Oceanography Committee

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REPORT OF THE

Working Group on Oceanic Hydrography (WGOH)

13–15 March 1999
Murmansk, Russia

International Council for the Exploration of the Sea

Conseil International pour l'Exploration de la Mer

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Table of Contents

1. Opening

The annual meeting of the Working Group on Oceanic Hydrography (WGOH) was held at the Knipovich Polar Research Institute of Marine Fisheries and Oceanography (PINRO), Murmansk, Russia, from April 13 to 15, 1999. Research Director, Dr. Valery Shleinik, of PINRO welcomed the WG to Murmansk and to the Institute. Information on the local arrangements was provided and a tentative schedule was established.

As Murmansk is located on the remote Kola peninsula to the northeast of Scandinavia, this meeting was probably the furthest north of the Arctic Circle that has ever been held by any ICES Working Group. Meeting at PINRO gave the WG two major benefits. First, the Working Group had an opportunity to meet and work with PINRO and other Russian scientists as a result of a Symposium, which was held prior to the start of WGOH's annual meeting. The Symposium was held to mark a historic landmark in Barents Sea oceanographic observations – the Centennial of oceanographic observations along the "Kola Meridian" which runs northwards from the Russian coast across the Barents Sea at 33° 30' E. Since one of the primary functions of ICES is to foster monitoring, detecting, and understanding climate variability, it was only appropriate that WGOH was there to celebrate the longevity and success of the Kola Section. Russian physical, biological and fisheries oceanographers described the development of their understanding of oceanographic and fisheries processes in what is seen as one of the longest and most complete series of observations anywhere in the World's oceans. The Working Group was not a passive participant in these proceedings, with several of them making presentations on a variety of topics that are of relevance to the objectives of the Symposium. The proceedings of the Symposium will be published at a later date.

The second benefit to ICES was to re-establish the link between WGOH and PINRO and to acquire an active member from that institute in the WG. Prior to this meeting, no PINRO scientist had been included in the WG. As a result of this meeting, WGOH was honoured to welcome Vladimir Ozhigin from PINRO, following his nomination by Dr. Shleinik.

The agenda for the meeting (Annex A, which also presents the *Terms of Reference*) was discussed and modified to include additional presentations that were of interest to WG.

2. Review of Membership

WGOH was informed that Johan van Bennekom would no longer be participating in activities of the WG due to his impending retirement and a replacement for him from the Netherlands may not be available; his expertise will be greatly missed. The WG welcomed Sheldon Bacon and Vladmir Ozhigin from PINRO, members from UK and Russia, respectively. WGOH was also informed that although Erik Buch may not be available to attend every WGOH meeting, he will continue to occupy and provide results from the west Greenland Sections. The attendees' list and the membership list are given in Annexes B and C, respectively.

3. Remarks from ICES Oceanographer

Harry Dooley from the ICES Secretariat discussed the activities undertaken by the ICES Oceanographic Data Centre in 1998 (Annex D). As in the past, ICES Oceanographic Data Centre not only operated as a data centre for ICES acquiring and managing data and metadata in the area of interest to ICES, but it also provided services to many programs such as ESOP, VEINS, MEDAR, etc. under contract. However, the volume of new submissions in 1998 had decreased significantly by approximately 75% when compared to 1997 figures. As well, most of these new additions to the database were through migrating data from published project-oriented data sets such as WOCE, JGOFS, etc. On the other hand, there was a significant increase in the amount of underway T/S data received, particularly from thermo-salinographs.

ROSCOP continues to play a fundamental part in the data management at ICES. To make the process of completing the ROSCOP forms more efficient and easy-to-use for the scientists, the software has been upgraded to Windows 95/NT system. This database may be searched through ROSEARCH via a web entry.

4. Update and Review Results from Standard Sections and Stations

Labrador Sea and North Atlantic

Hendry presented results from the Labrador Sea (Annex E). The standard section was occupied once in 1998. A general warming trend has been observed since 1995, representing a recovery from very cold conditions experienced during 1994/95. In this area the influence of the North Atlantic Oscillation (NAO) appears to be quite strong. Evidence of a meso-scale eddy was obtained during the 1998 survey, which affected the vertical density structure throughout the water column. This eddy had a horizontal scale on the order of 100km, and may have been associated with a severe storm in the area. At this moment the precise dynamics of the eddy are unknown, but it may represent a new type of meso-scale eddy generation process. Deep convection in the Labrador Sea was reduced in 1995/1996. Cooling in the area is expected following the winter of 1998/99.

Meincke presented results from the World Ocean Circulation Experiment (WOCE) A1 and A2 Sections. The A1 mid-Atlantic Section, Ireland - Greenland (Annex F) has been observed in 1991, 1992, 1994, 1995, 1996 and 1997. It will be repeated in 1999, possibly for the last time. One primary result of the repeat occupations is that the boundary of the sub-polar gyre appears to have moved west during 1996 and to have remained there. The pan-Atlantic WOCE A2 Section (France - Newfoundland) has been surveyed since 1993. The A1 and A2 Sections form a box, through which transports have been computed. The A2 Section most closely defines the overall vertical overturning through the North Atlantic area, while the situation becomes more complex at the more northerly A1 Section due to increased and more complex horizontal re-circulations.

Northwest Atlantic

Narayanan reported results from the Northwest Atlantic (Annex G). It was noted from a historical standpoint that the four standard sections on the Newfoundland Shelf (referred to as the NAFO Sections), and the standard Station 27, were in fact first established at the start of the century in order to provide advice relating to fisheries concerns. Today Station 27 is occupied by all passing DFO research vessels, and foreign vessels visiting Canada are encouraged to seek permissions to occupy the station. During the cod crisis years, data from the NAFO Standard Sections and Station 27 were the most useful time-series to provide information on environmental change during the period.

Air temperatures throughout the Northwest Atlantic during 1998 were higher relative to 1997, and they were also higher than the long-term (1961-1990) mean by up to 1.5 °C at some sites. Seasonally, air temperatures in most areas of the Northwest Atlantic were above normal in at least 10 out of 12 months of 1998. The 1998 North Atlantic Oscillation (NAO index was slightly above normal, but only slightly above the 1997 value. Sea ice on the Newfoundland and Labrador Shelves appeared late and left early resulting in a shorter duration of ice than normal for 1998. The areal extent of pack ice during 1998 was lower than average, less than the value in 1997 and comparable to the conditions in 1996.

Off Newfoundland, the depth averaged water temperature ranged from a record low during 1991, a near record high in 1996, and near the long-term mean in both 1997 and 1998. The depth averaged summer salinity, which was below normal during most of the early 1990s returned to near normal values during 1997, and continued near normal during 1998. The general trend in ocean temperature between the 1950s and the late 1960s was generally flat and above normal. However, since the early 1970s to present ocean conditions on the eastern Canadian Shelf have undergone near decadal periods of fresher and colder than normal conditions

The volume of sub-zero temperature water on the southern Labrador/Newfoundland shelf during the summer was still below normal in 1998, though the volume had increased compared to the 1997 value.

Iceland

Malmberg presented results from around Iceland (Annex H). In general, higher than normal temperature and salinity conditions were experienced in Icelandic waters during 1998. Since 1997, the salinity in the warm water from the south has been at its greatest value since the early 60s. Warm Atlantic conditions in 1998 also seemed to have influenced the Irminger Sea towards Greenland.

The present mild conditions follow extremely cold 1995 conditions in Icelandic waters. Conditions improved in 1996-97 and remained warm during 1998, with improvements in the warm water from the south. Despite this, the low saline layer in North Icelandic waters, observed since 1996, was still present in 1998. Salinities were relatively low (<34.7) in the East Icelandic Current.

Malmberg also showed the results of drifter releases in Icelandic waters. Drifters underwent remarkable complete circuits around these basins, revealing many aspects of the circulation in the area.

Bay of Biscay

van Aken showed results from Dutch hydrographic sections in the Bay of Biscay (Annex I/1). These sections were first surveyed in 1992, but as resources become reduced these sections may soon be no longer occupied. A distinct freshening event occurred between 1994-1995. van Aken also presented results prepared by van Bennekom of salinity in the southern Bight. Salinity in the southern Bight is determined partly by local runoff and partly by oceanic inflow through the Channel. (Annex I/2). Results showed a minimum in salinity in 1980-1985 followed by large amplitude variability and a maximum in 1990. Freshening occurred between 1994 and 1995, followed by a present increase, which is in line with results from the central and southern North Sea.

Spain

Lavín presented results from the Spanish Standard Sections (Annex J). Air temperature was above normal (compared to 1961-98 average) in the first few months of 1998, but stayed near normal for the rest of the year. NAO index was positive. Water temperatures were above normal in winter, but declined to below normal values in summer. On the shelf, increasing salinities have now followed the salinity minimum of 1995.

Faroe-Shetland Channel

Turrell presented results from the Scottish Standard Sections (Annex K). Oceanic water at the shelf edge north of Scotland is continuing to warm and increase in salinity. The recent trend of cooling and freshening of oceanic water on the Faroese shelf was halted in 1998.

The most significant change occurring within intermediate waters is the recovery following the dramatic freshening event recorded in the March 1997 survey. A suggestion has been put forward that this dramatic freshening may have been the result of the 1996 Icelandic Jökulhlaup, when 3.5 km^3 of freshwater was released from the southern coast of Iceland in just 3 days, following volcanic activity beneath a glacier. When transit times and along-path distances were examined, transit speeds of 10.3 cm s^{-1} and 8.5 cm s^{-1} were calculated from observations of the passage of the salinity minimum to the north and south of the Faroes, respectively.

Rockall Trough

Bacon presented results from the Rockall Trough Standard Section, which the UK continues to maintain (Annex L). The occupation of the Anton Dohrn Seamount Standard Section in May revealed that1998 was an extreme year in terms of the water mass properties and volume transports in the upper ocean. Eastern North Atlantic Water (ENAW) was unusually warm and saline and it moved through the region at a rapid pace, both in the Scottish Shelf Edge Current and in the interior of the basin. The deep reservoir of Labrador Sea Water (LSW) was observed to be continuing its slow cyclonic recirculation with gradually increasing salinity through vertical mixing.

Norwegian Sea and Barents Sea

Loeng presented results from Norwegian observations in the North Sea, Norwegian Sea and Barents Sea (Annex M). In general, the Norwegian Sea is presently freshening, following the recovery from the 1970s low salinity anomaly. Results from OWS Mike show a remarkable warming below 1000m.

