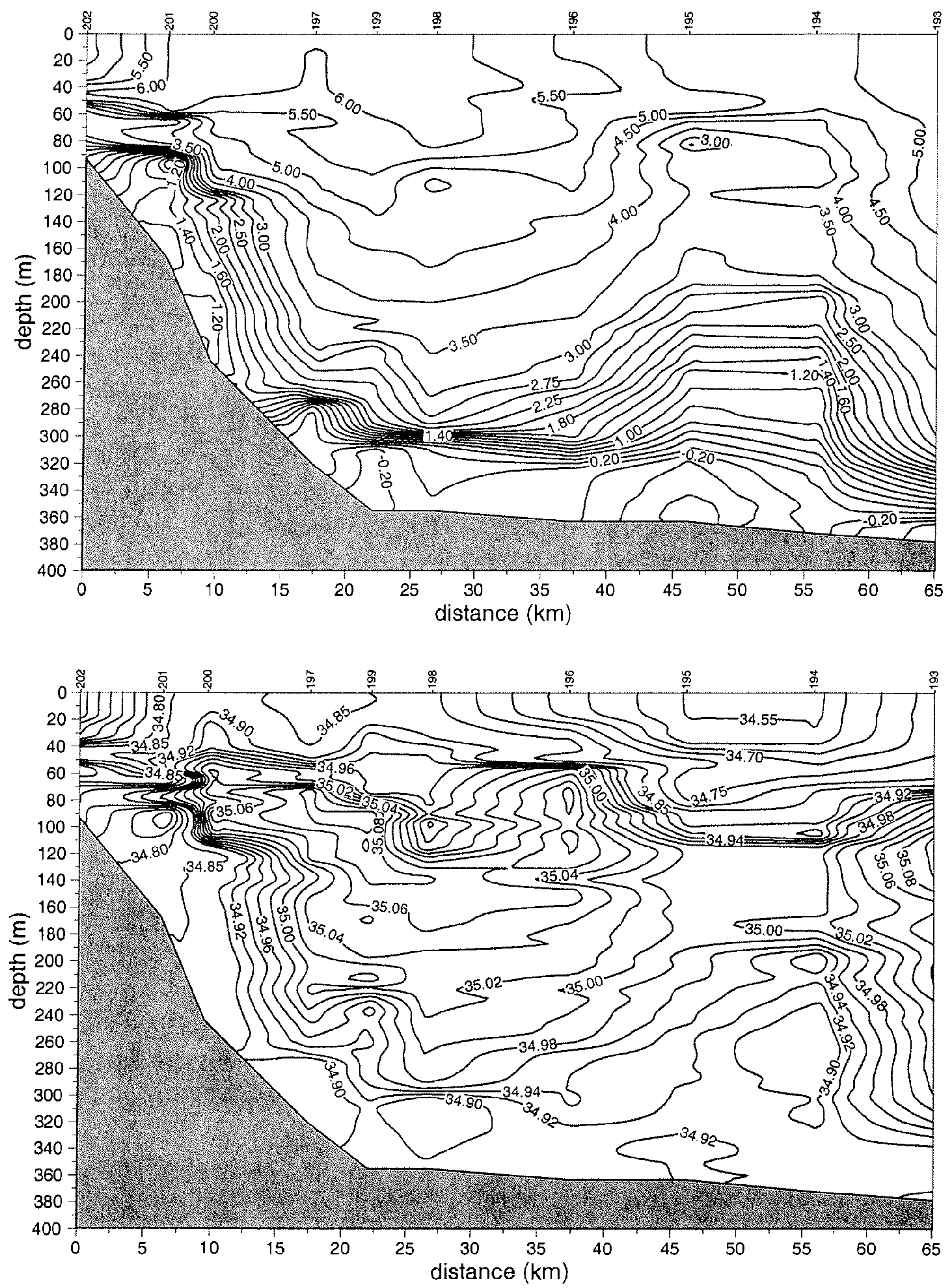

Fig. 17: Distribution of potential temperature and salinity at section I.

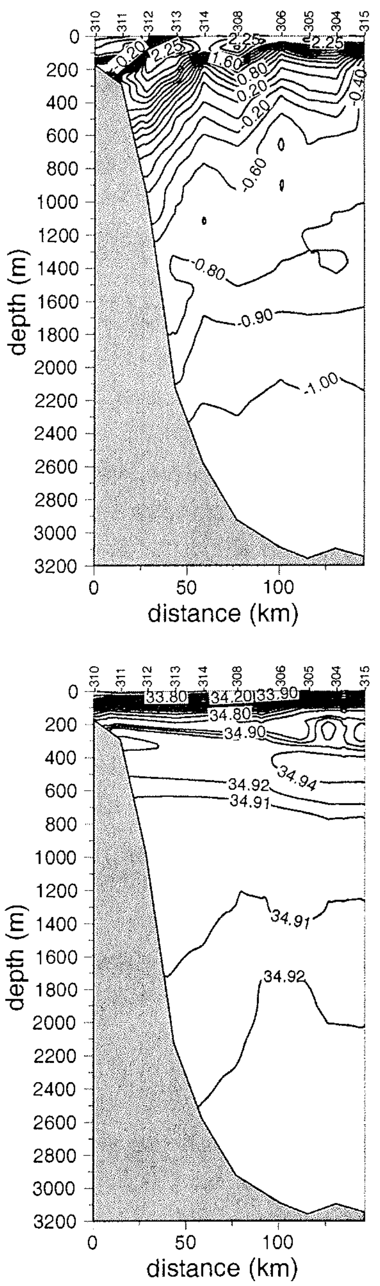

Fig. 18: Distribution of potential temperature and salinity at section V.

Distribution of oxygen and nutrients

Lipizer, Civitarese , Guerra (IST)

Chemical oceanography during this cruise contributed to the European research project VEINS. In order to characterise the water masses in this area according to chemical parameters and to estimate fluxes of dissolved matter between the Arctic and the Nordic seas a total of 80 hydrographic stations have been sampled. With the rosette sampler in combination with the CTD, about 1250 samples were collected for the analysis of dissolved oxygen and inorganic nutrients (silicate, nitrate, nitrite and phosphate) which were measured within a few hours after collection. Dissolved oxygen was determined according to the Winkler method (Strickland and Parson, 1972) using potentiometric titration, and inorganic nutrients were determined colorimetrically with an Autoanalyzer system. The determination of inorganic nutrients is based on the methods described by Armstrong et al. (1967) and by Grasshoff et al. (1983). At 20 stations in Fram Strait (sections II and III), about 200 samples have been collected for the analysis of total dissolved nitrogen (TDN), phosphorus (TDP), and dissolved organic carbon (DOC). The analyses will be carried out at Istituto Talassografico di Trieste after UV photo-oxidation according to the procedures described by Walsh (1989) (for TDP and TDN) and Sugimura and Suzuki (1985) (for DOC). In addition to the analysis of water, the nutrient content of ice cores from 16 ice-stations (see Chapter "Sea Ice Biological Studies") has been determined. DOC, TDN and TDP analyses of the ice cores will be carried out at IST.

The general pattern of the nutrient and oxygen distributions along the Fram Strait resembles that observed in summer 1997 and 1998 (Schauer and Osterhus, 1997; Fahrbach, 1999). The surface layer is nutrient depleted only at the ice-edge, in concomitance with higher biomass (see Chapter "Plankton Ecology and Vertical Particle Flux"). The subsurface layer is dominated by the presence of Atlantic Water characterised by a higher oxygen level in the eastern and central part of the strait. The most striking feature in the western side is the outflowing Polar Water, recognisable by the high silicate core located at about 100-200 m over the Greenland shelf (Fig. 19).

Significant differences between the different years appear in the deeper layers (Fig. 20). Compared with the situation in 1997 and 1998, the oxygen content in the layer below 2000 m in Fram Strait has decreased by about 8 μmoles/dm^3 during this cruise. The weak decrease of the oxygen saturation percentage (from 87% to 85%) and the lack of a clear increase in the nutrient content from 1997 to 1999 suggest that the change in oxygen concentration could be linked to a change in the water mass composition rather than to the biological ageing of that layer. The temperature and salinity distribution seems to confirm this finding.

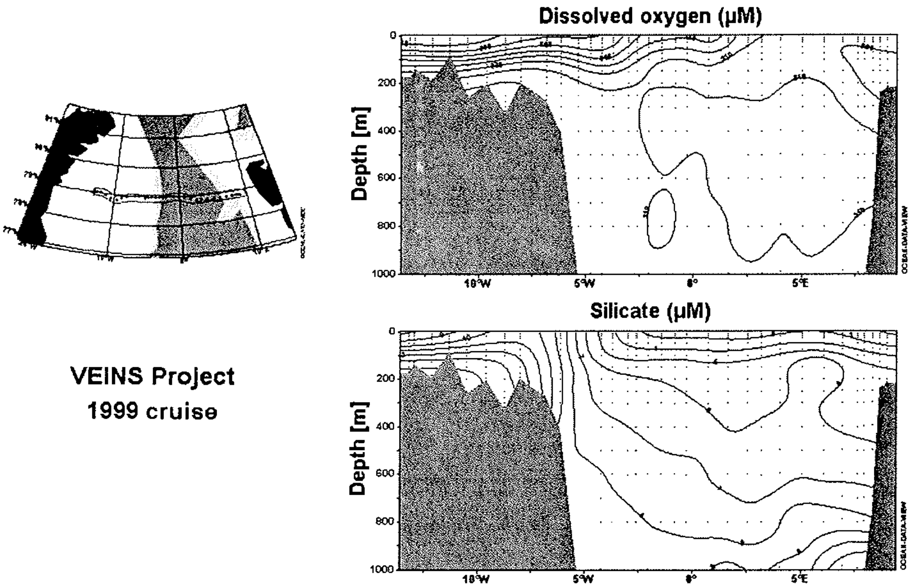

Fig. 19: Distribution of dissolved oxygen and silicate in the upper layer in the Fram Strait (section II).

