Die Expedition ARKTIS XIV/2
des Forschungsschiffes „Polarstern“
1998

The Expedition ARKTIS XIV/2
of the Research Vessel „Polarstern“
1998

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Fahrtabschnitt ARK XIV/2 Tromsø - Bremerhaven (27.08.98-15.10.98) - Zusammenfassung und Fahrtverlauf

E. Fahrbach (AWI)

Der Fahrtabschnitt ARK XIV/2 führte in das Europäische Nordmeer. Die Forschungsarbeiten begannen zwischen Nordgrönland und Spitzbergen in der Framstraße und endeten zwischen Island und Grönland südlich der Dänemarkstraße (Abb.1). Damit erfolgte eine der umfassendsten Aufnahmen der hydrographischen Bedingungen dieses Seegebiets insbesondere, da dank der günstigen Eis- und Wetterbedingungen alle Meßkurse bis an die grönländische Küste reichten. Der Schwerpunkt der Arbeiten lag bei physikalischen und chemischen Untersuchungen, die im Rahmen der Klimaforschung erfolgen, um die Mechanismen des Wärmeaustauschs zwischen Ozean und Atmosphäre sowie den Kreislauf organischer Substanzen im Ozean zu erforschen. Bei den biogeochemischen Untersuchungen stand die chemische Zusammensetzung, Konzentration und Verteilung von gelöstem organischem Material (DOM) im Vordergrund. Ferner wurde die Abgabe des Treibhausgases Methan aus dem Ozean in die Atmosphäre untersucht.

Auf dem Fahrtabschnitt wurden 282 Stationen ausgeführt, an denen 5.006 Wasserschöpferproben genommen und anschließend verarbeitet wurden. Ferner wurden 15 ozeanographische Verankerungen aufgenommen und 17 wieder ausgelegt. Neben Messungen von Temperatur und Salzgehalt mit einer CTD-Sonde (Conductivity, Temperature, Depth), an die ein Strömungsmesser, der Lowered Acoustic Doppler Current Meter (LADCP), angebracht war, untersuchten mehrere Arbeitsgruppen die Verteilung von Spurenstoffen im Meerwasser. Dazu zählen die natürlichen Spurenstoffe wie der gelöste Sauerstoff und die Nährstoffe Nitrit, Nitrat, Phosphat und Silikat. Die beiden letzteren spielen eine besondere Rolle, da sie im Einstrom in das Nordpolarmeer aus dem Pazifik besonders reichhaltig sind. Dieses relativ silikatreiche Wasser konnte im Ostgrönlandstrom von der Framstraße bis in die Dänemarkstraße verfolgt werden. Überraschend ist, daß in diesem eng begrenzten Stromband auch eine hohe Konzentration von gelöster organischer Substanz zu finden ist, deren Herkunft den sibirischen Flüssen zugeordnet wird. Weiterhin wurde die Verteilung künstlicher Spurenstoffe, wie der Fluorchlorkohlenwasserstoffe (FCKWs oder Freone) aufgenommen, um die Ausbreitung und das Alter der Wassermassen zu bestimmen. Unter dem Alter der Wassermassen versteht man die Zeit, die vergangen ist, seitdem der Wasserkörper die Oberfläche verlassen hat. Zu diesem Zwecke wurden auch Proben zur Messung des bei Kernwaffenversuchen entstandenen Tritiums und dessen Zerfallsproduktes Helium genommen. Der

Süßwassereintrag wurde mittels Verteilung der Sauerstoffisotope $^{16}O/^{18}O$ und des Bariums untersucht.

Das Europäische Nordmeer und das Nordpolarmeer stellen ein System von Becken dar, die in wechselseitigem Austausch stehen und in denen es auf unterschiedliche Weise zur Erneuerung der tiefen Wassermassen kommt. Ein Teil der Wassermassen, die in diesem Seegebiet absinken, verläßt das Europäische Nordmeer als "Overflow" über die Grönland-Schottlandschwelle und gelangt in den tiefen Nordatlantik. Damit speist der Ausstrom aus diesem Seegebiet die großräumige thermohaline Zirkulation und bewirkt so die Umwälzung des Tiefenwassers des Weltmeers. Die Geschwindigkeit, mit der sich die Tiefenwassererneuerung vollzieht, bestimmt die Wirkung des Ozeans als Wärmespeicher und damit seinen Einfluß auf unser Klima. Während die Wassermassenerneuerung in der Grönlandsee zumindest in der Vergangenheit durch tiefreichende Konvektion im offenen Ozean erfolgte, wird sie im Nordpolarmeer durch den Abfluß von Schelfwasser über den Kontinentalabhang bewirkt.

Die Messungen zeigten, daß die Konvektion in der Grönlandsee im Winter 1997/1998 nur eine Tiefe von 700 m erreichte. In den tieferen Schichten des Bodenwassers wurde im Vergleich zu 1997 eine Erwärmung um 0,01 K gemessen. Damit setzte sich eine Entwicklung fort, die mit einer kurzen Unterbrechung schon seit mehreren Jahren anhält. Demnach befinden wir uns in einer längeren Phase geringer Wassermassenerneuerung, und der gesamte Wasserkörper der Grönlandsee sinkt langsam ab. Der geringe Salzgehalt und die verhältnismäßig hohen Temperaturen in den oberen 1000 m legen die Vermutung nahe, daß auch im nächsten Winter keine tiefgreifende Konvektion einsetzen wird. Der tiefe Ausstrom aus dem Europäischen Nordmeer durch die Framstraße in das Nordpolarmeer war wärmer als im Vorjahr. Dies deutet an, daß sich die Veränderungen in der Grönlandsee auch auf das Nordpolarmeer auswirken werden. Andererseits war der Zustrom aus dem Nordpolarmeer in das Europäische Nordmeer sehr salzarm, was die Abnahme des Salzgehalts in den oberen Schichten der Grönlandsee bewirkt, und die tiefe Konvektion in der Grönlandsee erschwert.

Am Kontinentalabhang von Spitzbergen sinken Wassermassen, die aus dem Storfjord und aus der Barentssee stammen, in die Tiefsee ab und tragen zur Erneuerung des Tiefenwassers bei. Es stellte sich heraus, daß dieser Abfluß 1998 nur geringe Tiefen erreicht hat und wärmer als im Jahr davor war. Deshalb konnte auch hier nicht von einer umfassenden Erneuerung der tieferen Wassermassen ausgegangen werden.

Die Ausbreitung des Wassers aus der Grönlandsee wurde auf mehreren Meßkursen verfolgt. Dazu wurde u.a. die Konzentration eines künstlichen Spurenstoffs, des Schwefelhexafluorids (SF_6), gemessen. Dieser Stoff wurde im Sommer 1996 in der Grönlandsee in 300 m Tiefe über eine Fläche von 400 km^2 ausgebracht und verteilt sich seitdem mit der Wasserbewegung. Da er in sehr geringen Konzentrationen (10^{-18}) nachzuweisen ist, kann man ihn über große Entfernungen verfolgen. Die Messungen ergaben, daß die Wasserschicht, in die er ausgebracht worden war, inzwischen um mehrere hundert Meter abgesunken ist, und daß ein Teil des SF_6 bereits die Grönlandsee verläßt. Untermeerische Rücken behindern die Ausbreitung stark, auch wenn sie nicht bis in das Niveau des Spurenstoffflecks aufragen. So erfolgte über dem Mohnsrücken, der die Grönlandsee von der Norwegischen See trennt, ein drastischer Konzentrationsabfall. Allerdings muß es auch Durchlässe für den Spurenstoff geben, denn der Ausstrom in das Nordpolarmeer in der Framstraße wies schon merkliche Konzentrationen auf. Im Süden hatte der Rand der SF_6-Wolke die Dänemarkstraße gerade erreicht aber die Schwelle zum tiefen Nordatlantik noch nicht überschritten, da die SF_6-reiche Schicht unterhalb der Schwellentiefe liegt.

Eine genauere Berechnung des Austauschs zwischen der Grönlandsee und dem Nordpolarmeer durch die Framstraße kann erst aus den Strömungsmessungen mit verankerten Geräten erfolgen, die während der Reise aufgenommen wurden. Deren Daten sowie der Inhalt vieler Wasserproben können allerdings erst nach dem Abschluß der Reise in den Heimatlabors ausgewertet werden. Die weitere Analyse soll zeigen, wodurch das Ausbleiben der Erneuerung der tiefen Wassermassen begründet ist. Eine wahrscheinliche Erklärung liegt in Veränderungen der atmosphärischen Antriebsbedingungen, die im Rahmen der sogenannten Nordatlantischen Oszillation erfolgen. Diese atmosphärische Schaukelbewegung führt zur Veränderung der Luftdruckverteilung über dem Nordatlantik, die sich auf die Intensität und die Zugbahnen der atlantischen Tiefdruckgebiete auswirkt. Veränderungen des Windes an der Meeresoberfläche und des Niederschlags können die winterliche tiefreichende Konvektion begünstigen oder behindern.

Die Forschungsreise ist ein Beitrag zu einem internationalen Langzeitprogramm der "Arctic Climate System Study" (ACSYS) des "World Climate Research Programme" (WCRP) der UNESCO und wurde von der Europäischen Union in den Projekten "VEINS" (Variability of Exchanges in Northern Seas) und ESOP-2 (European Sub-Polar Oceans Programme phase 2) mitfinanziert. Ein weiterer Teil der Arbeiten stellt einen Beitrag zum Tiefseeforschungs-Projekt ARKTIEF des BMBF dar. Neben dem AWI, waren

Arbeitsgruppen der Universitäten Hamburg, Heidelberg, Kiel und Rostock sowie aus England, Finnland, Italien, Norwegen und den USA vertreten.

Die Reise begann am 27. August in Tromsø (Abb. 1). Von dort aus liefen wir in Richtung Spitzbergen, wo im Ausstrom aus dem Storfjord eine Verankerung ausgetauscht und ein hydrographischer Schnitt ausgeführt wurde. Anschließend wurden zwei Verankerungen auf einem Schnitt westlich von Spitzbergen aufgenommen. Die Fortsetzung der Arbeiten erfolgte auf einem zonalen Schnitt durch die Framstraße bei etwa 79°N. Dort wurden 10 Verankerungen aufgenommen und wieder ausgelegt, sowie 37 CTD-Profile mit Wasserschöpferproben ausgeführt. Bei 0° folgte ein Schnitt mit 9 Stationen nach Norden, der bei 79°40'N nach Osten eindrehte, um den Hang zum Yermakplateau möglichst senkrecht zu schneiden. Nach Abschluß dieses Schnittes kehrten wir zum 79°-Schnitt zurück und erreichten bei 79°11'N die Eisgrenze. Wenig südlich, bei 79°10'N, 2°W trafen wir das norwegische Forschungsschiff "Lance" und übernahmen Material für vier weitere Verankerungen. Die "Lance" hatte im Rahmen des VEINS-Projektes bereits einen Schnitt durch den Ostgrönlandstrom bei 77°30'N ausgeführt. Im Anschluß setzten wir den Zonalschnitt nach Westen fort. Die günstigen Eis- und Wetterbedingungen erlaubten es, bis nach 16°W in die Belgica-Rinne zu gelangen. Auf dem Rückweg nach Osten legten wir die vier norwegischen Verankerungen im Ostgrönlandstrom aus. Bei 0° bogen wir nach Süden ab, um auf einem Schnitt bis 77°30'N die Rezirkulation in der südlichen Framstraße zu erfassen. Anschließend kehrten wir an den Kontinentalabhang von Spitzbergen zurück und führten Messungen auf zwei hydrographischen Schnitten durch den Ausstrom aus dem Storfjord aus. Auf diesen Schnitten hatten wir schon einmal zu Beginn der Reise gearbeitet. Die Wiederholung diente dazu, der starken zeitlichen Veränderlichkeit des Ausstroms gerecht zu werden. Zusätzlich wollten wir Messungen nachholen, die zu Beginn der Reise auf Grund von Geräteproblemen ausfallen mußten. Wir unternahmen einen weiteren Versuch, eine der beiden Verankerungen, die trotz akustischer Rückmeldung nicht aufgetaucht waren, zu dredgen. Da auch dieses aufwendige und langwierige Manöver ohne Erfolg blieb, mußten wir die Bergung der Verankerung aufgeben. Die Vermutung liegt nahe, daß diese Verankerungen durch die intensive Fischerei in diesem Seegebiet beschädigt wurden. Da uns das Risiko eines weiteren Verlustes zu hoch erschien, sahen wir von der geplanten Neuauslegung ab.

Am 16. September liefen wir in den frühen Morgenstunden in den Isfjorden auf Spitzbergen ein. In Longyearbyen endete der erste Teil unserer Reise. Wegen des großen Tiefgangs von "Polarstern" lagen wir etwa 300 m von der

Stadtpier entfernt auf Reede. Unmittelbar nach dem Einlaufen begann eine Reihe von Transportflügen mit dem Helikopter. Dabei handelte es sich um Material aus der Koldewey-Station in Ny-Alesund, das wir nach Bremerhaven zurückbrachten. Auch tiefgefrorene wissenschaftliche Proben gehörten dazu. Da es in Longyearbyen keine Barkasse oder ein vergleichbares Transportmittel gab, wurde der Transport mit dem Helikopter ausgeführt. Am Vormittag wurden 24 Fahrtteilnehmer und Fahrtteilnehmerinnen mit Schlauchbooten an Land gebracht, wo der Agent den Transfer zum Flughafen übernahm. Um die Mittagszeit kam die neue Gruppe mit 20 Personen an Bord.

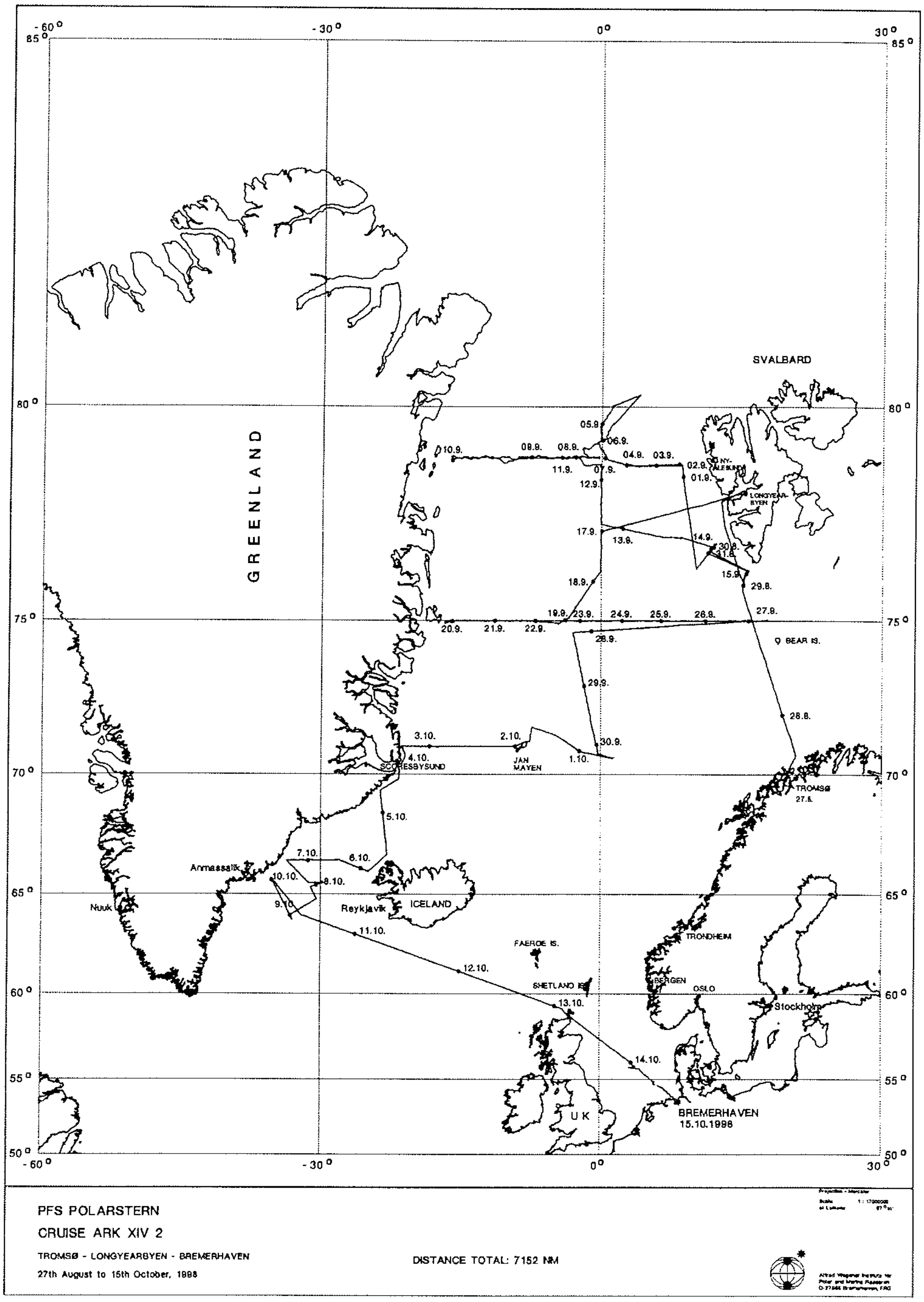
Von Spitzbergen aus dampften wird nach Westsüdwesten bis zum Meridian von Greenwich, um den hydrographischen Schnitt nach Süden fortzusetzten, den wir vor der Fahrt nach Longyearbyen begonnen hatten. Dieser Schnitt wurde bis in die zentrale Grönlandsee auf 75°N weitergeführt, wo am 19. September die Bergung und die Wiederauslegung von zwei Verankerungen erfolgte. Wir setzten die Fahrt nach Westen an die grönländische Küste in dichtem Eis fort. Am 20. September in 8 sm Entfernung von der Shannon Insel begann der hydrographischen Schnitt entlang 75°N durch die Grönlandsee. Das Eis bestand aus alten Schollen, die in eine solide Neueisdecke eingelagert waren. Der Schnitt erfolgte mit hoher horizontaler Auflösung, um den konvektiven Zustand dieses Seegebiets zu erfassen und führte bis in die Barentssee, wo er am 27. September bei 18°E endete. Im Anschluß kehrten wir in die zentrale Grönlandsee zurück, um den Meridionalschnitt bei 3°W nach Süden fortzusetzen. Das günstige Wetter ermöglichte uns, die Arbeiten zügig auszuführen. Deshalb konnten wir den Schnitt nach Süden über den Mohnsrücken bis in die Norwegische See ausdehnen. Anschließend legten wir mehrere Stationen in die Jan-Mayen-Bruchzone und in einen zweiten, weiter nördlich gelegenen, Durchbruch im Mohnsrücken. Damit soll die Veränderung der Wassermassen erfaßt werden, die von der Grönlandsee in die Norwegische See strömen. Aus der Norwegischen See wird einerseits der tiefe Einstrom in das Nordpolarmeer gespeist, andererseits der "Overflow" zwischen Island und Schottland in den Nordatlantik.

Am 2. Oktober erreichten wir Jan Mayen. Nach einer kurzfristigen Wetterverschlechterung, die zum ersten Mal auf dieser Reise - zum Glück nur kurzfristig - bis zu 8 Windstärken brachte, hatte sich das Wetter wieder gebessert. So bot sich die seltene Gelegenheit, den Beerenberg, einen mächtigen, schneebedeckten Vulkankegel von 2277 m Höhe, zeitweise ohne Wolken zu sehen. Hier begann ein Schnitt durch den Ostgrönlandstrom entlang von

71°N, der bis 3 sm vor die Küste reichte. Bei Sonnenschein und klarer Sicht konnten wir die Berge von Liverpool Land mit einer Höhe von knapp 1500 m schon aus einer Entfernung von mehr als 100 km am Horizont erkennen. Gegen Mittag des 3. Oktober hatten wir den Eisrand erreicht. Felder aus dickeren, alten Schollen, die im Ostgrönlandstrom von Norden herangeführt worden waren, lagen wie eingegossen in Neueisflächen.

Nach Abschluß dieses Schnittes drehten wir nach Süden, um bei 69°23'N, 23°43'W einen Schnitt in Richtung der isländischen Nordküste zu beginnen. Wir unterbrachen die Marschfahrt im Scoresbysund mit einem kurzen Besuch in der grönländischen Siedlung Ittoqqoortoormit. Am 5. Oktober folgte ein weiterer Schnitt, der den Ostgrönlandstrom querte und im Süden den Nordislandstrom (Irmingerstrom) abdeckte. Entlang der isländischen Nordwestküste dampften wir in die Dänemarkstraße, die wir mit einem Schnitt bei der geringste Tiefe der Schwelle durchquerten. Der Schnitt wurde auf dem grönländischen Schelf über das Storfjordtief entlang von 66°30'N bis zur Küste fortgesetzt. Küstenwärts dieser Rinne mußten wir eine Zone mit großer Eisbergdichte durchqueren, die in einen Gürtel mit riesigen Alteisträmmern überging. Weiter nach Westen nahm die Größe der Treibeisschollen stark ab, bis wir vor der Küste wieder ins offene Wasser kamen. Um einen möglichen Ausstrom aus dem Storfjordtief in die Irmingersee zu erfassen, erfolgte ein weiterer Schnitt auf 65°30'N entlang der Schelfkante über die südliche Schwelle. Allerdings konnten wir keine Hinweise auf den Ausstrom finden.

Die beiden letzten Schnitte lagen südlich der Dänemarkstraße. Sie begannen auf dem grönländischen Schelf und reichten bis in die tiefe Irmingersee. Sie durchquerten die Zunge des "Overflow", der aus der Dänemarkstraße entlang dem Hang absinkt. Die Arbeiten endeten am 10. Oktober auf grönländischen Schelf, von wo aus bei stürmischem Wetter die Rückreise begann. Am 15. Oktober 1998 erreichten wir Bremerhaven.



PFS POLARSTERN
CRUISE ARK XIV 2
TROMSØ - LONGYEARBYEN - BREMERHAVEN
27th August to 15th October, 1998

DISTANCE TOTAL: 7152 NM

Abb.1: Fahrtroute während ARK XIV/2.
Fig. 1: Cruise track during ARK XIV/2.

Leg ARK XIV/2 Tromsø - Bremerhaven (27.08.98-15.10.98) - itinerary and summary

E. Fahrbach (AWI)

The "Polarstern"-cruise ARK XIV/2 covered the Nordic Seas from Fram Strait to Denmark Strait (Fig. 1). Physical and chemical oceanography investigations were carried out as part of a climate research programme. The mechanisms of heat exchange between ocean and atmosphere and the cycles of organic matter were investigated. Biogeochemical investigations concentrated on the composition, concentration and distribution of dissolved organic matter (DOM) and the production of methane in ocean.

During the cruise, measurements were carried out on 282 stations by use of a CTD (Conductivity, Temperature Depth) probe combined with a water sampler and a Lowered Acoustic Doppler Current Meter (LADCP). The water samples were used to measure the concentrations of oxygen, nutrients (including nitrate, nitrite, phosphate and silicate), CFCs, tritium, helium, stable isotopes $^{16}O/^{18}O$, barium and sulfur hexafluoride (SF_6). During part of the cruise samples were taken for the determination of methane and DOM. In addition, 15 oceanographic moorings were recovered and 17 were redeployed.

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 and freezing into shallow fresh waters (and ice) and saline deep waters. The outflow from the Nordic Seas to the south provides the initial driving of the global thermohaline circulation cell; the outflow to the north has a major impact on the large scale circulation of the Arctic Ocean. 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.

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 water mass formation in the Nordic Seas, the transport of warm and saline Atlantic water significantly affects the water mass characteristics in the Arctic Ocean. The inflow from the Arctic Ocean into the Nordic Seas determines to a large extent the formation of water masses which are advected through Denmark Strait to the south and participate in the formation of the North Atlantic Deep Water. The obtained data will be used, in combination with a regional model, to investigate the nature and origin of the transport fluctuations as well as the modification of signals during their propagation through the strait.

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. For example, water masses from the Storfjord (Spitsbergen) and the Barents Sea sink along the continental slope off Spitsbergen into the deep ocean. The plumes of newly formed water can be detected by the measurement of temperature, salinity, tracers and, possibly, also suspended sediment (via light attenuation), the latter since it is hypothesised that the suspended matter can help create the density gain required for a sinking plume. As the plumes are subject of significant variability, time series are needed to understand the dynamics of the sinking plumes and their injection from the shelf into the open ocean.

The measurements indicated that during the last winter (1997/1998) the convection in the Greenland Sea reached only to 700 m depth. The deep layers of bottom water were subject to further warming by about 0.01 K per year as found with a short interruption during the last years. Both observations suggest that the phase of little water mass renewal of the last years still continues. Additionally, there is further evidence of the previously reported downwelling in the deeper layers of the central Greenland Sea. The low salinity and the high temperatures in the uppermost 1000 m suggest that there will be no deep convection in the next winter neither. The deep outflow from the Nordic Seas across Fram Strait seems to be warmer than in the last year indicating that the changes in the Greenland Sea are spreading into the Arctic Ocean. The shallow inflow from the Arctic Ocean was relatively fresh which could explain the low salinities in the Greenland Sea. The strong inflow of low salinity water can affect the potential for deep convection.

The spreading of the water from the Greenland Sea into the Denmark Strait overflow was studied with a series of sections across the East Greenland Current up to the Irminger Sea. Of particular importance were the measurements of the tracer sulfur hexafluoride (SF_6) which was deployed in 1996 in a 300 m deep layer over 400 km^2 in the Greenland Sea. The measurements showed that the layer sank by several hundreds of meters and had spreaded out of the Greenland Sea. However the strong drop in concentration over deep sea ridges indicates that they affect the spreading significantly, even if they do not reach the SF_6-layer. However there must be gaps, because SF_6-enrichment was observed in Fram Strait. In the south, the

SF_6-patch had reached the Denmark Strait, but it had not yet crossed the sill as the SF_6-rich layer was deeper than the sill depth.

The 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 in Fram Strait is partly funded by the European Union project "VEINS" (Variability of Exchanges in Northern Seas). In this context, the Norwegian vessel "Lance" operated simultaneously in Fram Strait. Four of the moorings in Fram Strait are maintained by the Norsk Polarinstitutt. The tracer observations and the moorings at the continental slope of Spitsbergen are a contribution to the Deep Sea Research programme ARKTIEF of the German Ministry of Education, Science and Technology (BMBF). The SF_6-measurements took place in the framework of the EU MAST-III programme ESOP-2 (European Sub-Polar Oceans Programme phase 2). Besides AWI, there were groups from the universities of Hamburg, Heidelberg, Kiel und Rostock and from England, Finland, Italy, Norway and the USA involved in the programme.

The cruise started on 27 August in Tromsø (Fig. 1). The first operations took place on the southern shelf of Spitsbergen where the outflow from the Storfjord was surveyed. One oceanographic mooring was exchanged and a hydrographic section was carried out. Along a section across the western continental slope of Spitsbergen, two moorings were recovered and a second section was completed. The observations continued along a zonal section across Fram Strait at approximately 79°N. On the section across Fram Strait, 10 oceanographic moorings were recovered, and 14 were redeployed. To determine the water mass properties CTD measurements with water sampler profiles were taken. At the Greenwich Meridian a meridional section started to the north, turned to the northeast and ended at the slope of the Yermak Plateau. After the end of the section we returned to 79°10'N, 2°W where we met the Norwegian RV "Lance". After finishing the zonal section at 16°W, we continued the meridional section to the south up to 77°30'N, to measure the recirculation in the southern Fram Strait. Finally, we returned to the western slope of Spitsbergen and repeated the inshore part of the two sections. Another effort to dredge one of the moorings was with no success. As there was intensive fishery in the area the moorings were not redeployed to avoid further losses. The first part of the cruise ended on 16 September in Longyearbyen, where 24 participants left and 20 new ones came on board. Furthermore, material from the Koldewey Station was collected by the helicopter and instruments recovered during the cruise were deposited at the airport.

The second part of the cruise started with the continuation of the southward meridional section across the Greenland Sea (Fig. 1). In the central Greenland Sea, two moorings were recovered and redeployed. Then, a zonal transect at 75°N with high horizontal resolution to determine the convective state of the Greenland Sea, started off the Greenland coast and ended in the Barents Sea at 18°E. The meridional transect was continued at 3°W towards the Mohns Ridge into the Norwegian Sea. Mohns Ridge was crossed with another section along a gap north of the Jan-Mayen-Fracture-Zone. At Jan Mayen the 2277-m-high Beerenberg was in sight. A further section across the East Greenland Current along 71°N ended at the Greenlandic coast. On our way to the next section which started at 69°22.7'N, 23°43.2'W, we stopped in the Scoresbysund for a short visit of the Inuit village Ittoqqoortoormit. The following section headed southward to the Islandic coast where we turned west into Denmark Strait. The section across the sill was continued along 66°30'N across the Storfjord Deep to the coast. The next section was directed from the coast into the Irminger Sea. It was interrupted for a small section across the southern sill of the Storfjord Deep, to find out if the shelfwater is spilling over the sill. But there was no indication of it. The last section went back from the deep Irminger Basin to the Greenland Coast. It ended on 10 October. From there, "Polarstern" returned to Bremerhaven, where the cruise ended on 15 October 1998.

The meteorological conditions

K. Dittmer and H. Köhler (DWD)

At the beginning of the cruise the synoptic situation was characterized by a high pressure system near Franz Joseph Land, providing easterly winds with force 4 to 6, when approaching the first station near the southern tip of Spitsbergen. At the end of August the dominating high pressure system drifted southwards. Winds veered to southeast and south and advected air with higher humidity. Thus, the visibility became poor and fog appeared at times, but short helicopter flights were possible.

During the first days of September the Arctic Front extended from northern Greenland across the Barents Sea towards northern Russia. "Polarstern" stayed mainly on the cold side of the front in a northwesterly flow with often good visibility. Low stratus and fog patches associated with snow grains occurred only for very short periods. The ice edge was reached on 5 September. During the further work in the Fram Strait, the high pressure system over Greenland dominated the weather. Winds of 3 or 4 Bft from northwest were associated with isolated light snow showers, which could be avoided by the helicopters. The sea ice cover was broken up by leads or areas of open water. The former hurricane "Danielle" had become stationary west of the British Isles in early September and was transformed to an extratropical storm depression. New low pressure systems developed over the Norwegian Sea and propagated to the Barents Sea. Thus, the Greenland high determined the weather in the operation area.

In Fram Stait fog patches and isolated light snow showers or snow grains occurred and allowed only short helicoper flights for mooring search or ice reconnaissance. On 10 September, the most western point in the Fram Strait near 79°N, 16°W was reached in close pack ice. Due to the lee effect and the flow of cold air from the Greenland ice cap very good weather conditions were encountered. Thus, the coast and the islands ahead were to be seen in more than 20 miles distance. From 11 September on, the Greenland high intensified still and spread towards Spitsbergen, providing weak winds in the Greenland Sea. The shower activity decreased and sunny weather dominated. On 14 and 15 September the warm front of an intensive low over southern Scandinavia approached and caused northeasterly winds up to 6 Bft near southern Spitsbergen.

From mid of September the Greenland high drifted to the northern Barents Sea and a depression moved from the Lofoten to Jan Mayen causing easterly winds force 6 to 7 on 18 September. Gales off the North Cape had induced a swell of 3 m. Thus, the significant wave height of wind, sea and swell together reached 4 to 5 m. On 21 September, the Iceland low had moved to the Barents Sea, while a new high built up over Greenland. In light to moderate northwesterly winds some fog was encountered, partly with snow grains. Towards the east the visibility improved. A secondary depression near the Lofoten led to a weather deterioration with strong northwesterly winds and snowfall. By 25 September, the intensive high over Greenland moved to the area near Jan Mayen. Simultaneously a polar low drifted from the Barents Sea to the Norwegian Sea. The cold northerly winds increased to Bft 5-6.

After the end of the 75°N section, when steaming to the South, the northern edge of the polar low was encountered once more with strong easterly winds. Meanwhile the low had induced a frontogenetic process and warm and moist air was advected in its rear, which glided above the polar air causing rain.

In early October a new depression developed near Spitsbergen. When the cold front passed "Polarstern" on 2 October, the wind increased to 8 Bft for a short time with no significant effect on the sea. Off the northeastern coast of Jan Mayen, the wind increased again within minutes from 6 to 9 Bft due to the orographic effect of the Beerenberg (2271 m).

During the first days of October, a storm depression had developed over Canada. Later, a secondary depression split near Cape Farvel. Both, the secondary low and the main system, weakened and crossed Denmark Strait on 6 and 7 October providing strong winds. Near the coast of Greenland numerous icebergs embedded in rests of multiyear sea ice were encountered. On 8 October, the trough of a low near Iceland provided northeasterly winds reaching nearly gale force. During the last stations, another secondary depression developed near southern Greenland with a northerly wind of 8 to 9 Bft and 5 m sea in the rear.

A summary of wind speed and direction during the cruise is given in Fig. 2. During September the percentage of strong winds was less than half of the frequency expected from climatology and gales or storms were not observed (Fig. 3). In the first decade of October the frequency of strong winds was higher than expected, but that of gales (Bft 8 and 9) lower and storms (Bft 10 and more) were not encountered at all (Fig. 4).

The voyage home to Bremerhaven was accompanied by strong to stormy westerly winds at times, but with the following sea, the ship's speed was not significantly reduced.

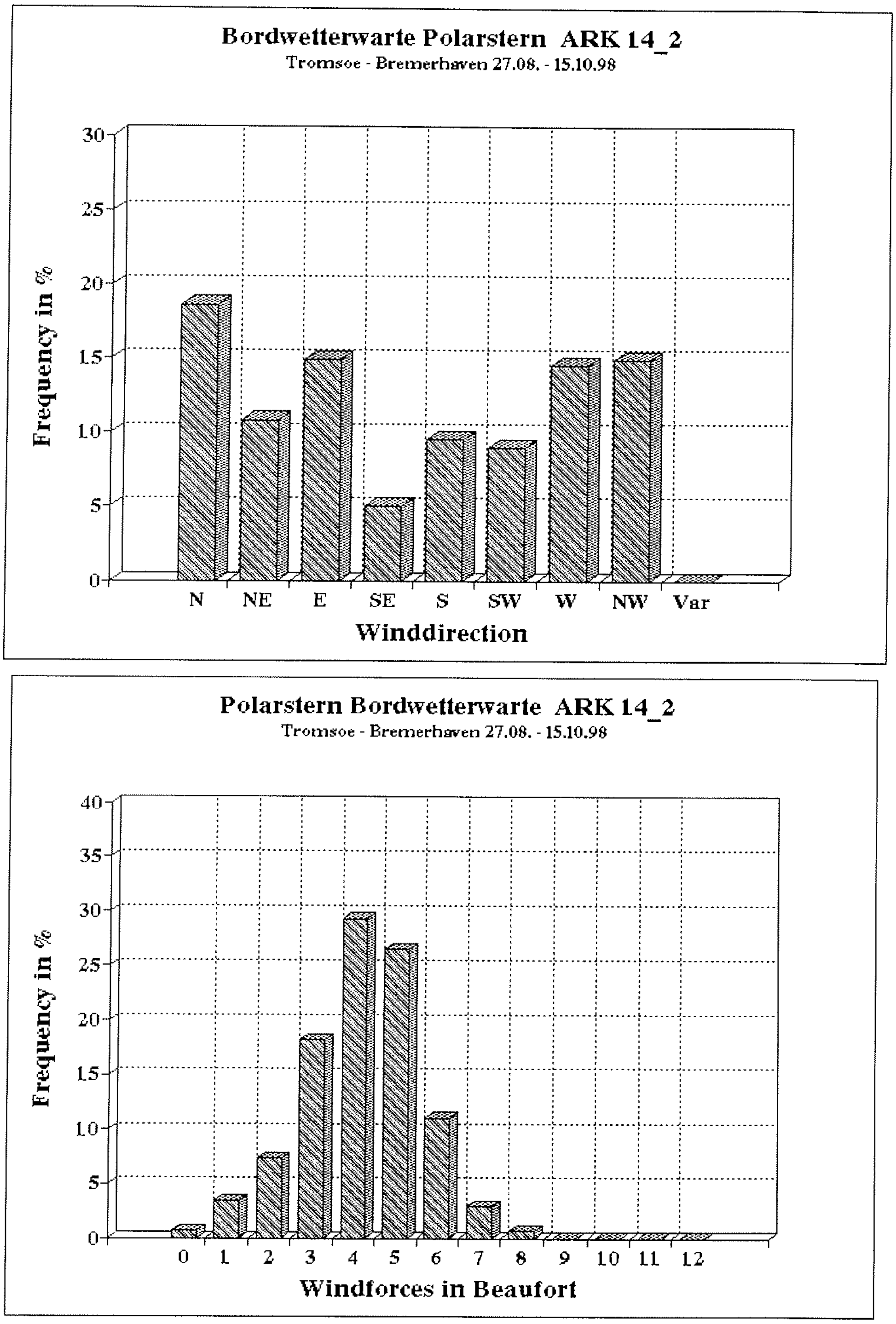


Fig. 2: Frequency distribution of wind speed and direction during the complete cruise.

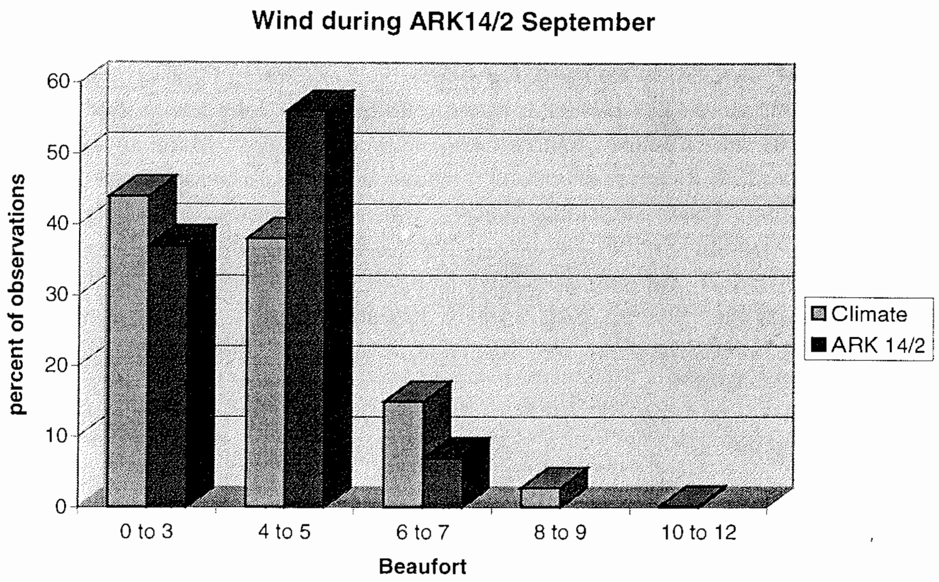


Fig. 3: Frequency distribution of wind force in September during the cruise and according to the longterm mean.