In the Barents Sea, after a period with high temperature in the first half of this decade the temperature has dropped to values slightly below the long-term average over the whole area in 1996 and 1997 (excluding March 1997). From March 1998, the temperature in the western area increased to just above the average, while the temperature in the eastern areas stayed below the average during 1998. The high temperature observed upstream in the Atlantic Current arrived at the western entrance of the Barents Sea between October 1998 and January 1999 when the temperature increased by more than half a degree. This temperature increase was observed to a lesser degree in the central part, while the temperature in the eastern part remained low. The increased temperature was also followed by increased salinity. The present temperature conditions are reflected in the ice conditions (little ice in the western area and severe ice conditions in the eastern areas of the Barents Sea).

Ozhigin presented results from Russian surveys in the Barents and Norwegian Seas (Annex N). In all, 1652 hydrographic stations were occupied by PINRO in 1998, both from a research vessel and from instrumented fishing vessels. 1998 was generally a cool year, although conditions began to warm towards the end.

Results from the Kola Section were presented. This section commenced following a recommendation at the International Conference on the Exploration of the Sea held in June 1899 in Stockholm. The Murmansk Fishery Research Expedition, led by N. M. Knipovich, occupied the Kola Section for the first time in 1900. The Expedition's aim was to assess fishery resources and the possibility of a year-round fishery in the southern Barents Sea. The Expedition was completed in 1908, and the Kola Section was not occupied again until 1921. The next gap in observations was related to World War II. The Kola Section has been occupied more than 10 times per year since the mid-1950s. This station has been occupied 945 times in total.

Piechura presented results collected by a Polish research vessel in the Barents Sea and east of Spitsbergen (Annex O). Geostrophic estimates of currents were compared to vessel mounted ADCP data. Transects performed across the west Spitsbergen Current showed complex structure. There were indications that the thickness of Atlantic water was increasing during 1998.

North Sea

Becker presented German results from the North Sea (Annex P). Weekly SST maps, prepared using a combination of in-situ data and remote sensing data, were used to derive monthly anomaly charts for 1998. A complex spatial pattern of anomalies showed generally warm conditions entering the North Sea from the northwest during the early part of the year. Summer anomalies were generally negative, while the autumn was again warm. The net result was an apparent damping of the seasonal cycle of SST during 1998 compared to the long-term mean cycle.

West Greenland

Dooley presented results submitted by Buch, of Danish observations around Greenland (Annex Q). Air temperatures during the period 1989 to 1994 were particularly cold. However, the reversal of the NAO in 1996 brought relatively mild conditions to the area, which persisted into 1998. Changes in the ocean climate in the waters to the west of Greenland generally followed those of air temperature, except that in 1997 an inflow of cool, fresh, Polar Water resulted in cold temperatures. In the summer of 1998, measurements performed in the waters west of Greenland revealed some of the highest surface layer temperatures ever recorded since regular oceanographic observations began in the area in 1950. Additional material prepared by Stein (Annex Q) was also presented, showing changes in the salinity of Labrador Seawater Water salinity.

An additional written submission was received from Hagen describing results from the Baltic Sea (Annex R).

5. Consider Format and Content of Fact Sheet and Annual Climate Summaries, and Compile Relevant Information for 1998

A detailed discussion on the usefulness, format and contents of the annual climate summary, a quick reference with a pointer to more information (a FACT SHEET), took place following the presentations on the results from the standard sections and stations. Questions raised included: "Who are the clients for the document?" "Who should take responsibility for producing it this year?" and "Which sections should be repeated annually and what type of information should be new?" It was generally agreed that the primary client will be the scientific community, especially those involved in stock assessments in the Atlantic. No format change will be made for this year's document, since the last one was just a prototype and perhaps did not receive sufficient distribution to allow a proper review. For the same reason, it was agreed that Turrell would produce a camera-ready copy to be sent to Meincke for printing in Germany. Each section of the draft climate summary was reviewed, gaps were identified, and appropriate individuals were assigned to contribute to the document. The revised summary is given in Annex S.

The working group was of the opinion that a comprehensive synthesis in addition to the WG meeting report and the annual climate summary may not be appropriate at this time. Such results may be more appropriate at the theme sessions or climate symposia.

6. Progress in National and International Projects in North Atlantic, and Shelf-Edge, Slope or Eastern Boundary Currents

Meincke reported on progress in the Variability of Exchanges In the Northern Seas (VEINS) project. VEINS is a component of the European Union (EU) Marine Sciences and Technologies (MAST) III Programme and its overall objective is to "measure and to model the variability of the fluxes between the Arctic Ocean and the Atlantic Ocean". VEINS began in February 1997 and will continue until July 2000. The first full year of hydrographic and moored array measurements has been successful. A mid-term science report is forthcoming. A second VEINS goal is to design a monitoring programme for the high-latitude northern oceans based on both models and observations. Additional observational effort is required to get quantitative measures of heat flux into the Arctic Ocean through Fram Strait and fresh water flux from the Arctic in the East Greenland Current. These are possible issues for a VEINS-2 that could begin in 2001 under the EU Fifth Framework Programme for Research, Technological Development and Demonstration Activities. Information on VEINS may be found at: http://ifmiserv.ifm.uni-hamburg.de/~veins/ or at http://www.ices.dk/ocean/project/veins/ .

Rossby (USA) reported on U.S. World Ocean Circulation Experiment (WOCE) activities. He presented recent interesting work on long-term T/S variations in the North Atlantic by Curry and co-workers at the Woods Hole Oceanographic Institution (WHOI). He summarised results from a number of U.S. float measurement programs. His own North Atlantic Current (NAC) RAFOS float work suggests a number of key branch points for the NAC system that might be monitored using float technology. RAFOS float work in the eastern North Atlantic by Bower and Richardson (WHOI) has contributed to the U.S. Atlantic Circulation and Climate Experiment (ACCE). PALACE floats have been used in the 18-degree water mass in the sub-tropical gyre (Riser, University of Washington). A recent review of the WOCE Data Assembly Centres by the U.S. WOCE Office Director Piers Chapman concluded that in general there was

a free flow of WOCE results to the general scientific community. The 1998 U.S. WOCE Report is available from the U.S. WOCE Office as *U.S. WOCE Implementation Report Number 10* at:
http://www-ocean.tamu.edu/WOCE/uswoce.html or at http://flux.ocean.washington.edu/.

Rossby also summarised results from upper ocean current velocity and surface temperature data collected by M/V *Oleander* during weekly transits between New Jersey and Bermuda over the past six years. This long-term project is studying upper-level seasonal and interannual variability of the Slope Water, Gulf Stream, and Sargasso Sea (http://rafos.gso.uri.edu/ole.html).

Narayanan (Canada) reported on the status of planning for a Global Ocean Observing System (GOOS). Profiling sub-surface drifters such as PALACE floats are envisioned as an important component of such a system. The present GOOS plan calls for a multi-national complement of 3000 such floats that would report their measurements to data centres in near-real time. Canada has proposed a contribution to this effort as part of a national GOOS plan.

Narayanan also commented on the activities of the GODAE (Global Ocean Data Assimilation Experiment) formed as a pilot project to assist in implementing GOOS and the related Global Climate Observing System (GCOS). GODAE is designed to demonstrate the integration of different types of data with dynamical models in near-real-time. Profiling floats are a key source of data for this effort (http://ioc.unesco.org/goos/Default.htm).

Turrell (UK) reported on work in progress to measure the Faroe Bank overflow using moored acoustic Doppler current profilers. Results from recent studies of the Faroe Shetland Channel will appear in the International WOCE Newsletter. Presentations are also planned for the 1999 ICES Annual Science Meeting.

Lavin (Spain) spoke briefly on Spanish activity in the Canary Islands Azores Gibraltar Observations (CANIGO) project, under the European Union MAST-III program. CANIGO aims to improve the interdisciplinary understanding of the marine system in the Canary-Azores-Gibraltar region of the Northeast Atlantic Ocean. The final CANIGO Conference will take place in Las Palmas in September 1999 (http://www.marine.ie/datacentre/projects/canigo/).

Lavin also reviewed her work on interannual changes in the North Atlantic heat and fresh water transport across 24° N on the basis of sections in 1957, 1981, and 1992. She reported that there was no significant change in the net heat transport among the three years considered. All three occupations were made in the summer season and it will be interesting to see the results of a recent wintertime (January-February) 1998 reoccupation of the 24N line by U.S. investigators (http://www.aoml.noaa.gov/phod/24n/).

Malmberg presented recent results from VEINS measurements in the waters surrounding Iceland. The general goals of this work were to measure the transport and water mass properties of the Denmark Strait Overflow, to improve estimates of the freshwater flux to the North Atlantic via the East Greenland Current and East Icelandic Current, and to measure the inflow of Atlantic Water to the Iceland Sea. Five hydrographic sections around Iceland were monitored for these purposes, and current meters from a number of sites were also recovered. Deep currents on the East Greenland slope were observed flowing in the reverse direction to the north in the February-April 1998 period. Among other moored results, a two-year record from a current meter mooring in the East Icelandic Current was obtained. The observed flows were weak, and there were no immediate plans to redeploy a mooring at this site. Malmberg reported that there was a proposal (Käse, Institut für Meereskunde, Kiel) to deploy three ADCP moorings to monitor the Denmark Strait Overflow.

There was a generally strong input of warm and saline Atlantic Water from the south of Iceland in 1998, with a relatively wide extension to the west. Considerable public interest was generated in Iceland by these anomalous conditions. An overview of the results aimed at the general public was prepared to publicize the results (http://www.hafro.is/hafro/Sjora/index.htm).

Becker (Germany) described a decadal-scale salinity correlation between the area south of Rockall and the western approaches to the English Channel near Plymouth. This generated considerable discussion, since the mechanisms were unclear. In the discussion, it was suggested that long-period recirculation within Rockall Trough may decouple this region from its surroundings.

Since the results of the investigations on the Eastern Boundary Currents were not available at the time of the meeting, this topic was not discussed.

7. Review the progress in the installation of vessel-mounted ADCP surveys on ships-of-opportunity

Preparations to instrument the container vessel *Nuka Arctica* with a narrow-band 150 KHz ADCP have reached an advanced stage. The system is being tested in Bergen in April 1999, and the plan is to install the entire system during the ship's next port call in Aalborg in early May. In addition to the ADCP, a thermo-salinograph has been installed and an XBT system will also be installed in early May. There will be undoubtedly some problems, but we are optimistic that it will work well after a 'shake-down' period.

Every 3 weeks, *Nuka Arctica* makes a round-trip voyage across the North Sea from Skagen to the Orkneys, across the North Atlantic to Cape Farewell and north to Nuuk. The University of Bergen is in charge of the operation with initial grant supplied by the University of Rhode Island, the University of Bergen, and a grant from the Wallenberg Foundation in Sweden. Operational budget is being sought from the Norwegian Research Council and the Danish Meteorological Institute.