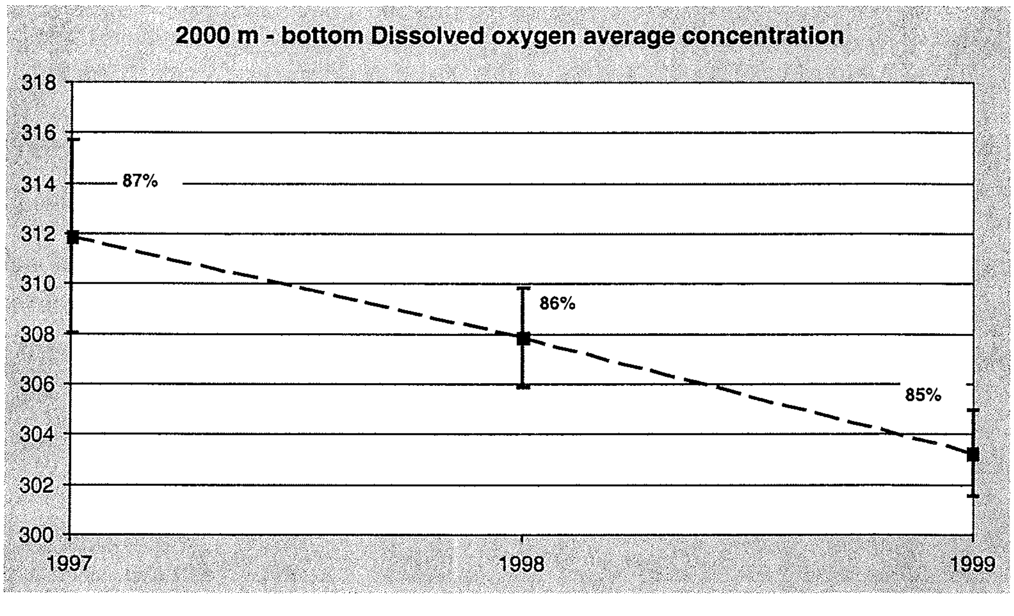

Fig. 20: Average concentration of dissolved oxygen in µmole/dm³ the layer below 2000 m in Fram Strait (section II) during three VEINS cruises.

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Optical measurements

Lindfors (UH)

At 30 stations, optical measurements were carried out in the surface water. An optical sensor, AC-9 (WetLabs), was used to measure the attenuation and absorption of light at nine different wavelengths. The instrument was lowered to a depth of 20 m from the starboard side of the ship at the same time as the CTD. Optical data provide an interface between physics and biology. From the recorded data we can calculate many physically and biologically interesting parameters, which are related to the light conditions in the near-surface layer of the sea. The most important application of the data is the possibility to study how the different wavelengths behave after penetrating the surface layer between atmosphere and sea. Characterizing different types of water masses is possible by these optical parameters.

Optical parameters are also of interest because they provide information about radiative transport of solar energy to deeper layers. Attenuation depends on wavelength, and the total radiation energy from sun and sky looses about half of its value in the first half metre of water. Seawater contains lots of particulate and suspended matter from land; its transport may be traced by optical measures. An example of collected data is given for station 55/207 in the West Spitsbergen Current (Fig. 21)

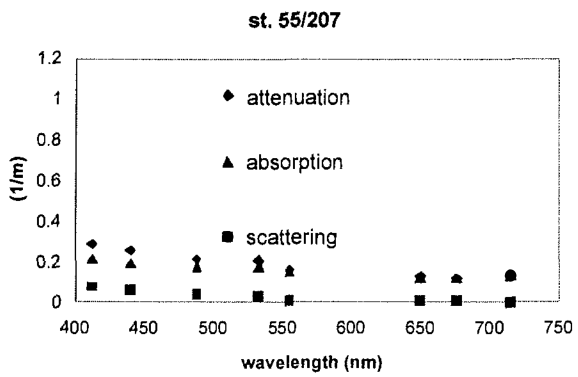

Figure 21: Attenuation, absorption and scattering of light at nine wavelengths in the West Spitsbergen Current (st. 55/207)

Plankton ecology and vertical particle flux

Krell, Lorenzen, Wang (AWI)

- Objectives

Latest investigations on the ecology of plankton in deep polar seas have shown a dominance of small autotrophic and heterotrophic flagellates in the pelagic system throughout the year; diatom blooms seem to be rather the exception. In the Greenland Sea and Fram Strait higher biomass can be correlated to hydrography and sea ice melting. The stability of the marginal ice zones and polynias might enhance primary production as well as determine plankton species composition, biomass, and vertical particle flux. During this expedition distribution of phyto- and protozooplankton in the water column were studied in its relations to hydrographical, chemical and other environmental conditions. The questions of interests were: Are there regional differences in the seasonal distribution patterns of phyto- and protozooplankton? What are the differences from year to year? What is the influence of the respective abiotic factors like hydrographical structure of the water column and nutrients availability? And what are the most remarkable features? How important is the influence of sea ice on the pelagic food web? How much particulary organic matter is transported to deeper waters and down to the sea floor?

- Work at Sea

At about 67 oceanographic and ice stations water samples were taken with the rosette sampling system attached to the CTD. On each station subsamples were obtained between two to ten discrete depths from the surface down to 300 m. Chlorophyll-a and phaeopigment concentrations were measured on board with a Turner Design Fluorometer after filtration of the samples, homogenisation and cold extraction in 90% acetone. Samples for species anlysis (ca. 200 ml) were fixed with hexamine-buffered ca 20% formalin (final concentration 0.5%). Microscopical analyses will be carried out in the home laboratory to investigate the distribution and biomass of the phyto- and protozooplankton. At selected stations additional samples were obtained in the upper 300 meters and in deeper layers for the following parameters: Samples for particulate organic carbon / nitrogen, DMSP, and biogenic silica were filtered on precombusted glassfibre filters (POC/PON, DMSP) or cellulose acetate filters (silica) and stored at -20°C (DMSP shock-frozen in liquid nitrogen) for later analysis in the home laboratory. Delicate algae and protozooplankton (> 2μm) as well as fecal pellet samples were collected via inverse filtration above and below the pycnocline at about every other station. The samples were fixed with hexamine-buffered formalin (final concentration 1 %) and will be analysed under the microscope at AWI. At some stations a multinet (20 μm mesh width) was towed down to 10m, samples were fixed with hexamine-buffered formalin (final concentration 2 %) and will be analysed under the microscope at AWI.

Furthermore on position 74° 25 N 10° 15W an oceanographic mooring with two sediment-traps (at 300 m and 3050 m) were successfully deployed to analyse the seasonal vertical flux down to the bottom for one year. Additionally seston samples were taken in certain depths of the whole water column of the mooring station. They were filtered on preweighted glassfibre filters and stored at -20°C for later analysis in the home laboratory.

- Preliminary results of the biomass distribution (Chlorophyll-a):

Detailed analysis of the data will be carried out later. Only a few of the observations can be presented in this report. In general the chlorophyll-a values were low. The level of 1μg/l was only exceeded at some stations: at station 209 close to Spitsbergen, and at stations 219, 226 – 247 in the western Fram Strait (section II). Stations 226-233 were situated in the transition zone between warm Atlantic and cold Polar water with a very stable surface layer. The other stations with higher chlorophyll-a values were further west in relatively cold and low salinity water indicating a phytoplankton biomass increase close to the ice edge. All other stations had chlorophyll concentarions below 1μg/l; stations under stronger ice exhibited values between

0.1μg/l and 0.5μg/l. Almost no chlorophyll-a was found in depths greater than 100m. All other samples mentioned above will be analysed at AWI.

Heavy metals in zooplankton

Zauke, Maletzke, Scharvogel (COUO)

- Aims

Recent studies on polar crustaceans showed that metal concentrations in these organisms are not generally at background levels, especially regarding cadmium in certain species (Hargrave et al., 1992; Petri & Zauke, 1993; Ritterhoff & Zauke, 1997b, c; and the literature cited therein). This high ability for accumulation of potentially toxic metals requires efficient mechanisms of storage and detoxification. In this context, metal binding proteins (e.g. mertallothioneins) play an important role in organisms from temperate and polar waters (Roesijadi, 1992; Ritterhoff & Zauke, 1998). We aim at investigating these problems in more detail using different Arctic crustaceans and some other taxa. Our approach is to combine field studies and toxicokinetic experiments on board, following the uptake and depuration of metals in the organisms. Thus, we intend to verify toxicokinetic model parameters for zooplankton collectives from the Fram Strait and Greenland Sea obtained within the Polarstern cruise ARK IX/1b (Ritterhoff & Zauke, 1997a, d).

- Methods

Meso- and macrozooplankton for determination of metals was mainly sampled along transects in the Fram Strait around 78-80°N (14 Stations), North of Svalbard around 81°N (5 Stations), South of Svalbard around 76°N (2 Stations) and on the East Greenland shelf around 75°N (3 Stations). Samples were obtained by vertical Bongo hauls (mainly 1000 - 0 m; hauling at 0.3 m s^{-1}; mesh size 100 and 310 μm, respectively), by oblique RMT tows trawled with 1 - 2 knots (0 - 1000 - 0 m; hauling at 0.4 m s^{-1}; mesh size 4.5 mm), by Agassiz Trawl trawled with 1 knot for 10 minutes above ground (100, 800 and 1000 m; mesh size 1 cm) and by deploying traps supplied with fish, meat and zucchini pie at ice floes to attract amphipods. Zucchini pie gave the best although not spectacular results. Organisms were identified to species level (if possible), sorted and immediately frozen at -27°C. Special care was taken to avoid contamination, e.g. by maintaining animals always in water or closed containers. Occurrence of paint particles or other materials was excluded by close inspection of each specimen collected using a binocular microscope.

In total, 9 toxicokinetic experiments were performed with the species *Themisto abyssorum*, *Themisto libellula*, *Euchaeta glacialis*, *Calanus finmarchicus*, *Hymenodora glacialis* and *Gammarus wilkitzkii*. Mainly a mixture of cadmium, lead, copper and zinc was employed, e.g. at exposure levels of 1.5 μg Cd l^{-1}; 3.0 μg Pb l^{-1}; 20 μg Cu l^{-1} and 100 μg Zn l^{-1}. Additional tests were run with a mixture of 3.0 μg Cr l^{-1}; 3.0 μg Ni l^{-1} and 1.5 μg Co l^{-1}. The experiments were set up as semi-static tests with daily renewal of test solutions, employing uptake and depuration phases of 5-6 days. During uptake phases the animals were exposed to the corresponding metal mixtures, while during depuration phases the animals were kept in clean sea water, taken at depth greater 200 m. Sampling of organisms and test water was done on each day of the trial.