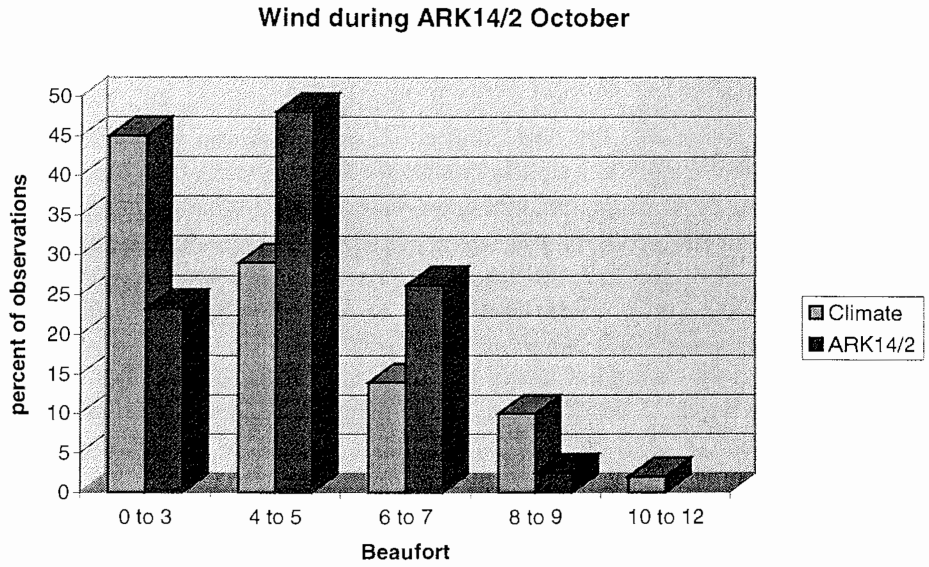


Fig. 4: Frequency distribution of wind force in October during the cruise and according to the longterm mean.

The hydrographic conditions in the Nordic Seas in summer 1998

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Introduction

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 and freezing into shallow fresh waters (and ice) and saline deep waters. The outflow from the Nordic Seas to the south provides the initial driving of the global thermohaline circulation cell; the outflow to the north has a major impact on the large scale circulation of the Arctic Ocean. 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.

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 water mass formation in the Nordic Seas, the transport of warm and saline Atlantic water significantly affects the water mass characteristics in the Arctic Ocean. The inflow from the Arctic Ocean into the Nordic Seas determines to a large extent the formation of water masses which are advected through Denmark Strait to the south and participate in the formation of the North Atlantic Deep Water. The obtained data will be used, in combination with a regional model, to investigate the nature and origin of the transport fluctuations as well as the modification of signals during their propagation through the strait.

Observations in the Greenland Sea indicate that deep water formation is reduced since the early eigthies, resulting in a quasi-continuous increase of bottom water temperature of 0.01 K per year, combined with a bearly significant increase of salinity. Whereas temperature and salinity increase would be consistent with continuous inflow from the Arctic Ocean, temperature increase and salinity decrease could be the consequence of gradual downwelling. However, the observed increase of the deep halocarbon concentrations suggest enhanced mixing over rough topography as a third process to determine the characteristics of Greenland Sea deep and bottom water. During 1994/95 a particularly large outflow of ice from the Arctic Ocean across Fram Strait was reported from upward looking sonar measurements. It suggests a further stabilisation of the water column due to the additional fresh water gain.

Polar oceans are generally weakly stratified and hence oceanic currents are primarily determined by the barotropic flow component. Thus, geostrophic calculations based on hydrographic sections are not sufficient to determine the current field to the required accuracy. In these ice-covered areas, the barotropic component can only be determined from direct current measurements, since satellite altimetry is not yet able to properly measure sea level fluctuations under ice. Due to relatively large contributions of boundary and frontal areas and the small Rossby radius of deformation, relatively high horizontal resolution is required for the measurements.

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. For example, water masses from the Storfjord (Spitsbergen) and the Barents Sea sink along the continental slope off Spitsbergen into the deep ocean. The plumes of newly formed water can be detected by the measurement of temperature, salinity, tracers and, possibly, also suspended sediment (via light attenuation), the latter since it is hypothesised that the suspended matter can help create the density gain required for a sinking plume. As the plumes are subject of significant variability, time series are needed to understand the dynamics of the sinking plumes and their injection from the shelf into the open ocean.

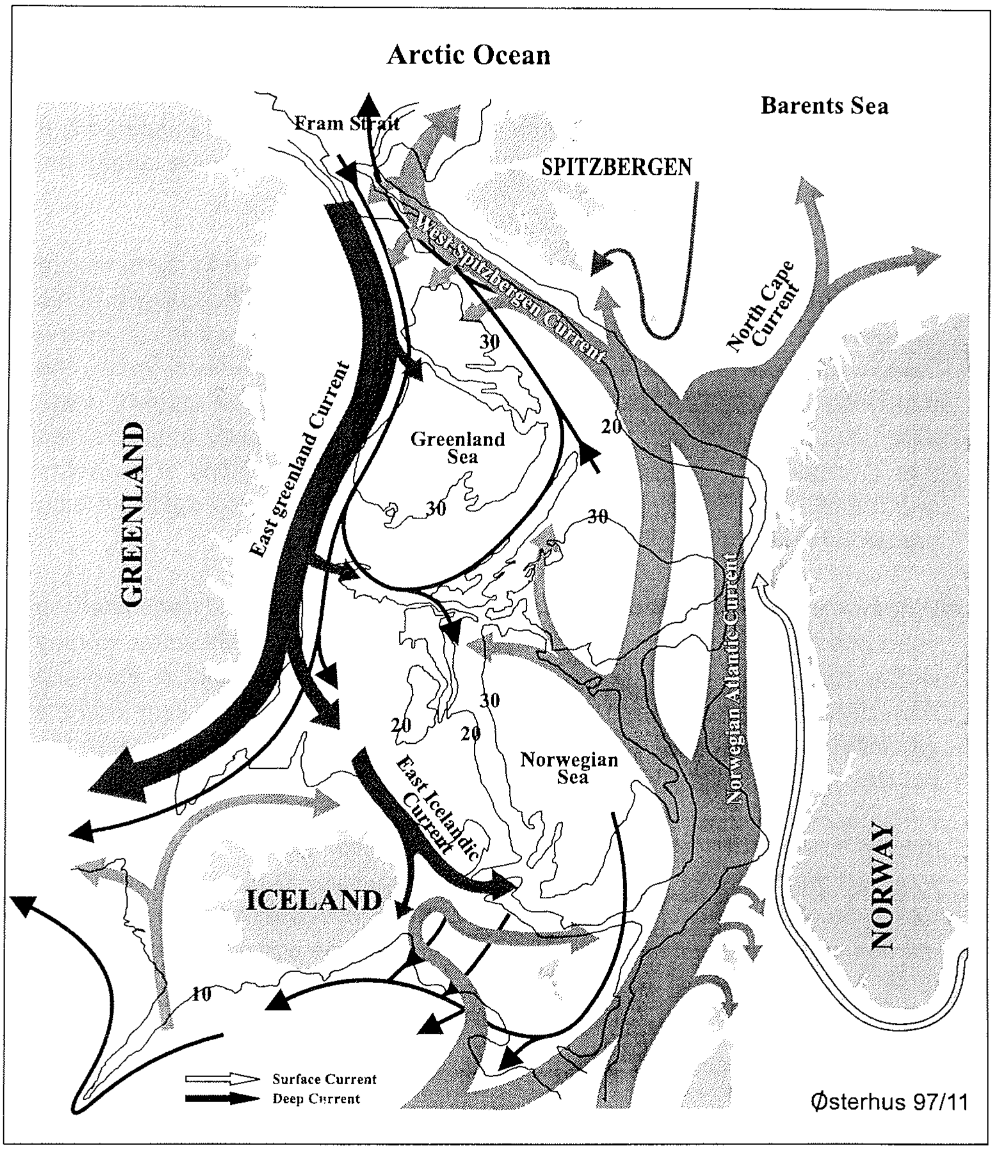


Fig. 5: Schematic circulation diagram of the Nordic Seas.

Objectives

In order to better understand the role of the Arctic Ocean and the Nordic Sea in climate through their effect on the thermohaline circulation, measurements were carried out with the following objectives:

- to determine the currents and the water mass characteristics on sections across Fram Strait,
- to determine the characteristic time scales of the property fluctuations in Fram Strait, in particular, the contribution of the seasonal cycle and to detect interannual variability,
- to understand the origin of the fluctuations,
- to calculate seasonal and annual mean transports of mass, heat and salt through the Fram Strait,
- to study the intensity and depth of convection in the Greenland Sea,
- to understand the processes which determine the deep water characteristics and their temporal evolution, especially the role of enhanced vertical diffusion above rough topography,
- to obtain the time series of tracer distributions in the various water masses, especially the deep water masses to derive time scales of the water mass formation and mean residence times,
- to calculate renewal rates and their variability,
- to investigate the origin and tracer characteristic of the deep outflow into the subpolar North Atlantic and its modification south of Denmark Strait,
- to estimate diapycnal diffusivities and quantify the deep water renewal due to vertical mixing,
- to quantify the contribution of different fresh water and salt sources such as continental runoff, sea ice melt water and recirculating Atlantic water,
- to trace brine-enriched shelf waters from the Storfjord (Spitsbergen) to estimate the contribution of these shelf waters to deep water formation,
- to derive transports in the Greenland Sea and the East Greenland Current to Denmark Strait to estimate the exchange between the Arctic Ocean, the Greenland Sea and the North Atlantic.

Methods and work at sea

CTD and water sampling system (AWI)

The CTD system (Conductivity, Temperature, Depth) used during the first part of the cruise (stations 1 to 113) consisted of a SBE 911+ and an SBE32 rosette water sampler with S/N 09P16392-0485 for the CTD, S/N 1642 for the SBE3 temperature sensor and 1493 for the SBE4 conductivity sensor. A

Seatech transmissiometer with 25 cm beam length was attached to the CTD as an additional sensor. The used water sampler is a 24 bottle type for 12 Liter Ocean-Test-Equipment bottles. Places 10, 11, and 12 were occupied by an ADCP (Acoustic Doppler Current Profiler). Bottles 1, 5, 13, 17, and 21 were equipped with electronic reversing instruments (SIS) for temperature and pressure measurements.

During the second part of the cruise (Stations No. 114 to 282), the instrument configuration from the first part was used up to station No. 125. After this station, the following sensors were used:
- Temperature sensors T0, T1: S/N 1491, 1642
- Conductivity sensors C0, C1: S/N 1198, 1493
- Transmissiometer (same as during leg 2a)
- Gelbstoff-fluorescence-sensor Dr. Haardt

The reversing instruments were the same as during the first part. In addition, a SBE35 reference thermometer (S/N 003) was used, to check calibrations of the CTD sensors at selected locations with sufficiently small temperature fluctuations.

The conductivity was corrected using salinity measurements from water samples. IAPSO Standard Seawater from the P-series P 133 and P 131 was used. A total of 2742 water samples were measured using a Guildline Autosal 8400A. On the basis of the water sample correction salinity is measured to an accuracy of more than 0.003.

Halocarbons (IFMK, IOW)

The chlorofluorocarbon components CFC-11 and CFC-12 are analysed on board with a GC-ECD (gaschromatograph-electron capture detection) technique as described by Bullister and Weiss (1988). The analysis of carbontetrachloride (CCl_4) is done with a similar system, but with different material for the cooling trap and gaschromatographic column. A capillary column is used to separate CCl_4 from other seawater components instead of a packed column applied for the CFC analysis.

Shortly after leaving Tromsø, the GC-ECD system dedicated to the analysis of CFC-11 and CFC-12 failed and could not be repaired on board. Thus our second GC-ECD system which was prepared to analyse carbon tetrachloride (CCl_4) had to be used as a backup for CFC. Due to the different connection between column and ECD for packed columns (CFCs) and capillary columns (CCl_4), the CFC analysis suffered a 10-fold decrease in the strength of the chromatographic signals compared to the usual performance. The smaller

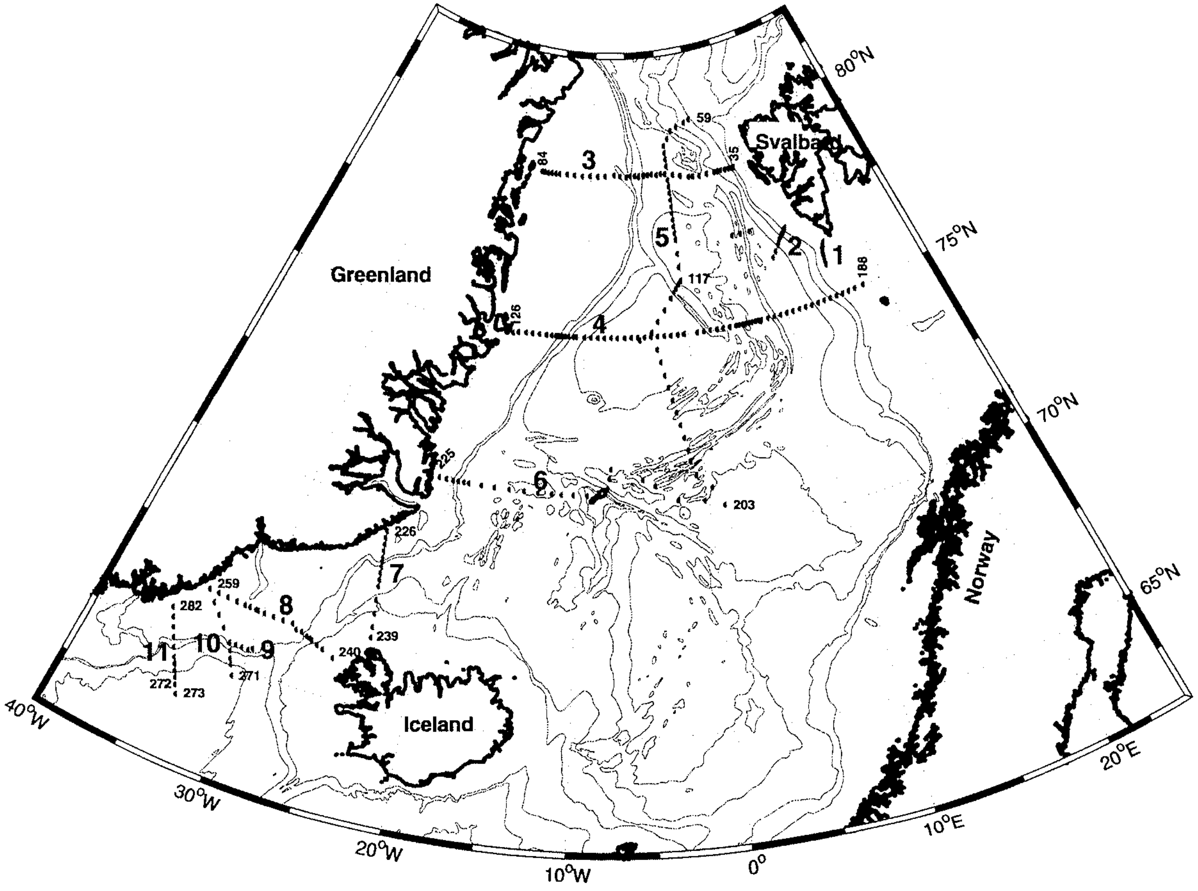


Fig. 6: Locations of the CTD stations. The sections are numbered from 1 to 11.

signal/noise ratio led to an accuracy of ±2% or ±0.012 pmol/kg (whichever is greater) for both, CFC-11 and CFC-12 instead of the usual ±1%. The accuracy of the data was determined by analysing about 10% of the samples twice and by closing all bottles in one depth (2300 m, CTD station 87). The unfavorable signal to noise ratio might also affect the precision of the tracer data, especially the relatively low concentrations in deep water. The small signals also forced us to prolongate the time between two measurements from 11 minutes to about 15 minutes, which decreased the numbers of samples which could be measured between two CTD casts. The blanks for the CFCs and CCl_4 were negligible. Calibration of the water samples (CFCs) was done with a gas standard kindly provided by D. Wallace, IFM Kiel. The concentrations are reported on the SIO93 scale. The first reliable CFC analysis could be carried out at CTD station 30, thus only few tracer observations were obtained off Spitsbergen to study the Storfjord outflow. During the rest of the cruise, the CFC system worked continuously and 1750 water samples have been analysed on 166 CTD stations.

A new GC-ECD system (for capillary columns) was sent to Longyearbyen to allow the analysis of CCl_4 on the second part of the leg. The system was operating from 26 September so that profiles from the Greenland Sea, the Norwegian Sea and Irminger Sea were taken. In total, 270 water samples from 28 CTD stations were analysed, the accuracy was checked by analysing 20 samples twice and was higher than $1^0/_{00}$. One of the gas standards used for calibration was lacking its CCl_4 signal. After the cruise, the second standard, which maintained a CCl_4 peak and was used for calibration of the CCl_4 measurements, will be calibrated again to check the precision, thus the presented concentrations are preliminary.

Bullister, J.L. & Weiss, R.F., 1988. Determination of CC13F and CC12F2 in seawater and air. Deep-Sea Research, 35A [5] , 839-853.; 1988.

Oxygen and nutrients (AWI, CNR, IFMK)

At each station discrete bottle 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 Winkler method (Strickland and Parson, 1972) using potentiometric titration. Inorganic nutrients were determined with a Technicon Autoanalyzer system. The determination of nitrate and nitrite is based on the method described by Armstrong et al. (1967), silicate was measured according to Grasshoff et al. (1983) and phosphate according to Eberlein and Kattner (1987). In some stations along the 79°N section samples have been collected for the analysis of total dissolved nitrogen (TDN) and phosphorus (TDP), which will be carried out at Istituto Talassografico di Trieste after UV photo-oxidation according to the procedures described by Armstrong et al. (1966) and Walsh (1989). During the cruise, 3100 samples were taken for the analysis of dissolved oxygen, 3670 for nutrients and 182 samples for the determination of TDN and TDP.

Armstrong, F. A. J., Williams, P. M. & Strickland, J. D. H., 1966, Photooxidation of organic matter in seawater by ultraviolet radiation, analytical and other applications. Nature, 211, 481-483.

Eberlein, K. & Kattner, G. 1987. Automatic method for the determination of orthophosphate and total dissolved phosphorus in the marine environment. Fresenius' z. Anal. Chem., 326: 354-357.

Grasshoff, K., Erhardt, M and Kremling, K., 1983. Methods of seawater analysis. 2nd revised and extended edition. Verlag Chemie, Weinheim, 419 pp.

Strickland, J. D. H. & Parson, T. R., 1972. A practical handbook of seawater analysis. Fish. Red. Bd. Canada Bull., 167, 2nd Ed., 311 pp.

Walsh, T. W., 1989. Total dissolved nitrogen in seawater: new-high-temperature combustion method and comparison with photo-oxidation. Marine Cemistry, 26, 295-311.

Helium-, tritium-, sulfur hexafluoride- and oxygen isotopes (IUPH)

During the cruise, 780 helium, 780 tritium/^{18}O, 365 additonal ^{18}O samples and 75 sulfur hexafluoride (SF_6) samples were taken from the water bottles. Additionally, 45 samples of helium were taken with an alternative in-situ sampling method. These samples will serve as a first test of the in-situ sampling device. The tracer sampling (helium, tritium, ^{18}O, SF_6) was done over the full water column along all of the sections. The vertical sampling resolution was adjusted in such a way, that the core water masses and transitions between them were sampled. The resolution of ^{18}O sampling was increased in the East Greenland Current as well as in the sections at the Barents Shelf near to Svalbard in the Storfjord (Spitsbergen) outflow region. SF_6 sampling was restricted to some stations in the Fram Strait, the Boreas Basin, the Greenland Basin, the Lofoten Basin, the Jan Mayen Fracture Zone, the Denmark Strait and the Irminger Basin. All of the samples will be analysed in the Heidelberg tracer laboratory.

Oxygen isotopes sampling (AWI, UEA)

To measure the oxygen isotope ^{18}O content 1590 samples were taken, around 700 from Tromsø to Longyearbyen. The first Storfjord (Spitsbergen) section was sampled completely, to enable interlaboratory comparison of results with the group from IUPH who also sampled this location for isotopes. The Fram Strait section was of prime importance for this leg due to its relevance to the VEINS program. For this section, the upper layers of each cast were sampled, with most casts also being sampled to the bottom. This strategy was also adopted for the northern meridional section, whilst the southern meridional section was much more sparsely covered to save bottles for sampling on the second leg. The bottles were shipped back to the U.K. for sample analysis in the Stable Isotope Laboratory of the University of East Anglia.

In addition to the water samples, four sets of ice samples were also collected. Three of these samplings were performed using the helicopters (78°57.9'N, 0°34.4'W; 79°3.8'N, 03°1.3'W; 78°59.0'N, 11°00.7'W), the other when the ice thickness permitted direct access from the ship (78°55.9'N, 16°12.9'W, adjacent to Greenland). Both surface snow and ice were collected, and allowed to melt slowly in sealed bottles in Polarstern's cold rooms to minimise sample equilibration with the atmosphere. Again, sample analysis will be performed at UEA. Results from these analyses will provide better determinations of the isotopic characteristics of the freshwater inputs to waters in the region, and enable their more accurate quantification.

The remaining bottles were used during the second part of the cruise, with priority being given to the two southernmost sections (Denmark Strait) due to the requirements of VEINS. 20 stations were also sampled to full depth on the 75°N section, with a few other stations from the other sections additionally being sampled.

Barium (AWI)

To identify different fresh water sources 1800 barium samples were taken for Dr. K. Falkner of Oregon State University, (USA), on 123 stations from the rosette water sampler.

Measurements with Acoustic Doppler Current Profilers (AWI, IFMK, IOW)

a) Vessel Mounted Acoustic Doppler Current Profiler (VM-ADCP)

A 150-kHz ADCP is mounted in the ship's hull and monitors continuously the velocity distribution in the upper water column. Navigation is provided by DGPS. The VM-ADCP data were processed with the CODAS 3.1 software from Eric Firing et al. Processing steps were done according to that program:

- estimating the time drift of the PC-clock and correcting the profile times,
- loading the data into a codas database,
- verification of the transducer temperature and determination of thresholds,
- viewing of all profiles for flagging bottom and hydrographic wire interference and other glitches,
- calculation of misalignment angle between gyro compass and data acquisition unit with water track method,
- rotation of the velocities by estimated angle,
- calculation of reference layer velocities,
- comparison of smoothed reference layer velocities with raw reference layer velocities in order to determine bad satellite fixes and Schuler oscillations,
- calculation of misalignment angle with watertrack method, this time with edited satellite fixes.

The data were almost finalized on board, the incorporation of the 3DGPS heading instead of the gyro compass heading will be done in the home lab. The velocity profiles reached down to 200 m depth during the first part and to 350 m depth during the second part of the cruise. The currents averaged between 50 and 100 m depth are presented in Fig. 7. Despite the tidal noise (about 5 cm/s) the main features of the circulation are evident in the data: the West Spitsbergen Current heading north, the recirculation of the Atlantic Water towards the east and the East Greenland Current flowing south along the Greenland coast.

b) Lowered Acoustic Doppler Current Profilers (LADCP)

The measurements were done with two RDI 150-kHz-NB ADCPs, one from the IfM Kiel, the other from the AWI. During the first part of the cruise, the AWI instrument was attached to the CTD rosette, while the Kiel instrument was lowered solitary on a wire. About 25 simultaneous casts of the two instruments, were taken. This allows for an intercomparison between the data quality from the two instruments.

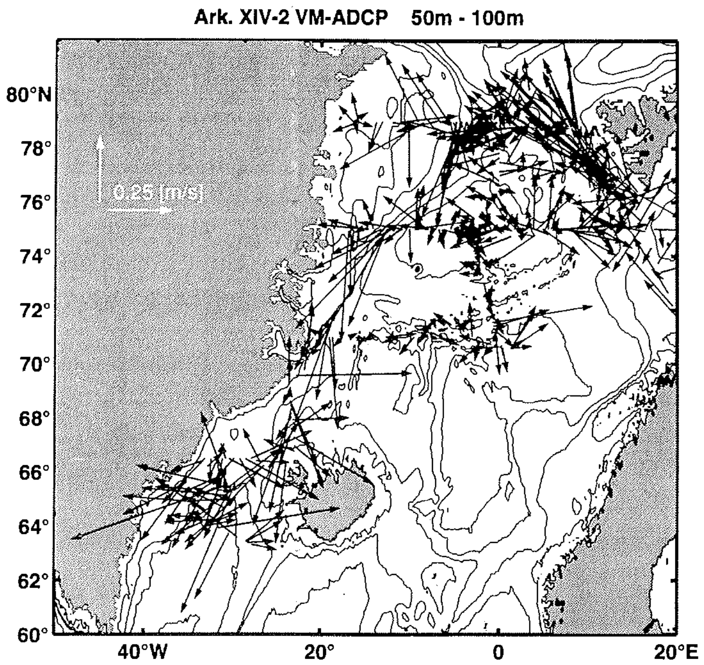


Fig. 7: Mean currents between 50 and 100 m depth measured with the VM-ADCP.

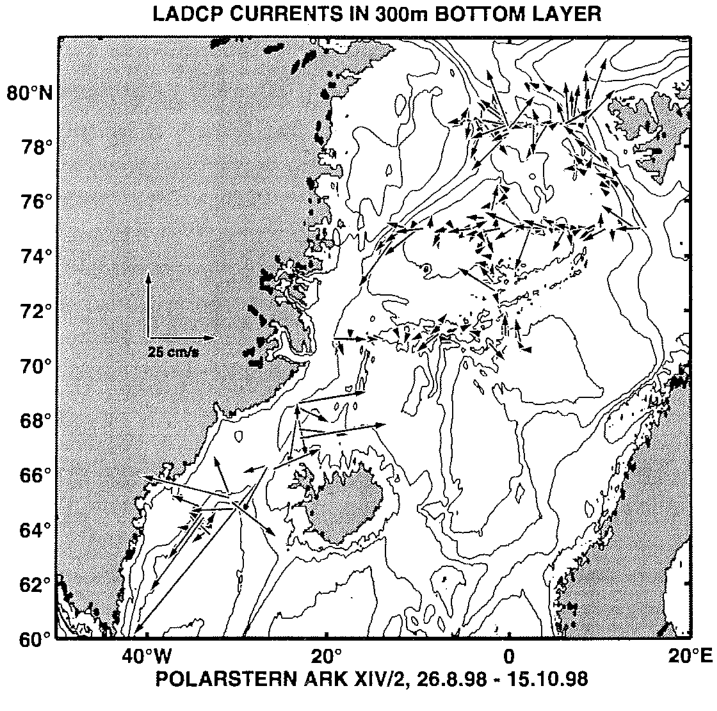


Fig. 8: Mean currents in the 300 m thick layer above the bottom obtained from the LADCP measurements.

On the second part of the cruise, due to malfunction of the AWI instrument, the Kiel LADCP was attached to the rosette. In total, 216 LADCP profiles were taken, from which 44 had to be rejected due to bad data quality. On most of these profiles the determination of the vertical velocity failed causing a wrong assignment of depth. One part of the rejected profiles were taken on the shelf, where the waterdepth was shallow compared to the range of the ADCP. The other part consists of profiles taken by the AWI instrument, whose range was reduced by one third compared to the Kiel instrument. The weaker performance and the unusually high consumption of energy of the AWI instrument was most likely due to moisture in the instrument's housing. At 9 September, at station 114, seawater penetrated into the instrument causing a fatal damage. The data set include numerous profiles from different topographic regimes, e.g. from abyssal plains, continental slopes, oceanic ridges and fracture zones. This offers the opportunity to study the influence of topography on vertical mixing.

The mean currents averaged over the 300 m above the bottom obtained from the LADCP measurements, are presented in Fig. 8. On the eastern side of the West Spitsbergen Current flows north and splits into two branches, one continuing to the north along Yermak Plateau, the other one recirculating in the Fram Strait and and joining the southward flowing East Greenland Current. The velocities in these boundary currents are of the order of 20-40 cm/s. Apart from the strong boundary currents, the flow field is less clear. In the Denmark Strait, the velocities are generally higher. South of the strait, the high velocities in the overflow plume are confined to the bottom layer and reach up to 80 cm/s.

XBT measurements (AWI)

24 XBT probes manufactured by Sparton from Canada were launched during the crossing of the Arctic Front. For location see station list (Part 4 of Annex).

Moorings (AWI, IFMHH, NPI)

To quantify the current fields of the East Greenland and the West Spitsbergen Currents by direct measurements, moored instruments were used. The current field was measured with 14 moorings, deployed across Fram Strait at latitudes between approximately 78 and 79°N, in water depths of between 200 m and 2600 m water depth (Part 6 of the annex, Fig. 9). For a sufficient vertical resolution, 3 to 4 instruments per mooring are required.

Temperatures and salinities are measured together with the currents, to determine heat and salt transports. Mooring VFS 1 to 10 were recovered from "Polarstern", VFS 11 could not be recovered and VFS 12 to VFS 14 were recovered from "Lance". All 14 moorings were redeployed from "Polarstern".

Another set of moorings (SF1 to 5) was deployed on the southwestern continental slope of Spitsbergen. However, SF3 and SF4 could not be recovered in spite of extensive dredging. It is most likely that they were damaged by the intensive fishing which could be observed during the work in the area. The ADCP of mooring SF3 was found in Denmark Strait and returned to AWI after the cruise. Because of the high risk of further losses, the programme was strongly restricted and only SF1 was redeployed.

Two moorings with a profiling CTDs were recovered and redeployed in the central Greenland Sea.

Preliminary results

Shelf plumes from the Storfjord (Spitsbergen)

The objective of the work on shelf plumes from the Storford is to study the ventilation of the deep Arctic Ocean Basins through dense shelf waters. 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 suspend sediment and transport material down the slope. In particular, the contribution of winter water from the Storfjord to the West Spitsbergen Current is investigated.

In summer 1997, five moorings were deployed, three of which were successfully recovered (Annex Part 6, moorings SF). One mooring (SF1) was located at the Barents Sea shelf edge to monitor the flow and characteristics of the Storfjord dense water plume when it approaches the shelf edge. Four moorings (SF2 to SF5) were deployed over the continental slope west of Spitsbergen between 600 m and 1500 m water depth in order to measure the plume penetrating to the deeper parts of Fram Strait. The moorings had instruments in the first 100 m above the bottom recording current, temperature, salinity and backscatter from suspended particles. Only the two deepest moorings were recovered, the two others could be located through the acoustic release but the moorings did not raise to the surface. The top

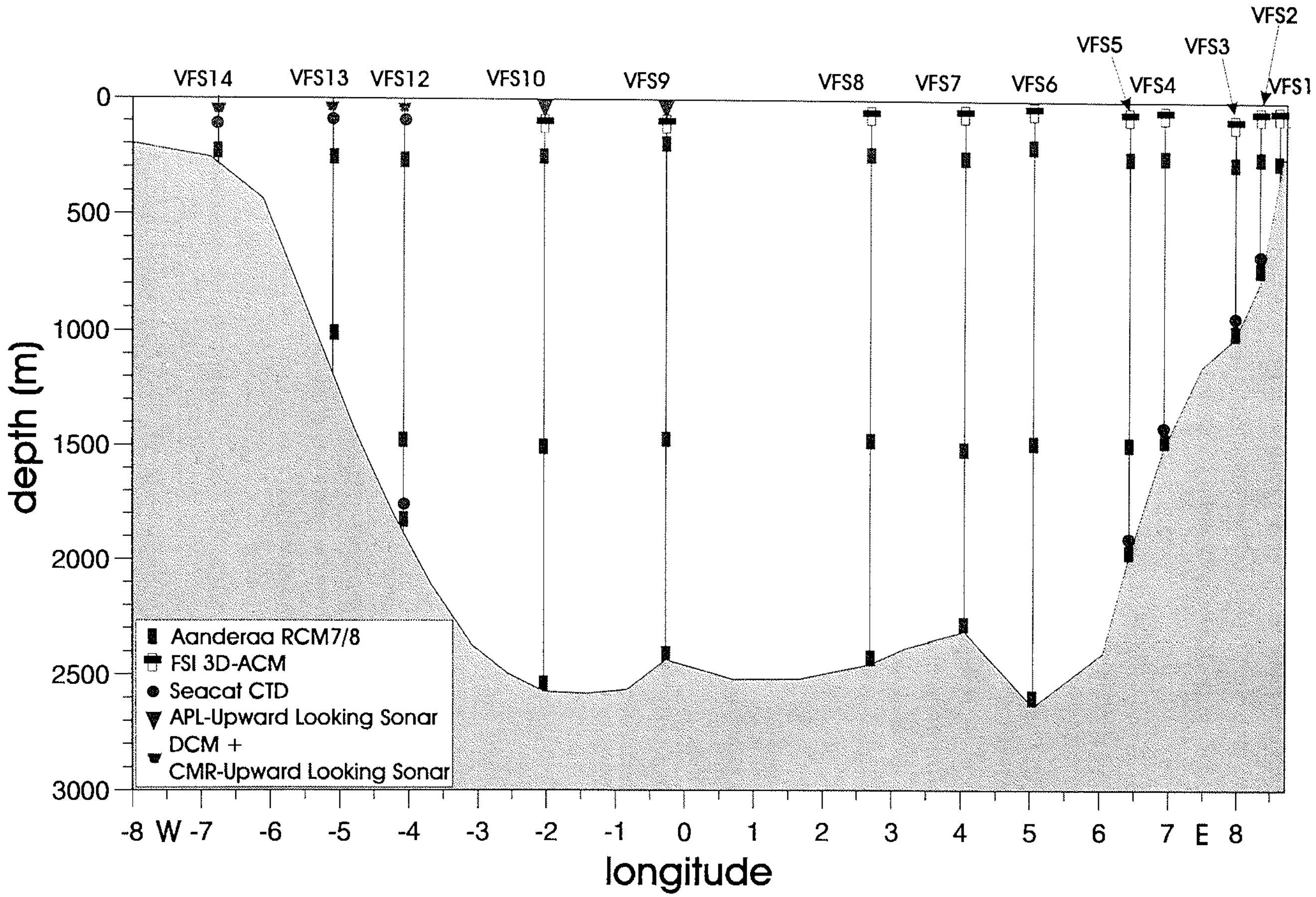


Fig. 9: Transect across Fram Strait with oceanographic moorings which were deployed in 1997 by “Lance“ and recovered in 1998 by “Lance“ and “Polarstern“.

part of one of the moorings was emerged in December 1997 and was later recovered by an Islandic trawler in the Denmark Strait.

Two hydrographic sections (1 and 2) were carried out, one parallel to the shelf edge and one across the continental slope southwest of Svalbard (Figs. 10 and 11). Parts of both sections were repeated two weeks later.

At some selected stations (4, 5, 6, 7, 16, 19), water samples were taken from the lowest two levels 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. In addition, at these stations (except at station 5) samples of the sediment surface were taken with the multicorer. They will also be analysed at home. In both years, a clear signal of a dense winter water covering the shelf bottom was present. The densest bottom water was colder and more saline in 1998 as compared to 1997. Since that late in summer, the plume flow is intermittant, it cannot be decided from hydrographic observations alone whether the change reflects interannual variation or whether it is caused by short term fluctuations. On three shelf stations (107,112,113) we observed water colder than 0°C at 350-370 m depth, which was saturated with CFCs. No indication of outflow water which had descended deeper was found in the few stations analysed for CFCs.

Fram Strait

The hydrographic section 3 across Fram Strait (Fig. 12) reaches from the West Spitsbergen continental slope to the coast of Greenland. It shows the warm and saline core of the northward West Spitsbergen Current, the westward return flow of Atlantic Water and the waters exiting the Arctic Ocean in the East Greenland Current. In comparison to 1997, most of the deep layers in the central and eastern Fram Strait became warmer, likely reflecting the presence of warmer Greenland Sea Deep Water.

Low salinity surface water exits the Arctic Ocean in the western part of the section (Fig. 12). The freshest water was found over the 200 km broad shelf with a mean salinity in the upper 30 m of 31. The respective mean salinity over a distance of 130 km across the East Greenland slope was 32. Below the surface layer, Arctic halocline water of the type formed in Canadian Arctic (with salinities around 32.5) spreads southward on the shelf, but not over the slope. There, halocline water of the Eurasian type with higher salinities was observed. Under the condition of favourable flow conditions, most of the oceanic fresh water flux from the Arctic Ocean into the Nordic Seas would occur over the East Greenland shelf.

The Arctic waters present a characteristic signature revealed particularly by silicate (Si) and phosphate (PO_4) concentration. The high concentrations of both parameters in the upper 100 m in the western part of the section identifies the outflow of a water mass of Pacific origin within the East Greenland Current system. NO_3 distribution in the upper layer (Fig. 13), in comparison with the other nutrients, suggests a nitrogen limitation on biological processes in this area.

The highest CFC concentrations are found near the surface and in the warm and saline Atlantic water tongue, which is about 400-500 m thick and extends to about 4°W. The bottom water with salinities >34.92 characterizing the Eurasian Basin Deep Water (EBDW) was found on various stations in Fram Strait and further north. Its CFC signal had not changed significantly since 1993, indicating the slow ventilation of the EBDW. However the deep water with lower salinities shows higher CFC values than in 1993.