8. Review Present Status of the Operational Use of New Oceanographic Equipment

Hendry discussed the recent improvements made to the Moving Vessel CTD, developed jointly by Bedford Institute of Oceanography and Brooks Ocean Technology in Canada. Recent advancements include flurometry and a laser optical plankton counter, deployable to a depth of 200 meters at a speed of 12 knots. This CTD has the potential to become part of ships-of-opportunity program on commercial vessels. There are other institutes as well where autonomous profiling CTDs are being developed. In view of the emphasis on ships-of-opportunity for GOOS, WGOH must keep up-to-date on these developments. Meincke will review the status of such developments and make a presentation at the next meeting of WGOH.

Meincke introduced a mooring design for ice-infested waters. This mooring will maintain the instrument package at a fixed depth from the surface, and if pack ice moves over it, the upper portion of the mooring has the flexibility to bend under ice, but at the same time maintain the instrument's depth. The design will be tested next winter at sea.

The implementation of nutrient analysers together with thermosalinographs was discussed. Germany is trying to incorporate an automated nutrient analyser with their CTD. The task team on instrumentation under EuroGOOS is also investigating the feasibility of such an instrument. The WG concluded that though this instrument is a possibility, it would be a while before reliable automated nutrient analysers are available in the market.

NIOZ is developing a more reliable hydro-pneumatic rosette system to replace their General Oceanics. Several other changes and improvements to existing oceanographic instrumentation are being made in many countries. These discussions were found to be very valuable to the participants not only to enhance their information base but also to adapt them to their own work when applicable.

9. Second Decadal Symposium Proposal

Plans for the Second Decadal Symposium are moving forward at an appropriate rate. The necessary reservations have already been made. The 'first notice for papers' will be drafted in the next few months with input from the steering committee members listed below.

- Co-convenors, Dickson (CEFAS, UK) and Meincke (IFMH, Germany)
- Hendrik van Aken, Netherlands (Physical oceanography, East Atlantic and European Shelf)
- Olafur Asthorsson, Institute of Marine Research, Reykjavik, Iceland (all aspects of plankton throughout the ICES area)
- Alicia Lavin, Instituto Español de Oceanografía de Santander, Spain (physical oceanography and associated biological input in the Southeastern area)
- Pentti Mälkki, Institute of Marine Research, Helsinki, Finland (all aspects of Baltic marine science)
- Manfred Stein, Hamburg, Germany (physical oceanography of West Greenland and the Northwest Atlantic, plus will act as an interface with NAFO whose interest and co-sponsorship are warmly welcomed)
- Bill Turrell, SOAEFD, Marine Laboratory, Aberdeen (will chair an editorial group consisting of himself, Ken Drinkwater, Canada, and a biologist to be selected. This group will be responsible for editing the volume of conference proceedings)
- Cisco Werner, UNC, Chapel Hill, North Carolina (cod and climate, fisheries and environmental change including Georges Bank physical oceanography)

At the 1998 June meeting, the NAFO Sub-Committee on Environment (STACFEN) unanimously supported the co-sponsorship of the Symposium. ICES will be sending a formal invitation to NAFO to co-sponsor the Second Decadal Symposium.

10. Current and Future Roles of ICES Oceanographic Data Centre

The WG was concerned about the decreasing resources of the ICES Data Centre at a time when there is a major thrust towards global observing systems and new instrumentation, and the requirement for real-time and near-real-time data exchanges. When ICES Data Centre was created, it was the only data centre for many of the member countries. However, with the formation of IODE and the designated world data centres, and data centres of various projects (WOCE, JGOFS, etc.) the mandate of ICES Data Centre is becoming vague. Many of the members expressed concern felt that the present services they are used to and expect from the ICES data centre may not be available for long if the financial resources continue to decline.

11. Assess developments in GOOS of relevance to ICES in the wake of the GOOS Agreements meeting, taking into account the work of the Steering Group on GOOS

The chair introduced the topic by recalling some of the background for ICES involvement in GOOS and by providing a brief summary from the ICES Workshop on GOOS that was conducted in Bergen from 22-24 of March 1999. The ICES-GOOS workshop was co-sponsored by IOC, and the attendees included Colin Summerhayes from GOOS project office, two members of WGOH, and Harry Dooley. A formal report will be submitted to the Bureau by the Steering Group of ICES on GOOS, chaired by Roald Saetre. The main recommendations of the workshop may be summarised as:

- IOC co-sponsor the ICES Steering Group on GOOS and nominate a GOOS representative to work with ICES; ICES should also get input from other relevant organisations and nominate ICES representatives to GOOS to serve as advisors to selected GOOS design panels and committees.
- The ICES standard sections and stations and the enhancements agreed upon by the member countries will form an Ocean Climate Observing System (OCOS).
- WGOH will produce climate summaries at appropriate time and periodicity
- ICES will establish an operational oceanography program in the North Sea.

To achieve these, ICES will collaborate with other agencies and programs such as EuroGOOS.

WGOH was positive to further ICES' involvement in GOOS and supported the recommendations put forward by the workshop.

12. Propose tactics, activities and products in support of the Oceanography Committee's Five-year Plan Objectives

After reading the *Terms of Reference* for the WG concerning this Agenda item, Loeng presented some background information. At the 1998 Annual Science Conference, 7 principal draft objectives for the Oceanography Committee were agreed, along with suggested activities and tactics to be pursued under each objective. The other ICES Committees did the same, and the Chair of the Consultative Committee then amalgamated these into a common format. The Oceanographic Committee's submission was in some way used as a model to structure the others. However, it was thought that the overall result produced too many individual objectives, and that some overlap existed, hence some objectives were combined to reduce the overall number. The 7 initial objectives proposed by the Oceanography Committee were reduced to 5. The re-structured objectives were presented to the Bureau in January 1999, but at that stage the objectives were not adopted. Hence presently there exists only the re-drafted preliminary objectives. These will be discussed at the Consultative Committee meeting to be held in May 1999. The Bureau may then be able to adopt the new objectives in June1999.

Loeng requested that the WG should consider the re-written objectives for the Oceanography Committee. Specific points WGOH was asked to consider were:

1. The combination of initial objectives 1 and 2.
2. The combination of initial objectives 3 and 5.
3. The replacement of initial objective 4 with suggested text from the Marine Habitats Committee.

In addition, many of the objectives appeared to be too detailed, and there was a requirement for two or three overall ICES objectives, to which the detailed objectives of each Committee would contribute. WGOH members were presented with the text of the seven initial objectives, along with the detailed activities and tactics, and were asked to read and consider these overnight. In addition, it was noted that the Seabird Ecology WG had prepared a table demonstrating how it thought its own work might contribute to each of the 29 individual objectives arising from all Committees. This table was also given to WGOH members for consideration.

On the whole it was considered that the seven initial objectives for the Oceanography Committee might be reduced to five by the suggested combination of four into two. The detailed table prepared by the Seabird Ecology WG was reproduced by WGOH by inserting its own contribution to each specific objective. Loeng will consolidate the inputs from all WGs under the Oceanography Committee into a package, which will form the basis of future discussions, particularly at the full-day session planned at the 1999 Annual Science Conference.

13. Any Other Business

Units and nomenclature in oceanography

Dooley drew the WG's attention to the confusion and uncertainty in the community about units and nomenclature in connection with salinity and density values. He pointed out that this confusion should be unnecessary as clear advice was provided some time ago by the IAPSO/SUN group on units (UNESCO, 1985, p 74, UNESCO Technical Papers in Marine Science, 45, "The International System of Units (SI) in Oceanography) and by JPOTS (UNESCO 1991, "Processing of Oceanographic Station Data"). Both of these groups were co-sponsored by ICES, and ICES is therefore obligated to ensure that the advice given is heeded.

With regard to salinity it was noted that salinity became a dimensionless unit with the introduction of PSS-78 (Practical Salinity Scale 1978) . Declaration of units in many published and unpublished texts is however commonplace (e.g., PSU, psu, ppt,$\%_0$), but it is incorrect to do so. If any description of the given salinity values is required then the values may be followed by (PSS). Nothing more is necessary, and declaring nothing is to be preferred.

With regard to density, both SUN and JPOTS advise that use of the symbol σ must be discontinued since EOS-80 (Equation of State 1980) yield density values in units of kg/m^3 rather than the dimensionless quantity of σ. The JPOTS book, pp16-17, argues as follows:

"Knudsen's equation of state at atmospheric pressure is expressed through the specific gravity anomaly ('sigma-t')

$$\sigma_t = 10^3 (\rho/\rho_m - 1)$$

where ρ_m is the maximum density of pure water then accepted by Knudsen as equal to 1 g/cm^3.

The new equation of state, EOS-80, is expressed through the density anomaly as

$$\gamma = \rho - 1000 \text{ [kg/m}^3\text{]}$$

Solving these equations, the following formula is obtained relating density anomaly γ to specific gravity anomaly σ_t:

$$\gamma = 10^{-3} \rho_m\sigma_t + (\rho_m - 1000.) \text{ [kg/m}^3\text{]}$$

Using the recently accepted value of maximum density of SMOW water, $\rho = 999.975$ kg/ m^3], this equation becomes:

$$\gamma = 0.999975\ \sigma_t - 0.025 \text{ [kg/m}^3\text{]}$$

This formula determines the main difference between the Knudsen-Ekman equation of state and EOS-80; it follows that in addition to instrumental differences, there exists between σ_t and γ a systematic numerical shift equal to 0.025 kg/m^3, values of γ being lower than σ_t (dimensions are different). Therefore direct substitution of γ for σ_t is unacceptable".

Thus the advice is that the nomenclature to be used is density anomaly (UNESCO 1985 also suggest density excess which seems preferable), and the recommended symbol is (gamma) with units kg/m^3. Since there is a large systematic difference between sigma values and gamma values (0.025) it is important that the (incorrect) use of sigma-t, sigma-theta, etc., be stopped and replaced by density excess (gamma-t, gamma-theta, etc.) in kg/m^3.

The WG advised that its member B. Hansen (Denmark) convey this advice to the Publication Committee, of which he is a member, to request the correct practice relating to salinity and density be used in all ICES publications. In order to set a good example, the 1999 report of the Working Group will attempt to use the correct nomenclature and units throughout.

Theme Sessions

WGOH expressed satisfaction in the fact that the Annual Science Conference (ASC) now has a few sessions of interest to oceanographers. However, there is a concern that young scientists who have not achieved the networking necessary for participation in international programs such as GLOBEC for example, may lack the opportunity for presenting his/her paper at ASC and thus may have difficulty becoming getting involved in ICES. Under the present system, a paper is accepted for presentation when it is on one of the theme session topics. WGOH strongly recommends that a recurring theme session titled 'North Atlantic Processes' be established at ASC. For the 2000 ASC the co-convenors will be Bill Turrell from UK and Tom Rossby from US.