- Results

During the cruise only the animal and water samples could be obtained, while the determination of metals will be done in the laboratory. Regarding the field study, a total of 274 samples were collected, including, for example, the copepods *Calanus finmarchicus*, *Calanus hyperboreus*, *Euchaeta norvegica*, *Euchaeta glacialis* and *Metridia longa*, the amphipods *Themisto abyssorum*, *Themisto libellula* and *Gammarus wilkitzkii*, the decopod *Hymenodora glacialis*, the euphausiids *Meganyctiphanes norvegica*, *Thysanoessa inermis* and *Thysanoessa longicaudata*, the ostracod *Conchoecia borealis* and the chaetognath *Eukrohnia hamata*. Regarding the toxicokinetic experiments, a total of 528 animal and 132 water samples were collected.

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Marine fungi in the Arctic Ocean

Schünke, Bröhl, Krack (AWI)

- Objectives

The mycological investigations during the expedition focused on the distribution of marine fungi and fungal like protists in different habitats of the Arctic Ocean and the Fram Strait. During the search for new bioactive metabolites within the marine environment, marine fungi have been described as a source of active substances recently. The strong association of the fungi suggests mechanisms of interactions among fungi and other sea inhabitants. Although only a few marine fungi were investigated for their metabolite production, a great number of metabolites with bioactivity was found.

The collection of samples should enable to detect free living fungi as well as associated species. Therefore, water and sediment samples were taken to isolate solitary forms of marine fungi, whereas net catches were used to detect associated fungi. The observation of sea ice samples should clear the participation and interaction of fungi in the microbial community of this special habitat and their possible role in the microbial loop.

Culturable fungi will be isolated and their physiological properties will be observed especially in view of their production of secondary metabolites. Bioactive substances of the isolated marine fungi will be detected by co-operating partners in the project "Active Substances of Marine Fungi" within the marine natural product research. Further biochemical investigations of the structure and the mechanisms of action will follow to yield substances of pharmaceutical interest.

- Sampling

A wide spectrum of material was collected for the mycological investigations during the cruise. The water samples were collected in four different areas: south and north of Spitsbergen and at two stations in the West Spitsbergen Current and the East Greenland Current in Fram Strait. At each station, samples were collected from three depths (surface, mid water, bottom layer) with Niskin bottles from the rosette. At 6 further stations, samples were taken from a box core: water was collected from the surface of the sediment and sediment samples were taken from different depths.

Fungi associated with macro organisms and plankton were collected at 9 stations by net catches with the Agassiz trawl, Apstein net, Rectangular Midwater Trawl and a hand net. Additionally a piece of drifting wood was recovered, which was well colonized by macroscopic organisms. The mycological investigation of the sea ice community was of main interest. Therefore we have sampled sea ice at 9 ice stations including new ice, first-year old ice and multi-year ice. Additional ice cores were collected at the same stations and stored for further observations. The samples were processed immediately to prevent changes of microbial population during a further storage. Samples were homogenised, concentrated and plated out on nutrient media for counting and isolation of higher fungi. The incubation was carried out at two temperatures to enhance the development of mesophile and psychrophile species. A second medium was used for the growth of yeasts. Furthermore, the fungal-like protists were baited with pine pollen in a liquid cultivation. For the observation of total marine population, plating methods for the enumeration of marine micro-organisms are not suitable, neither in bacteriology nor in mycology, since with plating only culturable organisms can be detected. However, plating allows the isolation of the fungi. Therefore, we used the plating method to isolate fungi and to determine the abundance.

During the cruise 116 samples were prepared, plated and inoculated. Incubation and evaluation of developing fungi will continue, especially the incubation of psychrophilic species and fungal like protists.

- Fungal Distribution

Because the counting of colony forming units is not finished, exact numbers of fungal colonization can not be evaluated now. Only some mesophilic fungi have developed so far. The fungi detected so far seem to show a specific distribution of the fungal colonization depending on the kind of samples. Hyphomycetes seem to be most abundant in the water column and in ice, whereas yeast organisms were mainly detected in plankton and sediment samples. More detailed analyses on population will be done after further incubation and evaluation.

- Isolation

First mesophile isolates were obtained from the plates inoculated at 20 °C. Further morphological and physiological characterization of the isolates will follow on land. Also, the identification of yeasts based on physiological parameters in biochemical assays will be done on land.

- Outlook

We will continue the evaluation of the fungal population and further isolation at our home laboratory. The investigation of the isolated fungi will follow including the identification, physiological characterization of e.g. their secondary metabolism. Bioactive metabolites with usefull pharmacological potential will be made available for further development.

Sea ice biological studies

Fehling, Gradinger, He, Meiners (IPÖ)

- General introduction

Sea ice floes are the habitat for the so-called sympagic community which consists of bacteria, protists and metazoans. During this expedition we studied physical, chemical and biological properties of ice floes to characterize the seasonal changes occuring in the autumn-winter transition. Ice samples were obtained by means of ice coring or brine sampling, under-ice studies were done by sampling water from the uppermost 10m of the water column. Additional watersamples were taken in the open water with the CTD at 10m waterdepth in the Fram Strait (section II). On six first-year and multi-year ice floes the sampling was done directly from the ship, six additional floes were reached by helicopter. Our investigations focused on the quantitative and qualitative investigation of the sea-ice based microbial food web. Additional samples were collected from different stages of new ice formation (grease ice, nilas , pancake ice), where we investigated only the biomass and composition of the initial ice communities.

- Physical, chemical and biological properties of Arctic sea ice

At 12 stations we sampled several ice cores to measure vertical profiles of the following parameters:

- ice temperature
- ice bulk salinity
- chlorophyll *a* and phaeopigment concentration
- nutrient concentrations (NO3, NO2, SiO4, PO4 – measurements done in co-operation with the working group of IST (Chapter „Distribution of Oxygen and Nutrients")
- particulate organic carbon (POC) and nitrogen (PON)

• dissolved organic carbon (DOC) and dissolved organic nitrogen (DON)(measurements done in co-operation with the working group of IST (Chapter „Distribution of Oxygen and Nutrients“)
• organism abundances (bacteria, protists, metazoans)
• concentration of transparent extracellular particles (TEP)
• electron transport capacity (ETS).

Most of the analyses will be conducted in the home laboratories, onboard Polarstern we could only determine the first 4 parameter sets mentioned above. A typical example of the available data set is given for the first-year ice station 266 (Fig. 22) and the multi-year ice floe 280 (Fig. 23).

Lowest temperatures were mostly observed in the upper part of the ice cores, due to the surface cooling by the low air temperatures. Highest algal biomass was always found in the bottom parts of the ice floes. High biomass was also encountered in the new ice samples, specifically in thicker nilas samples, pointing towards the existence of autumn algal blooms in Arctic sea ice.

- Formation of resting stages

Some members of the sympagic community like dinoflagellates and chrysophytes are able to form cysts. Cyst formation occurs when environmental conditions become unfavourable and is therefore a likely survival strategy for ice protists in the autumn-winter transition period when the dark polar winter begins and salinity increases within the brine channel network. Cells react to changing environment by building a thicker and differently looking cell-wall and by slowing down their metabolism. As cysts look very different to the motile stages, it is necessary to do hatching experiments in order to assign the cysts to the known motile forms. For that purpose life samples from the ice and water column are cultured for further analysis in Kiel. During life-microscopy of ice samples onboard "Polarstern“ cysts were already found and used for the establishment of first cultures. Video-recording of living specimens will support species identification in fixed samples. However, detailed taxonomical investigations on the cysts and different protist taxa have to be done by light and electron microscopy in Kiel.