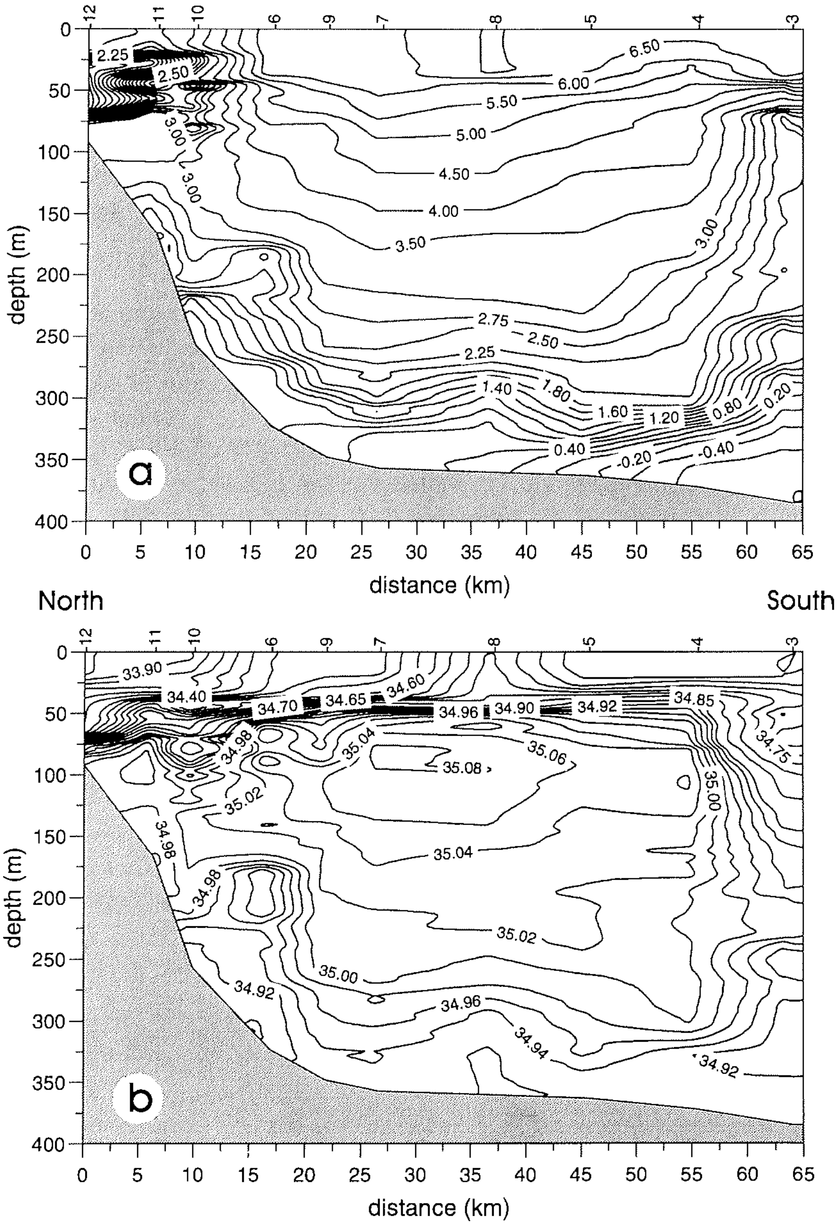
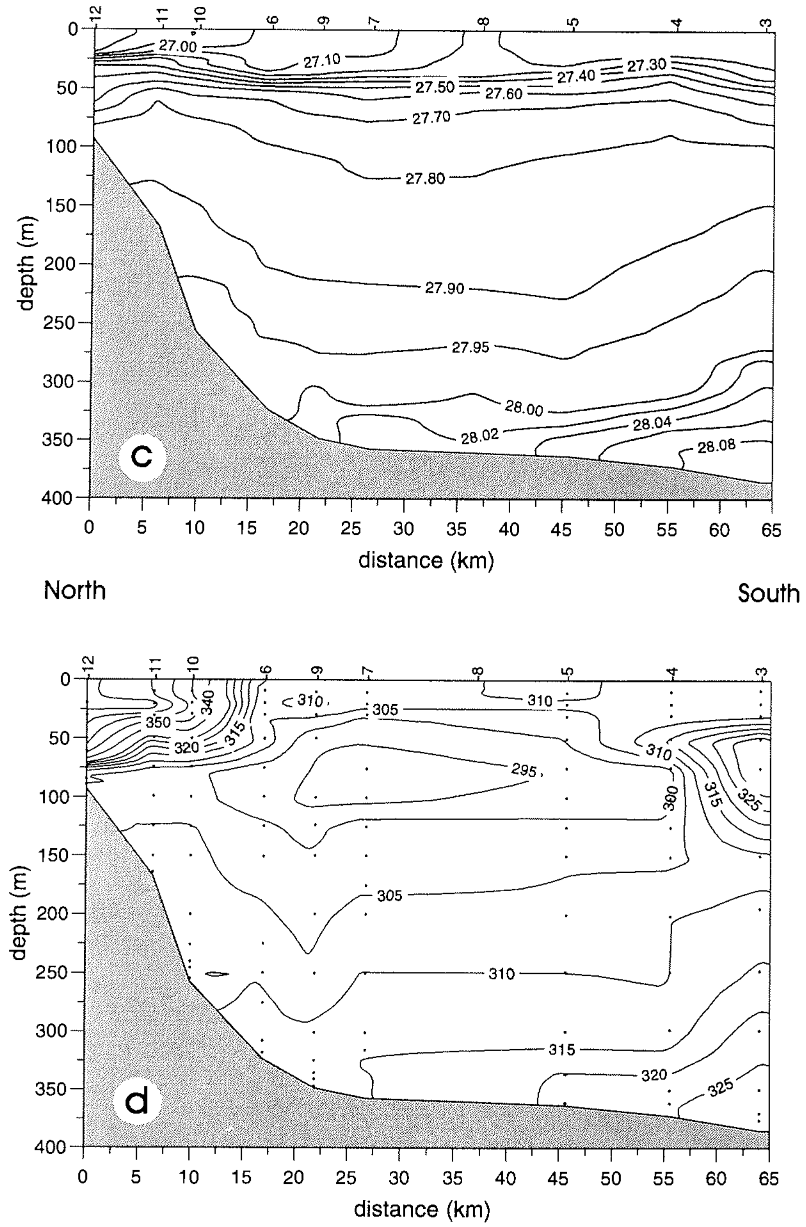


Fig. 10: Vertical section 1 of potential temperature (a), salinity (b), potential density (c), oxygen in µmol/kg (d), silicate in µmol/kg (e) and nitrate in µmol/kg (f).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11
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6
9
7
8
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4
3
27.00
27.10
27.30
27.40
27.50
27.60
27.70
27.80
27.90
27.95
28.00
28.02
28.04
28.08
c
depth (m)
distance (km)
North
South
350
340
320
315
310
305
295
300
325
310
315
320
325
d
depth (m)
distance (km)
0
50
100
150
200
250
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350
400
0
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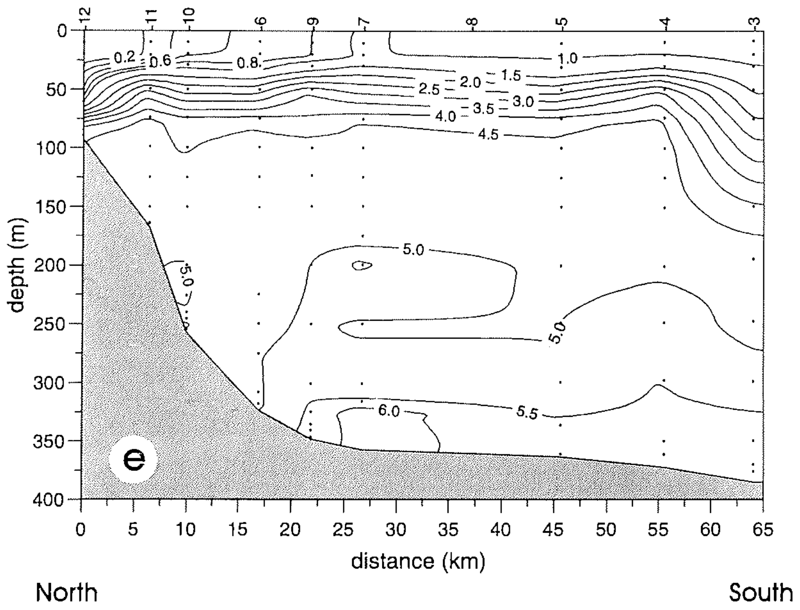
10
15
20
25
30
35
40
45
50
55
60
65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0.8
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2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
depth (m)
distance (km)
0
50
100
150
200
250
300
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400
0
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10
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20
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40
45
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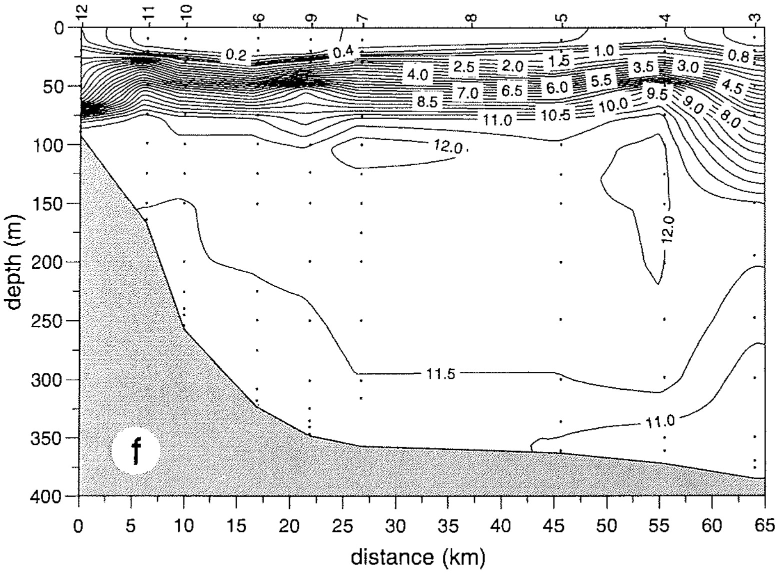
60
65
e
North
South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3.0
3.5
4.0
4.5
5.5
6.0
6.5
7.0
8.0
8.5
9.0
9.5
10.0
10.5
11.0
11.5
12.0
depth (m)
distance (km)
0
50
100
150
200
250
300
350
400
0
5
10
15
20
25
30
35
40
45
50
55
60
65
f

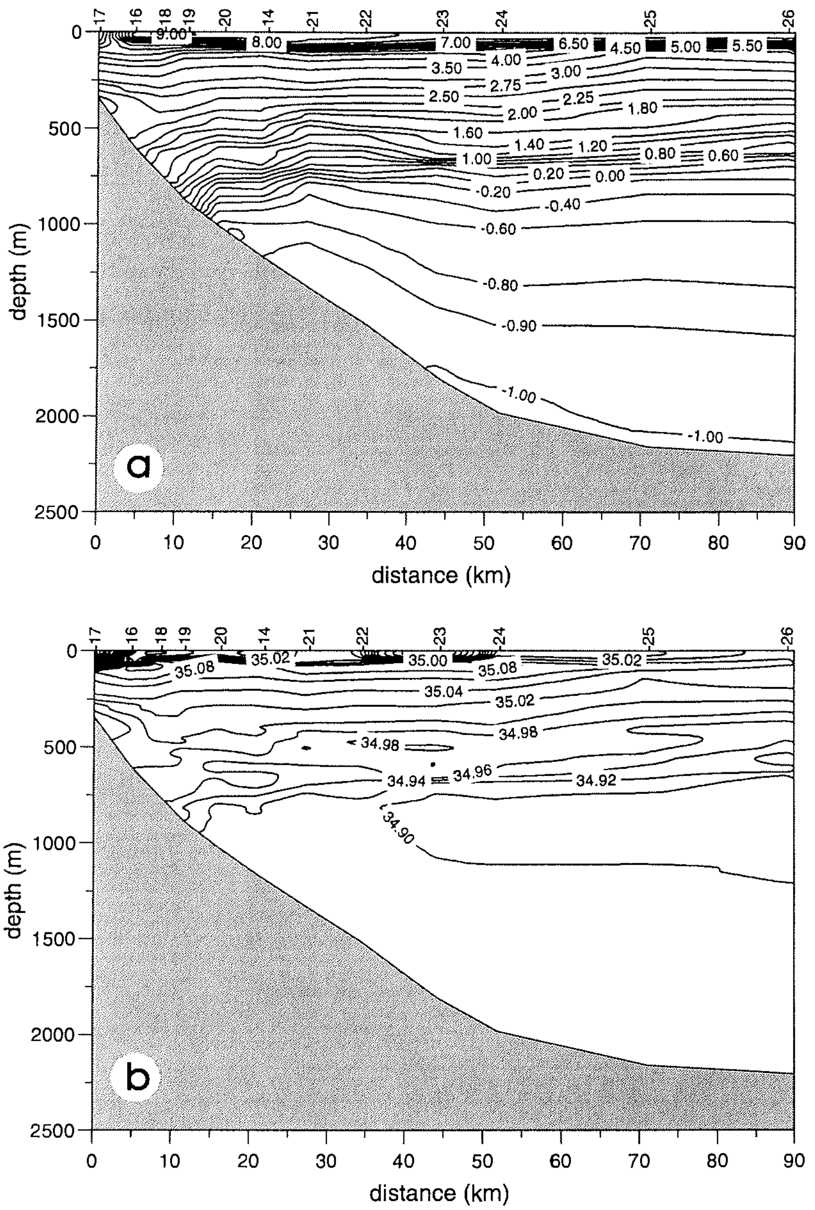
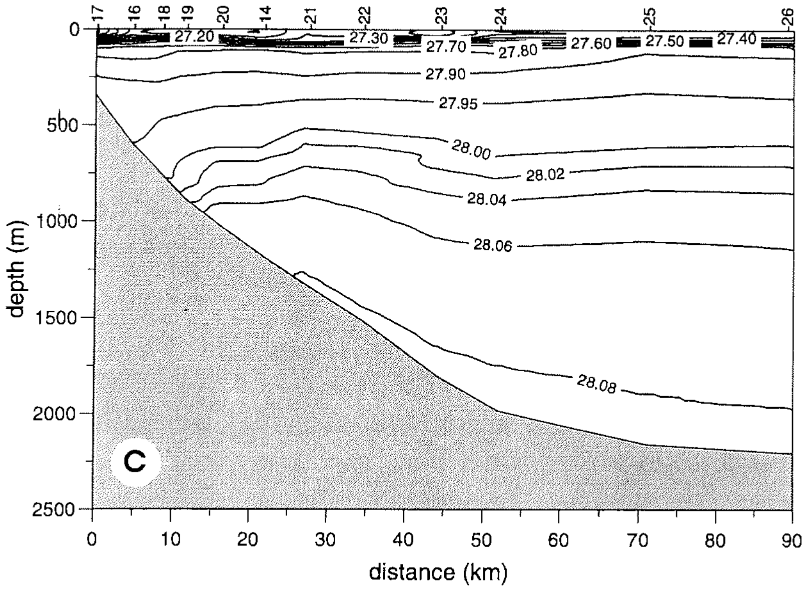


Fig. 11: Vertical section 2 of potential temperature (a), salinity (b), potential density (c), oxygen in µmol/kg (d), silicate in µmol/kg (e), nitrate in µmol/kg (f), phosphate in µmol/kg (g) and tracer SF_6 in fmol/l (h) at the continental slope southwest of Spitsbergen.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14
21
22
23
24
25
26
27.20
27.30
27.70
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27.60
27.50
27.40
27.90
27.95
28.00
28.02
28.04
28.06
28.08
c
depth (m)
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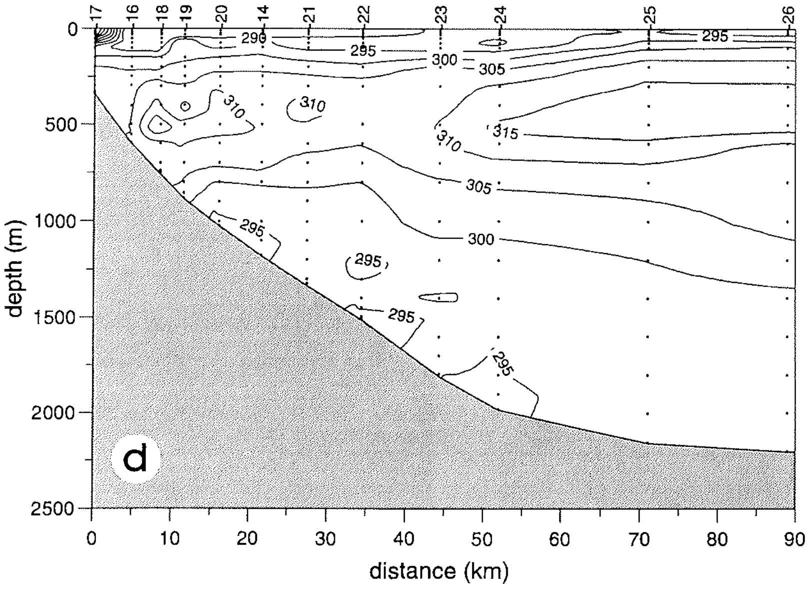
1000
1500
2000
2500
0
10
20
30
40
50
60
70
80
90
distance (km)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14
21
22
23
24
25
26
290
295
300
305
310
310
315
310
305
300
295
295
295
295
295
d
depth (m)
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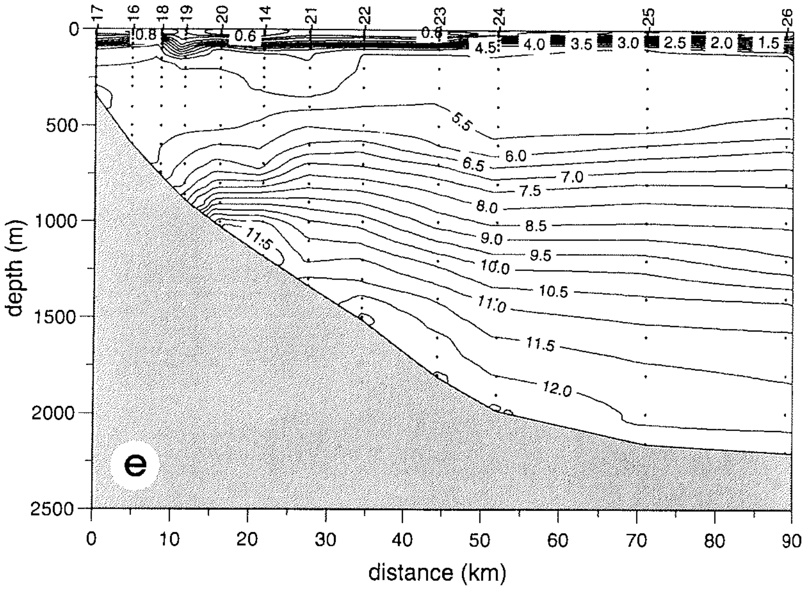
500
1000
1500
2000
2500
0
10
20
30
40
50
60
70
80
90
distance (km)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14
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22
23
24
25
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0.6
0.6
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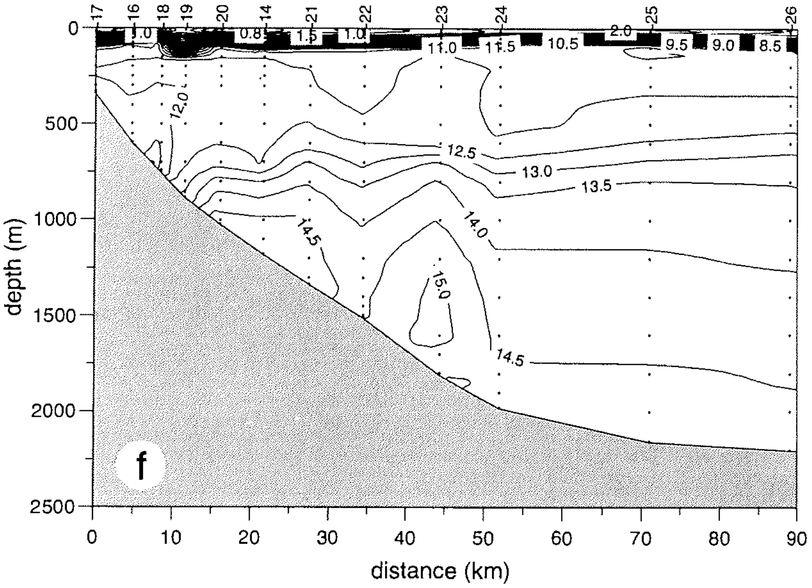
4.0
3.5
3.0
2.5
2.0
1.5
5.5
6.0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
10.5
11.0
11.5
11.5
12.0
0
500
1000
1500
2000
2500
depth (m)
0
10
20
30
40
50
60
70
80
90
distance (km)
e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1.5
1.0
2.0
11.0
11.5
10.5
9.5
9.0
8.5
12.0
12.5
13.0
13.5
14.0
14.5
15.0
14.5
0
500
1000
1500
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2500
depth (m)
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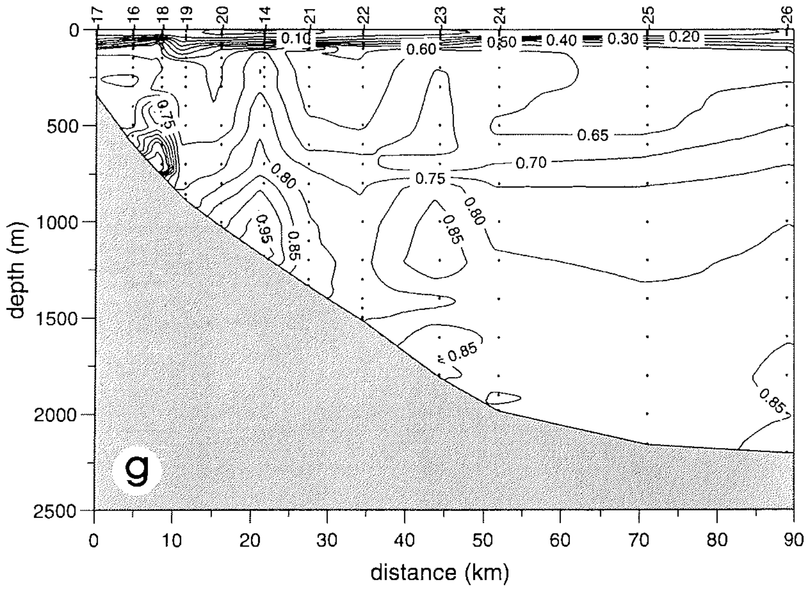
20
30
40
50
60
70
80
90
distance (km)
f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0.20
0.75
0.65
0.70
0.75
0.80
0.95
0.85
0.85
0.80
0.85
0.85
0.85
g
depth (m)
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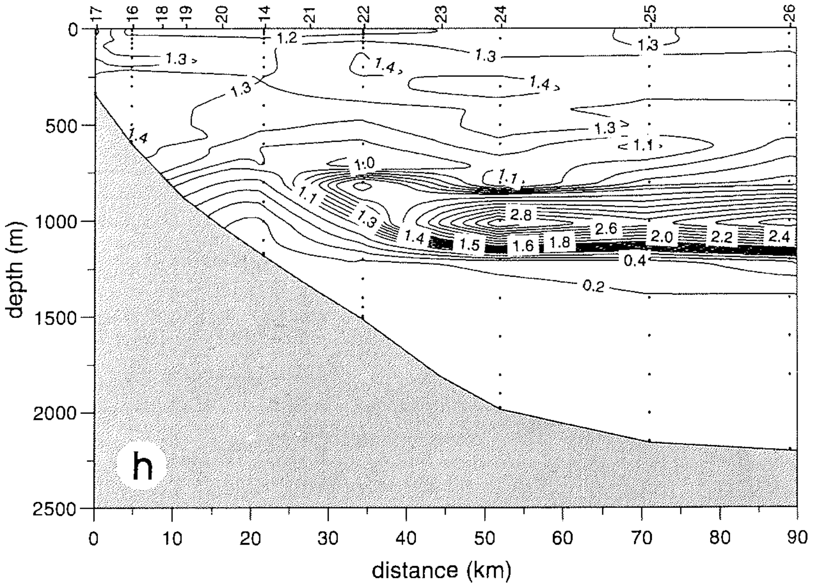
500
1000
1500
2000
2500
distance (km)
0
10
20
30
40
50
60
70
80
90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23
24
25
26
1.2
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1.3
1.4
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1.4
1.3
1.3
1.1
1.4
1.0
1.1
1.1
1.3
1.4
1.5
1.6
1.8
2.8
2.6
2.0
2.2
2.4
0.4
0.2
h
depth (m)
0
500
1000
1500
2000
2500
distance (km)
0
10
20
30
40
50
60
70
80
90

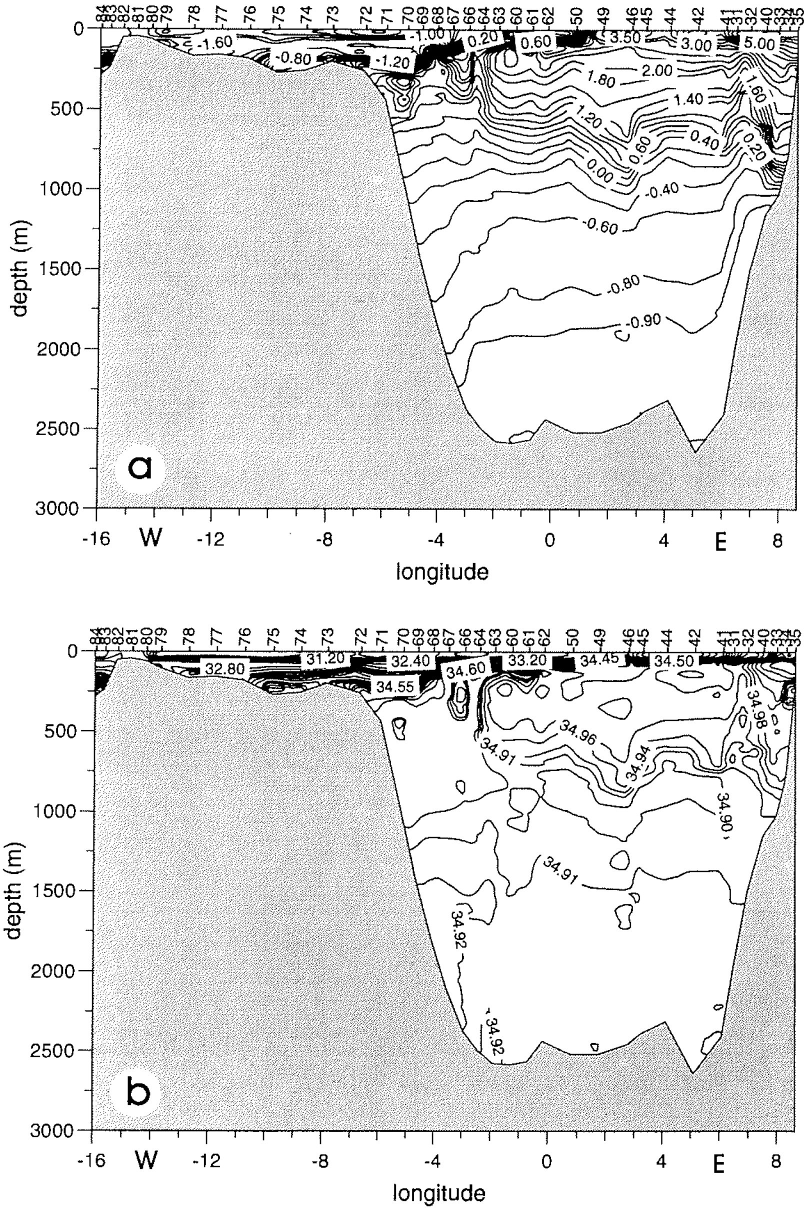
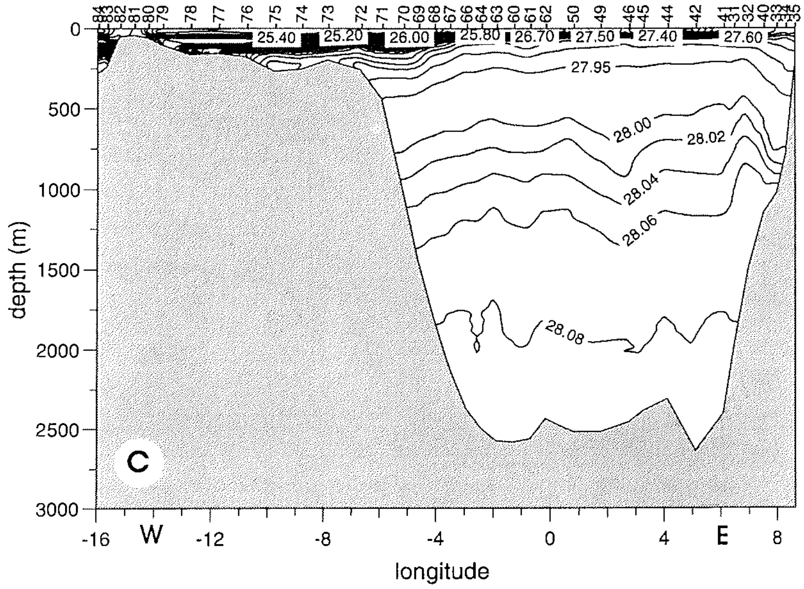


Fig. 12: Vertical section 3 of potential temperature (a), salinity (b), potential density (c), oxygen in µmol/kg (d), silicate in µmol/kg (e), nitrate in µmol/kg (f), tracer CFC-11 in pmol/kg (g) and tracer SF_6 in fmol/l (h) across Fram Strait at approximately 79°N.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25.20
26.00
25.80
26.70
27.50
27.40
27.60
27.95
28.00
28.02
28.04
28.06
28.08
c
depth (m)
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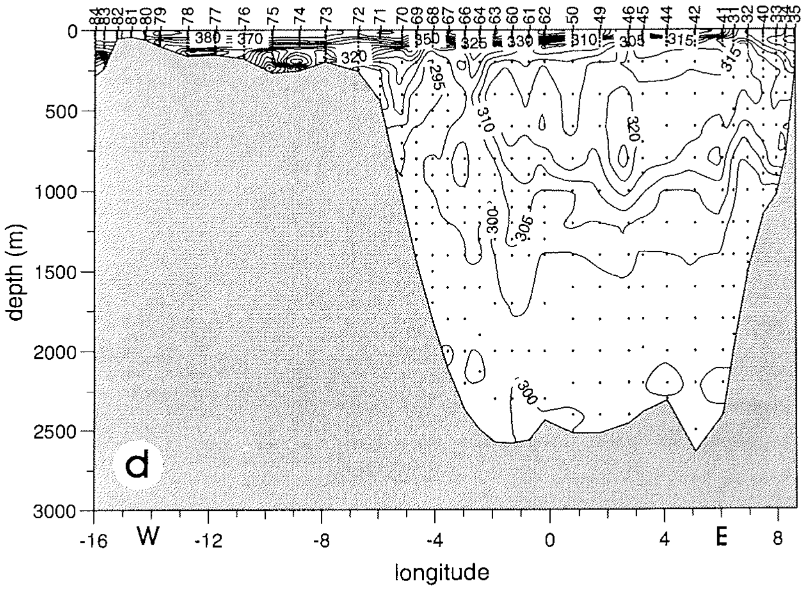
1000
1500
2000
2500
3000
-16
W
-12
-8
-4
0
4
E
8
longitude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380
370
320
350
325
330
310
305
315
295
310
320
300
305
300
d
depth (m)
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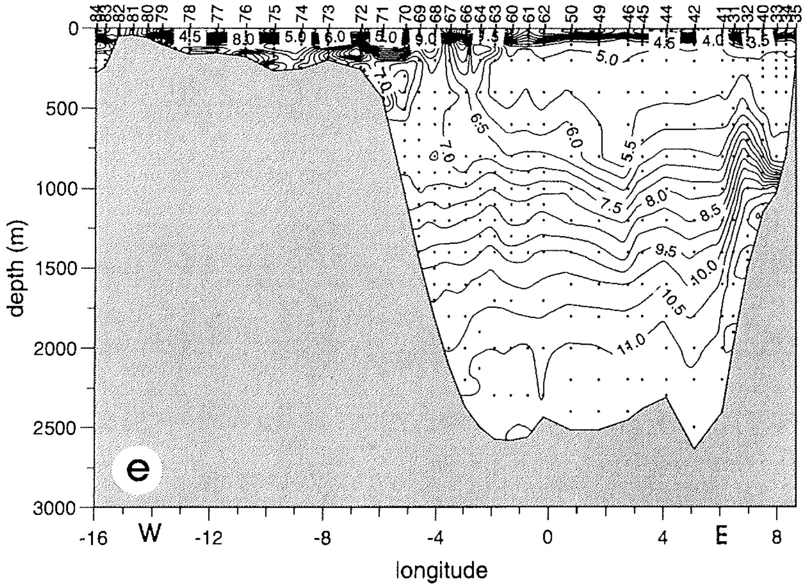
1000
1500
2000
2500
3000
-16
W
-12
-8
-4
0
4
E
8
longitude


e
depth (m)
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1000
1500
2000
2500
3000
longitude
-16
W
-12
-8
-4
0
4
E
8
84 83 82 81 80 79 78 77 76 75 74 73 72 71 70 69 68 67 66 64 63 60 61 62 50 49 46 45 44 42 41 31 32 40 33 34 35
4.5
8.0
5.0
6.0
9.0
7.5
4.5
4.0
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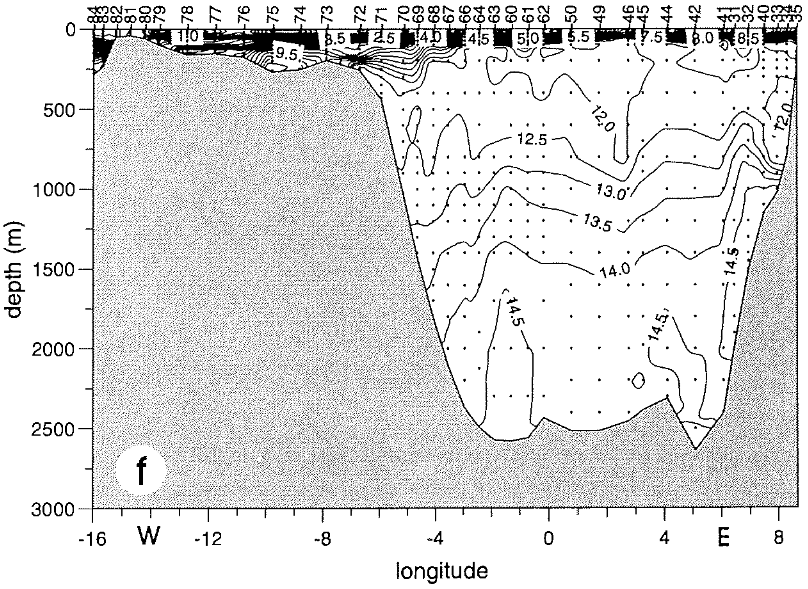
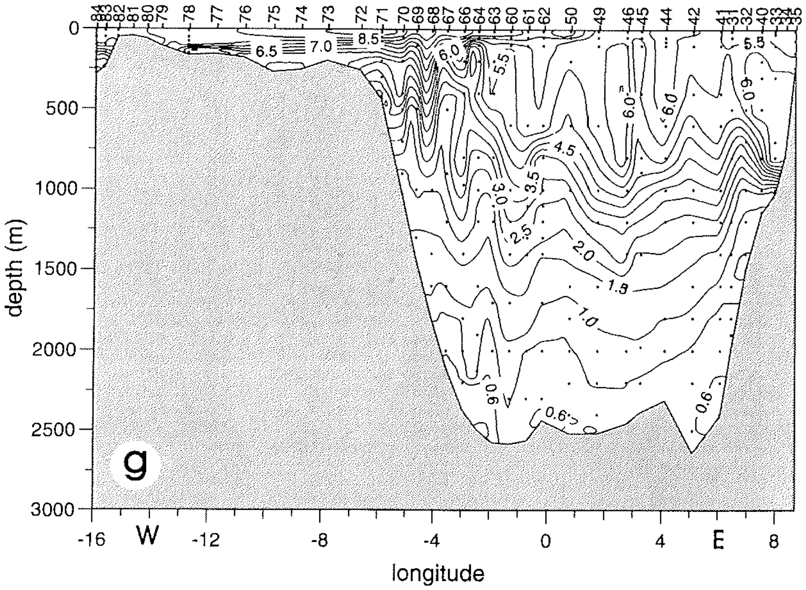
5.5
7.5
8.0
8.5
9.5
10.0
10.5
11.0


f
depth (m)
0
500
1000
1500
2000
2500
3000
longitude
-16
W
-12
-8
-4
0
4
E
8
84 83 82 81 80 79 78 77 76 75 74 73 72 71 70 69 68 67 66 64 63 60 61 62 50 49 46 45 44 42 41 31 32 40 33 34 35
1.0
9.5
3.5
2.5
4.0
4.5
5.0
5.5
7.5
8.0
8.5
12.0
12.5
13.0
13.5
14.0
14.5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8.5
6.0
5.5
5.5
6.0
6.0
6.0
4.5
3.5
3.0
2.5
2.0
1.5
1.0
0.6
0.6
0.6
g
depth (m)
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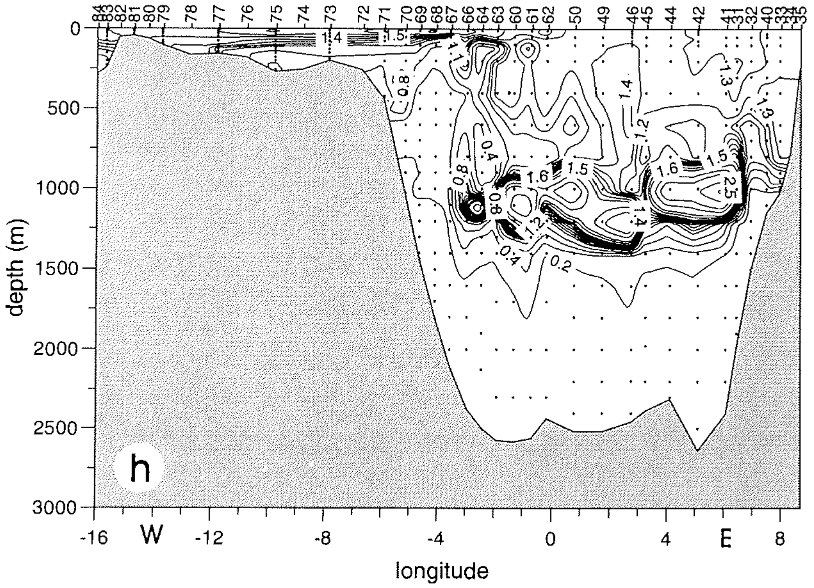
500
1000
1500
2000
2500
3000
-16
W
-12
-8
-4
0
4
E
8
longitude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1.4
1.3
1.3
1.2
0.4
0.8
1.6
1.5
1.6
1.5
2.5
0.8
1.2
1.4
0.4
0.2
h
depth (m)
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1000
1500
2000
2500
3000
-16
W
-12
-8
-4
0
4
E
8
longitude

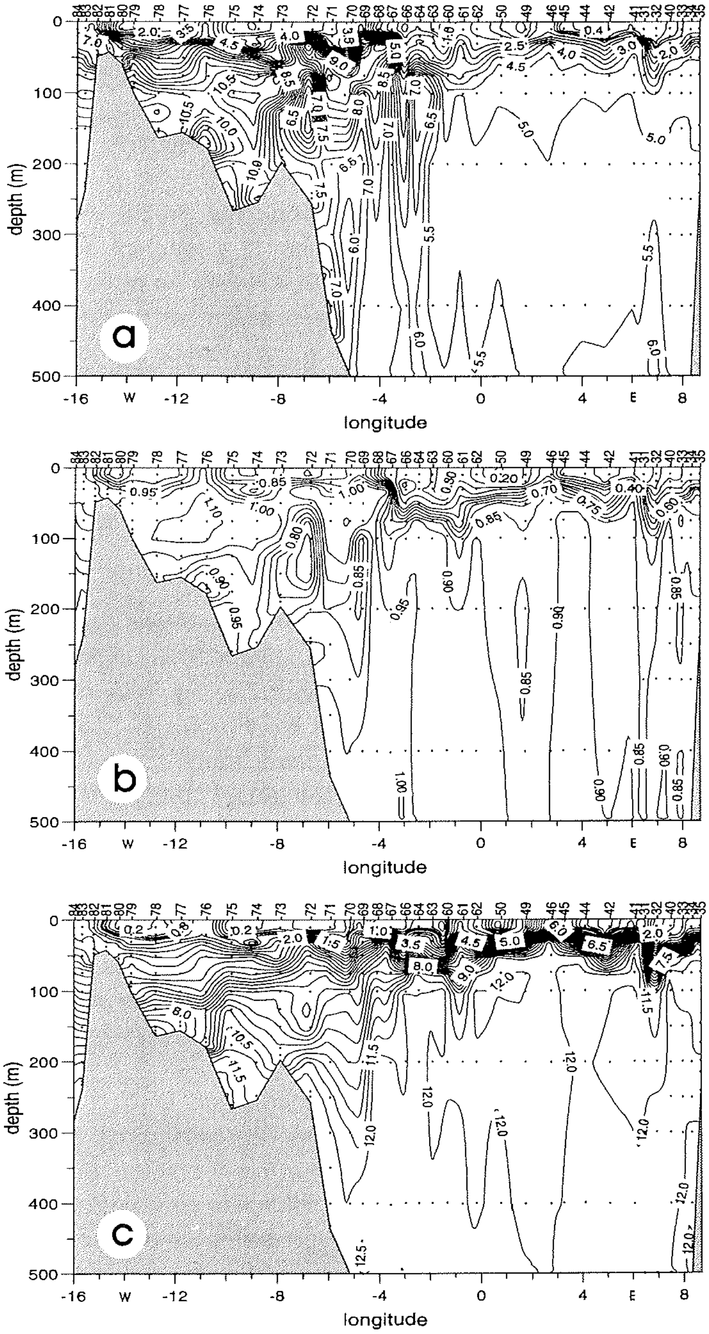


Fig. 13: Vertical section 3 of silicate in µmol/kg (a), phophate in µmol/kg (b) and nitrate in µmol/kg (c) in the upper 500 m across Fram Strait at approximately 79°N.