14. Election of the Chair

Narayanan announced her decision to step down from the Chairship and sought nominations for a replacement. Malmberg nominated Bill Turrell, and the nomination was accepted unanimously by the WG. Bill's enthusiasm for enhancing the role of ICES and in particular the role of WGOH, in addressing climate issues in the north Atlantic, and for building bridges between ICES and GOOS makes him a very suitable Chair for WGOH. The WG wished him success and offered him full support.

15. Date and Place of Next Meeting

Jan Piechura from IOPAS, Sopot, Poland extended an invitation to hold the next meeting at his institute. WGOH members were unanimous in their acceptance and thanked Jan for the invitation. WGOH wished to avoid a conflict between its meeting and that of the European Geophysical Society. WGOH proposes to meet from April 10 to 13, 2000, because the Millennium Conference on Earth, Planetary and Solar System Sciences and the 25th General Assembly of European Geophysical Society have been scheduled from April 3 to 7, 2000, at Fortezza da Basso, Florence, Italy.

16. Recommendations

A. WGOH recommends the following recurring theme session for the Annual Science Conference:

North Atlantic Processes co-convenors for 2000 are Turrell from UK and Rossby from US

B. The Working Group on Oceanic Hydrography (Chair B. Turrell) will meet at JOPAS, Sopot, Poland from April 1999 to:

1. Update and review results from Standard Sections and Stations;
2. Consolidate inputs from member countries into 'North Atlantic Climate Summary';
3. Review progress in national and international projects in the North Atlantic (WOCE, VEINS, CLIVAR/ACSYS, TASC, ESOP2, Trans-Atlantic Section of Currents, etc.);
4. Discuss management of *Nuka Arctica* ships-of-opportunity program and GOOS;
5. Update and review the surface and sub-surface drifting buoy initiatives;
6. Review North Atlantic climatologies and their availability and usage, and additional data sources for the ICES Annual Ocean Climate Summary;
7. Discuss early results from current Nordic Seas and Baltic Sea Research Project on Radioactive Tracers;
8. Review present status of operational use of new oceanographic equipment;
9. Review progress in the planning of the Second Decadal Symposium (C.Res.1997/2.2)
10. Compile list of oceanographic data sets in danger of being lost and consider means for their rescue;
11. Assess developments in GOOS of relevance to ICES in the wake of the I-GOOS IV and the Agreements meeting, taking into account the work of the Steering Group on GOOS;
12. Consider possible future directions for Oceanography Committee and the Annual Science Conference with specific regard to the part physical oceanography must play in ICES

Justifications:

A. Theme Session: North Atlantic Processes

There is still a concern that young scientists who may not have achieved the networking necessary for participation in international programs such as GLOBEC for example, may lack the opportunity for presenting his/her paper at ASC and thus may have difficulty becoming getting involved in ICES. Under the present system, a paper is accepted for presentation when it is on one of the theme session topics. The WGOH strongly recommends that a recurring theme session titled 'North Atlantic Processes' be established at ASC. ICES needs rejuvenation and this is one of the ways for doing it.

B. Agenda for 1999

1. This is a standard item to enable the group to closely monitor ocean conditions. Materials presented under this item will be used to prepare an overview of the state-of-the-environment in the North Atlantic for 1999.

2. WG recognises the need for disseminating climate information in a timely and appropriate manner. The Steering Group on ICES-GOOS has also identified the climate summary as an essential contribution from WGOH. This agenda item will allow the WG members to prepare the document during the meeting, thus avoiding delays in the dissemination of the information.
3. This agenda item will provide an opportunity for the WG to be informed of programs in the ICES area. Since many planned and funded activities are now being coordinated via funded proposals, such information is necessary to take advantage of national and international funds and to establish collaborations among members.
4. ADCP and other underway instruments mounted on *Nuka Arctica* will become operational in 1999. WGOH wishes to discuss the progress of this installation, and the end-to-end data management as well as potential installations on other commercial ships crossing the North Atlantic.
5. Under GOOS, there has been a major thrust in the development, instrumentation, and deployment of drifting buoys, providing new challenges and new opportunities. Large volume of data from these buoys are now available in real-time and more will be available in future. WGOH wishes to examine the opportunities for research using these data.
6. Even though WGOH reviews and discusses data from standard sections and stations, it is conscious of the fact that there exist other climatologies that are of potential use to the WG. This agenda item will compile a list of such known climatologies and discuss their applications.
7. There is a Nordic Project presently in place dealing with environmental consequences, in regards to radioactivity. It includes the following two components: a) important Nordic food chains, and b) radioactive tracers in Nordic Seas areas (including the Baltic Sea and its catchment and adjacent areas). This will be of particular interest to WGOH because of the significant field component which also addresses water masses and circulation and the use of these radioactive tracers to identify the time and space scales and its variability. WGOH will discuss this program and proposes to invite Henning Dahlgaard, Denmark, a specialist in this field, to next year's meeting.
8. Rapid technological developments as well as new applications of existing technologies continue to enhance our capabilities for measuring oceanographic parameters. However, there are many drawbacks if incorrectly used. This item therefore serves to inform WGOH members and the ICES community of the present status of the operational use of any new equipment.
9. This item is to review the progress in the planning of the Second Decadal Symposium.
10. The WG is concerned about the data sets that are at risk of loss due to retirements and restructuring in the member countries and around the world. WGOH members will compile lists of such known data sets and discuss them at the next meeting.
11. GOOS Agreements Meeting will take place during the IOC General Assembly this year, and most ICES member countries by then will have their national GOOS plans formulated. The ICES Bureau will also have had a chance to review the recommendations of the Steering Group on GOOS and decide on them. WGOH will discuss both the national plans and ICES plans, with respect to GOOS. All members will provide GOOS status reports.
12. This agenda is to discuss ICES decisions concerning the direction of the Oceanography Committee and the role of WGOH. Theme sessions provide an opportunity to collectively address a topic that is of importance to ICES. This agenda item will provide an opportunity to discuss the high priority oceanographic issues that need to be addressed.

Annex A – Agenda and Terms of Reference for 1998 April Meeting

Agenda

a Update and review results from Standard Sections and Stations;
b Consider the format and content of the Fact Sheet and annual climate summaries, and compile relevant information for 1998;
c Review progress in national and international projects in the north Atlantic such as WOCE, VEINS, CLIVAR/ACSYS, TASC, ESOP2, Trans-Atlantic Section of Currents, and others;
d Review recent research on shelf-edge, slope and eastern boundary currents;
e Review the progress in the installation of vessel-mounted ADCP surveys on ships-of-opportunity;
f Review present status of the operational use of new oceanographic equipment;
g Review progress in the planning of the Second Decadal Symposium (C.Res.1997/2.2)
h Appraise the current and future role of the ICES Oceanographic Data Centre;
i Assess developments in GOOS of relevance to ICES in the wake of the GOOS Agreements Meeting, taking into account the work of the Steering Group on GOOS;
j Propose tactics, activities, and products, in support of the Oceanography Committee's Five-year Plan Objectives.

Justifications:

a This is a standard item to enable the group to closely monitor the ocean conditions. The materials presented under this item will be utilised to prepare an overview of the state-of-the-environment in the North Atlantic at the Annual Science Congress, and a 1998 Fact Sheet on the climate.

b WGOH recognises the need for disseminating climate information in a timely and appropriate manner. The first issue of the climate review was prepared in 1997. The next issue of the climate review, and a Fact Sheet (a short summary for wider distribution) was produced in 1998. During this agenda item, WGOH will review how well these items were received by the ICES community and discuss changes in the format and content. The WGOH report contains considerable information on the state-of-the-environment in the North Atlantic, but these are on a country by country basis. A synthesis would be more useful for the general public. Two types of synthesis would be appropriate: a) a quick reference with a pointer to more information (a FACT SHEET); and b) a comprehensive synthesis. This agenda item will allow WGOH members to prepare these two documents during the meeting, thus avoiding delays in the dissemination of the information.

c This agenda item will provide an opportunity for the WG to be informed of programs in the ICES area. Since many planned and funded activities are now being coordinated via funded proposals, such information is necessary to take advantage of national and international funds, and to establish collaborations among members.

d Considerable activity is taking place in Spain, Holland and other countries, with respect to shelf-edge, slope, and eastern boundary currents. This agenda item is in aid of a focused discussion on these currents.

e Vessel-mounted ADCPs, properly managed, have been shown to provide valuable information on ocean currents. WGOH wishes to be informed of the progress on the ADCP installation on commercial ships crossing the North Atlantic, and to discuss opportunities for other installations.

f Rapid technological developments as well as new applications of existing technologies continue to enhance our capabilities for measuring oceanographic parameters. However, there are many drawbacks if incorrectly used. This item therefore serves to inform and update members and the ICES community about the present status of the operational use of any new equipment.

g This item is to review the progress on the planning of the Second Decadal Symposium.

h ICES Data Centre plays a very important role in ICES. As the funds decrease and the number of large international programs increase, the Data Centre activities need to be strengthened and realigned to meet the changes. The WG will discuss their expectations from the data centre

i GOOS Agreements Meeting will take place in September 1998, and most ICES member countries by then will have their national GOOS plans formulated. In order to acquire an ICES-wide perspective of national contributions and intentions, the WG wishes to keep these activities under close scrutiny. All members will provide GOOS status reports.

j At the 1998 Annual Science Conference, the Oceanography Committee agreed a set of draft objectives, yet to be ratified. The Committee invites the WG to provide relevant input based on these objectives.

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Annex D – Summary of 1998/1999 Activities at the ICES Oceanographic Data Centre

Harry Dooley, ICES, Copenhagen, Denmark

Background

The functionality of the ICES Oceanographic Data Centre has been in place since the formal beginning of ICES in 1902. It seeks to encourage and facilitate the collection and exchange of high quality oceanographic data and information amongst ICES Member Countries and beyond. It also serves to support the ICES community generally with oceanographic data and products in order to allow for the development of the understanding of the role of non-anthropogenic factors on the living marine resources. A fundamental role was to provide the ICES community with regular status reports of the natural state of the marine environment. However this role has been diminished somewhat in the past decade or so. The Data Centre preceded the formation of the National Oceanographic Data Centre System as adopted by IOC in the 1960s. Following this adoption it was expected that the ICES Data Centre would lessen its specific data management activities and concentrate on the preparation of products. However the preparation of products requires data that the National Oceanographic Data Centre System has not been able to provide in a timely way. Hence, the ICES Oceanographic Data Centre currently absorbs its former role.