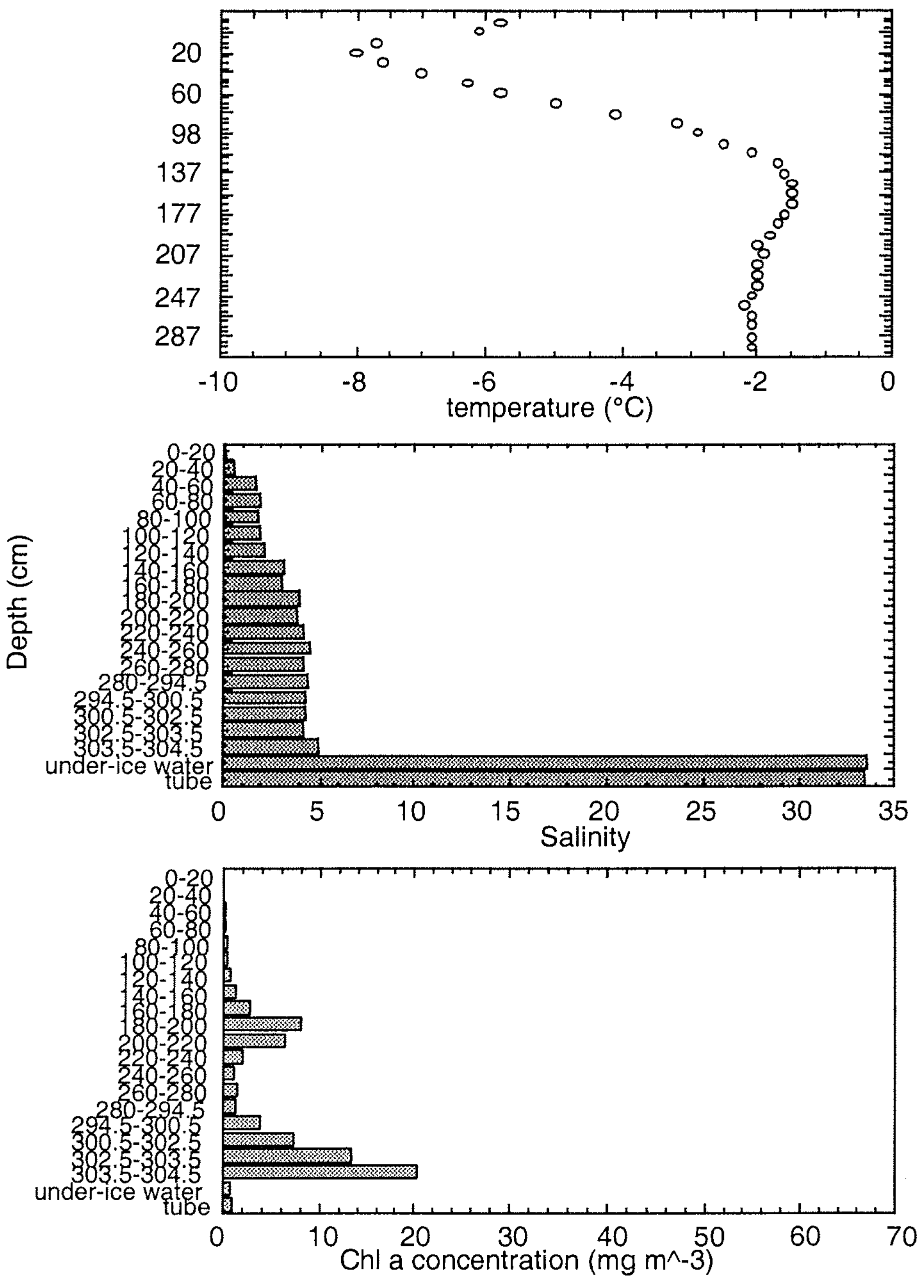

Fig. 22: Vertical distribution of temperature, salinity and algal pigments (chlorophyll a) in the ice floe at station 266.

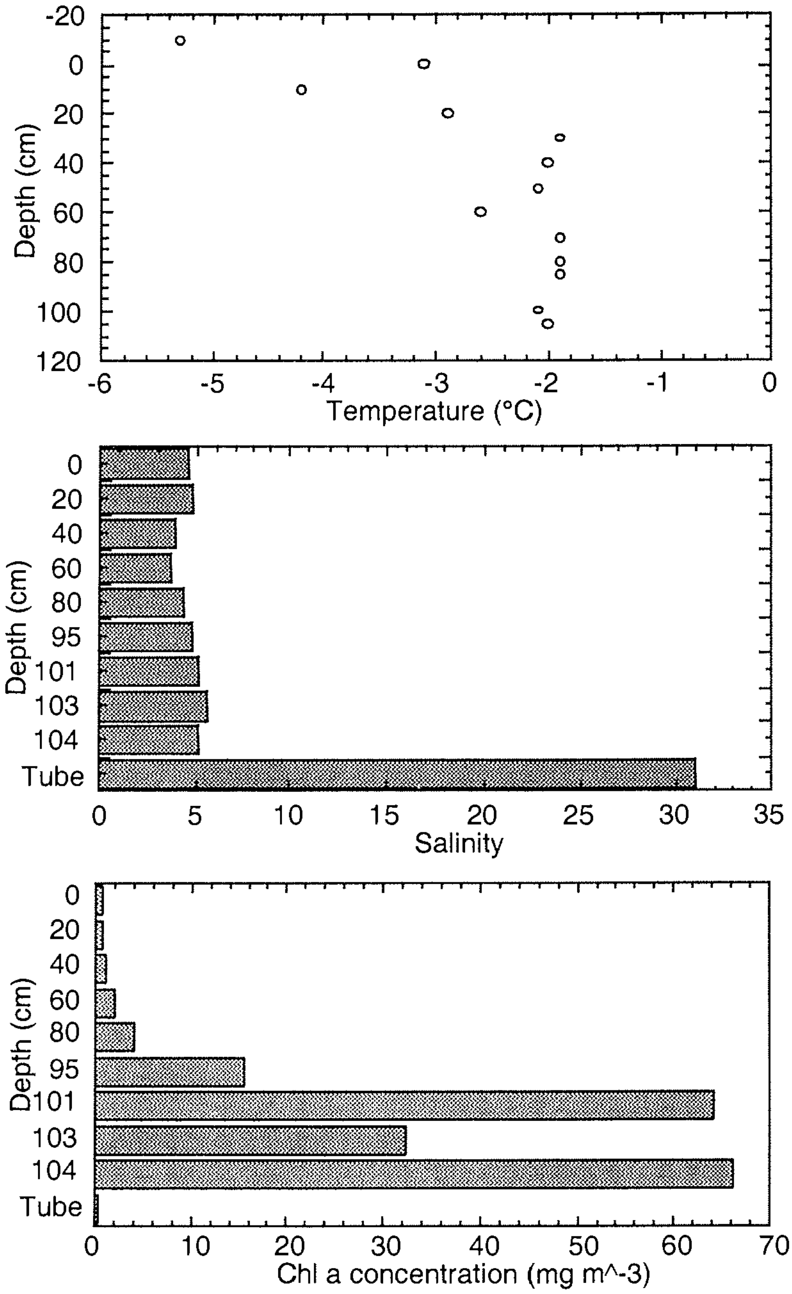

Fig. 23: Vertical distribution of temperature, salinity and algal pigments (chlorophyll a) in the ice floe at station 280.

- Investigation of the structure of the sea ice microbial food web

A. Serial dilution experiments and ingestion of fluorescent labeled bacteria

Different approaches were used to investigate the trophic relations between sympagic bacteria, algae , proto- and metazoans. On three ice floes, we collected larger amounts of brine (15l) in sackholes and used it for serial dilution experiments which were analysed by direct counting using epifluorescence microscopy onboard "Polarstern". These experiments will allow the determination of growth and grazing rates on bacteria and algae. Additional uptake-experiments with fluorescent labelled bacteria (FLB) were used to determine ingestion rates of flagellates and ciliates on a low taxonomic level.

B. Cell counts, grazing experiments and viability tests with Arctic sea ice organisms

In order to improve the general knowledge about sympagic organisms we took 10 ice cores in the Greenland Sea and northern Fram Strait to determine abundances of bacteria, protists and meiofauna. Ice cores were cut into sections of 1 - 20cm. These sections were melted in the dark by addition of seawater to avoid osmotic stress. Melted samples were subsampled and fixed either with formalin (1% final concentration) or with Bouin`s fluid (1% final concentration). Bouin fixed samples will be used for meiofauna investigation and taxonomy of ciliates. Formalin preserved samples were filtered onto 0.2μm and 0.8μm polycarbonate filters and stained with DAPI. These filters will be counted in the home laboratories using epifluorescence microscopical techniques to obtain vertical profiles of cell numbers and biomass of bacteria and protists. The estimated biomass of protists will be used to calculate the grazing impact by general allometric equations.

These indirect estimates will be compared with the results of direct grazing measurements which were conducted at 6 stations (see also above). Fluorescently labelled bacteria (FLB´s) were added to cultures, which were obtained by shaking 3 bottom segments (5cm thickness) of ice in 500ml of sterile seewater for 3 minutes. This method allows gentle extraction of protist-grazers without osmotic disturbance of the organisms. We measured the-long term disappearance of fluorescently labelled bacteria within the samples to provide data about the grazing impact of the total community. To check for discrimination of FLB´s additional experiments were performed using inhibitor-techniques. Both kinds of experiments were run as time-course experiments for 24 h. Subsamples were taken after 0, 6, 12, 18, 24 hours and fixed with formalin (1% final concentration). The decrease of the concentration of fluorescently labelled bacteria (FLB-experiments) and natural bacteria (inhibitor-experiments) will be determined in the home laboratories.

Viability test were run over the entire ice-thickness. 1cm segments of ice-cores from 6 stations were incubated with INT (0,02 % final concentration) in petri-dishes for 8h. INT is incorporated into living cells and is reduced to a red water-insoluble formazan-salt inside respiring cells. Using combined brightfield and epifluorescence microscopical techniques these experiments allow the quantification of total bacterial numbers and the number of actively (=respiring) cells. Cellspecific respiratory activity (formazan-grain-size) will be correlated to taxonomic groups (eukaryotes) and morphotypes (bacteria) after examination of the samples in our home laboratories.

In addition to this program we took bottom sections for the cultivation of different groups of sympagic biota (algae, protozoans and metazoans). Cultivated organisms will be used for further taxonomic work and additional grazing experiments in the home laboratories. Grazing studies will focus on the grazing impact to attached bacteria within artificial biofilms.

C. Measurement of the electron-transport-system (ETS) activity

To determine the activity of the ETS of melted ice-samples ice cores were cut into 1 - 20cm segments and melted in addition of 0.2μm filtered at 5°C. Subsamples were filtered on GF/F-filters and were frozen at -80°C until further analysis following standard procedures. In addition under-ice water samples and brine samples were collected to distinguish between metabolically different communities in these ice associated habitats. Diffferent communities will be characterised by their specific activation energy and their temperature-optimum of ETS activity.

- Measurement of transparent exopolymer particles (TEP)

Transparent exopolymer particles are a relatively new known class of particles produced from dissolved carbohydrate polymers exuded by phytoplankton and bacteria. While different studies indicate that TEP are important in the aggregation of diatom blooms, provide the matrix of marine snow, serve as a substrate and habitat for attached bacteria, the distribution, abundance and characteristics of this new class of particles within sea ice remain largely unknown. In order to improve our knowledge about TEP in sea ice we determined TEP spectrophotometrically (8 stations) and microscopically (3 stations) for entire ice cores. Ice cores were cut into 1 - 20cm segments and were melted by addition of 0.2μm filtered seawater. Subsamples were filtered onto 0.4μm polycarbonate filters (spectrophotometrically determination) and 0.2μm polycarbonate filters (microscopically determination). Filters were stained with Alcian-Blue and will be analysed in our home-labs.