Greenland Sea

The Greenland Sea was surveyed with two sections: section 4 along 75°N from the East Greenland coast into the Barents Sea (Fig. 14 g) and Section 5 reaching from the Yermak Plateau into the Norwegian Sea (Fig. 15 g).

The temperature/salinity characteristics reveal that during the last winter (1997/1998) the convection in the Greenland Sea reached only to 700 m depth. In contrast to our previous cruises (1993, 1997) no profiles with traces of a convective event were found. The deep layers of bottom water were subject to further warming by about 0.01 K per year as found with a short interruption during the last years. Both observations suggest that the phase of little water mass renewal of the last years still continues. Additionally, there is further evidence of the previously reported downwelling in the deeper layers of the central Greenland Sea. The low salinity and the high temperatures in the uppermost 1000 m suggest that there will be no deep convection in the next winter neither.

The CFC concentrations in the deep water of the Greenland Sea (Fig. 14 und 15) including the Boreas Basin had increased since 1993, although no deep convective events occured in that time period. The increase of tracers and the parallel warming and salt enrichment of the Greenland Sea Deep Water might be caused by intense vertical mixing over rough topography (Visbeck and Rhein, 1998). The vertical shear from the LADCP profiles will be used to estimate the vertical diffusion coefficient over smooth and rough topography.

The CCl_4/CFC-11 ratio in the Greenland and Norwegian Sea increases significantly below about 1000 m (Fig.16), indicating that the main tracer input into the deep water of these basins was 2-3 decades ago. South of Denmark Strait, however, all deep water components have similar ratios as the near surface water, reflecting the younger 'age' of the tracer input into these water masses.

In the deep Eurasian Basin north of 78°N the concentrations are considerably lower and decrease with depth. In the deep Lofoten Basin south of Mohns Ridge, the stratification of the water column is very weak, but a vertical CFC gradient is clearly visible. Our measurements confirmed the CFC-11 increase in the Lofoten Basin since 1993, caused by the inflow of CFC richer Greenland Sea Deep Water (GSDW).

Visbeck, M. & Rhein, M., 1999. Can Bottom Boundary Layer Mixing ventilate Greenland Sea Bottom Water? J. Phys. Oceanogr., revised, submitted.

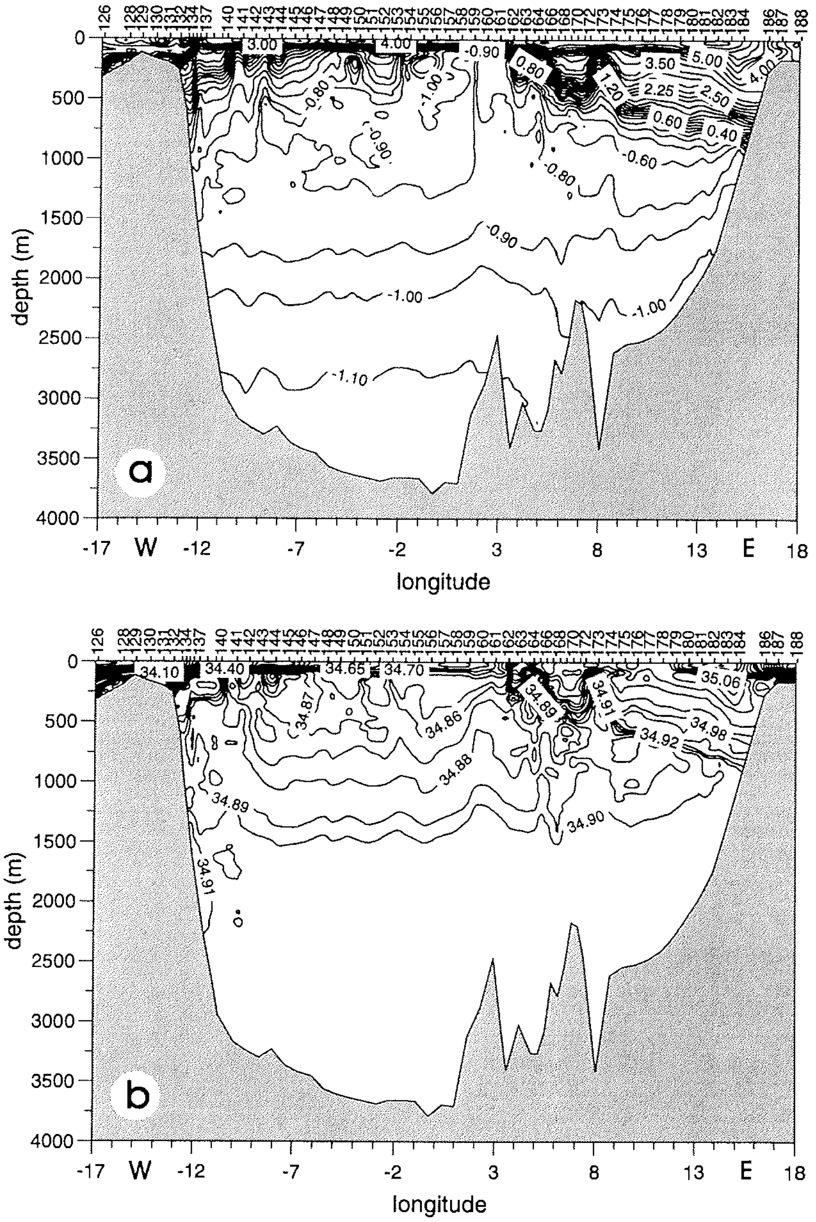
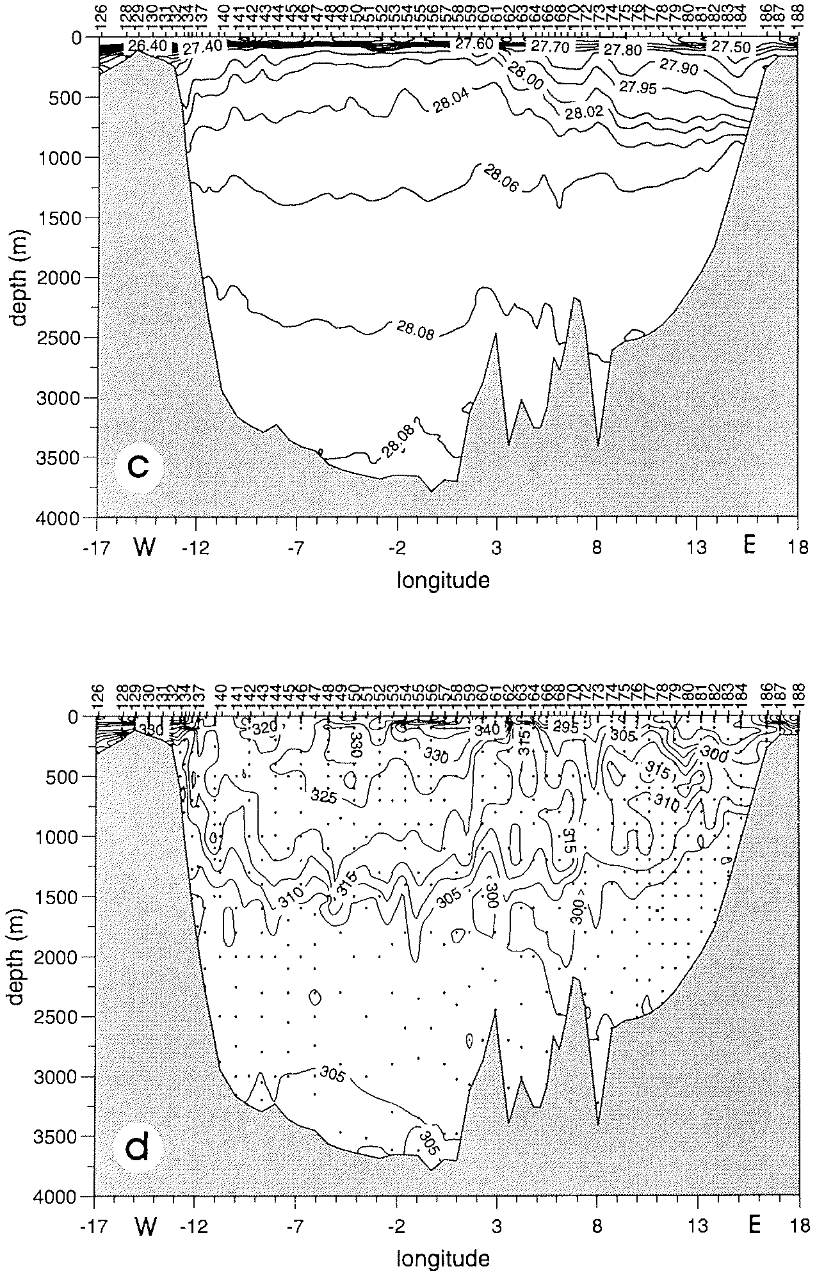


Fig. 14: Vertical section 4 of potential temperature (a), salinity (b), potential density (c), oxygen in µmol/kg (d), silicate in µmol/kg (e), nitrate in µmol/kg (f), tracer CFC-11 in pmol/kg (g) and tracer SF_6 in fmol/l (h) across the Greenland Sea at 75°N.


c
depth (m)
longitude
W
E
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27.40
27.60
27.70
27.80
27.50
27.90
27.95
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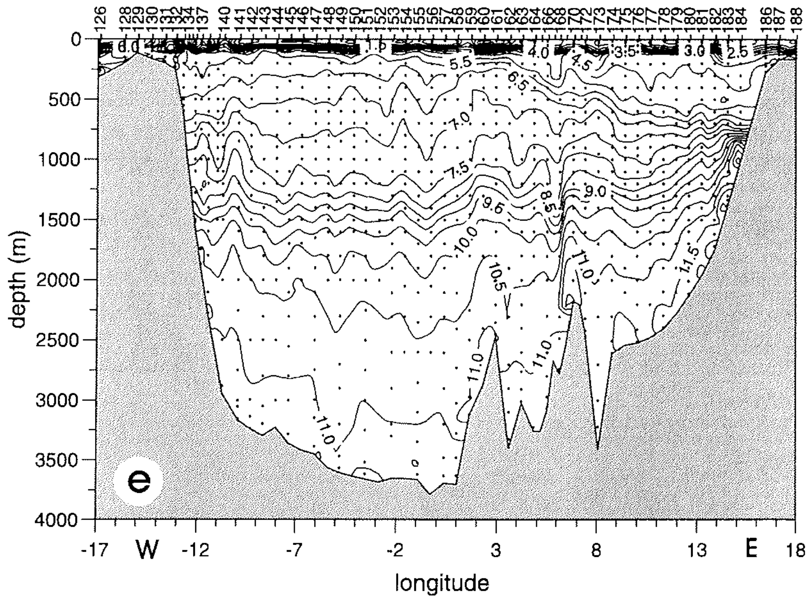
315
295
305
300
325
310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6.0
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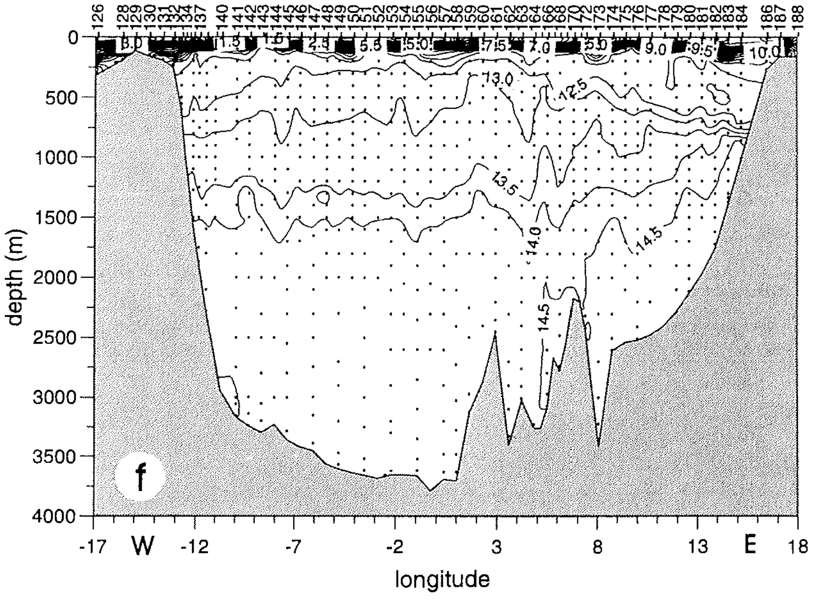
5.5
4.0
4.5
3.5
3.0
2.5
6.5
7.0
7.5
9.5
8.5
9.0
10.0
10.5
11.0
11.5
11.0
e
depth (m)
0
500
1000
1500
2000
2500
3000
3500
4000
-17
W
-12
-7
-2
3
8
13
E
18
longitude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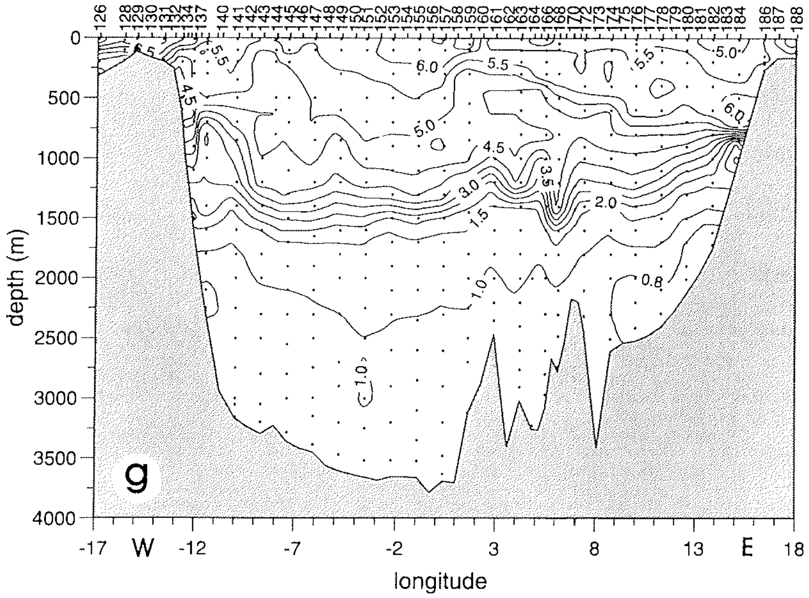
8.0
11.5
1.5
2.5
5.5
5.0
7.5
7.0
5.0
9.0
9.5
10.0
13.0
12.5
13.5
14.0
14.5
14.5
f
depth (m)
0
500
1000
1500
2000
2500
3000
3500
4000
-17
W
-12
-7
-2
3
8
13
E
18
longitude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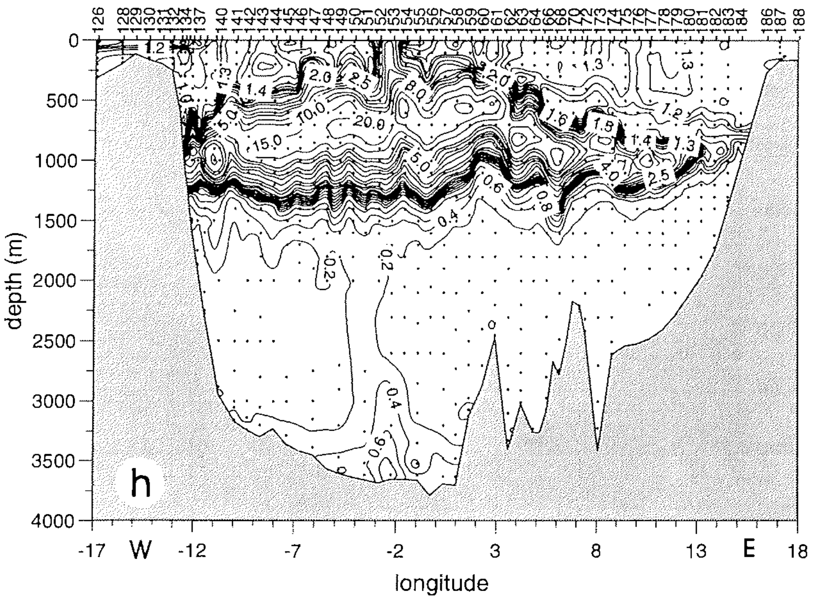
depth (m)
0
500
1000
1500
2000
2500
3000
3500
4000
-17
W
-12
-7
-2
3
8
13
E
18
longitude
6.0
5.5
5.0
4.5
3.5
3.0
2.0
1.5
1.0
0.8
g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depth (m)
0
500
1000
1500
2000
2500
3000
3500
4000
-17
W
-12
-7
-2
3
8
13
E
18
longitude
1.2
1.3
1.4
2.0
2.5
8.0
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20.0
1.6
1.8
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0.6
0.8
0.4
0.2
h

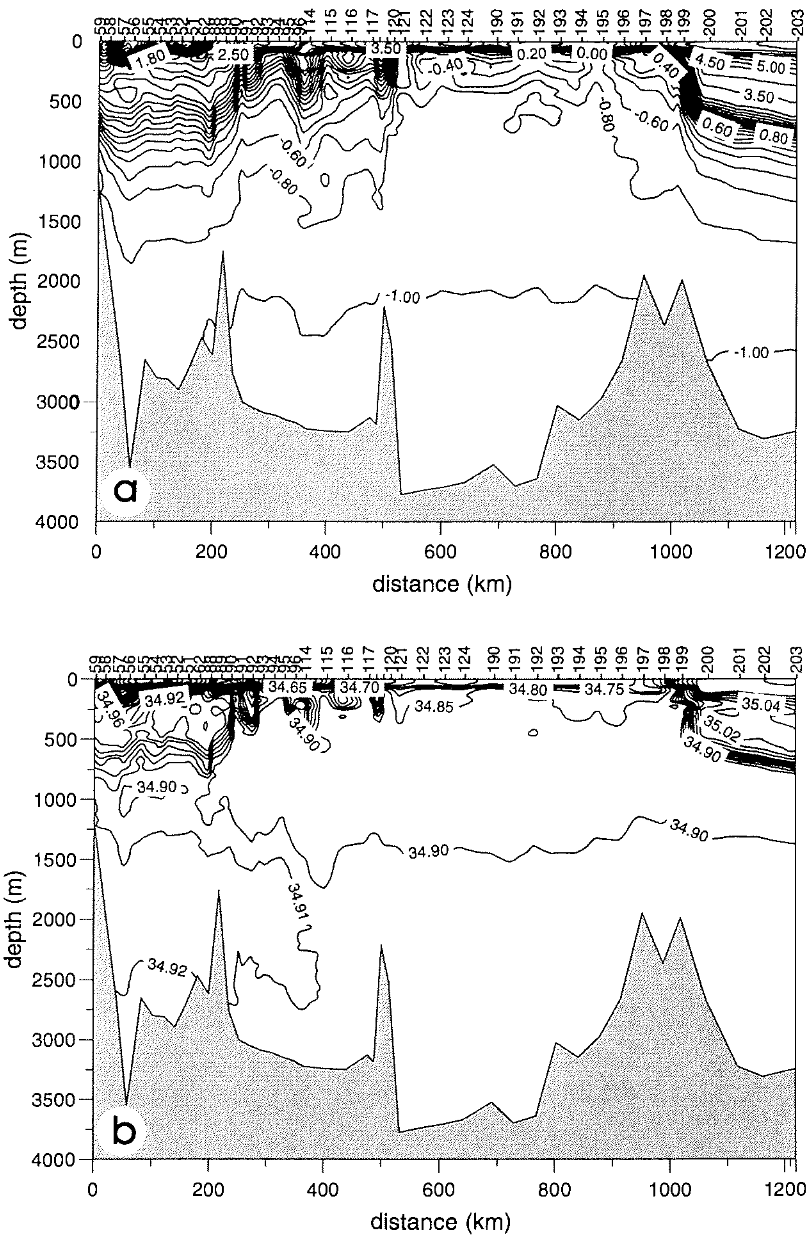
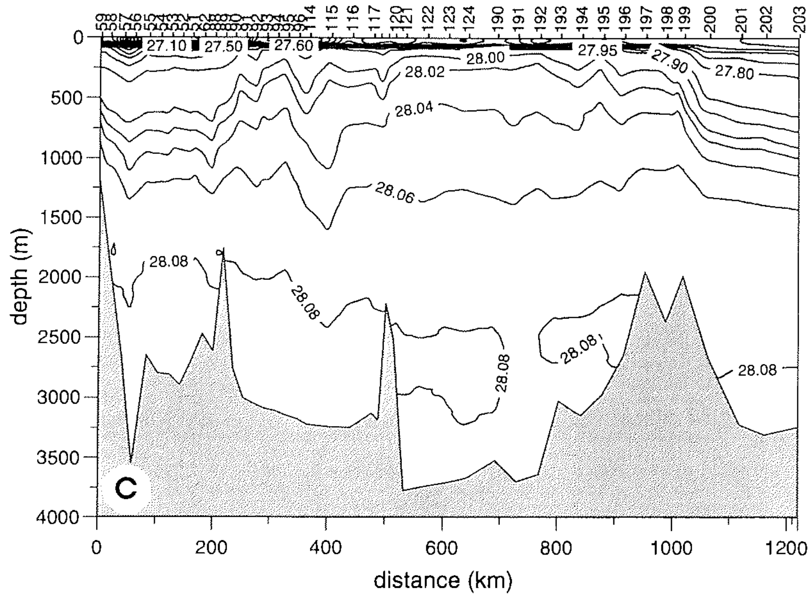


Fig. 15: Vertical section 5 of potential temperature (a), salinity (b), potential density (c), oxygen in µmol/kg (d), silicate in µmol/kg (e), nitrate in µmol/kg (f), tracer CFC-11 in pmol/kg (g) and tracer SF_6 in fmol/l (h) from the Yermak Plateau 80°13'N, 04°04'E to the Norwegian Sea 70°35'N, 01°15'E.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28.08
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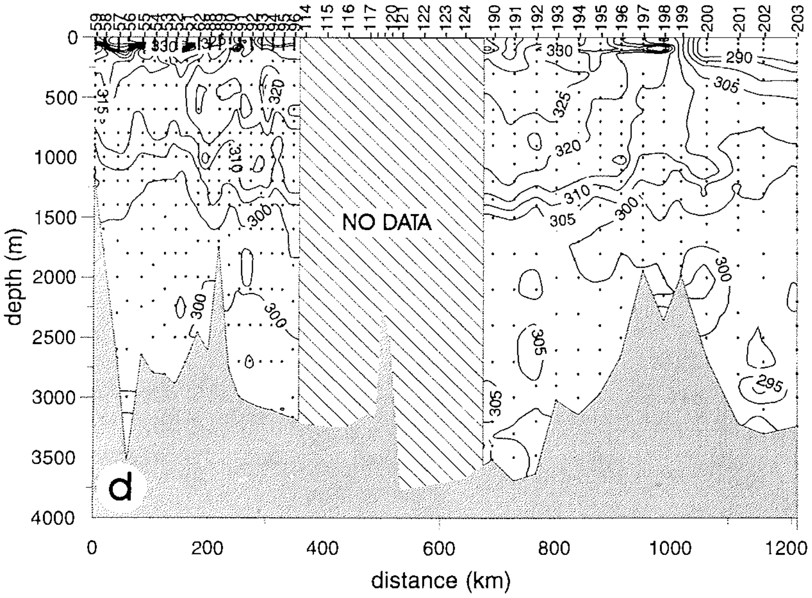
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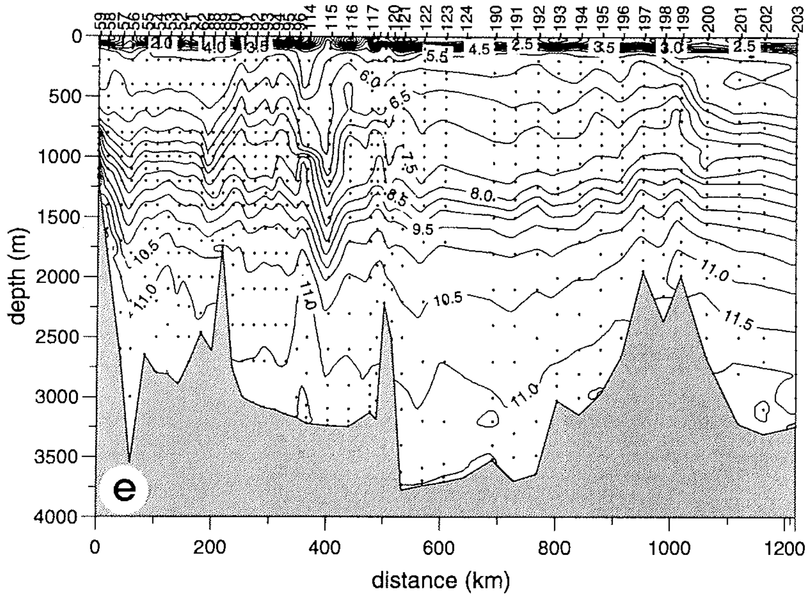
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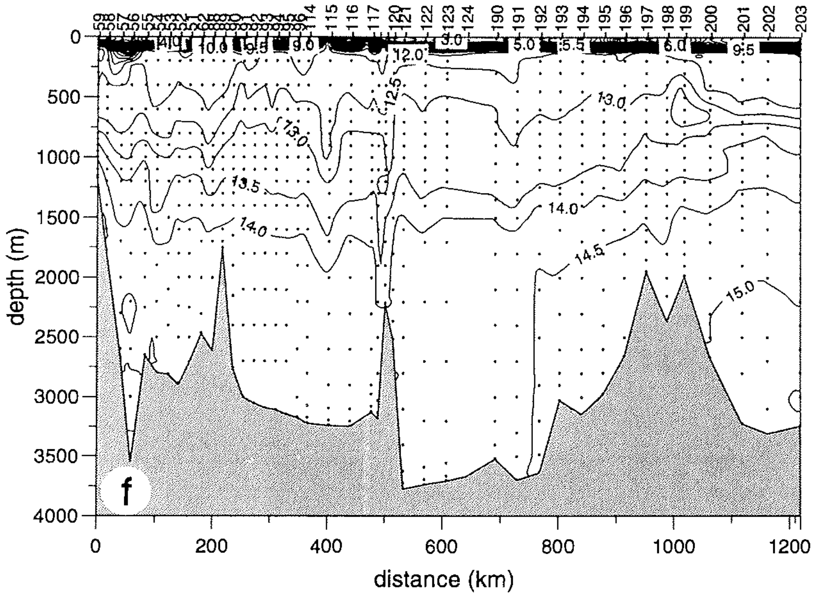
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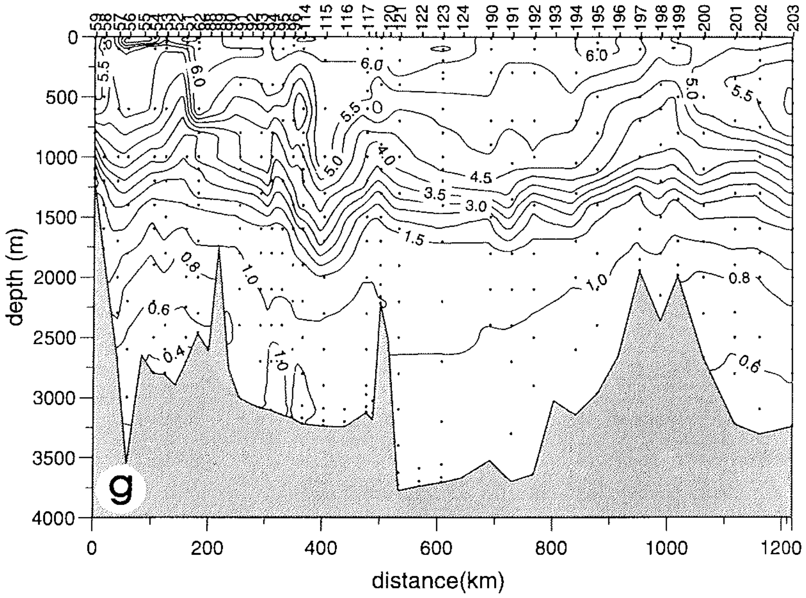
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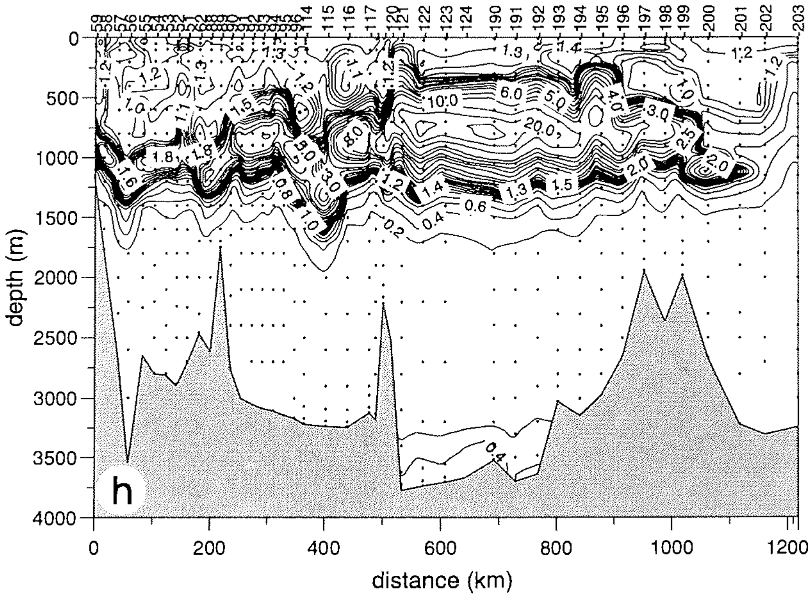
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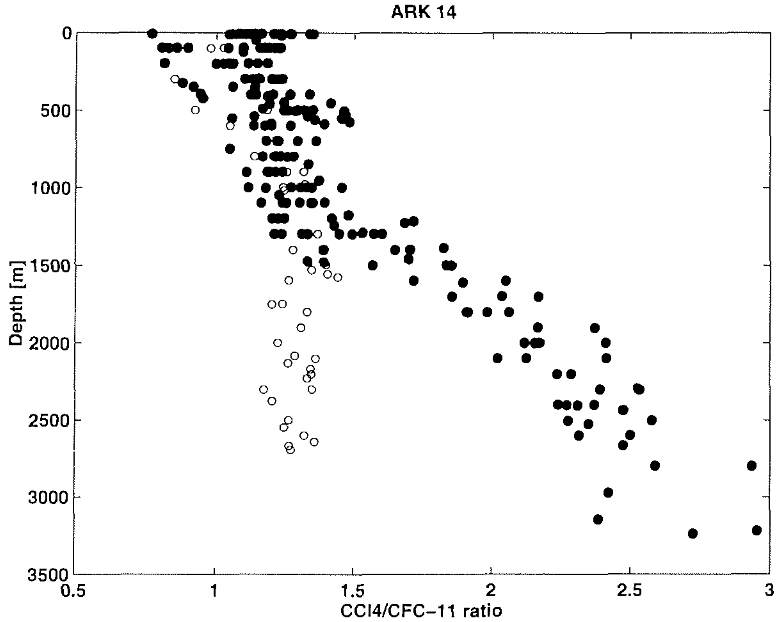


Fig. 16: Vertical distribution of the CCl_4/CFC-11 ratios

The East Greenland Current and Denmark Strait.

As the East Greenland Current (EGC) approaches the Jan Mayen Fracture Zone, it spreads towards the east. Part of the deflected water recirculates in the Greenland Sea, but a fraction crosses the Jan Mayen Fracture Zone, as is evident from the lateral increase of the layer warmer than 0°C. At 75°N it is confined to the slope, while at section 6 (Fig. 17) just south of the Jan Mayen Fracture Zone, temperatures above 0°C are observed at intermediate depth (200-800m) on the entire cross section. The temperatures and salinities of this layer are lower than the those of the Return Atlantic Current (RAC) core in the EGC and it resembles the Atlantic Water exiting from the Arctic Ocean. However, this exiting water mass becomes confined between the RAC and the continental slope, as the EGC encounters the recirculating waters of the West Spitsbergen Current (WSC) in Fram Strait, and it is not likely to pass through the RAC. This is supported by the fact, that the distinct warm and saline core of RAC water is still present at the western part of the section. A more probable explanation is, that water from the RAC becomes diluted, either by isopycnal mixing with lighter fractions of Arctic Intermediate Water (AIW), or if winter convection penetrates directly into the RAC bringing colder and less saline water into the eastern part of the EGC.

The intermediate salinity minimum in the Norwegian Sea, indicating the presence of AIW, has different characteristics in the northern and the southern part of the Norwegian Sea. To the north it derives from an overflow from the Greenland Sea across the Mohns Ridge (Blindheim, 1990) with a temperature below 0°C and a salinity smaller than 34.9. To the south the salinity minimum temperature is above 0°C and its salinity often above 34.9. It has been proposed to originate from the Iceland Sea (Stefansson, 1962). Whether the eastward flow of diluted Atlantic Water along the Jan Mayen Fracture Zone then provides the source for the AIW found in, and spreading from, the Iceland Sea into the Norwegian Sea is an open question.

The main part of the EGC, including the Polar Water, the RAC, and the intermediate and some deep, waters from the Arctic Ocean, continues along the Greenland continental slope across the Jan Mayen Fracture Zone. The waters below the RAC have lower temperatures and salinities than as they exit the Arctic Ocean through Fram Strait, indicating mixing with AIW from the Greenland Sea. This volume, added to the EGC, compensate (at least partly) for the reduced transport associated with the eastward flow in the Jan Mayen Current.