In the past year, the manpower resources of the Data Centre have consisted of the Harry Dooley (ICES Oceanographer), Garry Hopwood (Oceanographic Data Scientist), Susanne Reimert (Data Assistant), Else Juul Nielsen (Data Assistant) and Peter Rasch (MAST-ESOP/VEINS support). Harry and Garry work on Data Centre activities in a part time capacity.

Data Submissions

Figure 1 is a plot showing the trend in submissions since 1980. Regrettably, the volume of new submissions in the reporting period was sharply down from previous (12,978, only 25% of the preceding year). Very few of these data have arrived via the formal routes of originators/national data centres. Most have arrived via foraging techniques in sites of published project-oriented data sets such as WOCE, JGOFS, OMEX, etc. Figure 1 also indicates a loss of data around 1990. This is because one institute has withdrawn all of its data in that period because of quality concerns.

The decline in submissions is partly offset by a huge increase in the amount of underway T,s data being received. Indeed there had been a general decline in this type of data since the mid-1970s until 1995 when volume decreased below 2000 observations. By 1998 the level approached 44,000 observations. This satisfactory situation is the result of the devoted and personal efforts by Alain Dessier at the Brest WOCE Data Centre, and by Gilles Reverdin. The location of these underway observations are can be determined from Figure 2 which shows the distribution in the North Atlantic of all types of observations received in the period 1980-1998. The Project data sets can also be identified from this diagram which also demonstrates the intense coverage of observations in areas such as the North Sea, Baltic Sea and the Gulf of St Lawrence. It is also possible to identify the first station received by ICES located at 90°N.

Figure 3 is an attempt to pinpoint the origin of data that could potentially be contributed to the ICES databank. The figure is based on ROSCOP information, but has to be interpreted with caution particularly as ROSCOP submissions themselves tend to be incomplete, especially for some countries. The figure does, however, point to a serious shortfall in data submissions from Germany, with data from more than 800 cruises since 1990 not yet being brought together. German ROSCOP submissions are however extremely good, with possibly at least 90% of the research cruises being included in the ROSCOP database. At the other extreme, Russia shows no missing data simply because ICES does not receive any ROSCOP forms from that country, so the implication given in this plot that there are no data missing from Russia is very wide of the mark.

Contracted Project Activities

The Data Centre is a partner in three funded MAST contracts, viz ESOP, VEINS and MEDAR. The first two projects have scientific objectives and are located in the Nordic Seas, the latter is a data management (data rescue) project, rescuing historical data from the Mediterranean, and is being undertaken in close collaboration with SISMER (The French ODC), who lead the project.

ESOP (European Sub-Polar Ocean Project) formally ended on 28 February, but work leading to the publication of the data CDROM of the project is still continuing, and hopefully will be completed by the end of May. The CDROM itself will be mainly a copy of the ESOP data management web site that the Secretariat has maintained throughout the project. Figure 4 is an illustration of part of the introductory page for this web site. The site provides access to information and data relevant to ESOP data flow as well as direct access to the resulting data and information products. The CDROM will also include data on ice and modelling provided by NPRI and DMI, respectively. It will also include the publication of a number of data types that were not formally managed, in particular RAFOS floats and Carioca data, but will exclude a large amount of underway pCO_2 measurements, YO-YO CTDs and Niel Brown Mark III data because of instrument failures.

ESOP (1 and 2) oceanographic data were collected on 53 cruises/aircraft flights from 5 countries (Germany, Norway, UK, Iceland and Denmark). Figure 5 shows the distribution of stations worked for ESOP from 1993 to 1998, 2067 in total. Many of the data were collected along a section at 75°N in the Norwegian Sea - 320kg of inert SF6 (DSF6GCDX) tracer was released at 75°N 2°W at the start of ESOP-2. For the first time, the Data Centre formally managed data types beyond its traditional core parameter range. Figure 6 lists the 21 additional parameters (using BODC/JGOFS parameter codes) that were managed under the ESOP flag. In the absence of climatology and scientific appreciation of these additional data types, quality controlling such data is a challenge. For example, in the case of tetrachloromethane (CCL4 – QCMXGCDX), Figure 7 illustrates systematic differences in the resolution and absolute values of data on this parameter received by the Data Centre on various cruises since 1990. An investigation is underway to determine the causes and significance of these differences with a view to determining the value of an international archive of such data.

In the coming year, the Data Centre will continue with its VEINS and MEDAR activities. A contract has also been won with HELCOM to manage their BMP data set of the Baltic. It is hoped that this latter activity can be undertaken as a joint development with the ICES Environmental Data Centre who will be responsible for managing the Biological and Contaminants component of the BMP data set.

ROSCOP/Cruise Summary Reports

ROSCOP continues to play a fundamental part in the management framework of the Oceanographic Data Centre. The system now contains information on some 30,000 cruises. ROSCOP has been a fundamental part of our framework for managing data in the framework of ESOP and VEINS, and some developments have taken place in order to help us meet the needs of these projects. All software has been upgraded to Windows 95/NT based, and the search database, ROSEARCH, has been made to be more integrated with the web. As a result the database now includes links to sites with more information about specific cruises, including links to track charts, cruise reports, publications, and data sets. In due course some of the function of this database may be incorporated as providing search facilities from the web, but such an expansion will take place only if user demand appears to support this.

Figure 8 shows the ROSEARCH entry screen, indicating that it has just completed a search, and how the results of the search may be viewed. Note in particular that the BODC/JGOFS parameter codes have now been used to expand the basic 3 character ROSCOP parameter codes. In this way it is hoped that ROSCOP and data will become much more closely integrated. Figure 9 shows a summary of part of an extract illustrating how the system can utilise this expanding code system. Expansion of ROSCOP in this way provides the system with a more useful and integrated meta-information function. For example the expanded ROSCOP parameters will be able to give more precise parameter descriptions, and detail the method of analysis. International agreement on a universal parameter data dictionary is a priority before further expansion can occur.

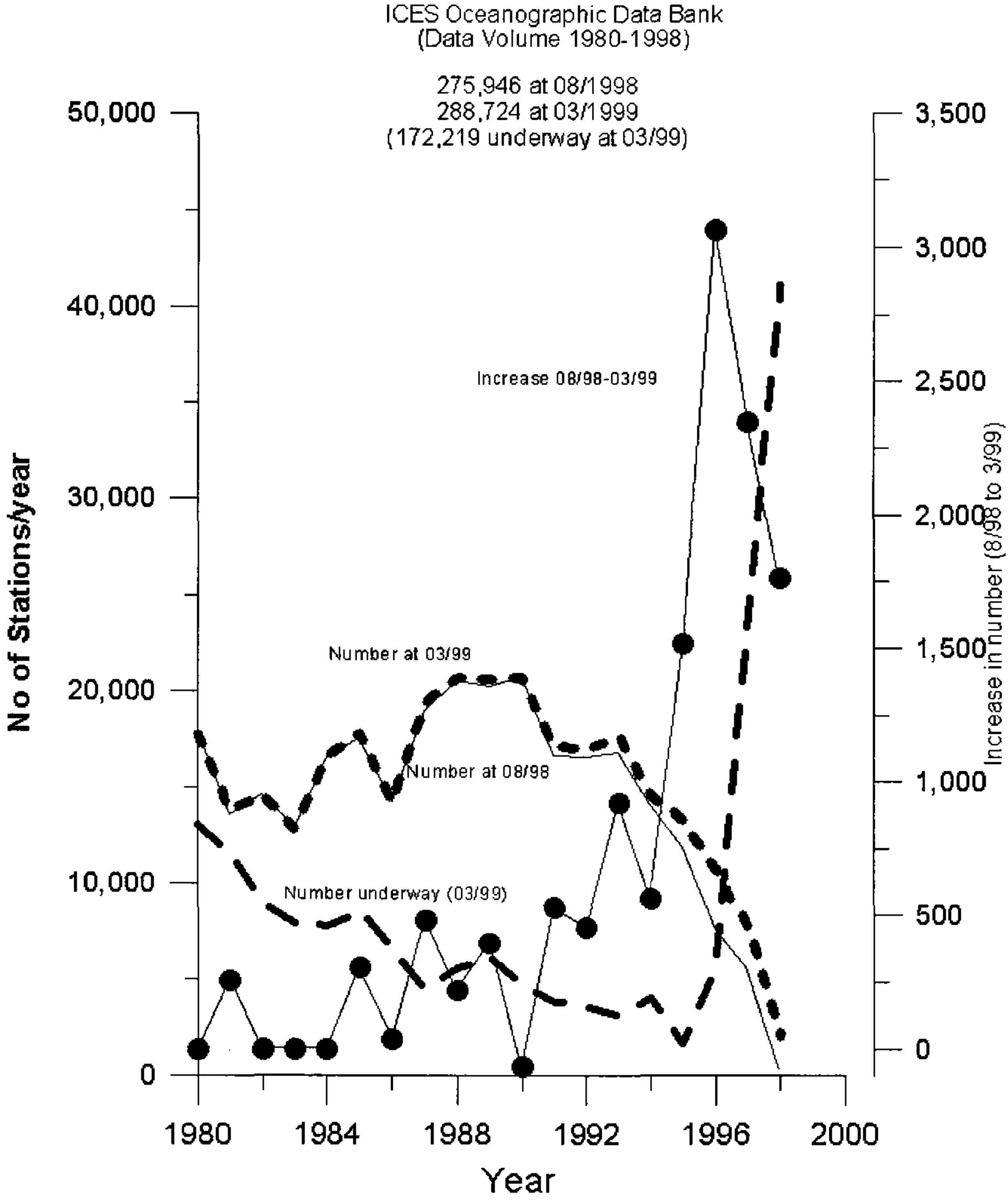


Figure 1 - Number of Stations /year since 1980.