Radionuclides in sea ice, water column, bottom sediments and benthic biota

Dethleff and Winkler (GEOMAR)

- Introduction

Arctic sea-ice widely contains fine grained sediments either incorporated as layers and diffusively distributed clouds or enriched in surficial patches after one or several melting cycles. The geological importance of sediment inclusions in Arctic sea-ice has been demonstrated by various studies conducted on the US-Canadian shelves (Reimnitz et al. 1993) and, particularly, in the Siberian shelf seas (e.g. Dethleff et al. 1998, Dethleff subm., Eicken et al. 1997). Accordingly, shelf surface deposits are entrained into newly forming ice through turbulent processes of suspension freezing thereby leading to strong regional shelf erosion. The incorporated material is exported from the shelf seas and, after melt release, contributes significantly to the sedimentary budged of the Arctic Ocean and the Northern European Atlantic. According to recent investigations, Arctic sea ice sediments partly contain enhanced concentrations of man-made radionuclides as compared to most shelf source sediments (e.g. Cooper et al. 1998, Landa et al. 1998, Meese et al. 1997, Nies et al. in press). Different studies identified particularly the Kara and Laptev Seas as potential source areas of contaminated sea ice sediments. Sea ice originating from the Kara Sea is preferrably transported toward - and melts in - the Barents Sea, while ice formed in the Laptev Sea is transported by the Siberian branch of the Transpolar Drift toward Fram Strait. Only little is known about the melt-release and fate of sea ice sediments and attached radionuclides in the Arctic region.

The purpose of our study is to investigate the occurrence and concentrations of different natural and man-made, short- and long-live radionuclides (^{7}Be, ^{210}Pb, ^{137}Cs, ^{238,239,240}Pu) in sea ice, sea ice sediments, water column, bottom sediments and benthic biota in the cruise area (Fig. 24). We will try to learn more about the impact of sea ice incorporated radionuclides on bottom sediment inventories in the ablation areas. A further target of the investigations is to figure out if radionuclide signals from Sellafield and LaHague detected in the environments sampled could be differed from signals originating from the Siberian Arctic. (e.g. Kara Sea)

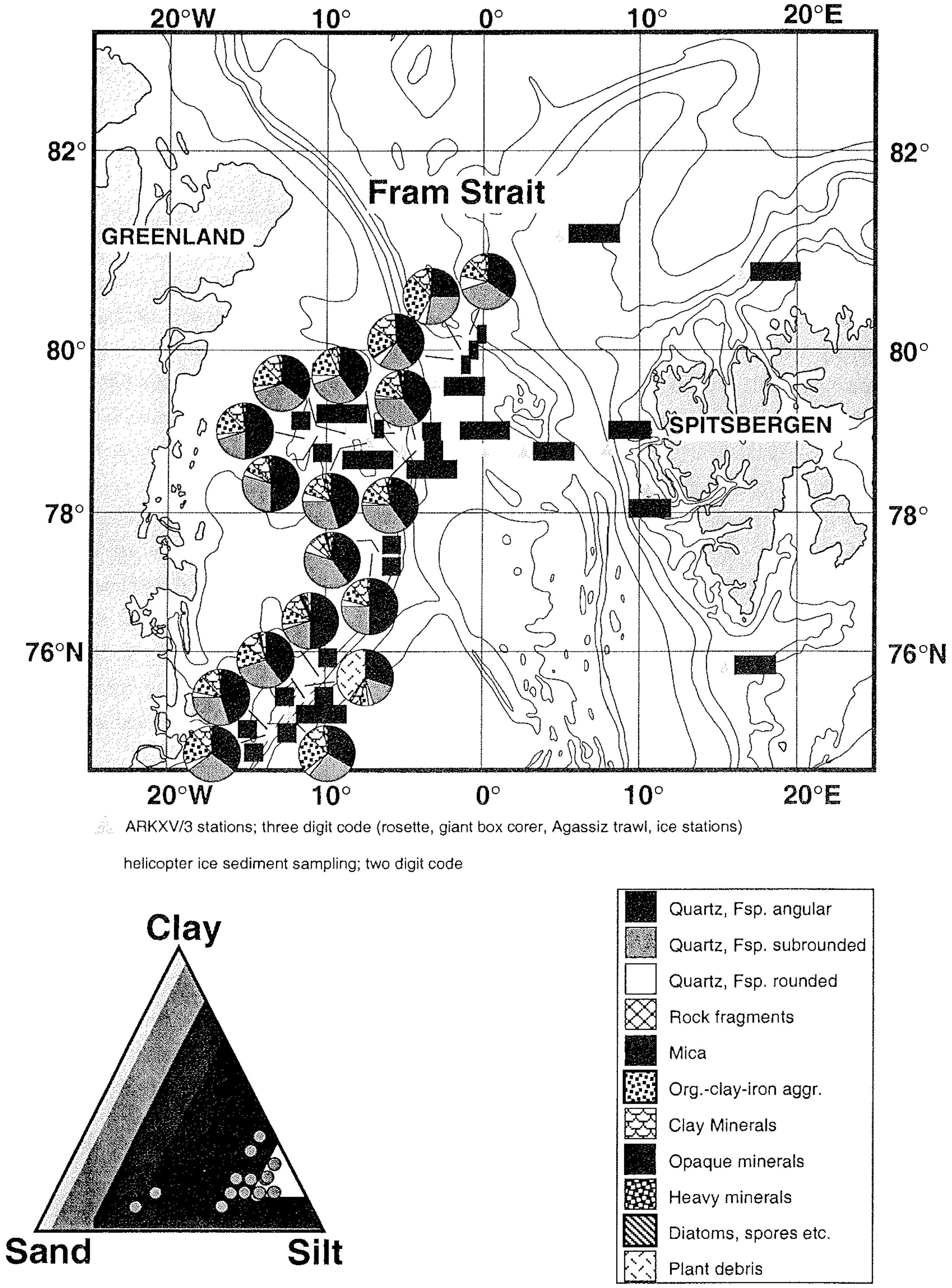

Fig. 24: Sampling locations and sea ice sediment compositions

- Field observations and sampling methods

Sea-ice observations were carried out during helicopter flights and from the vessel bridge. Ice sediments were obtained in western Fram Strait from enriched, patchy distributed surface layers and from different layers of tilted ice floes and ridges. For radionuclide analyses, ice cores were drilled and melted. Like ocean water samples from CTD/Rosette, the melted ice was pumped through a filtration candle into 100 l containers, acidificated with HCl down to a pH of 2 and run over an exchanger raisin of potassium-hexacyano-ferrate-(II)-cobaltate(II) (KCFC). Thereby, radionuclides were adsorbed from the dissolved phase with a chemical yield of >95 %. Bottom deposits were obtained by giant box corer. Samples of the surface mm were taken for different purposes (e.g. sedimentology). A core tube was taken from each giant box corer for paleoceanological and ^{210}Pb studies. Mixed surface sediment samples (0 - 20 mm depth) of ca. 400 - 800 g wet weight were stored frozen in plastic containers in order to determine ^{137}Cs and different other man-made radionuclides such as e.g. Pu. Benthic biota for radionuclide analyses were also stored frozen.
Smear slides were prepared from sea ice sediments and bottom surface deposits to roughly estimate the grain size distribution and mineralogical composition of the sampled material.

Further laboratory methods and quantitative analyses will include determination of sand/silt/clay percentages (wet sieving and Atterberg separation), silt grain size distribution (LaserGranulometer or/and Sedigraph), clay mineral assemblages (X-ray diffractometry) and radionuclide analyses (high purity germanium detectors - HPGe).

- Preliminary Results and Discussion

During ARKXV/3 cruise, unusual ice conditions with widely ice free water occurred in eastern Fram Strait and north of Spitsbergen. Thus, ice works were only conducted in western Fram Strait and on the E Greenland shelf. Ice works from our group were carried out at a total of 20 stations. At 2 of these stations, a total core-length of ca. 8 m sea ice was drilled, sawed into chunks, melted and filtered. Ice core lengths varied between 1.9 and 2.3 m. The ice thicknesses increased on the Greenland shelf toward the coast. Most of the drilled cores contained no visible particle inclusions or even turbid sections.

At all other ice stations (18), which were mainly accessed by helicopter, roughly 40 dirty sea ice surface sediment samples varying between tens and hundreds of gram weight were collected for different working groups. Observation revealed mostly low areal sediment load (<<5%) in sea ice of the northern investigation area, while pack ice in the southern part of the cruise track contained more sediment (5-20%). However, observations were not representative due to extended snow coverage.

6 giant box corers were taken on a transect across Fram Strait (≈78.5°N) at water depths varying between 200 and 2600 m. One additional box corerer was obtained in the outer Storfjord valley at 400 m water depth. Core success was between 44 and 55 cm. Water samples (70-110 l) for radionuclide analyses were taken from 3 different layers on a 4-station Fram Strait cross-section and in the outer Storfjord valley. One additional sample was obtained north of Spitsbergen from the Atlantic layer salinity maximum. Ice samples varying between 150 and 180 l were taken at 4 stations for radionuclide analyses. Benthic biota like ray fish, star fish and sponges were collected from two Agassiz trawls on the W Spitsbergen and E Greenland shelves, respectively. Smear slide analyses of ice surface and bottom sediments (not presented) reveal generally fine grained composition of the material with partly more than 90% in the fraction <63μm (Fig. 24). The sampled sediments consist mainly of silt sized, angular to subrounded Quartz and Feldspar. Partly, iron-organic-clay aggregates and plant debris revealed enhanced percentages (20-30%) in sea ice sediments, while rock fragments, mica and heavy/opaque minerals generally are generally less abundant (Fig. 24). Coarser grained sea-ice sediment was sampled at different southern ice stations on the Greenland shelf. The coarse material was partly enriched in plant debris which points to the entrainment of surface deposits through anchor ice formation or bottom adfreezing. The fine grained material was probably incorporated by turbulent oceanic mechanisms such as thermohaline convection, Langmuir circulation, wave action and tidal pumping. Most likely, the source areas of the sea ice entrained particles are located on the Siberian shelves or even in the western Arctic. This assumption may be supported by further sedimentological, clay mineralogical and radiochemical investigations in the home laboratories.

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Sea ice ridges

Lindfors (UH)

During several helicopter flights and ice stations, sediment samples were collected and at three ice floes, pressure ridge thickness was measured. The determination of sediment content and the analysis of chemical parameters, like heavy metal, will be done in the in Finland.