At section 7 (Fig. 18), between Iceland and Greenland, the width of the cross section is smaller, but the baroclinic structure of the EGC, with the isolines sloping downwards towards the west, is maintained. The low salinity polar water of the EGC expands eastward over the cross section. In particular, the temperature minimum located at a salinity of 34.3 is now present also above and not just west of the RAC, and the core of the RAC is displaced downward compared to section 6. On section 6, as well as on the section 4 at 75°N the low salinity water east of the RAC is not directly related to the polar outflow. It may originate from low salinity surface water in the Jan Mayen Current (JMC) or from ice drifting into the Greenland Sea gyre from the west and then melting within the Greenland Sea. This is supported by the larger spreading of the θ-S curves in the thermocline range, and the absence of a distinct temperature minimum at the salinity of 34.3, from stations on section 6 east of the RAC core. The deeper layers are similar on both sections and the salinity increases towards the bottom, indicating the presence of water from the Canadian Basin, Canadian Basin Deep Water (CBDW) or upper Polar Deep Water (uPDW). The rising of the deep isopycnals on the Iceland slope would also imply a deep boundary flow towards north-east, carrying water lying too deep and being too dense to cross the sill in Denmark Strait. Close to Iceland, saline Atlantic Water (AW), entering the Iceland Sea from the south, is seen.

At the sill in Denmark Strait (Fig. 19) the cross section area is divided about equally between warm AW from the Irminger Current (IC) and the cold, less saline waters of the EGC. A sharp horizontal gradient at about 26°15'W, separates the warm and CFC poorer Atlantic Water of the Irminger Current from the cooler and CFC rich outflow. The CFC saturation of the deepest water in the Denmark Strait ($\sigma_\theta = 28.03$) was about 45%. A recirculating branch, or an eddy, of IC water is found over the shelf to the west and splits the EGC into a lower, dense part and an upper lighter part. Deep water from the north with temperature <0°C was only found at the deepest stations at the sill. The θ-S curves at the sill change their slope in the intermediate and deep water range compared to those further to the north (sections 6 and 7). In essence, the temperature maximum layer is often almost absent at the sill, and the deep water lies almost directly below the less saline water of the thermocline. A vertical mixing between the thermocline, the temperature maximum layer, and the deep waters could bring about this flattening of the θ-S curves. It is somewhat surprising, however, that the temperature maximum water does not carry more weight in this mixing triangle, considering how prominent it is upstream. Here it suddenly just disappears.

Another possibility is that AIW from the central Iceland Sea reaches the sill from the north-east. Current measurements made on the northern Iceland continental slope showed transports towards south-west, towards Denmark Strait, at least down to 500 m (Jónson, pers.comm.). An input of AIW, meeting and mixing with the EGC at the sill, would change the θ-S properties of the overflow water. Whether this AIW from the Iceland Sea is a part of the intermediate water which separates from the EGC and crosses the Jan Mayen Fracture Zone further to the east, or if it originates from Atlantic Water entering the Iceland Sea from the Norwegian Sea, is not known.

South of Denmark Strait the descending plume can be followed along and down the continental slope. The overflow plume is stratified and consists mainly of two layers. A homogenous 50-100 m thick bottom layer with a salinity below 34.9 and a potential temperature below 1°C. The upper part is less saline and warmer, although a small temperature minimum is occasionally observed, and forms a low salinity lid, capping the plume. On the cross sections of the plume the less saline, but colder and denser, overflow water tends to be found higher up on the slope, but this feature is not systematic. It is the case on section 10 but not on section 11. The density of the overflow plume does not decrease from section 10 to section 11, as would be expected if entrainment of ambient waters occurs. The salinities and temperatures are higher on the southern (11) than on the northern section (10), although less high than at the deepest station on section 10. These differences rather indicate short term variability of the overflow water crossing the sill than a downstream evolution of the plume. Different parts of the EGC water column will dominate the overflow at different times, and perhaps also alternate with AIW from the eastern current from the Greenland Sea. These changes will be influenced by the variability of the IC water present at the sill.

If θ-S curves from stations north of the sill are compared with the ones from the overflow plume, it is seen that the Denmark Strait Overflow Water (DSOW) falls within the θ-S range present in the EGC on sections 6 and 7. The properties at the sill were, at the present crossing (section 8), more saline than those found in the overflow plume at section 10. This also supports the view of short term variations of the water crossing the sill. The fact that the θ-S properties of the overflow are in the same range as those north of the sill implies little entrainment of ambient water from the Irminger Basin into the plume. The change towards lower salinities then points toward mixing, within the plume, between water masses originating from the north. This would increase the density and the salinity of the low salinity lid and prevent it from being mixed into the surrounding water column. The characteristics of the upper and lower parts of the plume would also become more similar as the plume descends.

Compared to the Denmark Strait (section 8), the CFC concentrations in the Denmark Strait Overflow Water (DSOW) increased from 3.2-3.4 pmol/kg to 3.9 - 4.0 pmol/kg (saturation 55-60 %) at Sta.272. The density decreased due to warming of the outflow of about 1.4 K. The water we found between 500 and 700 m depth in the Irminger Sea was warmer than 4° C and had CFC concentrations comparable to the DSOW. Accepted entrainment rates vary between 2-3, thus mixing of the outflow with this water would give a temperature of 1.45-2.2° C and 3.7-3.8 pmol/kg instead of the observed 0.9° C (3.9-4.0 pmol/kg). Apparently, the mixing component should be colder and CFC richer than the water observed.

On section 11, higher up on the slope, low salinity water, somewhat less dense than the Labrador Sea Water (LSW), was observed at the bottom at around 1000 m (θ-S curves from 275, 276, 277, 278). This indicates the presence of less saline, and less dense water, which may not have passed with the main overflow water through the deep channel but instead has flown over the shelf further to the west. Because of its higher density compared to the AW of the IC, which flows at the east of the EGC south of Denmark Strait, it may sink beneath the AW and continue down the continental slope. This dense shelf water then constitutes a distinct source of less dense overflow water, which occasionally could merge with and augment the DSOW in the Deep Northern Boundary Current (DNBC). In the observed instances it formed a separate, shallower and less dense core of the boundary current. The cores observed from "Aranda" in 1997 and from "Valdivia" in 1998 were less saline and denser and located deeper than those seen from "Polarstern", which were more diluted by mixing with the surrounding water masses. How much water could be carried by such upper core and how much it could contribute to the ventilation of the deeper layers of the North Atlantic is not known. The ultimate origin of the water supplying these upper cores is also not determined. It has the same characteristics as the water of the thermocline in the EGC which is present along the entire Greenland continental slope and also in the interior of the Arctic Ocean. The core also has high CFC content which indicate recent ventilation. Will water be advected from the Arctic Ocean to Denmark Strait so rapidly as to be compatible with the CFC observations? Is it possible to create such dense water by freezing and brine rejection on the Greenland shelf with its ice cover and rapidly moving, low salinity waters of the EGC? Section (9) was taken on the shelf across the sill of the Storfjorden depression to determine if any flow of comparatively dense shelf water crosses at this deeper indent of the shelf break and continues down the continental slope. No such outflow was observed.

In September 1997 during Meteor cruise 395 the coldest and densest outflow water was found at the same location and depth as during the present cruise (Sta. 272 at 2200 m), but the water was denser and colder by about 0.4 K with CFC values of about 3.6 pmol/kg. The θ-S characteristic and CFC concentrations of the other components of the North Atlantic Deep Water, the Labrador Sea Water (LSW, σ_θ = 27.75-27.80) and Gibbs Fracture Zone Water (GFZW, σ_θ = 27.80-27.88) had not changed since September 1997. On one station (sta 268) we found water with densities of LSW, but the water was colder, less saline and had higher CFC values than LSW. We did not encounter this water in September 1997. Further measurements are needed to study if this water affects the local LSW characteristic.

Lit.:
Blindheim, J., 1990. Arctic intermediate Water in the Norwegian Sea. Deep Sea Research 37, 1475-1489.
Stefanson, U., 1962. North Icelandic Waters Rit. Fiskideild, Reykjavik, 269 pp.

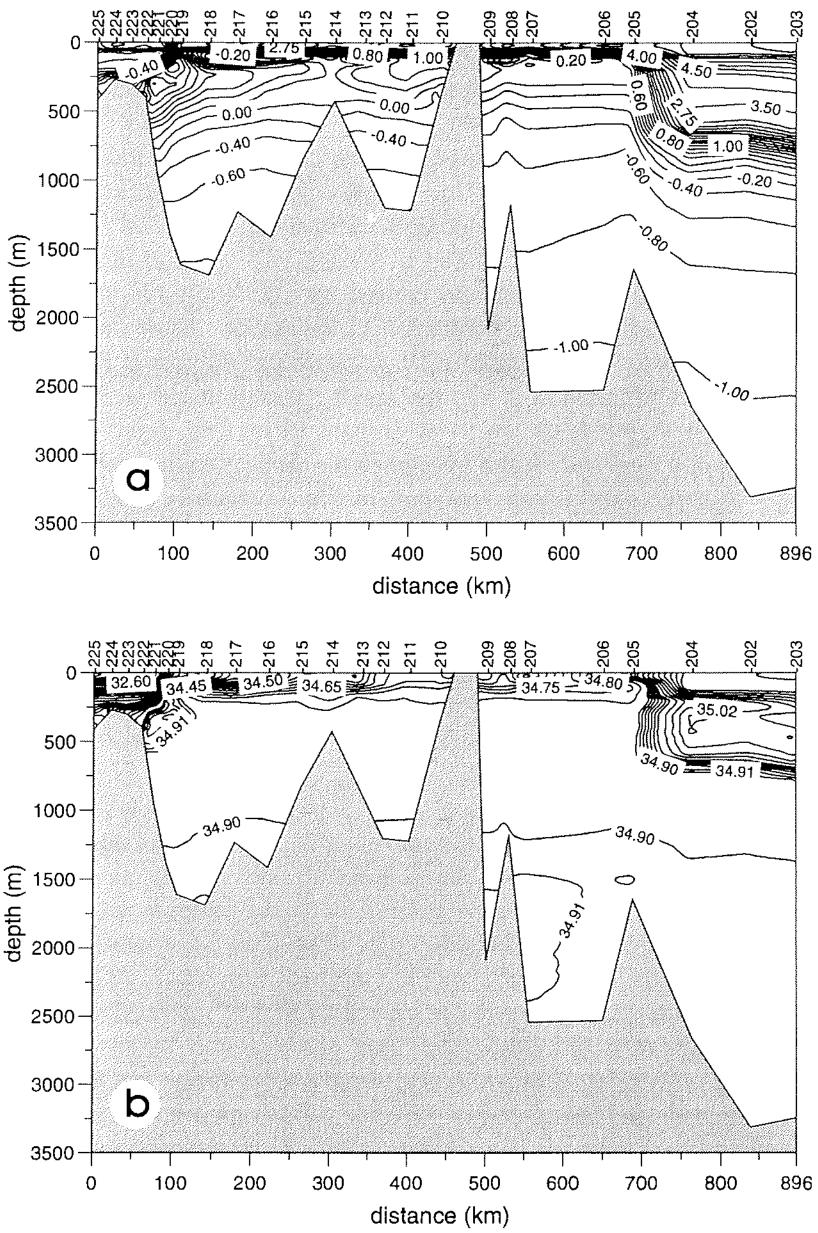
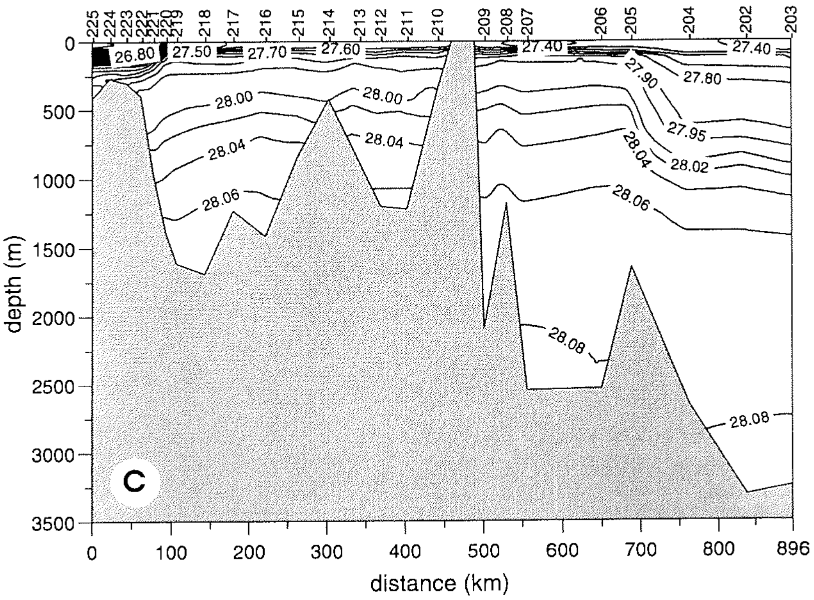


Fig. 17: Vertical section 6 of potential temperature (a), salinity (b), potential density (c), oxygen in µmol/kg (d), silicate in µmol/kg (e), nitrate in µmol/kg (f), tracer CFC-11 in pmol/kg (g) and tracer SF_6 in fmol/l (h) from the East Greenland Shelf 71°00'N, 21°26'W to the Norwegian Sea 70°35'N, 01°15'E.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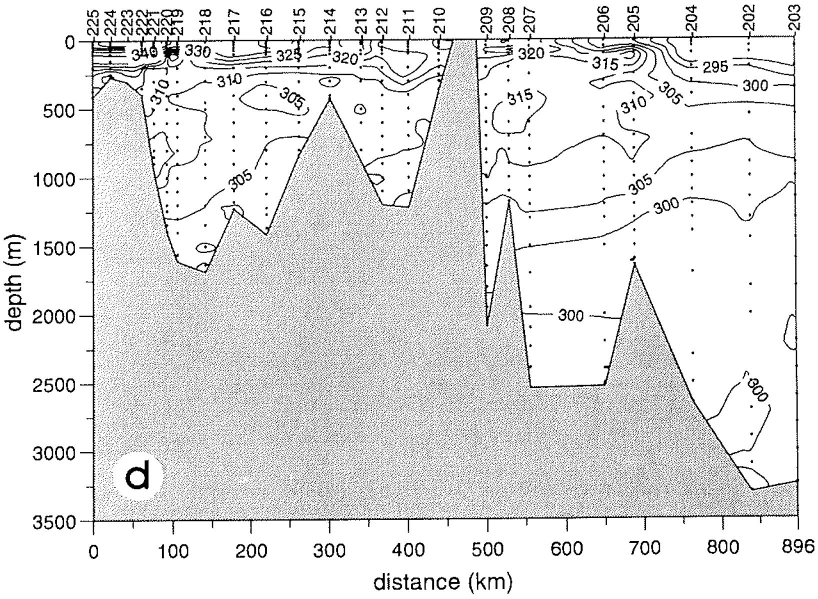
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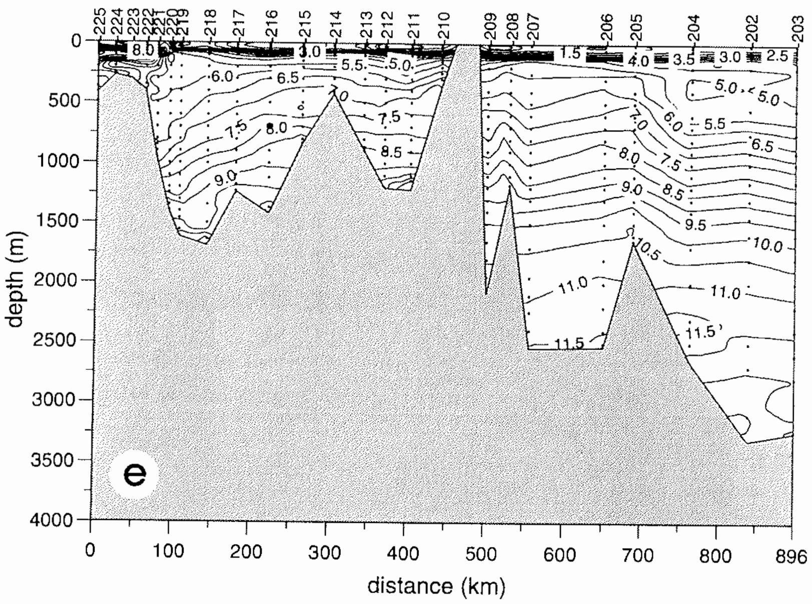
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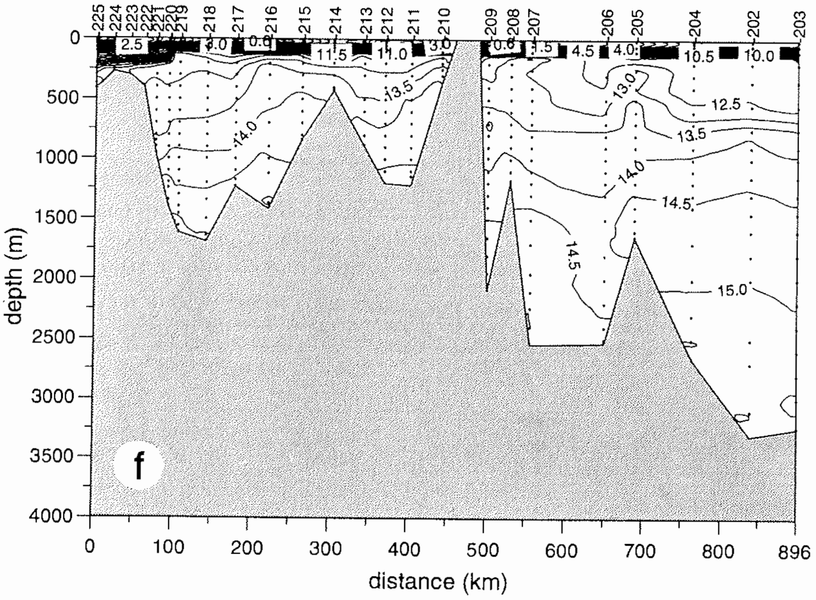
distance (km)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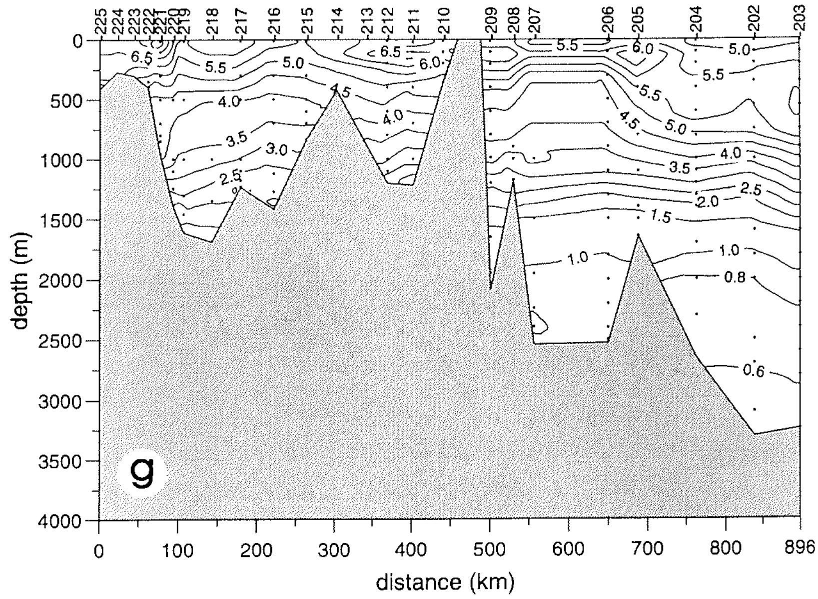
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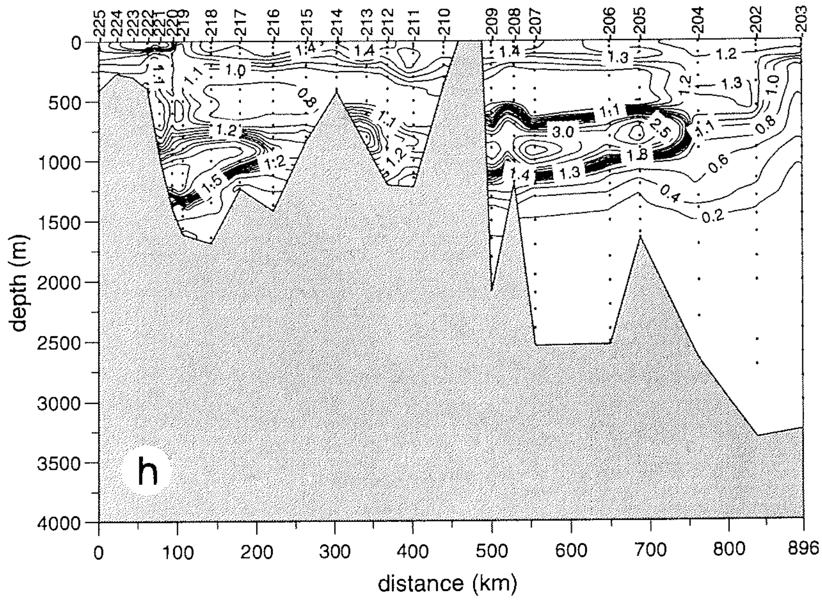
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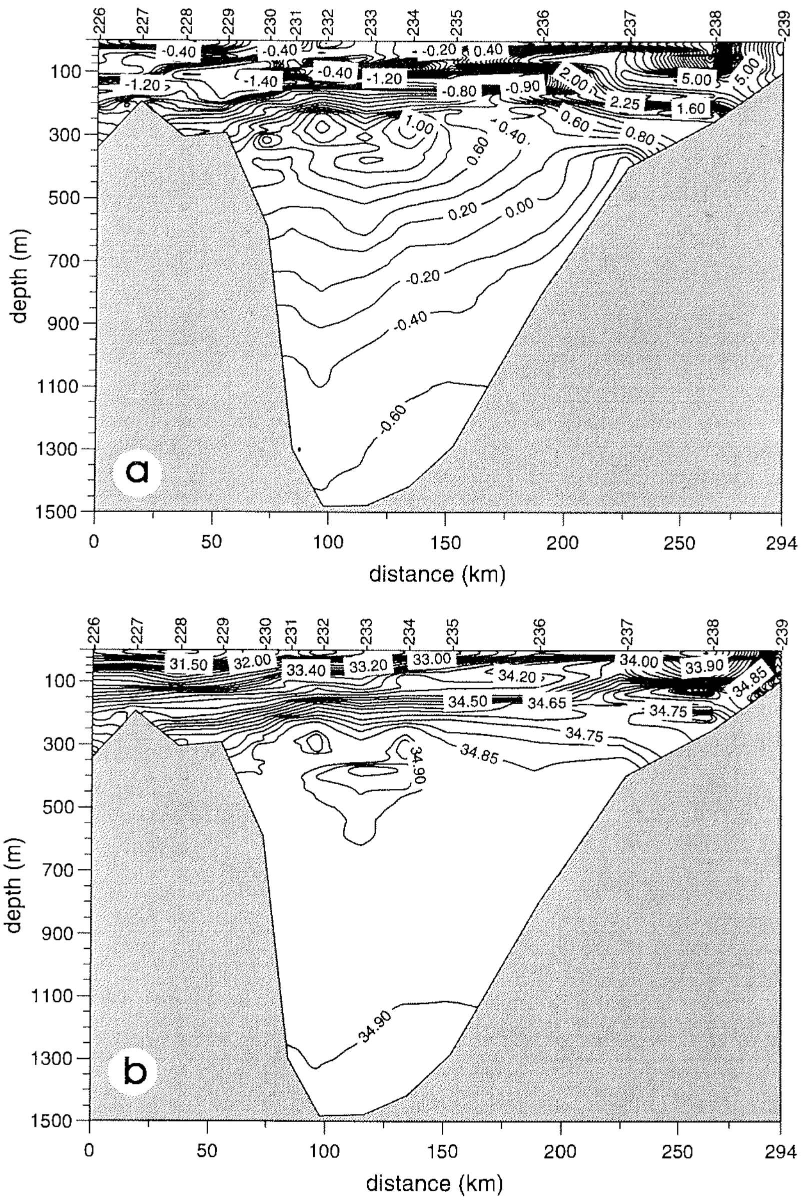
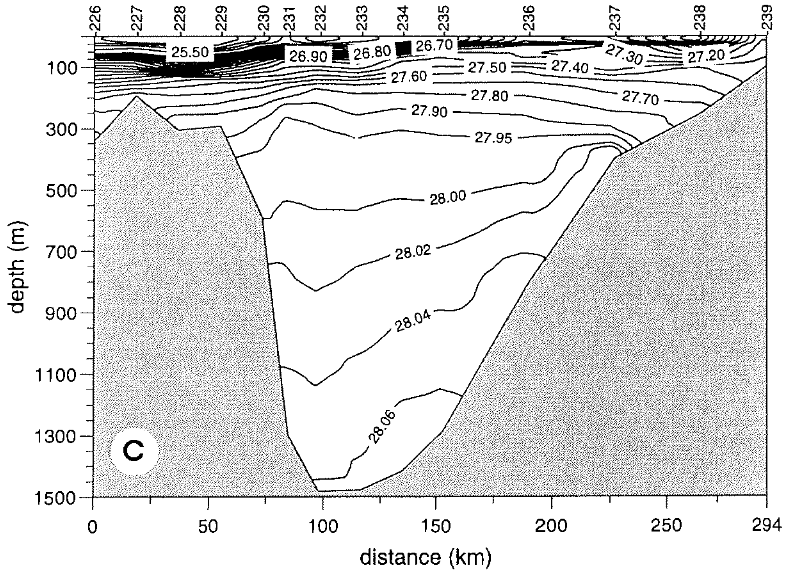


Fig. 18: Vertical section 7 of potential temperature (a), salinity (b), potential density (c), oxygen in µmol/kg (d), silicate in µmol/kg (e), nitrate in µmol/kg (f), tracer CFC-11 in pmol/kg (g) and tracer SF_6 in fmol/l (h) from East Greenland 69°23'N, 23°45'W to Iceland 66°45'N, 23°00'W.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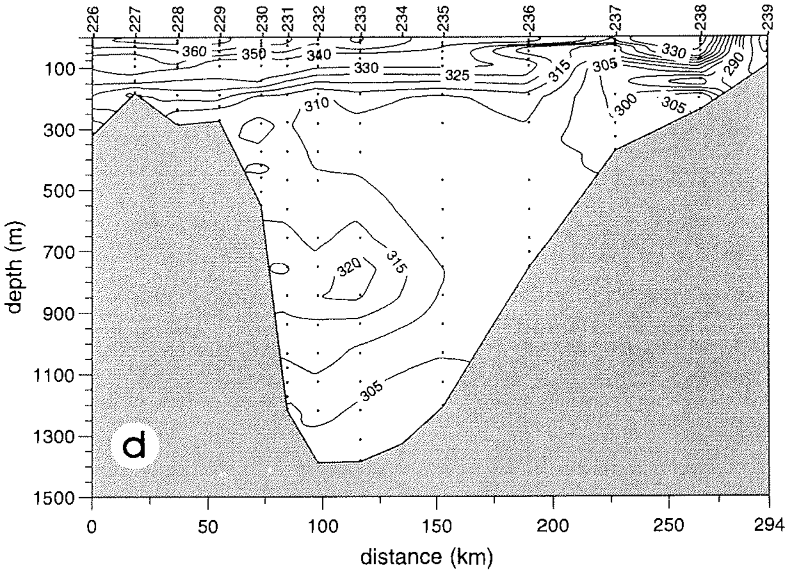
distance (km)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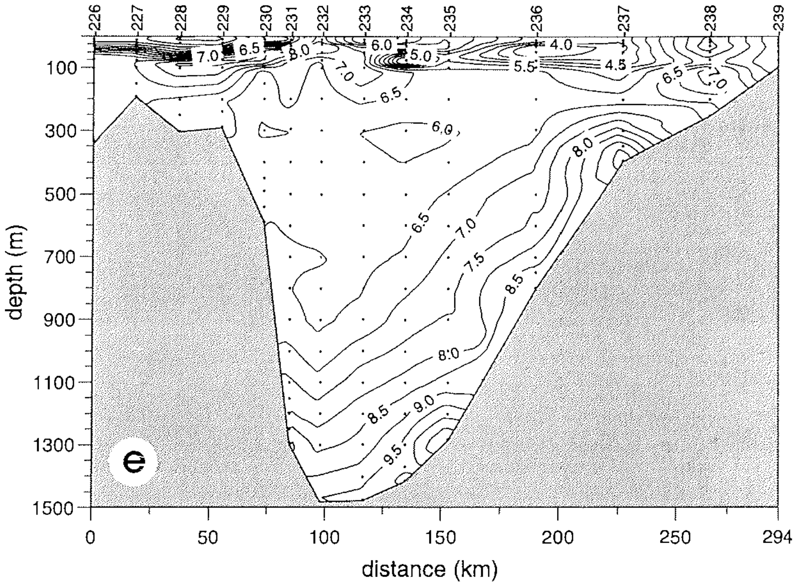
distance (km)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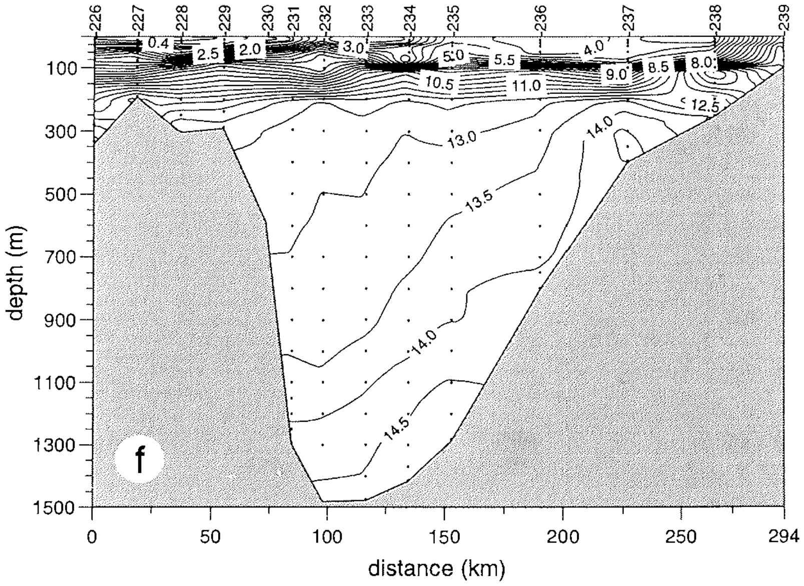
9.0
9.5
e
depth (m)
100
300
500
700
900
1100
1300
1500
0
50
100
150
200
250
294
distance (km)


226
227
228
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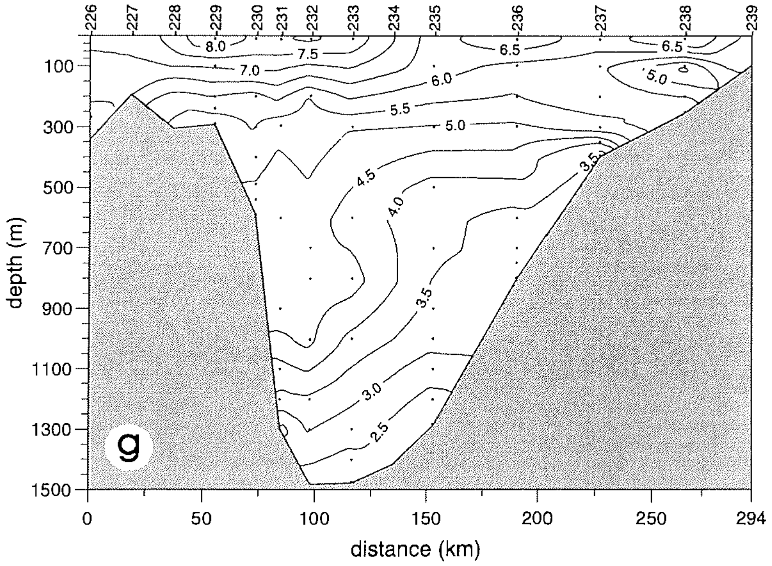
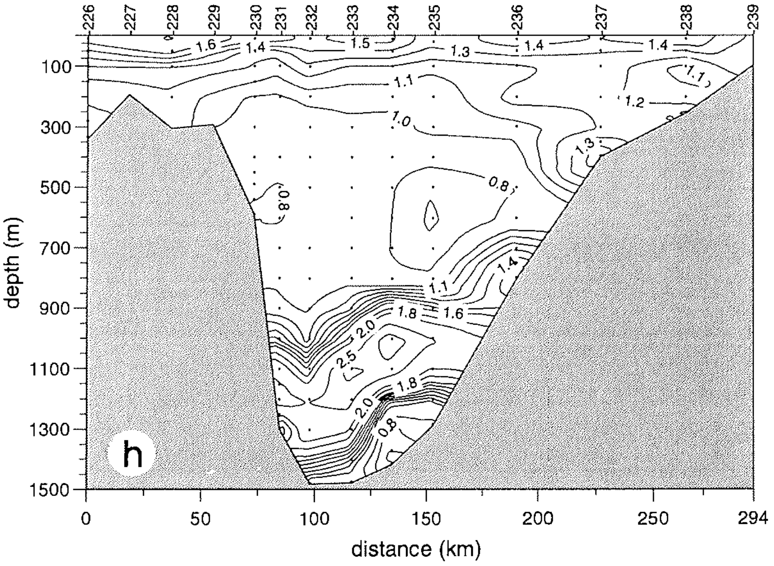
230
231
232
233
234
235
236
237
238
239
0.4
2.5
2.0
3.0
5.0
5.5
4.0
10.5
11.0
9.0
8.5
8.0
12.5
13.0
14.0
13.5
14.0
14.5
f
depth (m)
100
300
500
700
900
1100
1300
1500
0
50
100
150
200
250
294
distance (km)


226
227
228
229
230
231
232
233
234
235
236
237
238
239
8.0
7.5
7.0
6.5
6.5
6.0
5.0
5.5
5.0
4.5
4.0
3.5
3.5
3.0
2.5
g
depth (m)
100
300
500
700
900
1100
1300
1500
0
50
100
150
200
250
294
distance (km)


226
227
228
229
230
231
232
233
234
235
236
237
238
239
1.6
1.4
1.5
1.3
1.4
1.4
1.1
1.1
1.2
1.0
1.3
0.8
0.8
1.1
1.4
1.8
1.6
2.0
2.5
1.8
2.0
0.8
h
depth (m)
100
300
500
700
900
1100
1300
1500
0
50
100
150
200
250
294
distance (km)

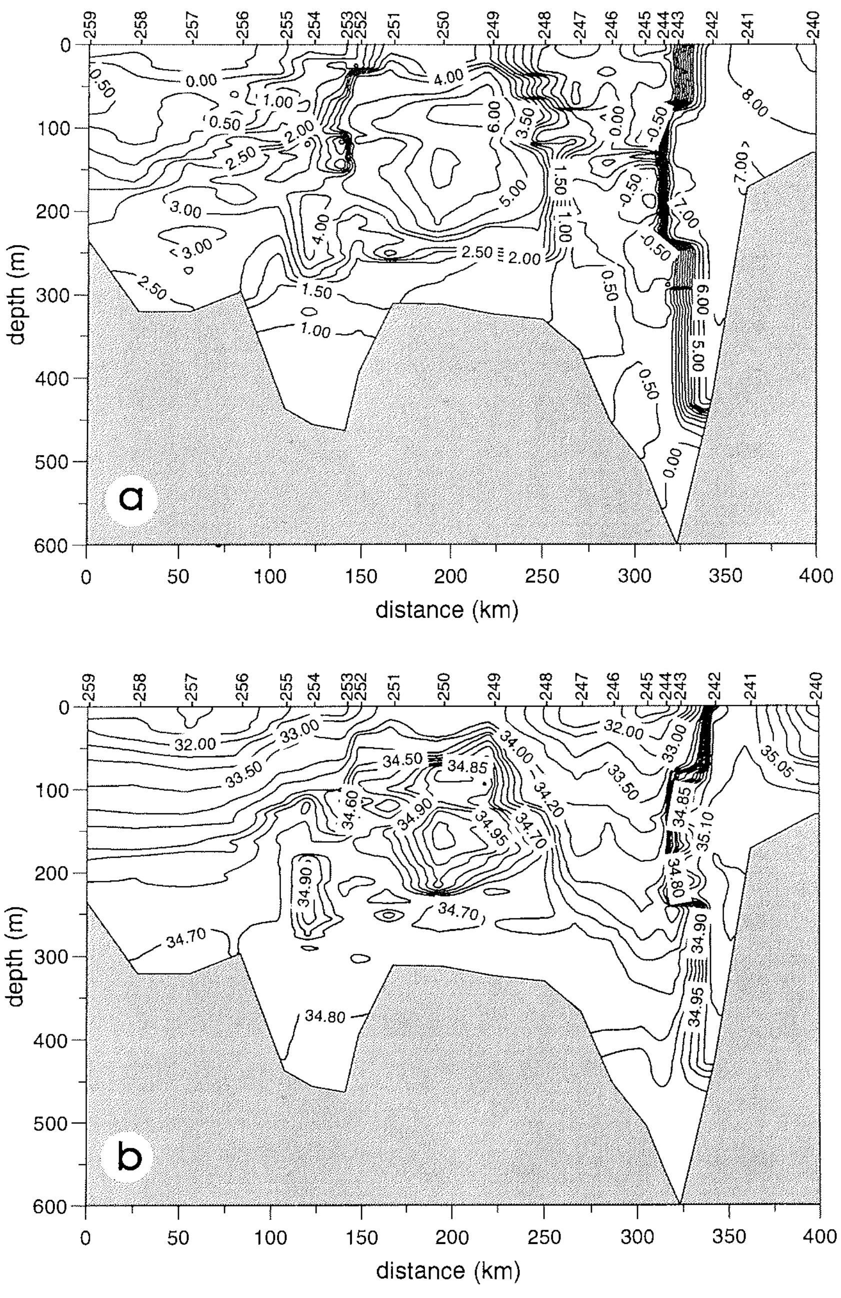
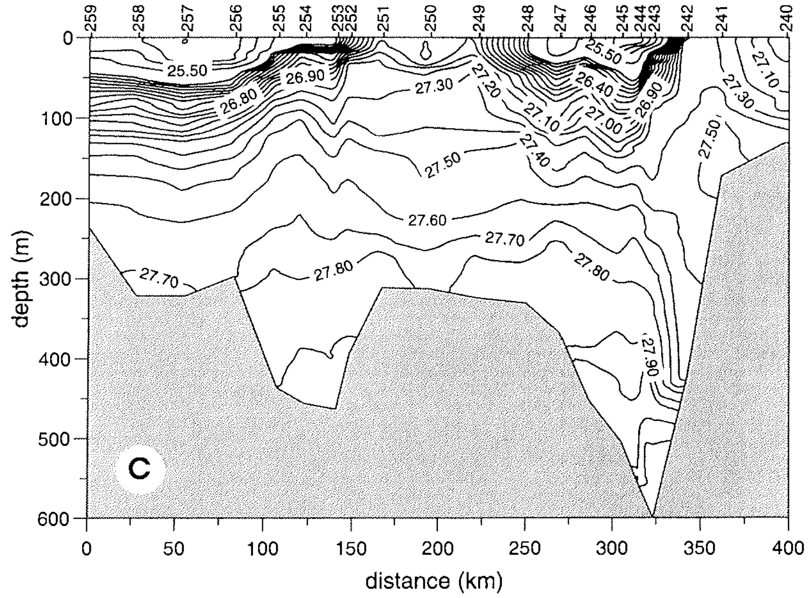
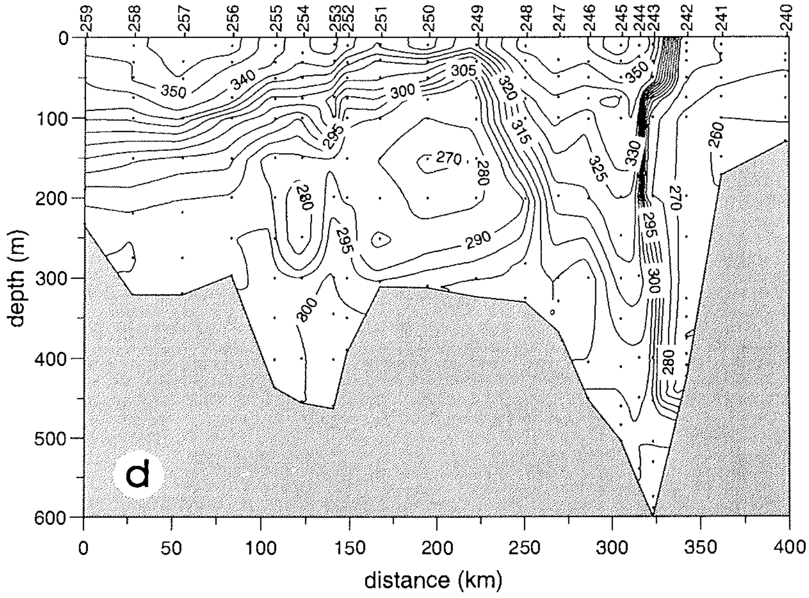


Fig. 19: Vertical section 8 of potential temperature (a), salinity (b), potential density (c), oxygen in µmol/kg (d), silicate in µmol/kg (e), nitrate in µmol/kg (f), tracer CFC-11 in pmol/kg (g) and tracer SF_6 in fmol/l (h) across the Denmark Strait from 66°30'N, 33°38'W to 66°00'N, 25°00'W.