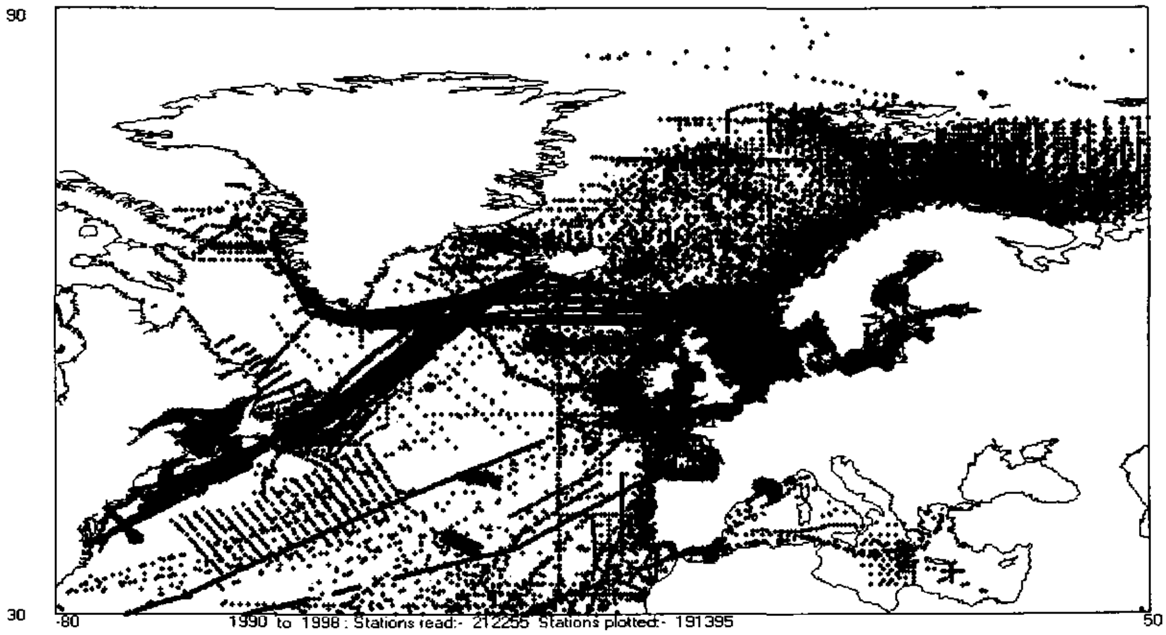


Figure 2- Distribution of Oceanographic data at ICES 1990-1998 (North Atlantic). 191,395 of the total 212,255 Stations plotted.

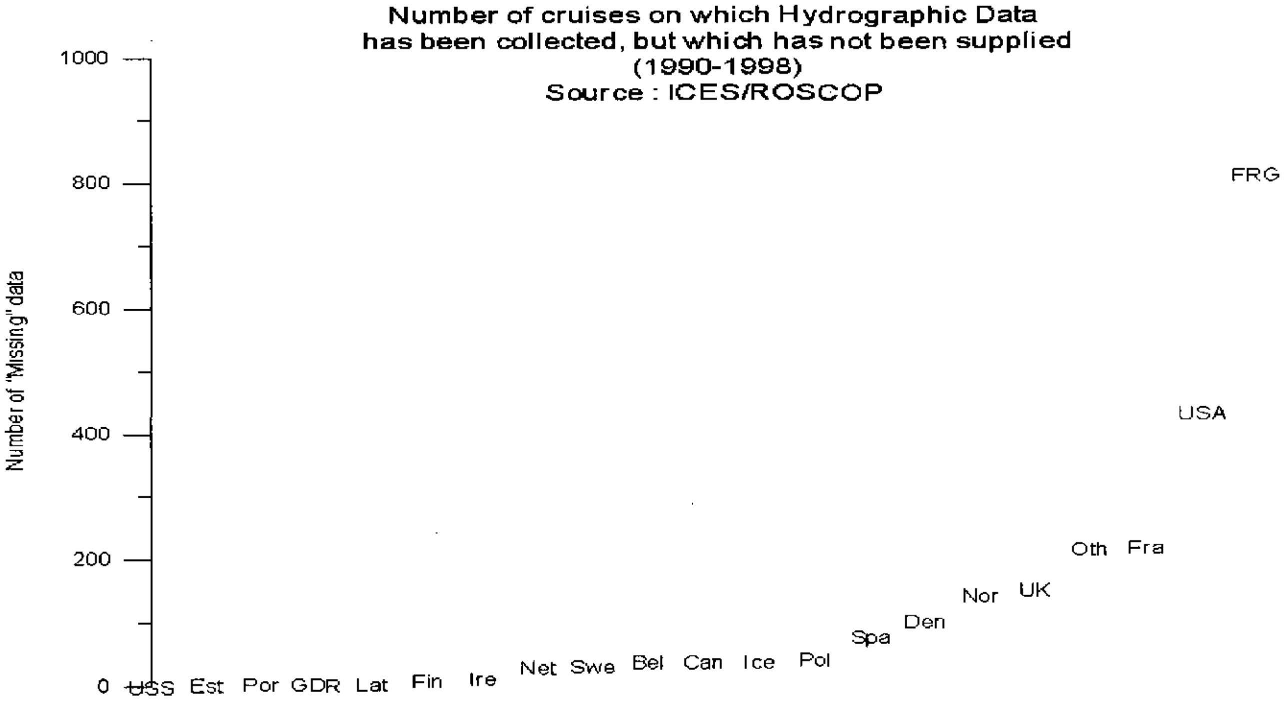
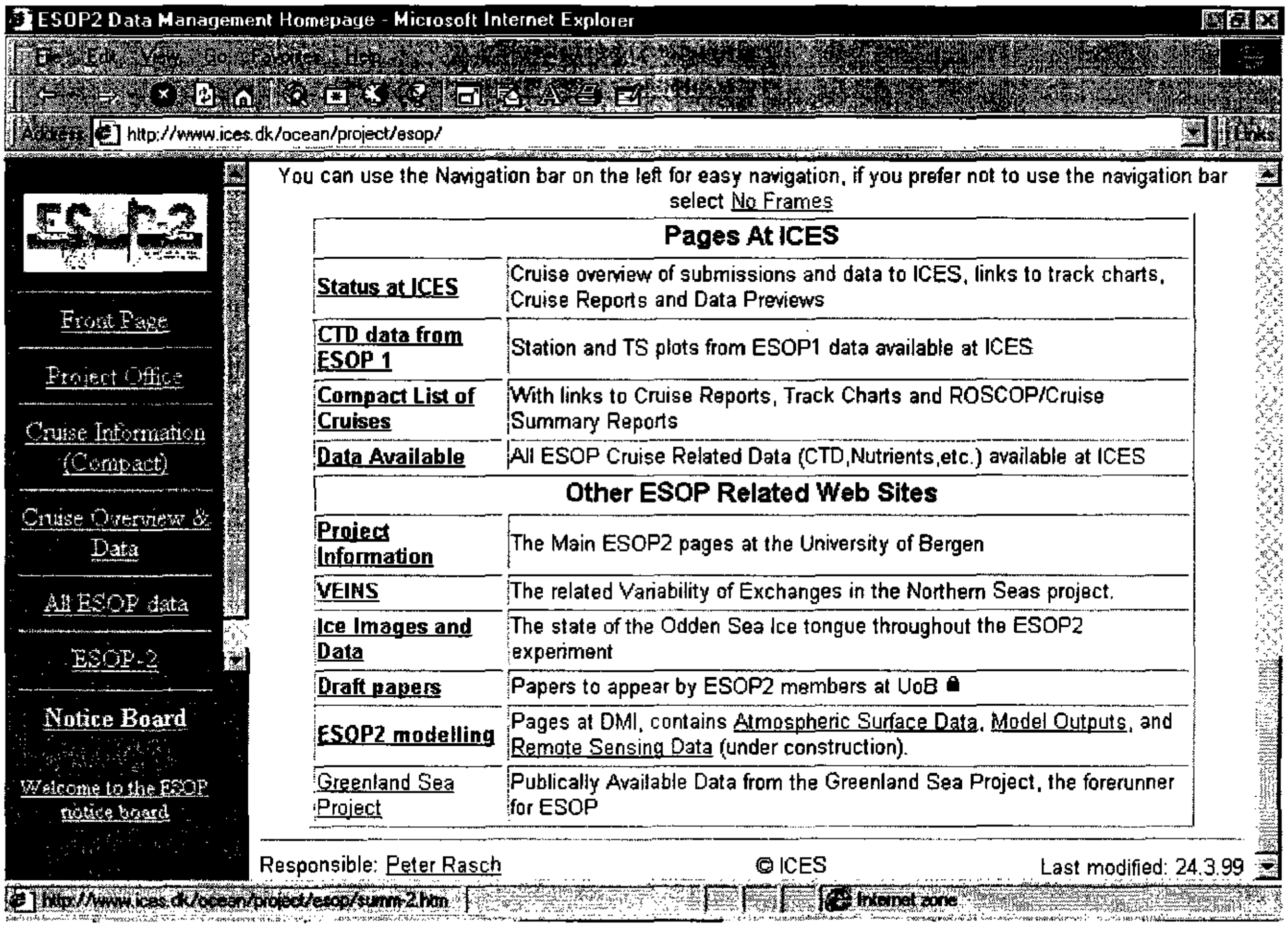


Figure 3 Number of “Missing” data since 1990.



You can use the Navigation bar on the left for easy navigation, if you prefer not to use the navigation bar select No Frames

Pages At ICES	
Status at ICES	Cruise overview of submissions and data to ICES, links to track charts, Cruise Reports and Data Previews
CTD data from ESOP 1	Station and TS plots from ESOP1 data available at ICES
Compact List of Cruises	With links to Cruise Reports, Track Charts and ROSCOP/Cruise Summary Reports
Data Available	All ESOP Cruise Related Data (CTD,Nutrients,etc.) available at ICES
Other ESOP Related Web Sites	
Project Information	The Main ESOP2 pages at the University of Bergen
VEINS	The related Variability of Exchanges in the Northern Seas project.
Ice Images and Data	The state of the Odden Sea Ice tongue throughout the ESOP2 experiment
Draft papers	Papers to appear by ESOP2 members at UoB 🔒
ESOP2 modelling	Pages at DMI, contains Atmospheric Surface Data, Model Outputs, and Remote Sensing Data (under construction).
Greenland Sea Project	Publically Available Data from the Greenland Sea Project, the forerunner for ESOP

Responsible: Peter Rasch © ICES Last modified: 24.3.99

Figure 4 ESOP (1 and 2) Web Page.