The thickness, height and shape of pressure ridges were measured by drilling a series of holes through the ridge (Fig. 25). Thickness of the ice was simply measured by coring with pre-marked drills. The aim for these studies is to collect data for computer models of sea ice cover aimed for increasing the safety of wintertime shipping.

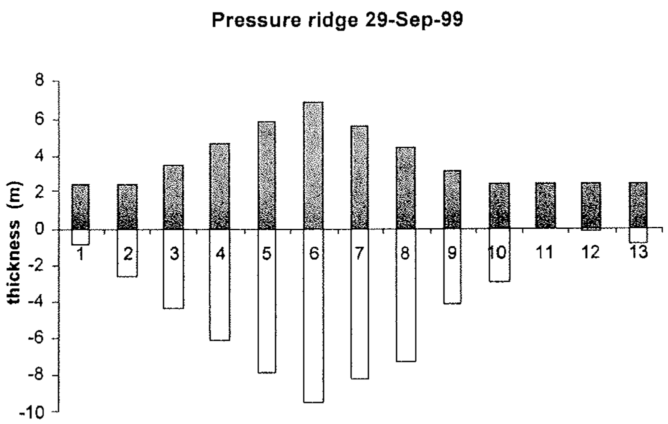

Figure 25. Thickness profile of a pressure ridge at 82°14.05´N, 10°12.36´E. The horizontal distance of the measurements varied between one and two meters.

Annex 1: Participants

Name		Institution
Brede	Thorsten	HSW
Broehl	Stefanie	AWI
Büchner	Jürgen	HSW
Buldt	Klaus	DWD
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Erdmann	Hilger	DWD
Fehling	Johanna	IPÖ
Fossan	Kristen	NPI
Gradinger	Rolf	IPÖ
Guerra	Bianca Rosa	IST
He	Jianfeng	PRIC, IPÖ
Krack	Axel	MPIB
Krause	Peter	HSW
Krell	Andreas	AWI
Lindfors	Antti	UH
Lipizer	Marina	IST
Lorenzen	Christiane	AWI
Macrander	Andreas	AWI
Maletzke	Tom	COUO
Meiners	Klaus	IPÖ
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Noack	Cornelius C.	UBTP
Pavlov	Vladimir	NPI
Roth	Peter	AWI
Schauer	Ursula	AWI
Schünke	Henning	AWI
Schütt	Ekkehard	AWI
Scharvogel	Heidi	COUO
Sonnabend	Hartmut	DWD
Thoms	Silke	AWI
Tverberg	Vigdis	UNIS
Verduin	Jennifer	AWI
Wang	Zipan	AWI
Winkler	Amelie	GEOMAR
Wisotzki	Andreas	AWI
Zauke	Gerd Peter	COUO

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Annex 3: Crew list

Pahl	Uwe	Master
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Schulz	Volker	Ch.Eng.
Rodewald	Volker	1. Offc.
Boche	Martin	2. Offc.
Fallei	Holger	2. Offc.
Mecklenburg	Gerd	Doctor
Hecht	Andreas	R. Offic.
Delff	Wolfgang	1. Eng.
Folta	Henryk	2. Eng.
Simon	Wolfgang	2. Eng.
Baier	Ulrich	Electron.
Bretfeld	Holger	Electron.
Fröb	Martin	Electron.
Holtz	Hartmut	Electron.
Piskorzynski	Andreas	Electron.
Loidl	Reiner	Boatsw.
Neisner	Winfried	Carpenter
Bindernagel	Knuth	A.B.
Bohne	Jens	A.B.
Hagemann	Manfred	A.B.
Hartwig	Andreas	A.B.
Moser	Siegfried	A.B.
Schmidt	Uwe	A.B.
Schultz	Ottomar	A.B.
Winkler	Michael	A.B.
Krösche	Eckhard	Storek.
Palm	Karl-Heinz	Storek.
Arias Iglesias	Enr.	Mot-man
Dinse	Horst	Mot-man
Fritz	Günter	Mot-man
Giermann	Frank	Mot-man
Fischer	Matthias	Cook
Möller	Wolfgang	Cooksmate
Tupy	Mario	Cooksmate
Völske	Thomas	Cooksmate
Jürgens	Monika	1.Stwdess
Czyborra	Bärbel	2.Stwdess
Deuß	Stefanie	2.Stwdess
Huang	Wu-Mei	2.Steward
Schmidt	Maria	2.Stwdess
Streit	Christina	2.Stwdess
Yu	Kwok Yuen	Laundrym.

Annex 4: Station list

Date	Station No.	Time (UTC)	Latitude	Longitude	Depth // Operation
12.09.99	55/193	05:08 - 08:58	75°48.0' N	15°18.6' E	393 m // CTD/RO, AGT, CTD/RO, BC
	55/194	09:55 - 11:03	75°53.0' N	15°19.2' E	385 m // CTD/RO, APSN, BO
	55/195	11:50 - 12:25	75°58.3' N	15°20.9' E	377 m // CTD/RO, HN, HN
	55/196	13:42 - 14:06	76°03.0' N	15°22.6' E	379 m // CTD/RO
	55/197	15:10 - 16:17	76°13.5' N	15°31.5' E	327 m // SF1 REC, CTD/RO
	55/198	17:27 - 17:51	76°08.7' N	15°24.7' E	369 m // CTD/RO
	55/199	18:53 - 19:18	76°10.9' N	15°29.7' E	361 m // CTD/RO
	55/200	20:17 - 20:37	76°15.9' N	15°45.7' E	254 m // CTD/RO
	55/201	21:10 - 21:26	76°17.7' N	15°47.7' E	175 m // CTD/RO
	55/202	22:13 - 22:25	76°21.0' N	15°50.2' E	101 m // CTD/RO
13.09.99	55/203	08:12 - 08:57	78°19.8' N	10°25.7' E	103 m // AGT
	55/204	12:04 - 12:35	78°50.3' N	08°38.2' E	294 m // V1-2 REC
	55/205	13:04 - 14:20	78°51.2' N	08°22.3' E	742 m // V2-2 REC (unsucc.)
14.09.99	55/206	15:09 - 00:00 00:00 - 02:11	78°50.1' N	07°56.8' E	1058 m // V3-2 REC, AC9, CTD/RO, APSN, V3-3 DPL, BC (unsucc.), BC, CTD/RO, BO
	55/207	02:54 - 03:40	78°51.2' N	08°20.6' E	773 m // AC9, CTD/RO
	55/208	04:21 - 04:48	78°50.3' N	08°38.7' E	262 m // AC9, CTD/RO
	55/209	05:29 - 05:45	78°49.8' N	09°00.3' E	216 m // CTD/RO
	55/210	08:05 - 09:36	78°50.5' N	08°37.3' E	337 m // V1-3 DPL
	55/211	10:20 - 11:21	78°50.6' N	08°18.1' E	816 m // V2-3 DPL
	55/212	13:10 - 17:33	78°50.1' N	06°55.3' E	1554 m // V4-2 REC, AC9, HN, CTD/RO, RMT
	55/213	18:28 - 19:17	78°50.0' N	07°39.5' E	1116 m // AC9, CTD/RO
	55/214	21:31 - 23:09	78°50.0' N	06°02.6' E	2456 m // AC9, CTD/RO,
15.09.99	55/215	00:02 - 01:41	78°50.0' N	05°31.8' E	2615 m // CTD/RO
	55/216	06:07 - 07:27	78°49.8' N	05°00.4' E	2708 m // VFS6-2 REC

	55/217	08:32 - 09:33	78°48.4' N	04°02.6' E	2360 m // V7-2 REC
	55/218	10:58 - 12:03	78°49.8' N	02°33.9' E	2532 m // V8-2 REC
	55/219	14:40 - 17:42	78°59.5' N	00°15.8' W	2517 m // V9-2 REC, AC9, CTD/RO, HN
	55/220	22:20 - 23:56	78°50.0' N	03°10.8' E	2441 m // AC9, CTD/RO
16.09.99	55/221	01:13 - 02:49	78°50.0' N	04°03.4' E	2380 m // AC9, CTD/RO
	55/222	04:17 - 08:07	78°50.0' N	05°02.1' E	2706 m // AC9, CTD/RO, V6-3 DPL
	55/223	10:04 - 14:13	78°49.4' N	06°27.5' E	2041 m // V-5/2 REC, CTD/RO, V5-3 DPL
	55/224	15:08 - 15:55	78°50.0' N	06°54.9' E	1569 m // V4-3 DPL
17.09.99	55/225	21:56 - 00:00 00:00 - 05:01	78°50.0' N	02°33.8' E	2530 m // AC9, CTD/RO, BO, CTD/RO, BC
	55/226	06:36 - 08:18	78°53.3' N	01°39.4' E	2580 m // AC9, CTD/RO
	55/227	09:55 - 12:00	78°56.7' N	00°44.9' E	2571 m // CTD/RO, AC9
		12:30	78°57.0' N	00°41.9' W ???	Drifting wood recovered
	55/228	13:55 - 15:31	79°10.0' N	00°00.5' W	2739 m // CTD/RO, APSN
	55/229	16:53 - 18:38	79°20.0' N	00°00.1' W	2926 m // CTD/RO
	55/230	20:01 - 21:42	79°30.0' N	00°00.1' W	2811 m // CTD/RO
18.09.99	55/231	22:57 - 00:00 00:00 - 00:37	79°40.0' N	00°00.3' W	2806 m // CTD/RO
	55/232	06:25 - 22:01	79°41.4' N	03°17.1' W	2341 m // Ice station, HN, BC, AC9, CTD/RO, BO
19.09.99	55/233	04:04 - 05:39	78°59.9' N	02°35.1' W	2537 m // CTD/RO
	55/234	08:00 - 09,07	79°02.6' N	02°02.0' W	2618 m // V10-2 REC
	55/235	10:16 - 11:21	79°00.8' N	03°00.8' W	2439 m // V11-2 REC
	55/236	13:02 - 16:56	78°58.9' N	04°15.7' W	1845 m // V12-2 REC, AC9, CTD/RO, HN, V12-3 DPL
	55/237	18:50 - 22:20	79°00.0' N	02°59.4' W	2463 m // BO, CTD/RO
20.09.99	55/238	23:39 - 00:00 00:00 - 01:20	79°00.2' N	02°03.9' W	2635 m // CTD/RO
	55/239	02:30 - 04:06	79°00.0' N	01°25.6' W	2645 m // CTD/RO
	55/240	05:25 - 09:03	79°00.0' N	00°49.9' W	2627 m // CTD/RO, RMT