259
258
257
256
255
254
253
252
251
250
249
248
247
246
245
244
243
242
241
240
25.50
26.80
26.90
27.30
27.20
27.10
27.00
26.40
25.50
26.90
27.10
27.30
27.50
27.40
27.50
27.60
27.70
27.70
27.80
27.80
27.90
c
depth (m)
0
100
200
300
400
500
600
0
50
100
150
200
250
300
350
400
distance (km)


259
258
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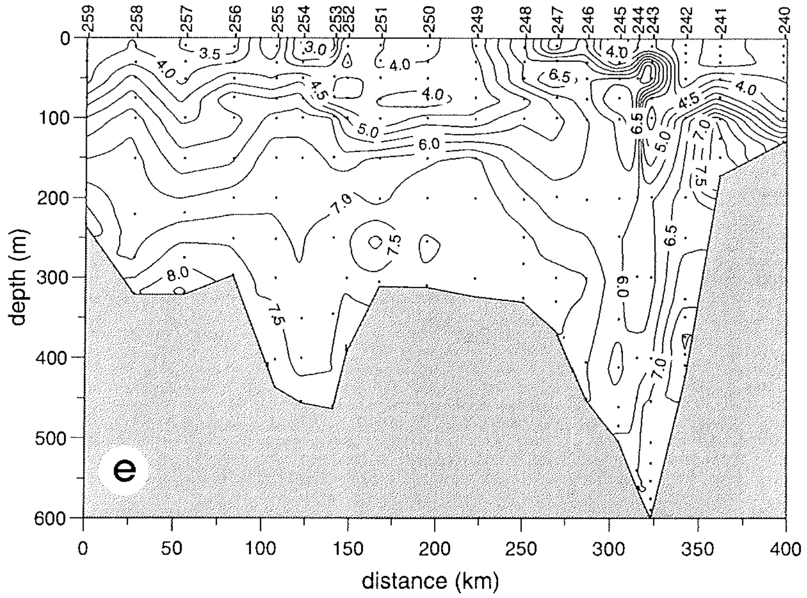
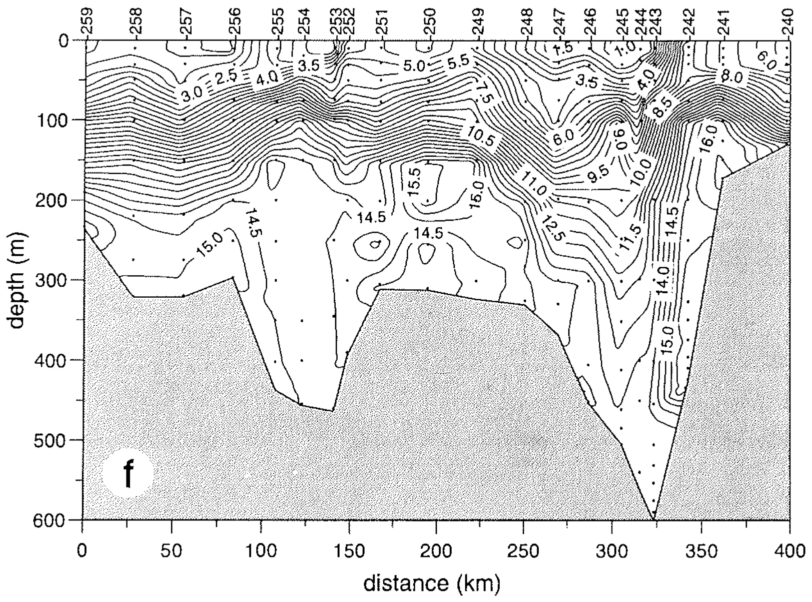
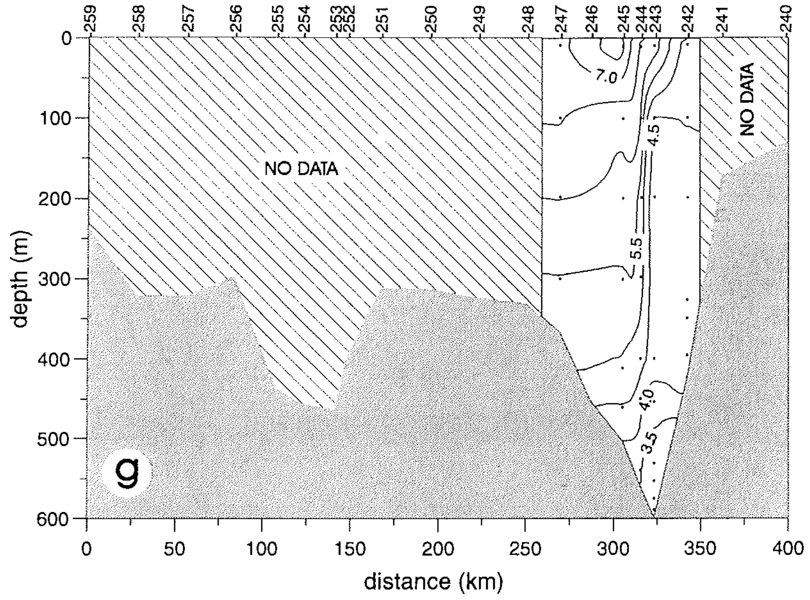
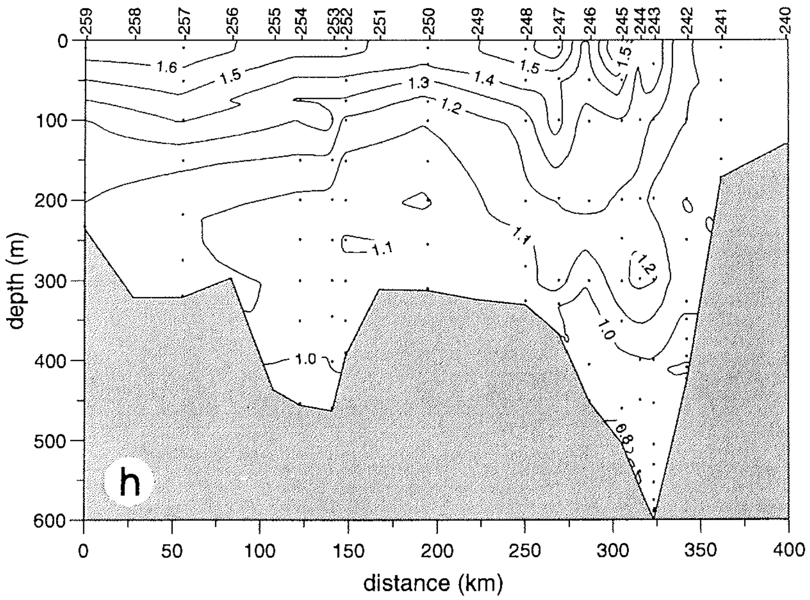
256
255
254
253
252
251
250
249
248
247
246
245
244
243
242
241
240
350
340
300
305
320
315
350
295
270
280
280
325
330
260
270
280
295
290
295
300
300
280
d
depth (m)
0
100
200
300
400
500
600
0
50
100
150
200
250
300
350
400
distance (km)


259
258
257
256
255
254
253
252
251
250
249
248
247
246
245
244
243
242
241
240
depth (m)
0
100
200
300
400
500
600
distance (km)
0
50
100
150
200
250
300
350
400
3.0
3.5
4.0
4.5
5.0
6.0
6.5
7.0
7.5
8.0
e


259
258
257
256
255
254
253
252
251
250
249
248
247
246
245
244
243
242
241
240
depth (m)
0
100
200
300
400
500
600
distance (km)
0
50
100
150
200
250
300
350
400
2.5
3.0
3.5
4.0
5.0
5.5
6.0
7.5
8.0
8.5
9.0
9.5
10.0
10.5
11.0
11.5
12.5
14.0
14.5
15.0
15.5
16.0
f


259
258
257
256
255
254
253
252
251
250
249
248
247
246
245
244
243
242
241
240
NO DATA
NO DATA
7.0
4.5
5.5
4.0
3.5
g
depth (m)
0
100
200
300
400
500
600
0
50
100
150
200
250
300
350
400
distance (km)


259
258
257
256
255
254
253
252
251
250
249
248
247
246
245
244
243
242
241
240
1.6
1.5
1.3
1.4
1.5
1.5
1.2
1.1
1.1
1.2
1.0
1.0
0.8
h
depth (m)
0
100
200
300
400
500
600
0
50
100
150
200
250
300
350
400
distance (km)

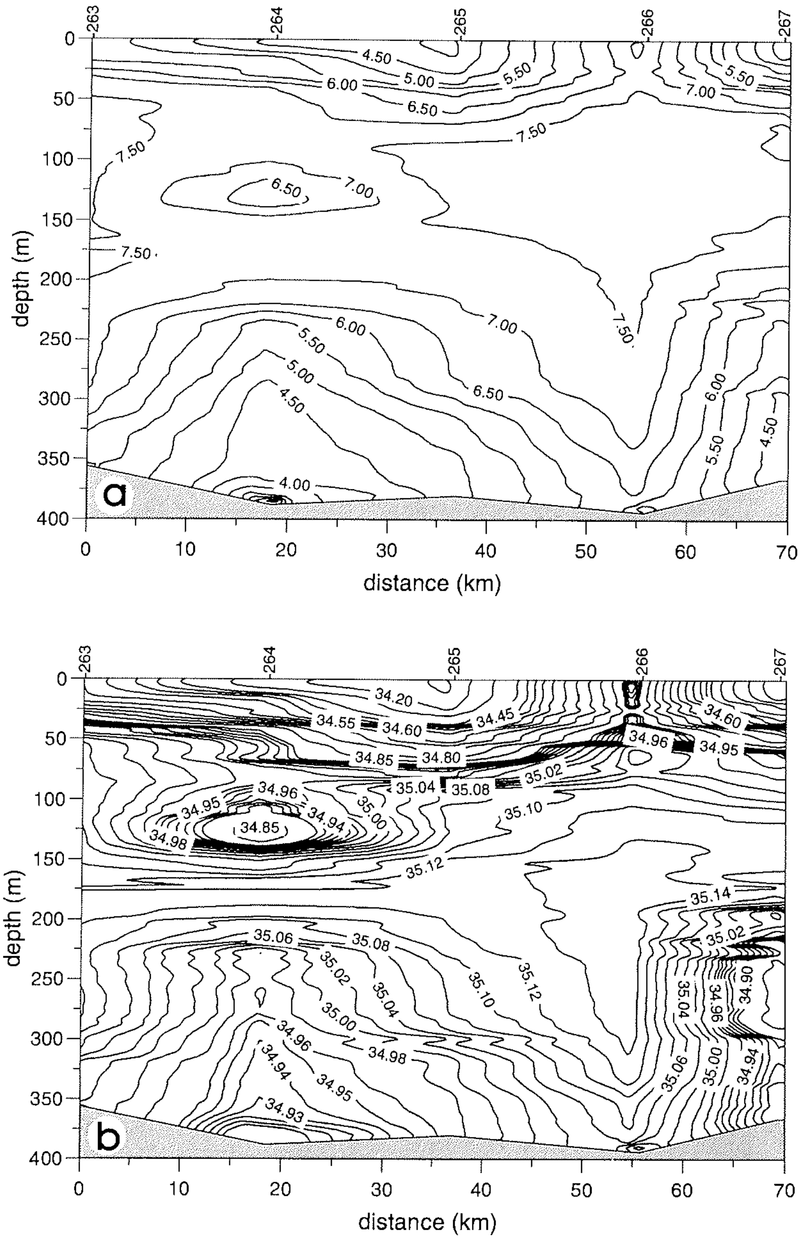
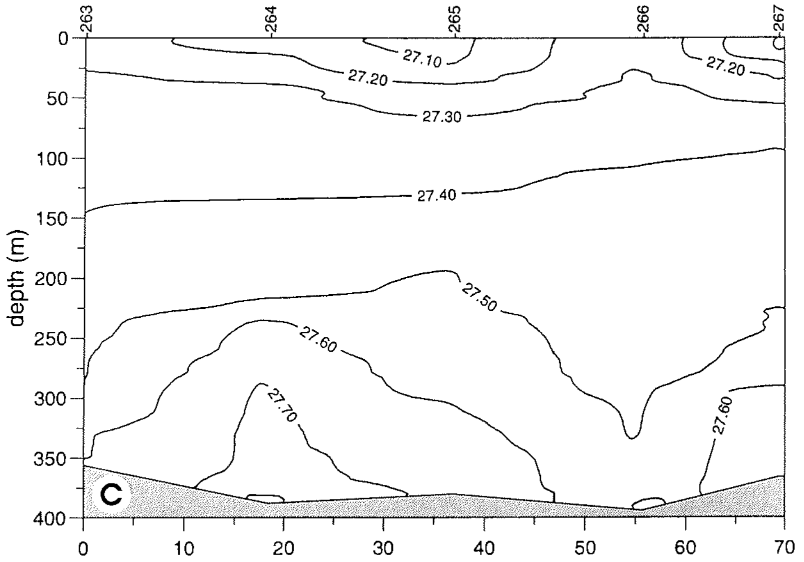
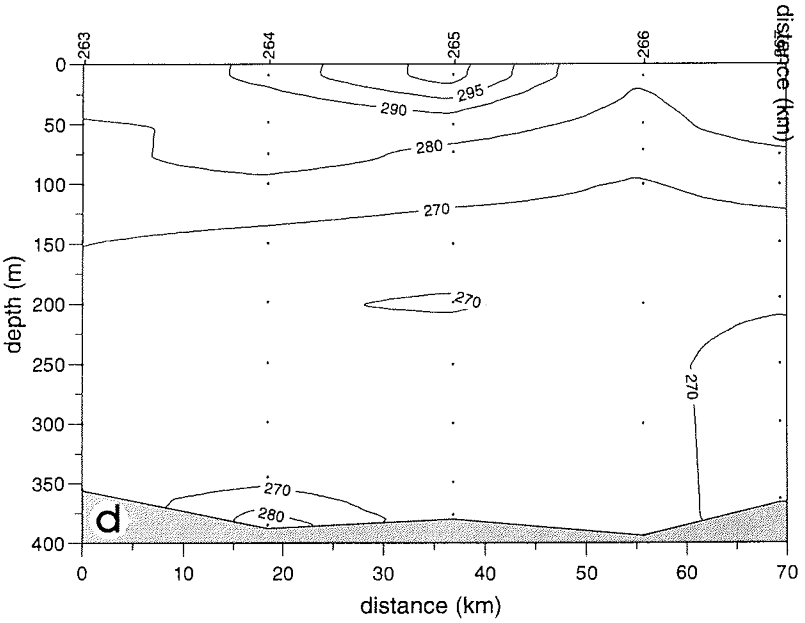
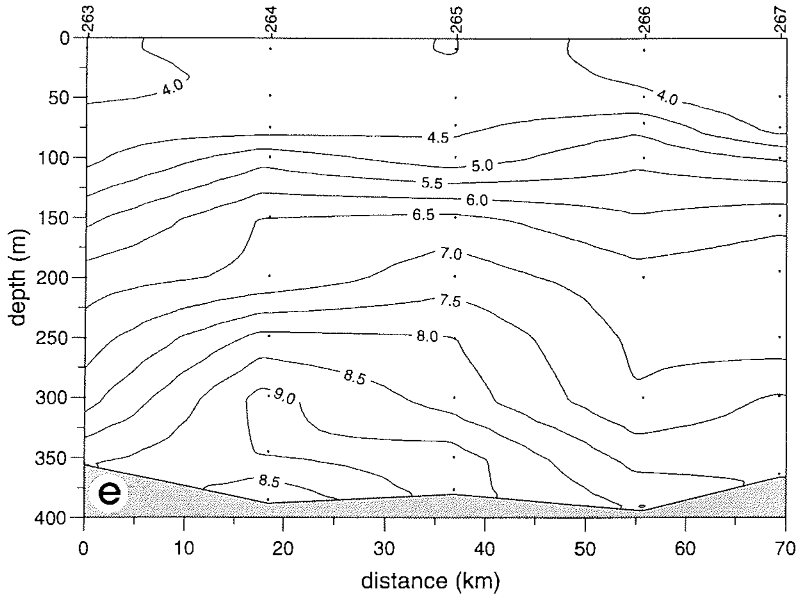
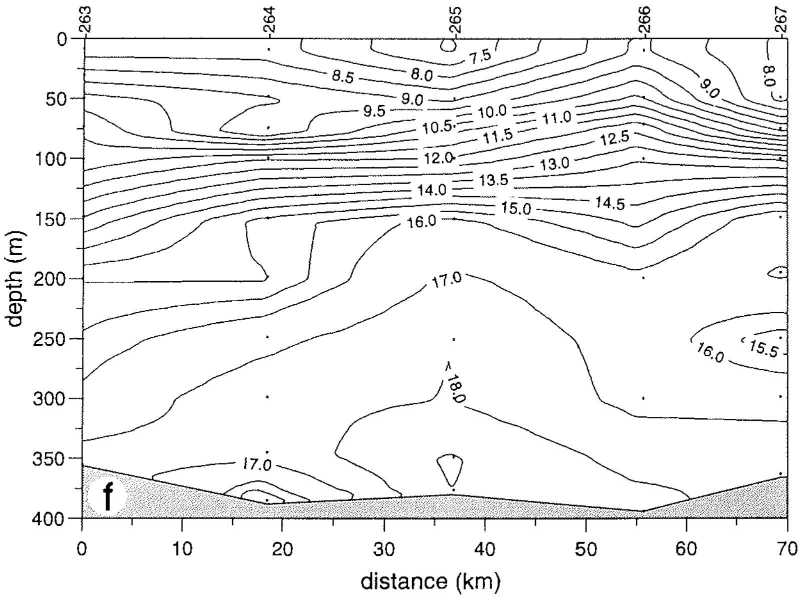


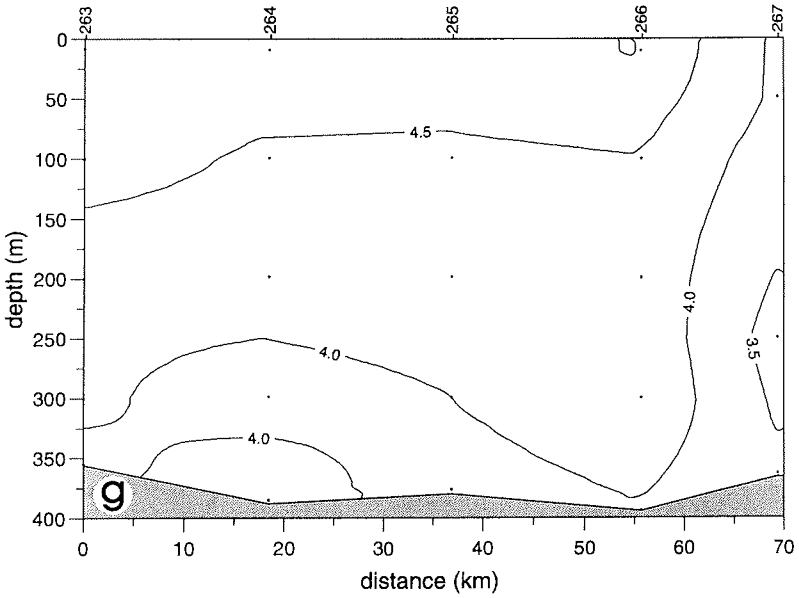
Fig. 20: Vertical section 9 of potential temperature (a), salinity (b), potential density (c), oxygen in µmol/kg (d), silicate in µmol/kg (e), nitrate in µmol/kg (f), and tracer SF_6 in fmol/l (g) at Storfjord shelf edge from 65°30'N, 31°15'W to 65°30'N, 29°38'W.


263
264
265
266
267
27.10
27.20
27.20
27.30
27.40
27.50
27.60
27.70
27.60
depth (m)
0
50
100
150
200
250
300
350
400
0
10
20
30
40
50
60
70
c


263
264
265
266
267
distance (km)
295
290
280
270
270
270
270
280
depth (m)
0
50
100
150
200
250
300
350
400
0
10
20
30
40
50
60
70
distance (km)
d


263
264
265
266
267
depth (m)
0
50
100
150
200
250
300
350
400
distance (km)
0
10
20
30
40
50
60
70
4.0
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
9.0
8.5
e


263
264
265
266
267
depth (m)
0
50
100
150
200
250
300
350
400
distance (km)
0
10
20
30
40
50
60
70
7.5
8.0
8.5
9.0
8.0
9.0
9.5
10.0
10.5
11.0
11.5
12.0
12.5
13.0
13.5
14.0
14.5
15.0
16.0
17.0
16.0
15.5
18.0
17.0
f


263
264
265
266
267
0
50
100
150
200
250
300
350
400
depth (m)
4.5
4.0
4.0
4.0
3.5
g
0
10
20
30
40
50
60
70
distance (km)

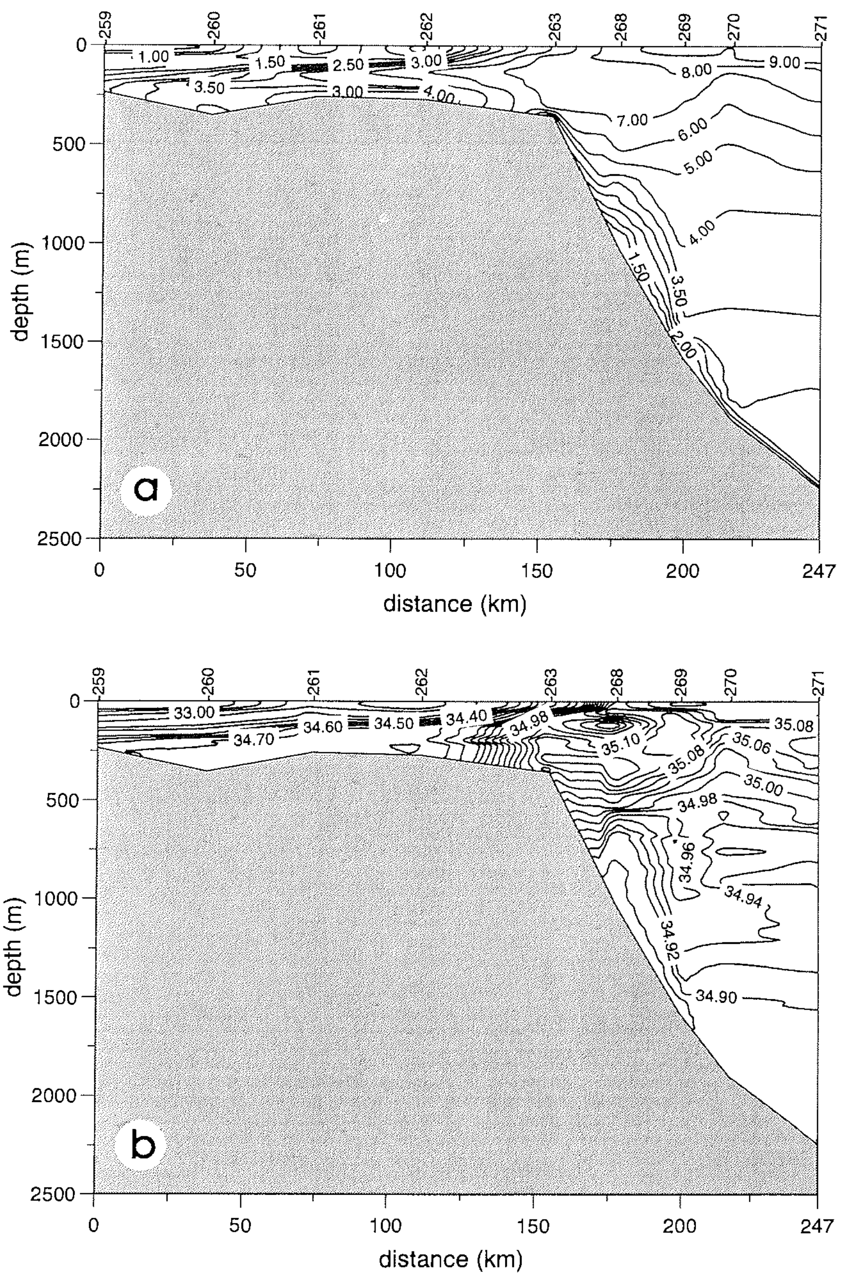
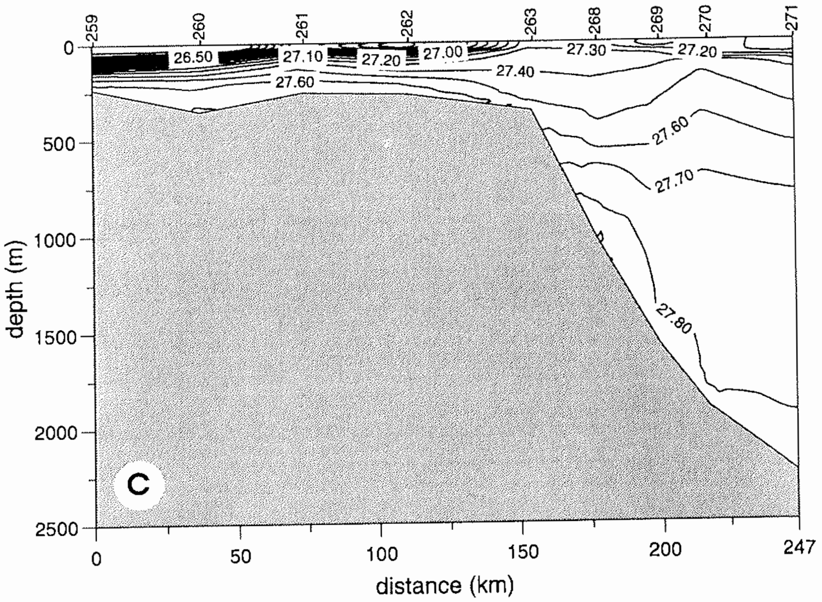
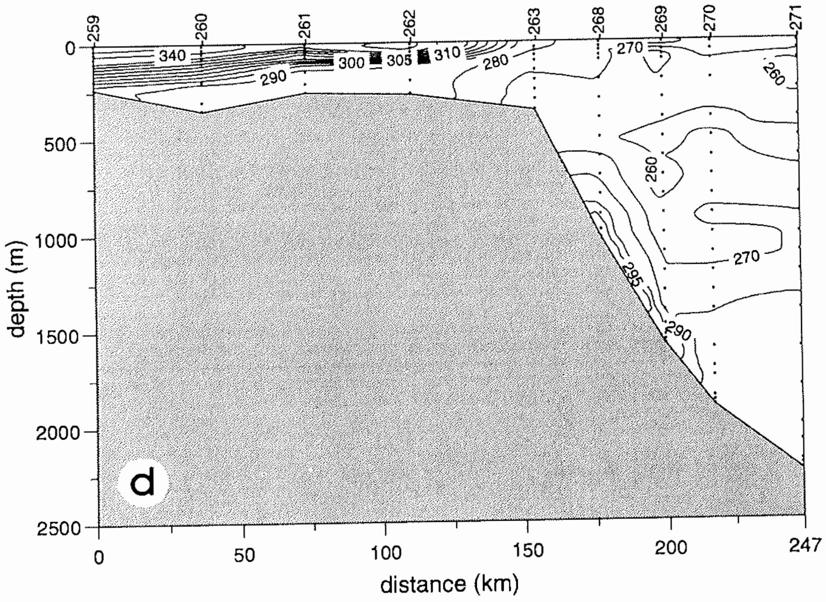
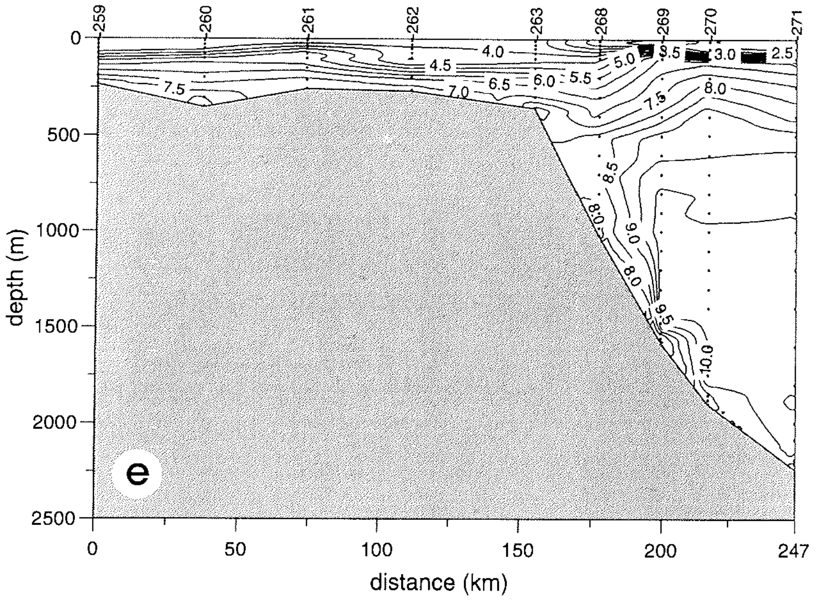
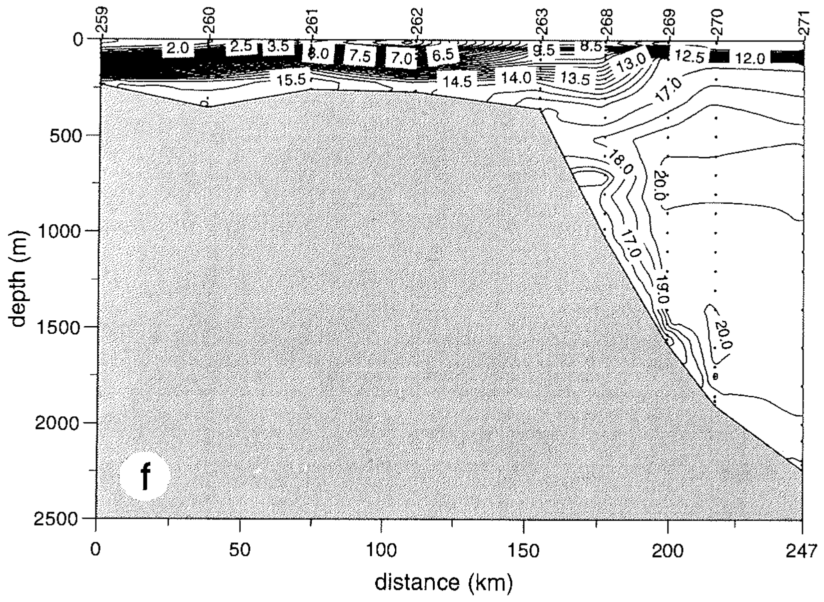


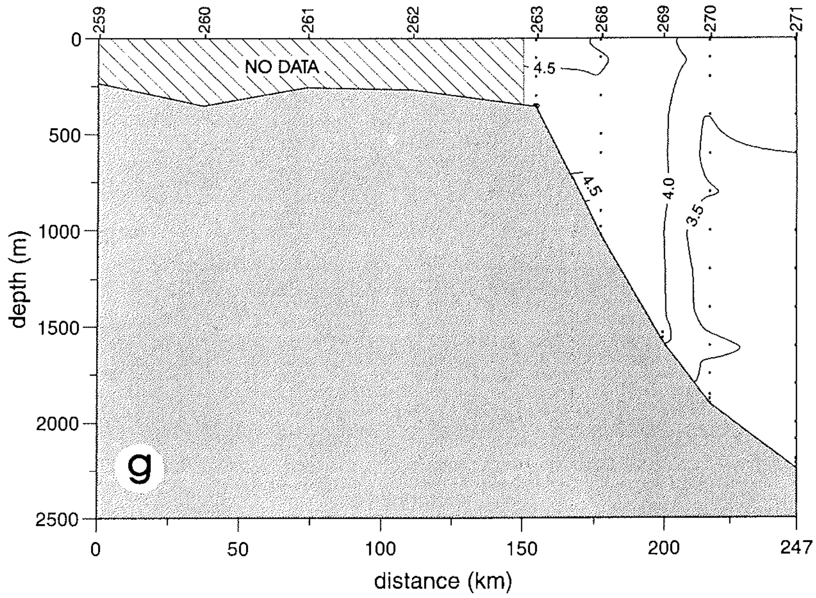
Fig. 21: Vertical section 10 of potential temperature (a), salinity (b), potential density (c), oxygen in µmol/kg (d), silicate in µmol/kg (e), nitrate in µmol/kg (f), tracer CFC-11 in pmol/kg (g) and tracer SF_6 in fmol/l (h) from the East Greenland Shelf 66°30'N, 33°38'W to the Irminger Basin 64°45'N, 30°25'W.