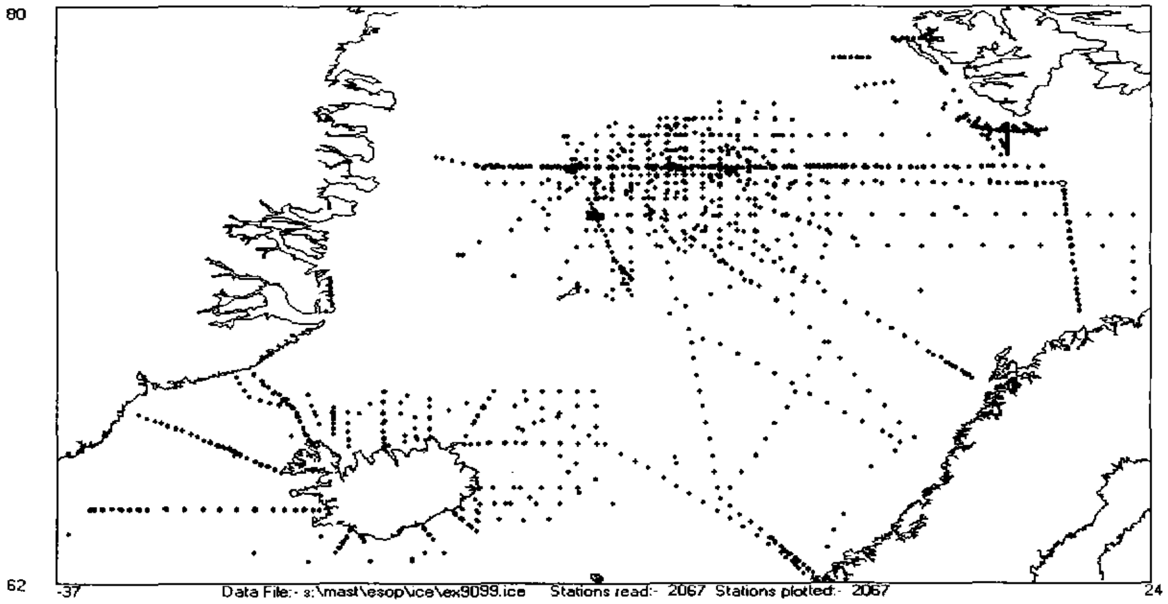


FIGURE 5 ESOP 1 and 2 Station Distribution (1993-1998).

ESOP1 and ESOP 2 - "Exotic" Parameters

Number of Stations	Parameter Code	Parameter Description
310	TCO2CBTX	Total dissolved inorganic carbon (TCO2)
125	PCO2GC01	pCO2
41	IORTAMDP	Iodine 129 to 127 ratio
41	SEIRAMDP	Standard Error of I129/127
119	PCOTXXXX	Temperature of pCO2 determination
174	DSF6GCDX	Dissolved sulphur hexafluoride
38	D13CMOPC	Particulate organic carbon 13C enrichment (delta-13C)
37	D18OMXFZ	Unspecified benthic foramenifera test 18O enrichment (delta-18O)
190	PHFXFLXX	Fluorometric phaeopigment flux
17	OCFXCZXX	Particulate organic carbon (POC) flux (acidification unspecified)
17	NTOTCNPZ	Particulate total nitrogen (PON')
16	IRRDPP01	Downwelling 2-pi PAR irradiance
16	SNCURSPB	Size-fractionated normalised carbon uptake (natural light)
16	SFPXPIPE	Size frac. photosynthetic maximum (Pmax)
11	POPTZZ01	Percentage transmission (details unknown) (obsolete parameter)
11	TCUPROPZ	Carbon uptake over incubation
45	FR11GCTX	Freon-11
45	F113GCTX	Freon-113
45	QCMXGCTX	Tetrachloromethane (CCl4)
22	TCEAGCD3	Dissolved Trichloroethane (C2H3Cl3)
45	FR12GCTX	Freon-12

Figure 6 List of additional parameters managed in the ESOP (1 and 2) MAST Projects.

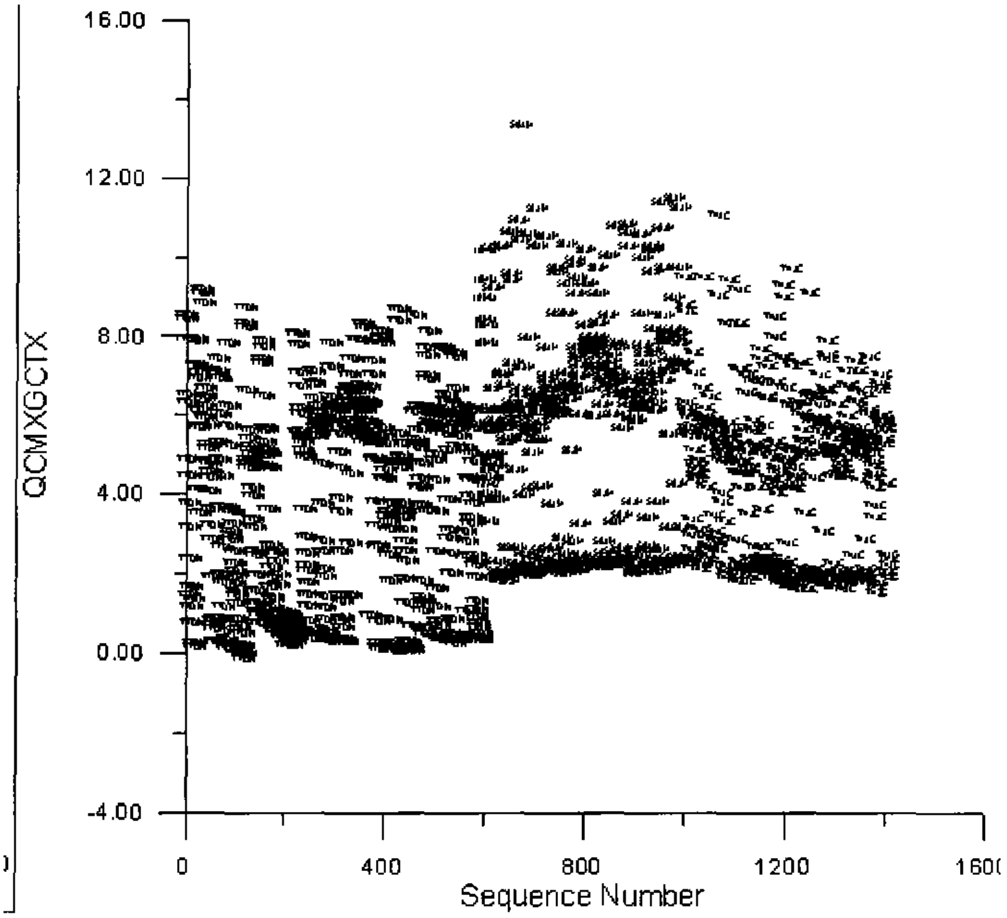
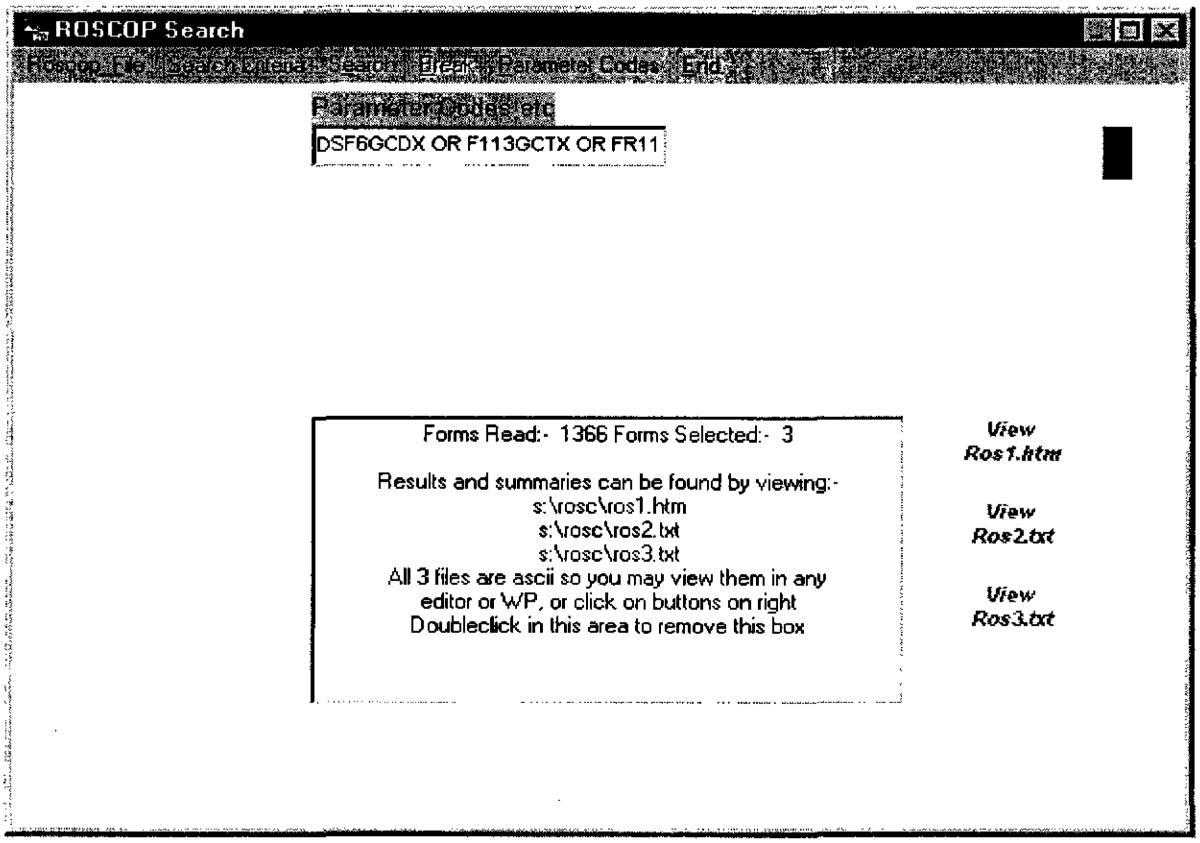


Figure 7 Distribution of values of tetrachloromethane (CCL4) on cruises since 1990.