	55/241	10:30 - 12:01	79°00.1' N	02°02.6' W	2637 m // V10-3 DPL
	55/242	13:26 - 15:26	79°00.9' N	03°03.2' W	2422 m // V11-3 DPL
	55/243	16:29 - 17:46	78°59.9' N	03°41.8' W	2158 m // CTD/RO
21.09.99	55/244	22:44 - 00:00 00:00 - 01:04	79°02.6' N	05°44.2' W	864 m // AGT, AC9, CTD/RO
	55/245	02:31 - 03:04	79°00.3' N	06°10.2' W	426 m // AC9, CTD/RO
	55/246	06:44 - 07:43	79°00.0' N	04°46.3' W	1493 m // CTD/RO
	55/247	09:28 - 13:26	78°58.3' N	05°18.9' W	1071 m // V13-2 REC, CTD/RO, AC9, V13-3 DPL
	55/248	17:08 - 20:52	79°01.7' N	06°50.6' W	279 m // VFS14-2 REC, AC9, CTD/RO, V14-3 DPL
	55/249	22:32 - 22:56	79°00.1' N	07°24.3' W	229 m // AC9, CTD/RO
22.09.99	55/250	06:54 - 16:13	78°57.4' N	07°28.0' W	216 m // ice station, CTD/RO, BC, AC9
	55/251	20:56 - 21:14	78°58.1' N	08°01.9' W	198 m // CTD/RO
23.09.99	55/252	01:38 - 02:05	78°55.3' N	08°45.5' W	332 m // CTD/RO, AC9
	55/253	03:38 - 03:59	78°49.6' N	09°37.8' W	202 m // CTD/RO, AC9
	55/254	07:20 - 07:51	78°52.5' N	10°32.9' W	256 m // CTD/RO, AC9
	55/255	14:40 - 15:02	78°56.7' N	11°21.0' W	73 m // CTD/RO, AC9
	55/256	18:24 - 18:49	79°02.3' N	12°09.9' W	192 m // CTD/RO, AC9
24.09.99	55/257	23:50 - 00:00 00:00 - 00:13	79°02.6' N	12°59.2' W	119 m // CTD/RO, AC9
	55/258	07:27 - 07:44	78°59.0' N	13°13.9' W	169 m // CTD/RO
25.09.99	55/259	06:12 - 16:08	79°08.8' N	08°49.7' W	152 m // ice station, CTD/RO
26.09.99	55/260	09:01 - 10:50	78°50.4' N	05°15.1' W	815 m // BO, BC
	55/261	13:05 - 14:54	78°51.5' N	04°18.9' W	1706 m // RMT
27.09.99	55/262	23:26 - 00:00 00:00 - 01:08	79°44.4' N	00°30.6' E	2841 m // CTD/RO
	55/263	02:16 - 03:40	79°49.1' N	01°39.8' E	2302 m // CTD/RO
	55/264	04:40 - 06:42	79°53.8' N	01°39.8' E	3582 m // CTD/RO
	55/265	07:46 - 09:26	79°58.4' N	02°14.2' E	2758 m // CTD/RO
	55/266	10:28 - 12:20	80°02.9' N	02°47.9' E	2554 m // CTD/RO, BO (unsucc.)

	55/267	13:46 - 15:00	80°07.5' N	03°21.9' E	1972 m // CTD/RO
	55/268	16:10 - 17:00	80°12.3' N	03°56.4' E	1270 m // CTD/RO
	55/269	18:00 - 18:41	80°16.8' N	04°32.8' E	962 m // CTD/RO
	55/270	19:43 - 20:16	80°21.4' N	05°09.0' E	713 m // CTD/RO
28.09.99	55/271	07:20 - 14:18	81°17.5' N	04°58.6' E	803 m // ice station, BO
29.09.99	55/272	07:02 - 07:45	82°28.8' N	10°03.3' E	923 m // CTD/RO
	55/273	08:40 - 09:20	82°24.4' N	10°19.1' E	804 m // CTD/RO
	55/274	09:55 - 10:28	82°22.0' N	10°19.4' E	705 m // CTD/RO
	55/275	14:03 - 14:46	82°05.0' N	10°04.3' E	1026 m // CTD/RO
	55/276	17:16 - 18:05	81°51.4' N	11°17.8' E	1268 m // CTD/RO
	55/277	18:49 - 21:41	81°50.3' N	11°28.0' E	1465 m // CTD/RO, BO
	55/278	22:18 - 23:23	81°46.3' N	12°01.5' E	1823 m // CTD/RO
30.09.99	55/279	00:32 - 01:47	81°39.7' N	13°02.2' E	2133 m // CTD/RO
	55/280	02:55 - 04:27	81°34.9' N	13°47.8' E	2528 m // CTD/RO
	55/281	05:29 - 07:01	81°29.8' N	14°30.1' E	2595 m // CTD/RO
	55/282	08:20 - 09:43	81°20.4' N	14°55.4' E	2316 m // CTD/RO, AC9
	55/283	10:51 - 14:11	81°12.1' N	15°16.2' E	2197 m // CTD/RO, RMT
	55/284	15:38 - 16:58	81°03.7' N	15°39.0' E	2211 m // CTD/RO
	55/285	18:08 - 19:24	80°56.1' N	15°56.3' E	1928 m // CTD/RO, AC9
	55/286	20:31 - 23:17	80°50.0' N	16°13.3' E	1523 m // CTD/RO, BO
01.10.99	55/287	00:25 - 00:55	80°44.4' N	16°27.0' E	580 m // CTD/RO
	55/288	01:56 - 02:12	80°39.4' N	16°37.7' E	148 m // CTD/RO
	55/289	03:19 - 03:30	80°34.7' N	16°48.8' E	95 m // CTD/RO, AC9
	55/290	04:33 - 09:01	80°29.9' N	17°00.5' E	51 m // CTD/RO, AGT, HN
	55/291	13:35 - 14:58	80°39.6' N	13°07.1' E	952 m // BO
02.10.99	55/292	06:04 - 09:16	78°50.1' N	00°00.3' W	2651 m // CTD/RO, BC
	55/293	10:52 - 11:55	78°39.9' N	00°00.3' W	1785 m // CTD/RO
	55/294	13:10 - 16:48	78°30.0' N	00°00.2' W	2790 m // CTD/RO, RMT
	55/295	17:55 - 19:40	78°20.0' N	00°00.8' W	3024 m // CTD/RO

03.10.99	55/296	08:03 - 09:42	78°09.9' N	00°00.3' W	3073 m // CTD/RO
	55/297	11:04 - 12:51	78°00.0' N	00°00.4' E	3129 m // CTD/RO
	55/298	14:13 - 16:03	77°50.0' N	00°00.6' W	3129 m // CTD/RO
	55/299	17:21 - 19:16	77°39.9' N	00°00.4' E	3164 m // CTD/RO
	55/300	20:56 - 22:33	77°30.1' N	00°00.1' E	3192 m // CTD/RO
04.10.99	55/301	07:00 - 13:45	77°30.4' N	05°39.3' W	633 m // ice station
	55/302	15:01 - 16:35	77°24.0' N	05°10.3' W	1026 m // BO
05.10.99	55/303	16:49 - 18:21	75°01.5' N	12°25.6' W	1031 m // AGT
06.10.99	55/304	01:04 - 02:52	74°15.9' N	10°24.9' W	3120 m // CTD/RO
	55/305	03:50 - 05:40	74°20.3' N	10°49.4' W	3162 m // CTD/RO
	55/306	06:44 - 08:31	74°24.5' N	11°15.0' W	3112 m // CTD/RO
	55/307	10:38 -19:41	74°24.5' N	10°14.0' W	3228 m // CTD/RO, HN, AWI419-1 DPL, CTD/RO, RMT, BO
	55/308	23:20 - 00:00	74°28.5' N	11°59.6' W	2953 m // CTD/RO
07.10.99		00:00 - 01:03			
	55/309	06:41 - 15:18	74°48.8' N	13°19.2' W	2412 m // ice station
	55/310	17:16 - 17:36	74°50.0' N	14°14.2' W	181 m // CTD/RO
	55/311	18:53 - 19:12	74°45.4' N	13°50.5' W	302 m // CTD/RO
	55/312	21:32 - 22:15	74°41.1' N	13°26.4' W	1018 m // CTD/RO
	55/313	23:46 - 00:00	74°36.9' N	13°00.1' W	2140 m // CTD/RO
08.10.99		00:00 - 01:15			
	55/314	02:57 - 04:34	74°32.6' N	12°34.0' W	2608 m // CTD/RO
	55/315	09:17 - 11:17	74°11.5' N	10°00.5' W	3171 m // CTD/RO
	55/316	16:05 - 16:45	73°22.2' N	08°59.1' W	2973 m..// CTD/RO

CTD/RO = Conductivity Temperature Depth System / Rosette
DPL = Mooring deployment
REC = Mooring recovery
AGT = Agassiztrawl
RMT = Rectangular Midwatertrawl
APSN = Apsteinnet
BO = Bongonet
HN = Handnet
BC = Box core
AC9 = Attenuation /absorption meter

Annex 5: Moorings

Recovered moorings

Mooring	Latitude Longitude	Date & Time (UTC) of first record	Water Depth	Type	SN	Instrument Depth

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Mooring	Latitude Longitude	Date & Time (UTC) of first record	Water Depth	Type	SN	Instrument Depth
S1-2	76° 13.4 N	29 Aug 98	320 m	RCM8	#10003	310 m
	15° 31.6 E	14:00		Mcat	#241	311 m