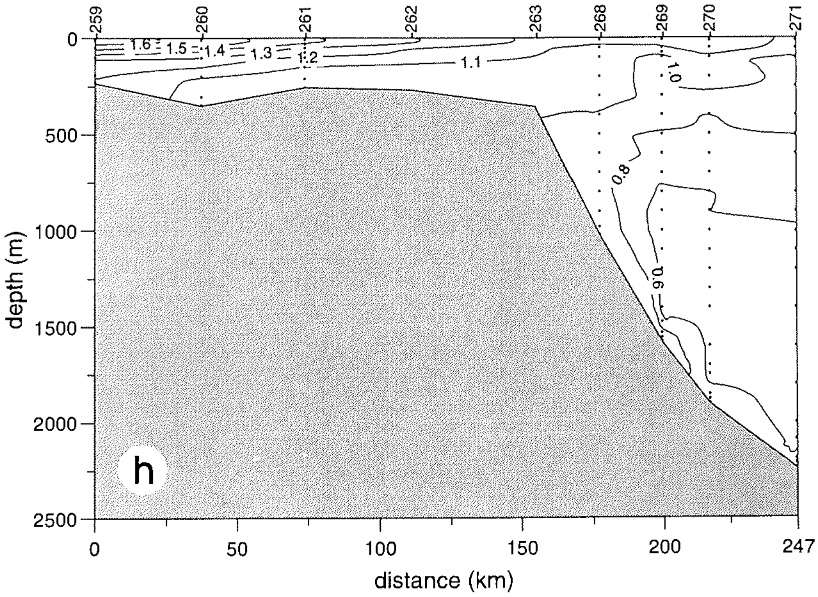

259
260
261
262
263
268
269
270
271
26.50
27.10
27.20
27.00
27.30
27.20
27.40
27.60
27.60
27.70
27.80
c
depth (m)
0
500
1000
1500
2000
2500
distance (km)
0
50
100
150
200
247


259
260
261
262
263
268
269
270
271
340
290
300
305
310
280
270
260
260
270
295
290
d
depth (m)
0
500
1000
1500
2000
2500
distance (km)
0
50
100
150
200
247


259
260
261
262
263
268
269
270
271
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
3.0
2.5
depth (m)
distance (km)
0
500
1000
1500
2000
2500
50
100
150
200
247
e


259
260
261
262
263
268
269
270
271
2.0
2.5
3.5
8.0
7.5
7.0
6.5
9.5
8.5
12.5
12.0
15.5
14.5
14.0
13.5
13.0
17.0
18.0
20.0
19.0
depth (m)
distance (km)
0
500
1000
1500
2000
2500
50
100
150
200
247
f


259
260
261
262
263
268
269
270
271
NO DATA
4.5
4.5
4.0
3.5
0
500
1000
1500
2000
2500
depth (m)
0
50
100
150
200
247
distance (km)
g


259
260
261
262
263
268
269
270
271
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.8
0.6
0
500
1000
1500
2000
2500
depth (m)
0
50
100
150
200
247
distance (km)
h

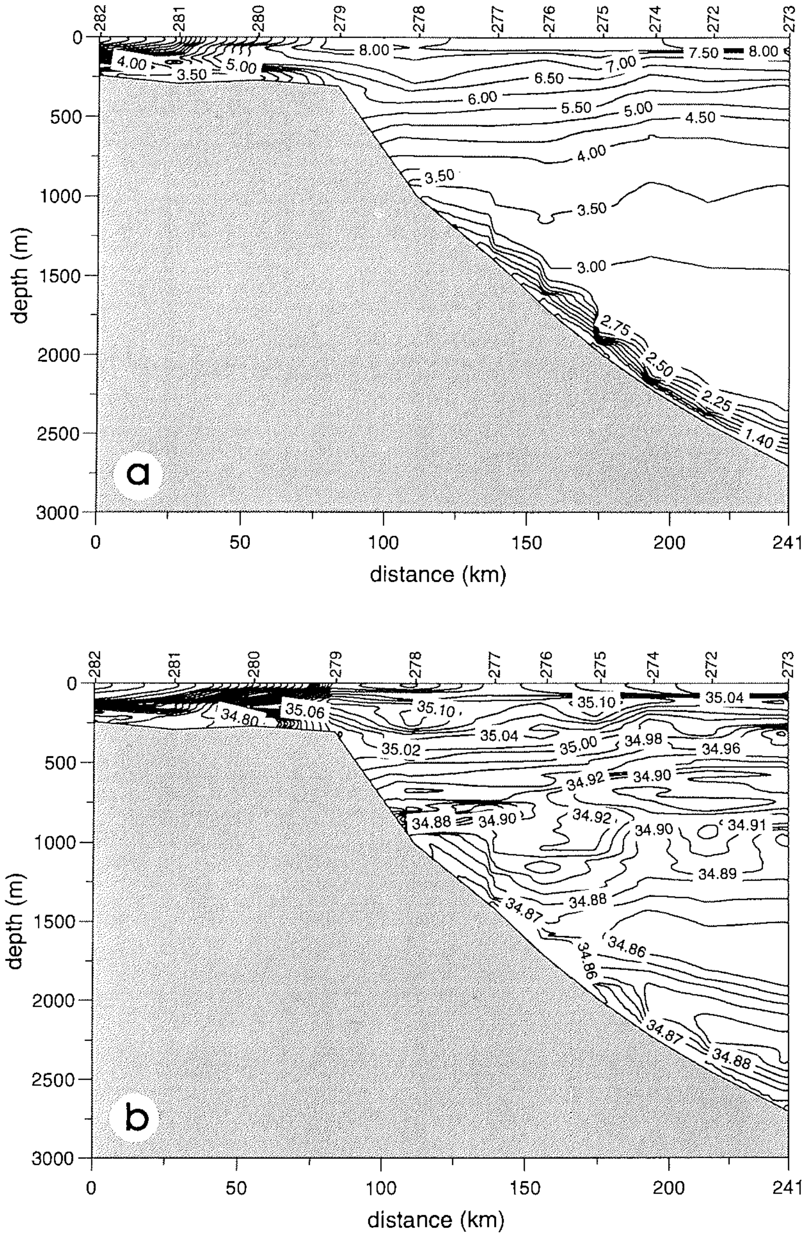
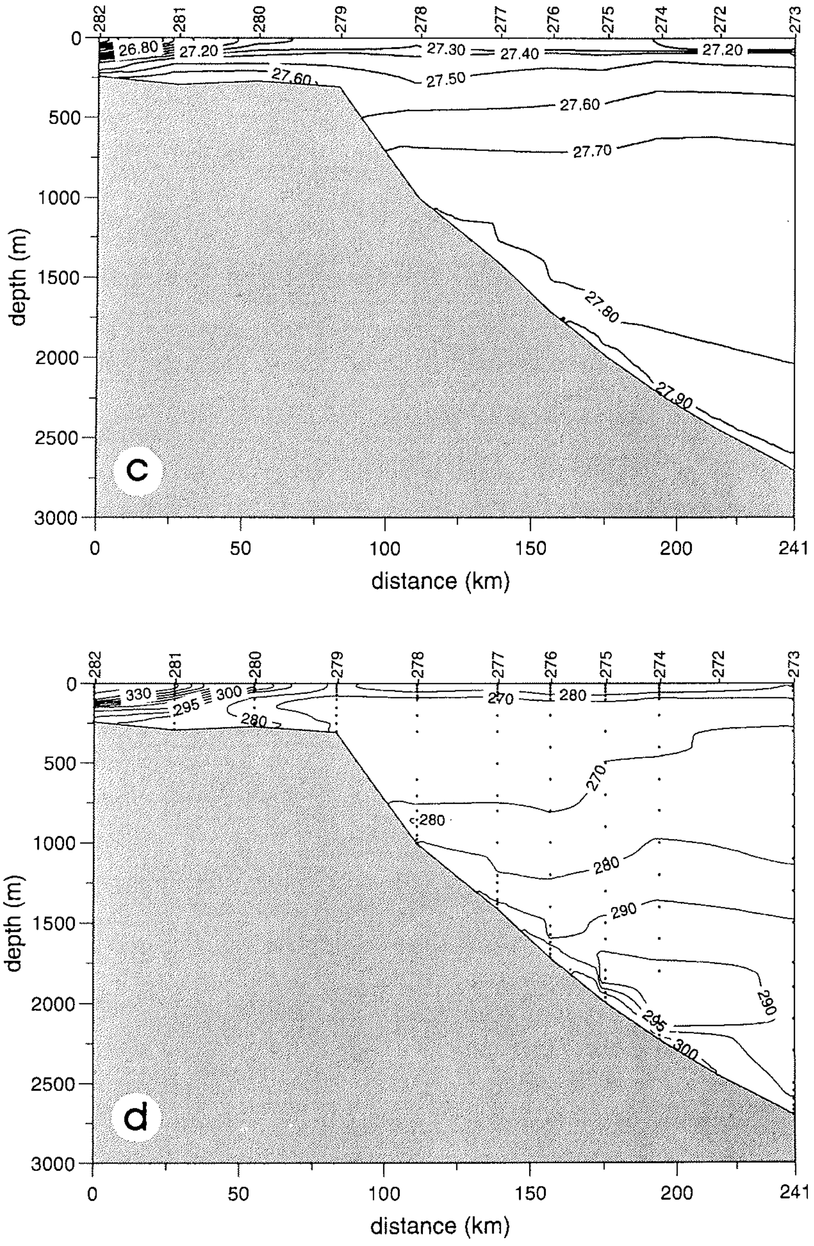
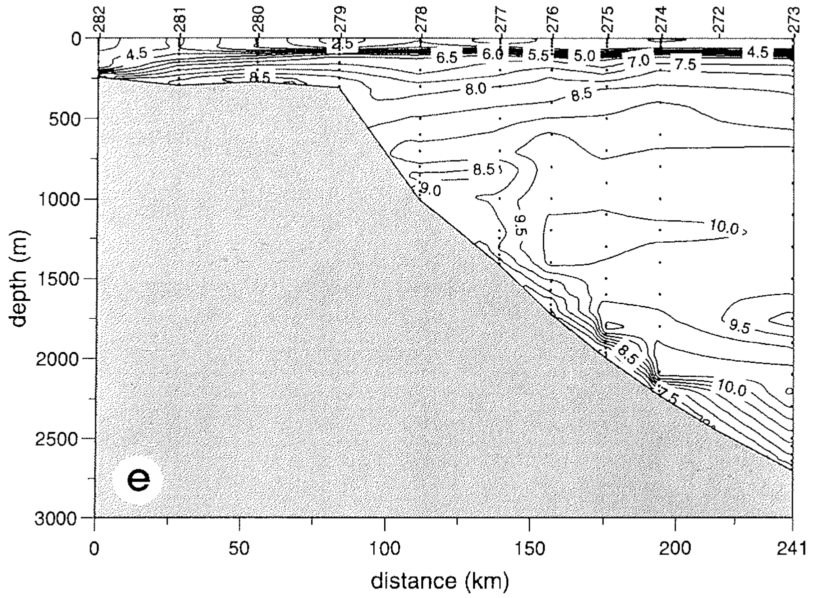
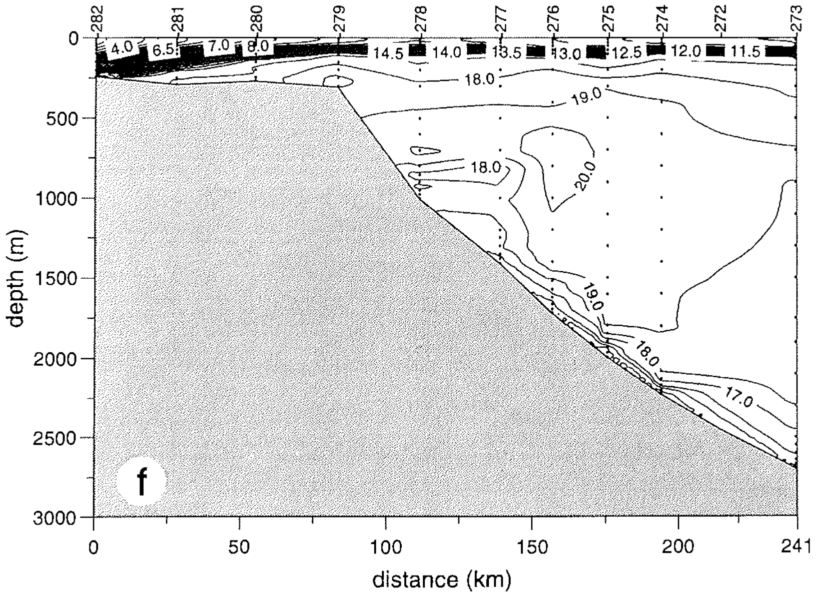
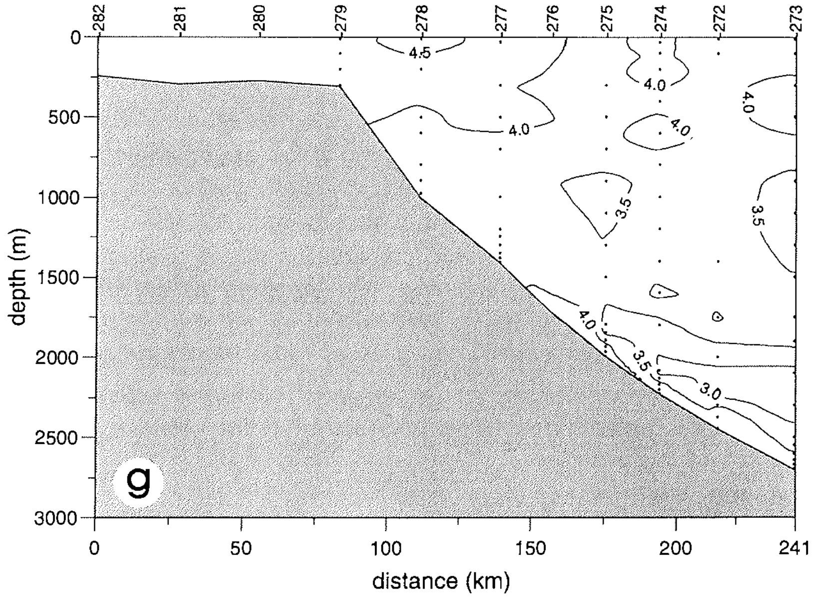


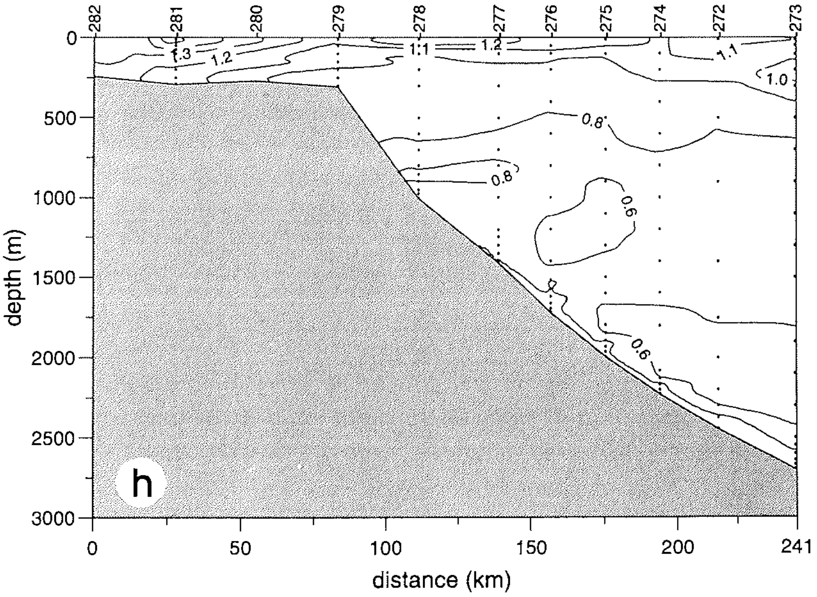
Fig. 22: Vertical section 11 of potential temperature (a), salinity (b), potential density (c), oxygen in µmol/kg (d), silicate in µmol/kg (e), nitrate in µmol/kg (f), tracer CFC-11 in pmol/kg (g) and tracer SF_6 in fmol/l (h) from the East Greenland Shelf 65°43'N, 35°16'W to the Irminger Basin 63°51'N, 33°05'W.


282
281
280
279
278
277
276
275
274
272
273
26.80
27.20
27.30
27.40
27.20
27.50
27.60
27.60
27.70
27.80
27.90
c
depth (m)
0
500
1000
1500
2000
2500
3000
0
50
100
150
200
241
distance (km)
330
295
300
280
270
280
270
280
280
290
290
295
300
d


282
281
280
279
278
277
276
275
274
272
273
4.5
2.5
6.5
6.0
5.5
5.0
7.0
7.5
4.5
8.5
8.0
8.5
8.5
9.0
9.5
10.0
9.5
8.5
7.5
10.0
e
depth (m)
0
500
1000
1500
2000
2500
3000
distance (km)
0
50
100
150
200
241


282
281
280
279
278
277
276
275
274
272
273
4.0
6.5
7.0
8.0
14.5
14.0
13.5
13.0
12.5
12.0
11.5
18.0
19.0
18.0
20.0
19.0
18.0
17.0
f
depth (m)
0
500
1000
1500
2000
2500
3000
distance (km)
0
50
100
150
200
241


282
281
280
279
278
277
276
275
274
272
273
4.5
4.0
4.0
4.0
4.0
3.5
3.5
4.0
3.5
3.0
depth (m)
0
500
1000
1500
2000
2500
3000
g
0
50
100
150
200
241
distance (km)


282
281
280
279
278
277
276
275
274
272
273
1.3
1.2
1.1
1.2
1.1
1.0
0.8
0.8
0.6
0.6
depth (m)
0
500
1000
1500
2000
2500
3000
h
0
50
100
150
200
241
distance (km)

Sulfur hexafluoride survey for the Greenland Sea tracer release experiment ESOP-II

D. C. E. Bakker, J. R. Ledwell, K. Oliver, (UEA, WHOI)

Objectives

A patch of 320 kg of sulfur hexafluoride (SF_6) was released in August 1996 in the center of the Greenland Sea Gyre, at 75°N and approximately 3°W. The tracer was released on the 28.049 potential density surface, at 300 meters depth. The purpose of the experiment, which is part of ESOP-II, is to study convection, vertical mixing, lateral dispersion, and exchange with the surrounding seas and current systems. The objective of the present SF6 survey was to determine the lateral and vertical extent of the patch 2 years after release, and to measure the amount of tracer that had reached the Icelandic Sea to the southwest, the Norwegian Sea to the southeast, Fram Strait to the north, and the East Greenland Current to the west.

Work at sea

SF6 was sampled at 204 of the 282 stations occupied during the cruise, from most of the rosette bottles tripped at these stations. Sampling depths were chosen to obtain 100-meter spacing in the tracer patch wherever this was compatible with the other needs of the scientific party. Samples were run, usually within 3 hours of being taken, by electron-capture gas chromatography. If not run immediately, the samples were stored successfully in a refrigeration van below deck. The number of rosette samples successfully analyzed for SF_6 during the 49-day cruise was 3785. Concentration data were analyzed and plotted during the cruise, both as individual profiles and as sections, and a preliminary report of the high resolution SF_6 component for each leg of the cruise was produced.

Preliminary results

SF_6 from the tracer patch was found at nearly every station reaching potential density anomolies greater than 28.02 kg/m^3 and that were north of the Denmark Strait sill. Notable exceptions were the station closest to the slope on the eastern side of Fram Strait at 79°N, the 3 stations closest to the western side of Fram Strait and the station farthest into the Norwegian Abyssal Plain (Fig. 12 and 15). These stations help to delimit the patch. The majority of the tracer was found over the Greenland Abyssal Plain (Fig. 14 and 15), with maximum concentrations greater than 25 fM (1 fM = 10^{-15} moles/L). Significant tracer concentrations were found, however, over the

Boreas Abyssal Plain and through most of Fram Strait to the north. The tracer had penetrated the West Spitsbergen Current flowing north into the Arctic Ocean, as it was observed all the way to the Spitsbergen slope at 80.2°N (Fig. 12). In the Greenland Sea itself the tracer had spread east of the Knipovich Ridge and all the way to the Spitsbergen Bank. On the other hand, concentrations appeared to decrease most rapidly to the southeast, falling to background levels in the station furthest into the Norwegian Abyssal Plain (Fig. 15). Concentrations increased again from that station toward the west along the Jan Mayen Ridge and into the East Greenland Current (Fig. 17).

In fact, the tracer had clearly penetrated into the East Greenland Current from Fram Strait to the sill in Denmark Strait. Maximum concentrations in this current at Fram Strait were less than 2 fM, but peak concentrations of 3 to 4 fM were found in the current at 75°N, 71°N and a section from Greenland to Iceland across Denmark Strait at 23°W. Even at the sill of Denmark Strait, a bottom mixed layer 100 meters thick with potential density anomaly 28.03 kg/m^3 was found with tracer concentrations that were enhanced above background by approximately 0.3 fM (Fig. 19). Hence, the start of outflow of released SF_6 over the Denmark Strait has most likely been observed. Downstream of the sill in the overflow water the density anomalies are much less than 28.03 kg/m^3, and no signal from the release was apparent, no doubt obscured by mixing.

The vertical distribution of the tracer patch was characterized by relatively sharp peaks with maximum concentrations found between potential density anomalies of 28.04 and 28.05 kg/m^3. The vertical profiles were distributed fairly symmetrically about the peak, with root mean square widths of 150 to 200 meter, corresponding to confinement of the tracer patch between the 28.02 and 28.06 kg/m^3 potential density anomaly surfaces.

The vertical and diapycnal distributions, possibly influenced by surface fluxes of both tracer and buoyancy and by lateral advection, will be used to estimate rates of diapycnal dispersion due to convection and to shear-induced turbulence, averaged over two full years and over much of the area of the Greenland Sea gyre. The lateral distribution will be used to estimate rates of homogenization and dispersion in the gyre, and rates of exchange with the currents and seas bounding the gyre.

Dissolved organic matter (DOM) in the Nordic Seas

R.M.W. Amon (AWI) and P. Louchouran (UT)

Objectives

As part of an international cooperation between the Department of Biological Oceanography at the AWI and the Marine Science Institute at the University of Texas at Austin this research cruise served to extend the DOM sample set collected during the last 3 years in the Arctic Ocean. We mainly focused on the extraction of dissolved organic matter (DOM) from different water masses leaving the Arctic Ocean. Special effort was directed towards the surface waters of the East Greenland Current (EGC) which seem to carry enhanced concentrations of terrestrial derived organic matter, as indicated by last years samples from the Fram Strait. This "outflow" was sampled along several cross sections at 75°N, 71°N, and in the Denmark Strait. Additionally, we collected water samples in the Greenland, Norwegian and Irminger Basins at different depths.

Work at sea

Large volume samples (200 l) were collected at about 17 stations for ultrafiltration of DOM for detailed chemical analysis and experimental work. Medium size samples (30 - 60 l) were collected at 60 stations on reverse-phase Liquid Chromatography columns for extraction of DOM's hydrophobic components. Molecular identification of lignin-derived compounds in extracted DOM will be performed to trace sources and transport of terrigenous organic matter throughout the water masses studied. Depth profiles of small volume samples (100 ml) were collected at about 100 stations for determination of dissolved organic carbon and nitrogen. The sampling locations for the above sample types are shown in Figure 23.

Experiments were performed to study the bacteria mediated transformation of concentrated dissolved organic matter. This should show how bacteria change the chemical signal of DOM during long term decomposition under nutrient replete conditions.

Preliminary results:

Since no analytical measurements were performed on board first results from this cruise can only be qualitative. This years observations confirmed the existence of a stream enriched in terrestrial derived organic matter in the surface EGC. We found enhanced coloration in extracted DOM samples collected in the EGC near the Greenland coast at 75°N, 71°N, the Denmark Strait, and at about 65°N. A first estimation of the extent of that terrestrial-carbon enriched outflow shows that the layer is between 50 and 100 m deep and between 60 and 90 km wide. Detailed chemical analysis will give more insight in the origin of that DOM. We hypothesize that the terrestrial material originates in the Eurasian rivers, crossing the Arctic Ocean in the Transpolar Drift and leaving the Arctic Ocean through Fram Strait as part of the EGC, flowing south all the way into the North Atlantic Ocean. The fate of this outflow in the North Atlantic remains to be determined.

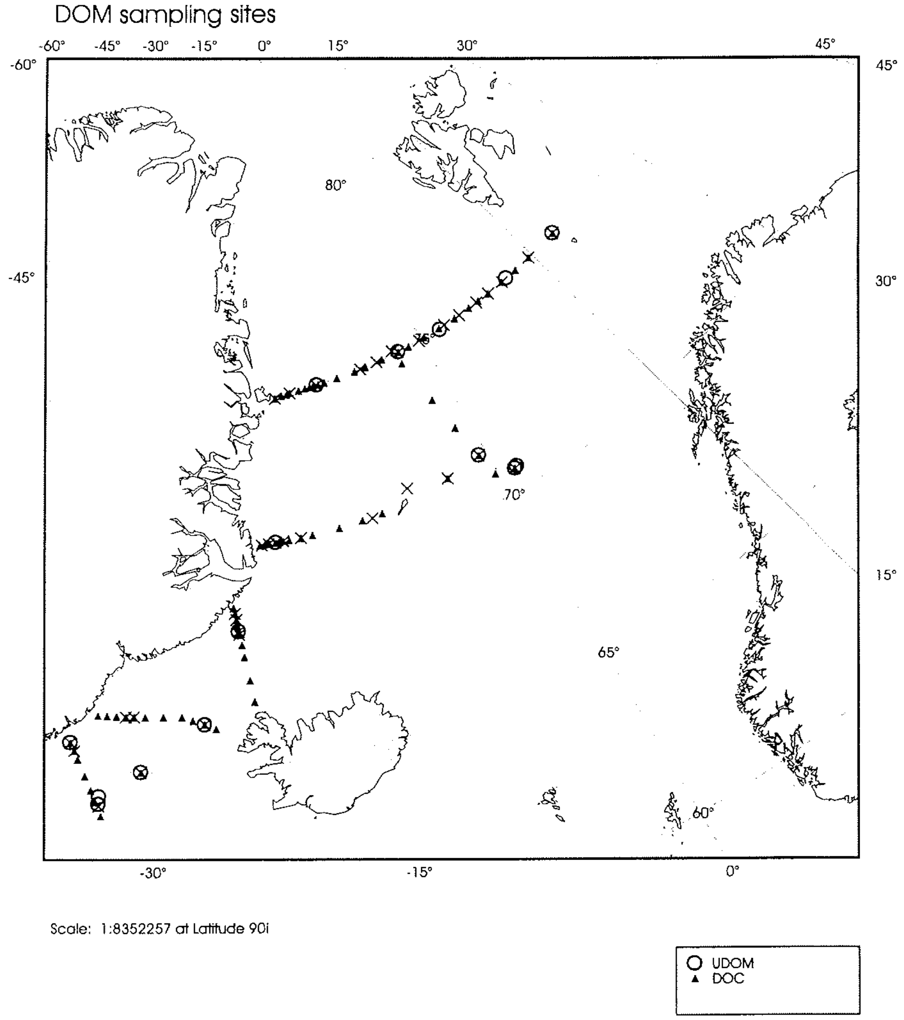


Fig.23: Sampling locations of the DOM-programme

Methane in the upper water column in Fram Strait

E. Damm, A. Dauelsberg (AWI)

Objectives

Methane is an important component of the global carbon cycle and a potent greenhouse gas. The surface ocean water is usually supersaturated with respect to atmospheric methane, caused by biological productivity. The goal of our investigations was to estimate methane concentrations and their in-situ production in different water masses in relation to the plankton bloom. Investigations of the stable carbon isotopic ratio of methane will be carried out to understand mechanisms and pathways of formation and consumption of methane in the surface ocean.

Work at sea

Water samples have been taken with the rosette from different water depths at 27 stations. The dissolved gases were immediately extracted from the water and were analysed for methane by gas chromatography. Gas samples were stored for investigations of the $\delta^{13}C$ signature of methane to be carried out in the home laboratory. Furthermore water samples were taken and filtered for the analysis of chlorophyll a, for the quantitative analysis of plankton and its composition and for DMSP analysis. All samples were fixed and stored refrigerated for analysis in the home laboratory.

Preliminary results

The methane profiles in the upper water column reflect in situ methane production in water depths between 30-200 m at the western part of the transect from Spitsbergen to Greenland (Fig. 24, profiles 74 and 69). In contrast, the stations close to the Spitsbergen coast were characterized by the absence of in-situ production in the euphotic zone (Fig. 24, profiles 49 and 33). Background values were measured at deeper water masses. The differences between the western and eastern Fram Strait is probably related to different water masses, which represent different temporal development of plankton production. Detailed information about distinct distribution pattern will be available after thorough analysis of the biological parameters.

The stations of the transect southwest of Spitsbergen are affected by injections from bottom sources. At these shelf stations the bottom concentrations are up to an order of magnitude higher than the values of the surface water (Fig. 25).

Since the concentration is decreasing upwards, probably by microbial consumption, the surface water is in equilibrium with the atmosphere at stations with water depths deeper than 100 m. However, the shallowest station (52/107) is characterized by supersaturation of up to 300% at the surface water, indicating that this shelf region acts as source for atmospheric methane. The planned investigations of $\delta^{13}C$ signature will contribute to explane the origin of the bottom methane.

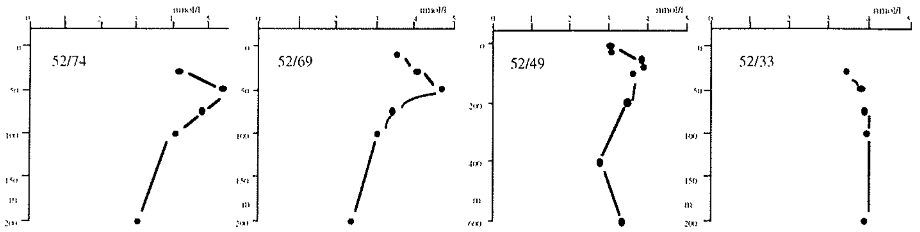


Fig. 24: Methane concentrations in the Fram Strait (notice the different scale of water depths).

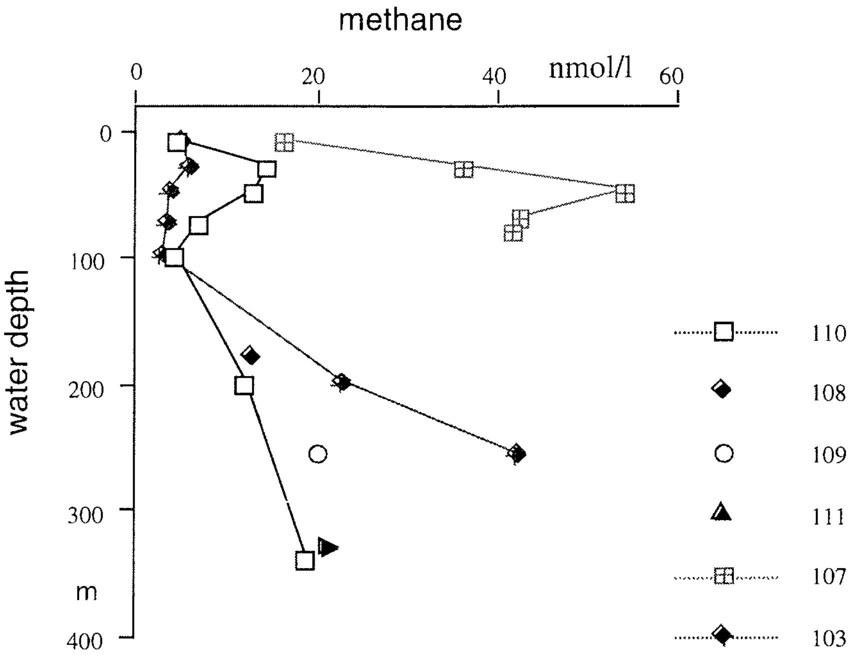


Fig. 25: Methan concentrations southwest of Svalbard

Acknowledgements

The achievements during the cruise were to a large extent due to the effective and friendly cooperation between the ship's crew and the participating scientific personal. We are grateful to Master Pahl and his crew for the continous active support. At the same time, we want to thank all those who were involved in the different levels of the preparations for the cruise and contributed to our success by working up the material and the data after the cruise and to prepare this report.

Annex 1: Participants

ARK XIV/2 part 1 + 2

Name		Institution	part
Amon	Rainer	AWI	2
Anderssen	Karen	IfMHH	1, 2
Badewien	Thomas	IOW	1
Bakker	Dorothee	UEA	2
Budéus	Gereon	AWI	2
Civitarese	Guiseppe	CNR	1
Christl	Marcus	IUPH	2
Damm	Ellen	AWI	1
Dankert	Jutta	IOW	1, 2
Dauelsberg	Anke	AWI	1
Dieck	Wolfgang	AWI	2
Dietze	Heiner	IfMK	2
Dittmer	Klaus	DWD	1, 2
Elbrächter	Martina	IfMK	1, 2
Fahrbach	Eberhard	AWI	1, 2
Fehmer	Dirk	IfMK	2
Feldt	Oliver	HSW	1
Hartmann	Carmen	AWI	1, 2
Hauschildt	Heike	IfMK	2
Herklotz	Kai	AWI	2
Hildebrandt	Hauke	IUPH	1
Köhler	Herbert	DWD	1, 2
Langreder	Jens	IUPT	1
Lahrmann	Uwe	HSW	1
Ledwell	James	WHOI	1, 2
Le Roy	Patrick	IFREMER	1
Lipizer	Marina	CNR	1
Louchouarn	Patrick	UT	2
Lübben	Andrea	IfMHH	1, 2
Makus	Jürgen	HSW	1
Meredith	Michael	UEA	1
Meyer	Ralf	AWI	1, 2
Monsees	Matthias	IUPT	1
Morsdorf	Felix	IfMK	1

Name	Vorname	Institution	part
Neumann	Thomas	IfMK	2
Oliver	Kevin	UEA	1
Plugge	Rainer	AWI	2
Ratje	Andreas	AWI	1, 2
Rhein	Monika	IfMK	2
Ries	Jonas	AWI	2
Ronski	Stephanie	AWI	2
Rost	Björn	AWI	2
Roth	Peter	AWI	1
Röthig	Lutz	DWD	1, 2
Rudels	Bert	IMR	2
Schauer	Ursula	AWI	1
Schuler	Steffen	IUPH	1
Schünemann	Henrike	IfMK	2
Schütt	Ekkehard	AWI	1
Schewski	Mario	IfMK	2
Schuster	Sandra	IfMK	1
Trieschmann	Babette	IfMK	1
Tverberg	Vigdis	UNIS	1
Walter	Maren	IfMK	1, 2
Walz	Volker	IUPH	2
Westernstroeer	Ulrike	AWI	1, 2
Wisotzki	Andreas	AWI	1
Woodgate	Rebecca	AWI	1

Annex 2: Participating Institutions

		Participants	
Address		Part 1	Part 2
Finland			
IMR	Finnish Institute of Marine Research P.O.B. 33 Lyypekinkuja 3 a FIN-00931 Helsinki		1
France			
IFREMER	IFREMER/DITI/NOE Technopolis 40 155 rue J. J. Rousseau F-92138 Issy les Moulineaux cedex	1	
Germany			
AWI	Alfred-Wegener-Institut für Polar- und Meeresforschung Columbusstraße D-27568 Bremerhaven	12	13
DWD	Deutscher Wetterdienst - Seewetteramt - Bernhard-Nocht-Str. 76 D-20359 Hamburg	3	3
HSW	Helicopter-Service Wasserthal GmbH Kätnerweg 43 D-22393 Hamburg	3	
IfMHH	Institut für Meereskunde an der Universität Hamburg Troplowitzstr. 7 D-22529 Hamburg	2	2

Address		Participants	
		Part 1	Part 2
IfMK	Institut für Meereskunde an der Universität Kiel Düsternbrooker Weg 20 D-24105 Kiel	5	9
IOW	Institut für Ostseeforschung an der Universität Rostock Seestraße 14 D-18112 Rostock	2	1
IUPH	Institut für Umweltphysik der Universität Heidelberg Im Neuenheimer Feld 366 D-69120 Heidelberg	2	2
IUPT	Institut für Umweltphysik Abt. Tracer-Ozeanographie Universität Bremen, FB 1 Postfach 33 04 40 D-28334 Bremen	2	
Italy			
CNR	Istituto Sperimentale Talassografico Viale R. Gessi, 2 34123 Trieste	2	
Norway			
NPI	Norsk Polarinstitutt Storgata 25A Box 399 N-9001 Tromsoe		
UNIS	The University Courses on Svalbard P. O. Box 156 N-9170 Longyearbyen	1	

Address		Participants Part 1	 Part 2
UK			
UEA	School of Environmental Sciences University of East Anglia NORWICH NR4 7TJ	2	1
USA			
WHOI	Woodshole Oceanographic Institution Woodshole, Massachusettes 02543-1053	1	1
UT	University of Texas at Austin Marine Science Institute 750 Channel View Drive Port Aransas, TX 78373		1

Annex 3: Ship's Crew

Pahl	Uwe	Master	German
Schwarze	Stefan	1. Offc.	German
Knoop	Detlef	Ch. Eng.	German
Behnes	Stefan	2. Eng	German
Block	Michael	2. Offc.	German
Fallei	Holger	2. Offc.	German
Spielke	Steffen	2. Offc.	German
Evers	Fridtjof	Doctor	German
Koch	Georg	R. Offc.	German
Erreth Monostori	Gyula	2. Eng.	German
Fleischer	Martin	2. Eng.	German
Ziemann	Olaf	2. Eng.	German
Bretfeld	Holger	Electron.	German
Greitemann-Hackl	Andreas	Electron.	German
Muhle	Helmut	Electron.	German
Muhle	Heiko	Eletr.	German
Roschinsky	Jörg	Electron.	German
Clasen	Burkhard	Boatsw.	German
Reise	Lutz	Carpenter	German
Bäcker	Andreas	A.B.	German
Bindernagel	Knuth	A.B.	German
Burzan	G.-Ekkehard	A.B.	German
Gil Iglesias	Luis	A.B.	Spain
Kreis	Reinhard	A.B.	German
Moser	Siegfried	A.B.	German
Pousada Martinez	S.	A.B.	Spain
Schultz	Ottomar	A.B.	German
Müller	Klaus	Storek.	German
Grafe	Jens	Mot-man	German
Hartmann	Ernst-Uwe	Mot-man	German
Ipsen	Michael	Mot-man	German
Preußner	Jörg	Mot-man	German
Voy	Bernd	Mot-man	German
Haubold	Wolfgang	Cook	German
Martens	Michael	Cooksmate	German
Völske	Thomas	Cooksmate	German
Jürgens	Monika	1. Stwdess	German
Hußmann	Mechthild	Stwdess/Kr.	German
Czyborra	Bärbel	2. Stwdess	German
Deuß	Stefanie	2. Stwdess	German

Huang	Wu-Mei	2. Steward	China
Mui	Kee Fung	2. Steward	Hongk.
Neves	Alexandre	2. Stwdess	Portug.
Yu	Kwok Yuen	Laundryman	China

Annex 4: Station list ARK XIV/2 Part 1

Date	Station No.	Time (UTC)	Latitude	Longitude	Depth (m)	Operation
28.08.98	52/001	16,12 17,37	73°24.7'N	18°11.2'E	455	CTD
	52/002	19,05 19,28	73°42.5'N	17°50.9'E	299	CTD
29.09.98	52/003	06,11 06,41	75°48.4'N	15°18.6'E	381	CTD
	52/004	08,05 09,18	75°53.0'N	15°19.4'E	373	CTD, MUC
	52/005	10,06 10,36	75°58.3'N	15°21.3'E	364	CTD
	52/006	12,03 15,12	76°13.3'N	15°31.9'E	319	SF1 REC, SF1 DPL, CTD, MUC
	52/007	16,04 17,03	76°08.8'N	15°24.5'E	359	CTD, MUC
	52/008	17,49 18,19	76°02.9'N	15°22.6'E	363	CTD
	52/009	19,27 19,57	76°10.9'N	15°29.7'E	349	CTD
	52/010	20,53 21,14	76°16.0'N	15°44.8'E	256	CTD
	52/011	21,58 22,17	76°17.7'N	15°47.0'E	164	CTD
	52/012	22,56 23,18	76°21.0'N	15°50.2'E	90	CTD
30.08.98	52/013	07,04 08,25	76°47.9'N	11°31.6'E	1548	SF2 REC (unsucc.)
	52/014	09,18 11,34	76°53.1'N	11°51.6'E	1188	SF5 REC, CTD
	52/015	12,19 17,04	76°56.6'N	12°10.4'E	898	SF4 DRD (unsucc.)
	52/016	17,37 20,05	76°59.9'N	12°17.1'E	593	SF3 REC (unsucc.) CTD, MUC
	52/017	20,83 21,03	77°01.0'N	12°26.9'E	320	CTD
	52/018	21,56 22,41	76°57.9'N	12°14.5'E	773	CTD
 31.08.98	52/019	23,22 01,06	76°56.7'N	12°09.7'E	903	CTD, MUC
	52/020	01,34 02,33	76°54.6'N	12°03.5'E	1051	CTD
	52/021	03,21 04,28	76°50.8'N	11°43.8'E	1363	CTD
	52/022	06,14	76°47.7'N	11°32.1'E	1566	SF2 REC, CTD