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Mooring	Latitude Longitude	Date & Time (UTC) of first record	Water Depth	Type	SN	Instrument Depth
V1-2	78° 50.3 N	2 Sept 98	330 m	FSI	#1559	93 m
	8° 37.7 E	11:00		Mcat	#232	94 m
				RCM7	#9401	274 m
V2-2	78° 51.1 N	2 Sept 98	755 m	FSI	#1560	66 m
	8° 21.1 E	12:00		Mcat	#233	67 m
		surfaced on 25.8.99		RCM7	#9402	247 m
	Attempt to recover rest of mooring on			Seacat	#1166	743 m
	13.9.99 remained unsuccessful			RCM8	#9183	744 m
V3-2	78° 50.1 N	2 Sept 98	1035 m	FSI	#1563	76 m
	7° 56.6 E	14:00		Mcat	#239	77 m
				RCM8	#9767	257 m
				Seacat	#630	1023 m
				RCM8	#9561	1024 m
V4-2	78° 50.0 N	2 Sept 98	1505 m	FSI	#1564	66 m
	6° 55.5 E	17:00		Mcat	#236 *)	67 m
				RCM8	#9770	247 m
				Seacat	#631	1493 m
				RCM8	#9768	1494 m

*) no data

Mooring	Latitude Longitude	Date & Time (UTC) of first record	Water Depth	Type	SN	Instrument Depth
V5-2	78° 49.4 N	3 Sep 98	1990 m	FSI	#1569	55 m
	6° 27.3 E	14:00		Mcat	#240	56 m
				RCM8	#10004	236 m
				RCM8	#10503	1492 m
				Seacat	#1979	1978 m
				RCM8	#10498	1979 m
V6-2	78° 49.8 N	3 Sep 98	2640 m	FSI	#1566	56 m
	5° 0.4 E	12:00		Mcat	#235	57 m
				RCM8	#10872	247 m
				RCM8	#9187	1493 m
				RCM8	#9185	2629 m

V7-2	78° 48.5 N	4 Sep 98	2305 m	FSI	#1568	51 m
	4° 2.7 E	11:00		Mcat	#238	52 m
				RCM8	#11887	242 m
				RCM8	#9785	1498 m
				RCM8	#9390	2294 m

V8-2	78° 49.9 N	4 Sep 98	2470 m	FSI	#1557	76 m
	2° 33.8 E	16:00		Mcat	#237	77 m
				RCM8	#11888	257 m
				RCM8	#9786	1503 m
				RCM8	#9782	2459 m

V9-2	78° 59.6 N	7 Sep 98	2480 m	APL-ULS	#31 *)	74 m
	0° 16.3 W	18:00		FSI	#1562	86 m
				Mcat	#223	87 m
				RCM8	#11890	267 m
				RCM8	#9995	1523 m
				RCM8	#9184	2469 m

**) no data*

V10-2	79° 0.2 N	8 Sep 98	2580 m	APL-ULS	#47	64 m
	2° 2.6 W	12:00		FSI	#1561	76 m
				Mcat	#435	77 m
				RCM8	#11892	257 m
				RCM8	#6856	1513 m
				RCM8	#9188	2569 m

V11-2	79° 0.9 N	11 Sep 98	2365 m	CMR- ES300	#31 *)	49 m
	3° 1.1 W	21:00		DCM12	#17	49 m
				Seacat	#1253	62 m
				RCM7	#10349	246 m
				RCM7	#9464	1450 m
				RCM8	#10071	2355 m

**) water inside instrument*

V12-2	78° 58.8 N	11 Sep 98	1795 m	CMR- ES300	#37	56 m
	4° 15.3 W	13:00		Seacat	#1975	65 m
				RCM7	#9706	66 m
				RCM7	#11845	271 m
				RCM7	#11475	1475 m
				Mcat	#242	1780 m
				RCM8	#11625	1785 m

V13-2	78° 58.3 N	11 Sep 98	1030 m	CMR- ES300	#45	53 m
	5° 18.7 W	8:00		DCM12	#47	53 m
				Mcat	#247	60 m
				RCM7	#7718	263 m
				RCM7	#10303	1020 m

V14-2	79° 1.7 N	9 Sep 98	282 m	CMR- ES300	#34	55 m
	6° 50.8 W	11:00		Seacat	#1973	63 m
				RCM7	#11854	64 m
				RCM7	#11059	270 m

Deployed moorings

Mooring	Latitude Longitude	Date & time (UTC) of deployment	Water depth	Type	SN	Instrument depth

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Mooring	Latitude Longitude	Date & time (UTC) of deployment	Water depth	Type	SN	Instrument depth
V1-3	78° 50.27 N	14 Sept 99	266 m	Argos	#144	52 m
	8° 38.50 E	9:27		FSI	#1556	63 m
				Mcat	#218	65 m
				BB-ADCP UP	#1561	105 m
				RCM7	#9403	211 m
				RT661	#301	
				AR261	#25	
V2-3	78° 51.27 N	14 Sept 99	784 m	Argos	#117	35m
	8° 18.59 E	11:20		FSI	#1447	46 m
				Mcat	#216	47 m
				RCM7	#8401	277 m
				Seacat	#1167	773 m
				FSI	#1442	775 m
				AR261	#24	
				AR661	#450	
V3-3	78° 50.29 N	13 Sept 99	1023 m	Argos	#166	60 m
	7° 57.42 E	20:24		FSI	#1450	71 m
				BB-ADCP UP	#1563	143 m
				RCM7	#8400	249 m
				BB-ADCP DOWN	#1626	806 m
				FSI	#1474	1013 m
				RT661	#238	
				RT661	#199	
V4-3	78° 50.10 N	16 Sept 99	1497 m	Argos	#158	48m
	6° 55.39 E	15:55		FSI	#1451	59 m
				RCM7	#10929	240 m
				FSI	#1324	241 m
				FSI	#1473	1486 m
				Seacat	#1978	1487 m
				AR161	#886	
				RT161	#839	
V5-3	78° 49.14 N	16 Sep 99	1970 m	Argos	#110	46 m
	6° 27.84 E	14:10		FSI	#1456	57 m
				RCM8	#12326	238 m
				FSI	#1325	239 m
				RCM8	#12333	1494 m
				FSI	#1472	1960 m
				Benthos	#774	
				Benthos	#775	

V6-3	78° 49.98 N	16 Sep 99	2630 m	Argos	#162	40 m
	5° 02.528 E	08:06			Id 10352	
				FSI	#1553	47 m
				Mcat	#227	48 m
				RCM8	#12329	238 m
				RCM8	#12328	1484 m
				FSI	#1470	2620 m
				AR261	#27	
				AR661	#544	

V7, V8 and V9 not deployed in 1999

V10-3	78° 59.74 N	20 Sep 99	2578 m	APL-ULS	#25	56 m
	2° 3.3 W	12:01		Argos	#106	61 m
				FSI	#1567	68 m
				Mcat	#225	69 m
				RCM7	#8050	249 m
				LR-ADCP UP	#825	506 m
				RCM8	#12332	1512 m
				RCM8	#12330	2568 m
				AR661	#452	
				AR261	#17	

V11-3	79° 0.1 N	20 Sep 99	2376 m	Argos	#041	40 m
	3° 5.45 W	15:27		DCM12	#17	40 m
				CMR-ES300	#32	40 m
				Seacat	#2414	57 m
				RCM7	#4040	58 m
				RCM7	#12643	254 m
				RCM7	#12644	1460 m
				RCM8	#12587	2366 m
				AR661	#577	

V12-3	78° 59.39 N	19 Sep 99	1832 m	Argos	#048	49 m
	4° 10.95 W	16:56		DCM12	#134	49 m
				CMR-ES300	#48	49 m
				Seacat	#2415	58 m
				RCM7	#9465	59 m
				RCM7	#6798	305 m
				RCM7	#9708	1511 m
				Mcat	#224	1817 m
				RCM8	#10069	1822 m
				Releaser	#9279	1823 m
				AR661	#30	

V13-3	78° 57.0 N	21 Sep99	967 m	DMC12	#47	33 m
	5° 21.09 W	13:27		CMR-ES300	#44	38 m
				RCM7	#8402	45 m
				Mcat	#229	46 m
				RCM7	#12646	221 m
				RCM7	#10909	957 m
				Releaser	#6512	958 m
				AR661	#110	

V14-3	79° 0.64 N 6° 49.23 W	21 Sep 99 20:53	286 m	CMR-ES300	#17	48 m
				Seacat	#2416	59 m
				RCM7	#8396	60 m
				RCM7	#10907	276 m
				Releaser	#6139	277 m
				AR661	#84	

ARKTIEF II

AWI419-1	74° 24.5 N 10° 15.0 W	6. Oct.99 15:13	3163 m	APL-ULS	32	88 m
				Argos	116/2422	93 m
				FSI	1471	100 m
				RCM7	8403	211 m
				Sediment trap		308 m
				RCM8	9769	1314 m
				Sediment trap		3061 m
				ADCP-WH	951	3067 m
				Influx ADM	09/78	3153 m
				RT661	300	
				AR661	451	

Moorings which could not be recovered

VEINS FRAM STRAIT

Mooring	Latitude Longitude	Water Depth	Type	SN	Instrument Depth	Remark
V2-2	78° 51.1 N 8° 21.1 E	755 m				*Upper part had surfaced on 25.8.99*
			Seacat	#1166	743 m	*Attempt to recover rest of mooring on 13.9.99*
			RCM8	#9183	744 m	*remained unsuccessful*

Acronyms of instruments (manufacturer in brackets):

RCM7	Recording Current Meter (Aanderaa)
RCM8	Recording Current Meter (Aanderaa)
DCM12	Acoustic Doppler Current Profiler (Aanderaa)
Mcat	CTD Microcat (Seabird)
Seacat	CTD Seacat (Seabird)
FSI	Acoustic Current Meter (Falmouth Scientific Inc)
APL-ULS	Upward Loking Sonar (Applied Physics Lab)
CMR- ES300	Upward Loking Sonar (Christen Michelsen Institute)
BB-ADCP	Broadband Acoustic Doppler Current Profiler (RD Instruments)
LR-ADCP	Long-range Acoustic Doppler Current Profiler (RD Instruments)
Argos	Argos Transmitter
RT661	Acoustic Releaser
AR261	Acoustic Releaser
AR661	Acoustic Releaser

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