		13,06				
	52/023	16,31	76°43.6'N	11°19.3'E	1840	CTD
		17,48				
	52/024	19,03	76°40.2'N	11°09.4'E	2015	CTD
		20,34				
	52/025	22,00	76°31.9'N	10°42.9'E	2187	CTD
		23,32				
01.09.98	52/026	00,46	76°24.5'N	10°16.1'E	2238	CTD
		02,22				
	52/027	13,05	78°49.8'N	08°37.7'E	355	VFS1-1 REC
		13,46				
	52/028	14,14	78°51.6'N	08°19.8'E	780	VFS2-1 REC
		15,08				
	52/029	15,43	78°50.7'N	07°57.6'E	1062	VFS3-1 REC
		16,37				
	52/030	17,49	78°49.6'N	06°56.1'E	1553	VFS4-1 REC
		18,48				
	52/031	19,33	78°50.0'N	06°26.3'E	2078	CTD, LADCP
		23,25				
02.09.98	52/032	00,13	78°50.0'N	06°55.0'E	1546	CTD, LADCP
		02,27				
	52/033	03,39	78°50.0'N	07°58.2'E	1049	CTD , CTD, LADCP
		05,55				
	52/034	06,50	78°50.1'N	08°19.5'E	803	CTD, LADCP
		08,06				
	52/035	08,44	78°49.9'N	08°39.8'E	255	CTD, VFS1-2 DPL
		10,25				
	52/036	11,01	78°50.1'N	08°19.9'E	796	VFS2-2 DPL
		11,56				
	52/037	13,01	78°50.0'N	07°56.6'E	1046	VFS3-2 DPL
		13,46				
	52/038	15,05	78°50.1'N	06°56.1'E	1528	VFS4-2 DPL
		16,16				
	52/039	17,11	78°49.4'N	06°27.5'E	2053	VFS5-1 REC
		18,20				
	52/040	19,24	78°50.0'N	07°39.1'E	1184	CTD, LADCP
		21,14				
	52/041	22,50	78°50.0'N	06°02.8'E	2458	CTD, LADCP
03.09.98		02,22				
	52/042	03,40	78°50.1'N	05°02.6'E	2712	CTD, LADCP, CTD,
		11,01				VFS6-1 REC,
						VFS6-2 DPL
	52/043	12,43	78°49.4'N	06°27.3'E	2038	VFS5-2 DPL
		13,45				
	52/044	16,30	78°48.8'N	04°03.3'E	2370	VFS7-1 REC, CTD,
		21,20				LADCP
	52/045	22,38	78°49.8'N	03°11.4'E	2421	CTD, LADCP, CTD

04.09.98		02,42				
	52/046	03,27	78°50.1'N	02°41.4'E	2494	CTD, LADCP
		06,48				
	52/047	08,47	78°48.7'N	04°02.4'E	2346	VFS7-2 DPL
		10,06				
	52/048	11,58	78°49.8'N	02°35.7'E	2508	VFS8-1 REC,
		15,06				VFS8-2 DPL
	52/049	17,44	78°53.3'N	01°39.7'E	2580	CTD, LADCP, CTD
		21,19				
	52/050	22,26	78°56.7'N	00°44.3'E	2557	CTD
		00,06				
	52/051	01,36	79°10.1'N	00°00.9'E	2739	CTD
		03,28				
	52/052	05,23	79°20.1'N	00°00.9'E	2920	CTD
		07,22				
	52/053	08,35	79°29.9'N	00°00.6'W	2812	CTD
		10,29				
	52/054	11,51	79°40.3'N	00°00.7'E	2825	CTD
		13,43				
	52/055	15,08	79°49.9'N	00°36.6'E	2527	CTD, CTD
		17,40				
	52/056	18,59	80°01.2'N	01°13.6'E	3511	CTD
		21,10				
	52/057	22,37	80°05.2'N	02.04.8'E	2673	CTD
06.09.98		00,24				
	52/058	01,52	80.09.9'N	03.15.8'E	1801	CTD
		03,08				
	52/059	04,13	80°13.3'N	04°04.3'E	1194	CTD, CTD
		05,53				
	52/060	22,55	78°59.1'N	01°25.7'W	2634	CTD, LADCP
07.09.98		00,34				
	52/061	03,18	79°00.0'N	00°49.8'W	2559	CTD, LADCP
		06,51				
	52/062	07,54	78°59.1'N	00°18.0'W	2458	CTD, VFS9-1 REC,
		17,11				CTD, VFS9-2 DEP
	53/063	19,42	79°00.4'N	02°03.0'W	2633	VFS10-1 REC, CTD,
08.09.98		06,20				LADCP, CTD
	52/064	07,14	79°00.0'N	02°34.5'W	2539	CTD
		09,00				
	52/065	09,56	79°00.6'N	02°02.4'W	2617	VFS10-2 DEP
		11,11				
	52/066	12,30	79°00.0'N	03°07.0'W	2410	CTD, CTD
		16,55				
	52/067	18,11	78°59.7'N	03°41.4'W	2143	CTD, LADCP, CTD
		21,46				
	52/068	22,35	78°59.7'N	04°13.9'W	1822	CTD, LADCP
09.09.98		01,18				

	52/069	02,01 04,51	79°00.0'N	04°47.5'W	1484	CTD, LADCP, CTD
	52/070	05,35 07,12	78°58.2'N	05°19.3'W	1047	CTD, LADCP
	52/071	08,16 08,44	79°00.0'N	06°06.6'W	443	CTD
	52/072	09,46 11,00	79°01.8'N	06°52.9'W	250	CTD, VFS14-2 DEP
	52/073	12,30 12,48	79°00.0'N	08°00.5'W	202	CTD
	52/074	14,02 14,23	78°59.7'N	09°00.9'W	265	CTD
	52/075	16,01 16,24	78°59.9'N	09°59.4'W	278	CTD
	52/076	17,57 18,15	78°59.1'N	11°00.7'W	168	CTD
	52/077	19,44 19,58	78°59.8'N	12°01.4'W	158	CTD
	52/078	21,18 21,30	78°59.9'N	13°01.0'W	160	CTD
	52/079	22,50 23,01	78°59.9'N	14°00.0'W	93	CTD
10.09.98	52/080	00,02 00,12	78°59.6'N	14°30.4'W	55	CTD
	52/081	01,23 01,30	78°59.8'N	15°00.8'W	35	CTD
	52/082	02,22 02,34	78°59.0'N	15°30.6'W	44	CTD
	52/083	03,25 03,44	79°00.3'N	15°58.5'W	238	CTD
	52/084	06,33 07,03	79°00.4'N	16°18.3'W	284	CTD
11.09.98	52/085	05,05 07,26	78°58.4'N	05°19.3'W	1066	CTD, VFS13-2 DPL
	52/086	08,47 12,25	78°59.7'N	04°12.8'W	1872	CTD, VFS12-2 DPL
	52/087	13,50 20,35	78°58.9'N	03°06.7'W	2437	VFS11-1 REC (unsucc.) CTD, VFS11-2 DPL
12.09.98	52/088	00,42 04,28	78°49.5'N	00°01.7'W	2641	CTD, LADCP
	52/089	05,39 08,12	78°39.9'N	00°00.0'W	1776	CTD, LADCP
	52/090	09,24 13,13	78°30.2'N	00°00.5'W	2768	CTD, LADCP
	52/091	14,24 16,33	78°20.1'N	00°00.3'E	3023	CTD
	52/092	17,39	78°89.9'N	00°00.1'W	3075	CTD

		19,45				
	52/093	20,55	78°00.1'N	00°00.5'W	3124	CTD
		23,07				
13.09.98	52/094	00,19	77°50.0'N	00°00.3'W	3133	CTD
		02,39				
	52/095	03,43	77°40.0'N	00°00.3'W	3100	CTD
		06,01				
	52/096	07,13	77°29.9'N	00°00.3'W	3171	CTD
		09,15				
		09,29	77°29.8'N	00°04.7'E	3173	XBT
		10,02	77°28.5'N	00°31.9'E	3193	XBT
		10,34	77°27.2'N	01°01.1'E	3205	XBT
		11,03	77°25.9'N	01°29.1'E	3221	XBT
		11,40	77°24.5'N	01°59.2'E	3217	XBT
		12,15	77°23.2'N	02°39.5'E	3254	XBT
		12,49	77°21.7'N	02°59.1'E	3079	XBT
		13,24	77°20.1'N	03°29.1'E	2708	XBT
		14,00	77°18.9'N	04°00.1'E	2744	XBT
		14,34	77°17.5'N	04°30.5'E	2422	XBT
		15,07	77°16.2'N	04°58.6'E	2434	XBT
		15,45	77°14.9'N	05°30.9'E	2597	XBT
		16,16	77°13.5'N	05°58.2'E	2537	XBT
		16,44	77°12.3'N	06°21.6'E	2065	XBT
	52/097	16,58	77°12.1'N	06°30.0'E	2100	CTD, LADCP
		19,56				
		20,10	77°11.9'N	06°36.8'E	2090	XBT
	52/098	21,16	77°11.3'N	07.27.0'E	3590	CTD
		23,34				
		23,43	77°12.1'N	07°28.7'E	3588	XBT
14.09.98		00,18	77°11.1'N	08°00.5'E	2809	XBT
	52/099	01,31	77°11.4'N	08°31.3'E	2108	CTD, LADCP
		04,25				
		04,32	77°11.3'N	08°34.1'E	2079	XBT
		05,02	77°09.5'N	09°01.2'E	2228	XBT
		05,35	77°07.5'N	09°30.2'E	2178	XBT
		06,12	77°05.4'N	10°01.9'E	1963	XBT
		06,46	77°03.3'N	10°31.4'E	1664	XBT
		07,21	77°01.3'N	11°00.2'E	1384	XBT
		07,55	76°59.4'N	11°28.6'E	1138	XBT
	52/100	08,55	76°56.6'N	12°10.4'E	906	SF4 DRD (unsucc.), CTD
		19,42				
	52/101	20,08	76°58.0'N	12°12.9'E	762	CTD
		20,55				
	52/102	21,23	76°59.7'N	12°20.7'E	569	CTD
		21,54				
	52/103	22,28	77°01.4'N	12°28.1'E	260	CTD
		22,48				

	52/104	23,48	76°54.6'N	12°03.4'E	1039	CTD
15.09.98		00,33				
	52/105	01,02	76°53.0'N	11°53.2'E	1210	CTD
		01,52				
	52/106	02,24	76°50.7'N	11°44.1'E	1363	CTD
		03,21				
	52/107	09,28	76°21.6'N	15°51.2'E	85	CTD
		09,48				
	52/108	11,15	76°17.9'N	15°43.0'E	179	CTD
		11,38				
	52/109	12,14	76°15.9'N	15°40.9'E	271	CTD
		12,33				
	52/110	13.13	76°13.1'N	15°36.0'E	328	CTD
		13.32				
	52/111	14,08	76°11.0'N	15°31.6'E	360	CTD
		14.26				
	52/112	15.13	76°05.5'N	15°26.3'E	377	CTD
		15.34				
	52/113	16.23	75°58.2'N	15°21.2'E	375	CTD
		16,44				

ARK XIV/ Part 2

Date	**Station No.**	**Time (UTC)**	**Latitude**	**Longitude**	**Depth (m)**	**Operation**
17.09.98	52/114	10,10	77°20.2'N	0°00.5'E	3240	CTD
		12,30				
	52/115	14,37	76°59.9'N	00°00.3'E	3232	CTD
		16,48				
	52/116	19,09	76°39.9'N	00°00.3'W	3245	CTD
		21,06				
	52/117	23,11	76°19.8'N	00°00.2'W	3152	CTD
		01,24				
18.09.98	52/118	03,30	76°15.0'N	00°16.7'W	3202	CTD
		05,40				
	52/119	07,11	76°09.4'N	00°33.7'W	2228	CTD
		08,50				
	52/120	10,22	76°03.6'N	00°50.0'W	2578	CTD
		12,15				
	52/121	13,47	75°55.4'N	01°13.3'W	3782	CTD
		16,08				
	52/122	18,04	75°38.8'N	01°58.6'W	3750	CTD
		20,30				
	52/123	22,27	75°22.2'N	02°44.8'W	3717	CTD
19.09.98		00,52				
	52/124	02,48	75°06.4'N	03°23.8'W	3596	CTD, AWI-J004 REC,
		11,14				AWI-J006 DPL
	52/125	13,15	74°54.7'N	04°36.5'W	3629	AWI-J003 REC,

		19,36				AWI-J005 DPL, CTD
	52/126	14,30	74°56.7'N	16°55.9'W	325	CTD
20.09.98		14,52				
	52/127	16,19	74°58.9'W	16°24.7'W	310	CTD
		16,40				
	52/128	18,27	74°59.8'N	15°39.8'W	190	CTD
		18,42				
	52/129	20,17	75°00.0'N	15°02.1'W	110	CTD
		20,34				
	52/130	22,40	75°00.0'N	14°20.2'W	145	CTD
		22,54				
	52/131	00,07	75°00.0'N	13°39.8'W	202	CTD
21.09.98		00,26				
	52/132	01,28	74°59.9'N	13°08.7'W	250	CTD
		01,46				
	52/133	02,32	74°59.9'N	12°44.2'W	623	CTD
		03,09				
	52/134	03,51	74°59.8'N	12°31.3'W	1024	CTD
		04,49				
	52/135	05,41	75°00.1'N	12°21.5'W	1212	CTD
		06,35				
	52/136	07,20	74°59.9'N	12°08.7'W	1547	CTD
		08,30				
	52/137	09,24	75°00.0'N	11°52.4'W	1925	CTD
		10,40				
	52/138	11,43	75°00.2'N	11°28.4'W	2330	CTD
		13,25				
	52/139	14,28	74°59.9'N	11°01.7'W	2754	CTD
		16,21				
	52/140	17,04	75°00.1'N	10°44.4'W	2981	CTD
		18,45				
	52/141	19,59	74°59.9'N	09°57.0'W	3223	CTD
		22,00				
	52/142	23,19	75°00.2'N	09°18.9'W	3288	CTD
		01,20				
22.09.98	52/143	02,28	75°00.0'N	08°40.0'W	3373	CTD
		04,48				
	52/144	05,57	75°00.0'N	08°01.2'W	3408	CTD
		08,10				
	52/145	09,21	75°00.1'N	07°22.0'W	3451	CTD
		11,25				
	52/146	12,39	75°00.0'N	06°45.3'W	3499	CTD
		14,46				
	52/147	15,50	75°00.0'N	06°04.9'W	3534	CTD
		17,53				
	52/148	19,21	75°00.0'N	05°25.3'W	3564	CTD
		21,20				

	52/149	22,46	75°00.1'N	04°48.3'W	3601 CTD
		00,33			
23.09.98	52/150	01,53	74°59.9'N	04°07.9'W	3634 CTD
		03,51			
	52/151	04,58	75°00.1'N	03°31.0'W	3655 CTD
		07,03			
	52/152	08,12	75°00.4'N	02°51.3'W	3680 CTD
		10,15			
	52/153	11,22	75°00.2'N	02°13.3'W	3634 CTD
		13,28			
	52/154	14,52	75°00.0'N	01°35.1'W	3747 CTD
		16,52			
	52/155	17,57	75°00.1'N	00°55.9'W	3740 CTD
		20,03			
	52/156	21,18	75°00.0'N	00°18.2'W	3753 CTD
		23,19			
	52/157	00,42	75'00.0'N	00°21.9'E	3789 CTD
24.09.98		02,43			
	52/158	04,09	74°59.9'N	00°58.9'E	3792 CTD
		06,10			
	52/159	07,17	75°00.0'N	01°37.9'E	3198 CTD
		09,10			
	52/160	10,14	75°00.2'N	02°16.9'E	2924 CTD
		12,01			
	52/161	13,15	75°00.0'N	02°56.0'E	2532 CTD
		14,47			
	52/162	15,57	75°00.1'N	03°35.1'E	3495 CTD
		17,49			
	52/163	18,57	75°00.1'N	04°14.2'E	3101 CTD
		20,44			
	52/164	21,55	75°00.1'N	04°51.3'E	3305 CTD
		23,54			
	52/165	00,42	75°00,1'N	05°10.2'E	3272 CTD
		02,33			
	52/166	03,15	75°00.1'N	05°30.2'E	3148 CTD
		05,12			
	52/167	06,27	75°00.0'N	05°49.5'E	2730 CTD
		07,51			
	52/168	08,27	75°00.0'N	06°07.9'E	2956 CTD
		10,10			
	52/169	11,15	75°00.2'N	06°26.8'E	2608 CTD
		12,45			
	52/170	13,34	75°00.0'N	06°48.0'E	2231 CTD
		15,11			
	52/171	15,56	75°00.0'N	07°07.9'E	2254 CTD
		17,21			
	52/172	17,54	74°59.9'N	07°25.1'E	2491 CTD

		19,23				
	52/173	20,47	75°00.0'N	08°03.8'E	3516	CTD
		22,30				
	52/174	23,32	75°00.0'N	08°44.2'E	2668	CTD
		01,09				
26.09.98	52/175	02,13	74°59.9'N	09°22.2'E	2605	CTD
		03,48				
	52/176	04,51	75°00.0'N	10°00.3'E	2589	CTD
		06,27				
	52/177	07,38	75°00.0'N	10°38.0'E	2546	CTD
		09,07				
	52/178	10,14	75°00.1'N	11°18.0'E	2462	CTD
		12,35				
	52/179	13,40	75°00.0'N	11°56.2'E	2340	CTD
		15,14				
	52/180	16,16	75°00.1'N	12°34.9'E	2188	CTD
		17,47				
	52/181	18,46	75°00.0'N	13°13.3'E	2019	CTD
		19,56				
	52/182	21,00	75°00.3'N	13°51.9'E	1781	CTD
		22,09				
	52/183	23,20	75°00.3'N	14°31.3'E	1400	CTD
		00,37				
27.09.98	52/184	01,42	75°00.0'N	15°10.0'E	1028	CTD
		02,40				
	52/185	03,47	75°00.0'N	15°49.2'E	282	CTD
		04,06				
	52/186	05,05	75°00.0'N	16'26.1'E	285	CTD
		05,20				
	52/187	06,24	75°00.0'N	17°05.5'E	165	CTD
		06,37				
	52/188	07,56	75°00.0'N	18°00.2'E	160	CTD
		09,00				
	52/189	12,21	75°00.0'N	15°49.1'E	281	CTD
		12,36				
	52/190	15,09	74°40.0'N	03°00.2'W	3551	CTD
28.09.98		17,14				
	52/191	19,13	74°20.4'N	02°45.0'W	3706	CTD
		21,24				
	52/192	23,34	73°59.8'N	02°28.7'W	3650	CTD
		01,42				
29.09.98	52/193	03,40	73°41.2'N	02°15.3'W	3046	CTD
		05,33				
	52/194	07,30	73°21.6'N	02°00.9'W	3873	CTD
		09,19				
	52/195	11,19	73°02.0'N	01°46.3'W	2949	CTD
		13,08				

	52/196	15,06	72°42.5'N	01°33.1'W	2677	CTD
		16,45				
	52/197	18,48	72°22.8'N	01°19.8'W	1990	CTD
		20,05				
	52/198	22,17	72°03.6'W	01°06.1'W	2405	CTD
		23,50				
	52/199	01,31	71°47.0'N	01°00.6'W	2002	CTD
30.09.98		02,50				
	52/200	05,12	71°24.0'N	00°40.4'W	2688	CTD
		05,25				
	52/201	09,58	71°03.9'N	00°27.4'W	3240	CTD
		11,53				
	52/202	13,57	70°44.9'N	00°15.0'W	3319	CTD
		15,50				
	52/203	19,00	70°34.9'N	01°15.1'E	3261	CTD
		03,51				
01.10.98	52/204	01,59	70°35.1'N	01°15.5'W	2765	CTD
		03,51				
	52/205	16,00	71°13.3'N	03°57.3'W	1683	CTD
		17,12				
	52/206	19,34	71°23.4'N	04°54.1'W	2572	CTD
		21,14				
	52/207	01,44	71°40.0'N	07°24.9'W	2571	CTD
02.10.98		03,17				
	52/208	04,46	71°26.0'N	07°32.1'W	1170	CTD
		05,46				
	52/209	07,20	71°10.7'N	07°40.7'W	2111	CTD
		08,48				
	52/210	12,00	71°00.0'N	09°14.8'W	378	CTD
		12,20				
	52/211	14,24	71°00.0'N	10°19.8'W	1254	CTD
		15,17				
	52/212	16,56	71°00.0'N	11°15.3'W	1234	CTD
		17,45				
	52/213	19,09	71°00.0'N	12°00.2'W	917	CTD
		19,55				
	52/214	21,54	70°59.9'N	13°05.0'W	449	CTD
		22,15				
	52/215	00,15	71°00.0'N	14°10.1'W	864	CTD
03.10.98		01,00				
	52/216	03,04	71°00.0'N	15°20.1'W	1450	CTD
		04,08				
	52/217	06,14	71°00.0'N	16°30.0'W	1263	CTD
		07,14				
	52/218	09,00	70°59.8'N	17°30.8'W	1726	CTD
		10,11				
	52/219	121,02	70°59.8'N	18°30.2'W	1643	CTD

		13,10			
	52/220	14,16	70°59.9'N	18°52.4'W	1408 CTD
		15,20			
	52/221	16,43	70°59.5'N	19°22.1'W	976 CTD
		17,33			
	52/222	18,51	70°59,4'N	19°44.2'W	418 CTD
		20,00			
	52/223	21,39	71°00.0'N	20°15.4'W	318 CTD
		22,01			
	52/224	23,25	71°00.0'N	20°50.2'W	290 CTD
		23,48			
	52/225	01,58	71°00.4'N	21°27.1'W	440 CTD
04.10.98		02,19			
	52/226	01,16	69°22.7'N	23°43.2'W	353 CTD
05.10.98		01,38			
	52/227	02,59	69°12.9'N	23°42.8'W	207 CTD
		03,15			
	52/228	04,30	69°02.8'N	23°39.4'W	324 CTD
		04,50			
	52/229	06,06	69°53,2'N	23°36.3'W	301 CTD
		06,25			
	52/230	07,29	68°43.3'N	23°33.1'W	602 CTD
		08,47			
	52/231	09,37	68°37.2'N	23°30.7'W	1310 CTD
		10,37			
	52/232	11,24	68°30.0'N	23°28.4'W	1510 CTD
		12,27			
	52/233	13,29	68°20.2'N	23°26.4'W	1514 CTD
		14,36			
	52/234	15,37	68°10.6'N	23°23.8'W	1452 CTD
		16,42			
	52/235	17,41	68°00.6'N	23°20.6'W	1321 CTD
		18,39			
	52/236	20,28	67°40.6'N	23°15.3'W	826 CTD
		21,11			
	52/237	23,00	67°20.8'N	23°09.0'W	411 CTD
		23,28			
	52/238	01,17	67°00.8'N	23°03.9'W	269 CTD
06.10.98		01,41			
	52/239	03,08	66°44.9'N	23°00.0'W	106 CTD
		03,25			
	52/240	09,20	66°00.0'N	24°59.4'W	135 CTD
		09,30			
	52/241	11,29	66°07.9'N	25°43.9'W	176 CTD
		11,44			
	52/242	12,53	66°11.5'N	26°08.3'W	436 CTD
		13,23			

	52/243	14,38	66°14.8'N	26°30.1'W	619 CTD
		16,24			
	52/244	17,18	66°17.7'N	26°40.9'W	584 CTD
		17,48			
	52/245	18,36	66°19.4'N	26°54.1'W	527 CTD
		19,04			
	52/246	20,06	66°23.4'N	27°16.9'W	479 CTD
		20,44			
	52/247	21,37	66°26.9'N	27°39.6'W	384 CTD
		22,02			
	52/248	23,01	66°30.4'N	27°59.4'W	343 CTD
		23,46			
	52/249	01,03	66°30.0'N	28°37.5'W	334 CTD
07.10.98		01,29			
	52/250	02,59	66°30.0'N	29°15.2'W	323 CTD
		03,27			
	52/251	04,57	66°30.1'N	29°53.1'W	324 CTD
		05,22			
	52/252	06,28	66.30.0'N	30°17.8'W	406 CTD
		06,56			
	52/253	07,39	66.30.0'N	30°27.9'W	482 CTD
		08,10			
	52/254	09,30	66°30.4'N	30°52.4'W	471 CTD
		10,03			
	52/255	11,00	66°30.4'N	31°13.0'W	454 CTD
		11,35			
	52/256	13,06	66°30.0'N	31°45.8'W	308 CTD
		13,25			
	52/257	14,58	66°30.1'N	32°23.4'W	335 CTD
		15,16			
	52/258	16,55	66°30.0'N	33°01.5'W	336 CTD
		17,12			
	52/259	18,45	66°29.9'N	33°38.9'W	248 CTD
		19,00			
	52/260	21,03	66°15.5'N	33°03.5'W	354 CTD
		21,24			
	52/261	23,23	66°01.5'N	32°29.4'W	272 CTD
		23,40			
	52/262	01,26	65°47.1'N	31°54.9'W	281 CTD
08.10.98		01,45			
	52/263	04,08	65°30.1'N	31°15.0'W	368 CTD
		04,32			
	52/264	05,28	65°30.0'N	30°50.9'W	397 CTD
		05,58			
	52/265	07,04	65°30.0'N	30°26.7'W	391 CTD
		07,25			
	52/266	08,26	65°29.9'N	30°02.4'W	410 CTD

		08,45				
	52/267	10,00	65°34.2'N	29°47.8'W	371	CTD
		10,19				
	52/268	13,34	65°19.1'N	31°02.3'W	1038	CTD
		14,31				
	52/269	15,49	65°08.2'N	30°51,3'W	1589	CTD
		17,03				
	52/270	18,03	64°59.9'N	30°41.7'W	1905	CTD
		20,15				
	52/271	21,54	64°45.2'N	30°25.1'W	2240	CTD
		23,24				
	52/272	07,00	64°00.0'N	33°14.9'W	2450	CTD
09.10.98		12,36				
	52/273	14,12	63°47.1'N	33°00.5'W	2696	CTD
		15,55				
	52/274	18,20	64°09.6'N	33°25.6'W	2216	CTD
		19,40				
	52/275	20,54	64°18.7'N	33°35.7'W	1974	CTD
		22,17				
	52/276	23,22	64°27.7'N	33°45.9'W	1695	CTD
		00,36				
10.10.98	52/277	01,41	64°36.4'N	33°56.3'W	1398	CTD
		02,13				
	52/278	04,13	64°49.7'N	34°12.2'W	1000	CTD
		05,15				
	52/279	06,36	65°03.3'N	34°27.9'W	305	CTD
		07,03				
	52/280	08,35	65°16.9'N	34°44.3'W	270	CTD
		08,59				
	52/281	10,31	65°30.5'N	34°59.9'W	300	CTD
		10,58				
	52/282	12,35	65°43.4'N	35°16.2'W	247	CTD
		13,40				

CTD=Conductivity, temperature, depth-sonde
LADCP=Lowered Acoustic Doppler Current Profiler
MUC=Multicorer
DPL= Mooring deployment
REC=Mooring recovery
DRD=Dredging of mooring
XBT=Expandible bathythermograph

Annex 5: Moorings

Recovered moorings

Mooring	Latitude Longitude	Date & Time (UTC) of first record	Water Depth	Type	SN	Instrument Depth	Record length (days)
ARKTIEF							
SF1-1	76 13.3 N	10 Sep 97	310m	RCM7	#6854[6]	298 m	353 d
	15 32.3 E	21:00		Seacat	#2413	299 m	353 d
SF2-1	76 47.8 N	12 Sep 97	1500 m	RCM7	#9998[6]	1397 m	353 d
	11 32.4 E	9:00		Seacat	#2422[2]	1488 m	353 d
				Influx ADM	#4[6]	1489 m	353 d
SF5-1	76 53.0N	12 Sep 97	1200 m	RCM7	#12330	1095 m	352 d
	11 53.5 E	13:00		TK	#944/ #1875	1100 m[3]	352 d
				Seacat	#1254[2]	1186 m	352 d
				Influx ME	#38	1188 m	328 d
VEINS FRAM STRAIT							
VFS1-1	78 49.8 N	13 Sep 97	321 m	FSI	#1447	89 m	353 d
	8 38.2 E	15:00		RCM7	#8419	265 m	353 d
VFS2-1	78 51.6 N	6 Sep 97	755 m	FSI	#1471	71 m	360 d
	8 20.1 E	10:00		RCM7	#8050	247 m	360 d
				Seacat	#2418[2]	743 m	360 d
				RCM8	#12325	744 m	360 d
VFS3-1	78 50.8 N	7 Sep 97	1035 m	FSI	#1442[6]	101 m	359 d
	7 57.7 E	21:00		RCM7	#8367	277 m	359 d
				Seacat	#2419[2]	1023 m	359 d
				RCM8	#12326	1024 m	359 d
VFS4-1	78 49.7 N	8 Sep 97	1500 m	FSI	#1456	66 m	358 d
	6 56.0 E	8:00		RCM7	#8370	242 m	358 d
				Seacat	#2420[2]	1488 m	358 d
				RCM7	#8395	1489 m	358 d
VFS5-1	78 49.4 N	8 Sep 97	2000 m	FSI	#1470[4]	80 m	no data
	6 27.0 E	14:00		RCM7	#8048	246 m	359 d
				RCM7	#8396	1502 m	359 d
				Seacat	#2421[2]	1988 m	359 d
				RCM8	#10495	1989 m	359 d

VFS6-1	78 49.7 N	5 Sep 97	2610 m	FSI	#1472	41 m	363 d
	4 59.7 E	21:00		RCM7	#8400	197 m	363 d
				RCM8	#8037[1,4]	1453 m	no data
				RCM8	#12333[5]	2599 m	90 d

VFS7-	78 48.7 N	31 Aug 97	2310 m	FSI	#1451	71 m	292 d
	4 02.7 E	16:00		RCM7	#8401	257 m	368 d
				RCM8	#7727	1513 m	368 d
				RCM8	#10531	2299 m	368 d

VFS8-1	78 49.9 N	31 Aug 97	2465 m	FSI	#1473[1,4]	76 m	no data
	2 36.7 E	10:00		RCM7	#8402	242 m	369 d
				RCM8	#12329	1448 m	369 d
				RCM8	#10532	2454 m	369 d

VFS9-1	78 59.4 N	30 Aug 97	2460 m	APL-ULS	#49[7]	59 m	?
	0 15.7 W	9:00		FSI	#1474	71 m	375 d
				RCM7	#8403	217 m	375 d
				RCM8	#12328	1443 m	375 d
				RCM8	#10530	2449 m	375 d

VFS10-1	79 0.4 N	28 Aug 97	2575 m	APL-ULS	#32	62 m	373 d
	2 2.5 W	18:00		FSI	#1450	76 m	373 d
				RCM7	#8405[6]	252 m	373 d
				RCM8	#12332	1508 m	373 d
				RCM8	#9769	2564 m	373 d

Central Greenland Sea

AWI-	74 54.9 N	3565 m
J 003	04 36.0 W	

AWI-	75 05.0 N	3565 m
J 004	03 29.1 W	

Remarks:
1: water inside instrument
2: intense marine growth on instrument
3: upper level of 11 instruments with 8 m spacing
4: no data recorded
5: instrument stopped recording data
6: extensive periods with erroneous data
7: battery problems; data might be recovered later

Deployed moorings

ARKTIEF

Mooring	Latitude Longitude	Date & time (UTC) of deployment	Water depth	Type	SN	Instrument depth
S1-2	76 13.4 N	29 Aug 98	320 m	Argos	#143	
	15 31.6 E	13:14			Id 9280	
				RCM8	#10003	310 m
				Mcat	#241	311 m
				RT661	#373	

VEINS FRAM STRAIT

Mooring	Latitude Longitude	Date & time (UTC) of deployment	Water depth	Type	SN	Instrument depth
V1-2	78 50.3 N	2 Sept 98	330 m	Argos	#107	
	8 37.7 E	10:23			Id 24316	
				FSI	#1559	93 m
				Mcat	#232	94 m
				RCM7	#9401	274 m
				RT661	#374	
V2-2	78 51.1 N	2 Sept 98	755 m	Argos	#118	
	8 21.1 E	11:55			Id 2420	
				FSI	#1560	66 m
				Mcat	#233	67 m
				RCM7	#9402	247 m
				Seacat	#1166	743 m
				RCM8	#9183	744 m
				AR661	#543	
				AR261	#20	
V3-2	78 50.1 N	2 Sept 98	1035 m	Argos	#119	
	7 56.6 E	13:47			Id 7868	
				FSI	#1563	76 m
				Mcat	#239	77 m
				RCM8	#9767	257 m
				Seacat	#630	1023 m
				RCM8	#9561	1024 m
				AR661	#544	
				AR261	#22	
V4-2	78 50.0 N	2 Sept 98	1505 m	Argos	#110	
	6 55.5 E	16:12			Id 24315	
				FSI	#1564	66 m
				Mcat	#236	67 m
				RCM8	#9770	247 m
				Seacat	#631	1493 m
				RCM8	#9768	1494 m
				RT661	#285	
				AR261	#27	

V5-2	78 49.4 N	3 Sep 98	1990 m	Argos	#112	
	6 27.3 E	13:45			Id 8347	
				FSI	#1569	55 m
				Mcat	#240	56 m
				RCM8	#10004	236 m
				RCM8	#10503	1492 m
				Seacat	#1979	1978 m
				RCM8	#10498	1979 m
				RT661	#286	
				AR261	#28	

V6-2	78 49.8 N	3 Sep 98	2640 m	Argos	#147	
	5 0.4 E	11:05			Id 27862	
				FSI	#1566	56 m
				Mcat	#235	57 m
				RCM8	#10872	247 m
				RCM8	#9187	1493 m
				RCM8	#9185	2629 m
				RT661	#453	
				AR361	#19	

V7-2	78 48.5 N	4 Sep 98	2305 m	Argos	#105	
	4 2.7 E	10:07			Id 24577	
				FSI	#1568	51 m
				Mcat	#238	52 m
				RCM8	#11887	242 m
				RCM8	#9785	1498 m
				RCM8	#9390	2294 m
				RT661	#304	
				RT161	#817	

V8-2	78 49.9 N	4 Sep 98	2470 m	Argos	#108	
	2 33.8 E	15:06			Id 5426	
				FSI	#1557	76 m
				Mcat	#237	77 m
				RCM8	#11888	257 m
				RCM8	#9786	1503 m
				RCM8	#9782	2459 m
				RT661	#443	
				RT661	#288	

V9-2	78 59.6 N	7 Sep 98	2480 m	Argos	#109	
	0 16.3 W	17:11			Id 24313	
				APL-ULS	#31	80 m
				FSI	#1562	86 m
				Mcat	#223	87 m
				RCM8	#11890	267 m
				RCM8	#9995	1523 m
				RCM8	#9184	2469 m
				RT661	#303	
				RT661	#287	

V10-2	79 0.2 N	8 Sep 98	2580 m	Argos	#116	
	2 2.6 W	11:10			Id 2422	
				APL-ULS	#47	64 m
				FSI	#1561	76 m
				Mcat	#435	77 m
				RCM8	#11892	257 m
				RCM8	#6856	1513 m
				RCM8	#9188	2569 m
				RT661	#840	
				RT661	#239	

V11-2	79 0.9 N	11 Sep 98	2365 m	Argos	Id 23050	
	3 1.1 W	20:35		CMR-ULS	#31	49 m
				DCM12	#17	49 m
				Seacat	#1253	62 m
				RCM7	#10349	246 m
				RCM7	#9464	1450 m
				RCM8	#10071	2355 m
				AR661CC	#77	

V12-2	78 58.8 N	11 Sep 98	1795 m	CMR-ULS	#37	56 m
	4 15.3 W	12:24				
				Seacat	#1975	65 m
				RCM7	#9706	66 m
				RCM7	#11845	271 m
				RCM7	#11475	1475 m
				Mcat	#242	1780 m
				RCM8	#11625	1785 m
				Releaser	#290	

V13-2	78 58.3 N	11 Sep98	1030 m	CMR-ULS	#45	53 m
	5 18.7 W	7:25				
				DCM12	#47	53 m
				Mcat	#247	60 m
				RCM7	#7718	263 m
				RCM7	#10303	1020 m
				Releaser	#292	

V14-2	79 1.7 N	9 Sep 98	282 m	CMR-ULS	#34	55 m
	6 50.8 W	10:59				
				Seacat	#1973	63 m
				RCM7	#11854	64 m
				RCM7	#11059	270 m
				AR661	#291	

Central Greenland Sea

AWI- J 005	74 54.9 N 004 36.8 W	19.Sep. 98 17:04	3604 m	Seacat	#2639	3405 m

AWI-	75 04.6 N	19.Sep. 98	3658 m	Seacat	#2638	3495 m
J 006	03 26.7 W	11:14		Microcat	#429	3495 m

Moorings which could not be recovered

ARKTIEF

Mooring	Latitude Longitude	Water Depth	Type	SN	Instrument Depth	Remark
SF3-1	76 59.9 N 12 17.3 E	600 m	ADCP Influx ADM Oceano Hbg	#1563 #5 #375	389 m 588 m 590 m	Upper part (ADCP and Argos sender) emerged in December 1997 and was found in Denmark Strait in May 1998. Trial to recover the rest: 30.8.98: Reply from releaser ok, dredging, no success.
SF4-1	76 56.5N 12 10.3 E	900 m	Benthos Tr RCM7 TK Seacat Influx RT661	#58275 #8399 #981/ #1877 #318 #39 #23	 795 m 880 m 886 m 888 m 890	Trials to recover: 30.8.98 and 14.9.98: Reply from releaser ok, no reply from the transponder. Dredging. No success

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