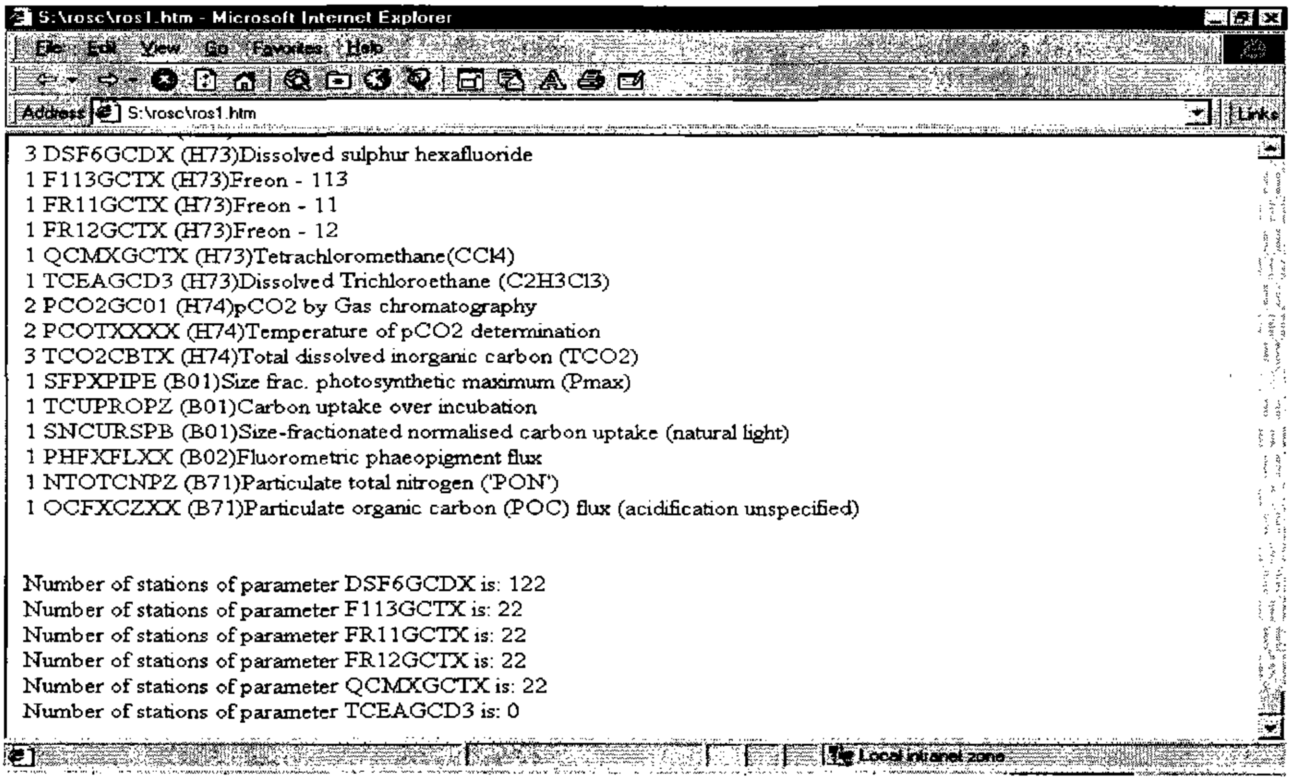


Parameter Codes etc: DSF6GCDX OR F113GCTX OR FR11

```
Forms Read:- 1366 Forms Selected:- 3

Results and summaries can be found by viewing:-
s:\rosc\ros1.htm
s:\rosc\ros2.txt
s:\rosc\ros3.txt
All 3 files are ascii so you may view them in any
editor or WP, or click on buttons on right
Doubleclick in this area to remove this box
```

Figure 8 ROSEARCH Entry Screen



```
3 DSF6GCDX (H73)Dissolved sulphur hexafluoride
1 F113GCTX (H73)Freon - 113
1 FR11GCTX (H73)Freon - 11
1 FR12GCTX (H73)Freon - 12
1 QCMXGCTX (H73)Tetrachloromethane(CCl4)
1 TCEAGCD3 (H73)Dissolved Trichloroethane (C2H3Cl3)
2 PCO2GC01 (H74)pCO2 by Gas chromatography
2 PCOTXXXX (H74)Temperature of pCO2 determination
3 TCO2CBTX (H74)Total dissolved inorganic carbon (TCO2)
1 SFPXPIPE (B01)Size frac. photosynthetic maximum (Pmax)
1 TCUPROPZ (B01)Carbon uptake over incubation
1 SNCURSPB (B01)Size-fractionated normalised carbon uptake (natural light)
1 PHFXFLXX (B02)Fluorometric phaeopigment flux
1 NTOTCNPZ (B71)Particulate total nitrogen ('PON')
1 OCFXCZXX (B71)Particulate organic carbon (POC) flux (acidification unspecified)


Number of stations of parameter DSF6GCDX is: 122
Number of stations of parameter F113GCTX is: 22
Number of stations of parameter FR11GCTX is: 22
Number of stations of parameter FR12GCTX is: 22
Number of stations of parameter QCMXGCTX is: 22
Number of stations of parameter TCEAGCD3 is: 0
```

Figure 9 Part of Summary of a ROSCOP (ROSEARCH) Search.

Annex E – Labrador Sea Section

Ross Hendry, Bedford Institute of Oceanography, Fisheries and Oceans Canada

The ninth consecutive annual occupation by the Bedford Institute of Oceanography (Department of Fisheries and Oceans, Canada) of a Labrador Sea section from Hamilton Bank to southern Greenland was made on CCGS Hudson Mission 98023 during June 23 - July 9, 1998. The goal of the continued measurement program is to monitor interannual variations in the properties of Labrador Sea Water. A total of 22 stations were occupied before the program was interrupted by a medical emergency. Figure 1 shows the station plan and section plots of potential temperature and salinity. The 1998 results suggest that relatively weak deep convection occurred during the 1997-98 winter, continuing a trend established during the past few years. A remarkable baroclinic feature was observed at 3510m depth near the base of the continental rise off southern Greenland. A tentative interpretation is that we sampled an anticyclonic eddy that extended throughout the water column. To our knowledge, this is the first report of such a feature in the Labrador Sea.

This Labrador Sea section has a long history, beginning with work by the International Ice Patrol in the 1930's. The recent annual repeats were begun by Dr J.R.N. Lazier in 1990. Dr Lazier has been largely responsible for the continuation of the section up to the present time. This work contributed to the World Ocean Circulation Experiment (WOCE) Hydrographic Programme as WOCE repeat section AR7W. A June 1999 reoccupation is planned.

Labrador Sea Section
Hudson 98023 - June 23 - July 9, 1998

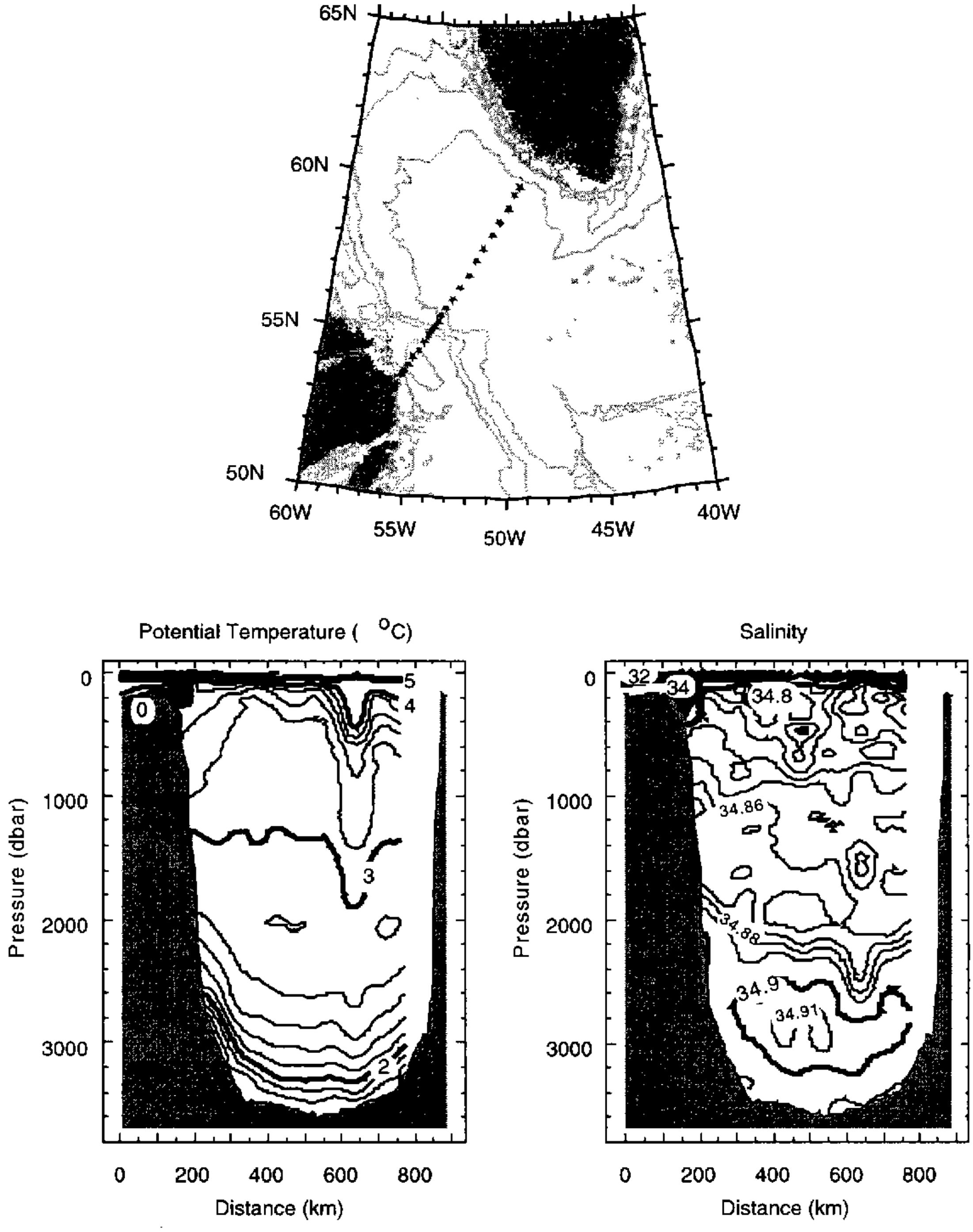


Fig. 1 Labrador Sea section station map (top). Section plots (bottom) run from Hamilton Bank on the left to Greenland on the right.

Annex F – Atlantic Hydrography In 1998-99 – Continued Recovery From Extreme Forcing?

Robert. R. Dickson* and Jens Meincke⁺

1. Background

The North Atlantic Oscillation (NAO) is the dominant recurrent mode of atmospheric behaviour in the North Atlantic sector accounting for more than one-third of the total variance in winter sea-level pressure; its variability also explains about one third of the variance in extratropical Northern Hemisphere temperatures over the past 65 winters, so that in one way or another, NAO variability appears to be bound up with the long, slow trends of global change.

In its variability, the NAO alternates between a "high-index" pattern, characterised by an intense Iceland Low with a strong Azores Ridge to its south (hence strong mid-latitude westerlies), and a "low index" pattern in which the signs of these anomaly cells are approximately reversed. The conventional index of NAO activity is the mean pressure difference between the two main cells and various station pairs have been used in its calculation. In contrast to last year's report, which used the Lisbon-Stykkisholmur winter (DJFM) index of Hurrell (1995a;1996), we rely here on the winter (DJFM) index of Jones *et al* (1997) which makes use of longer instrumental records from Gibraltar and SW Iceland to extend the time-series back to 1823 (Figure 1).

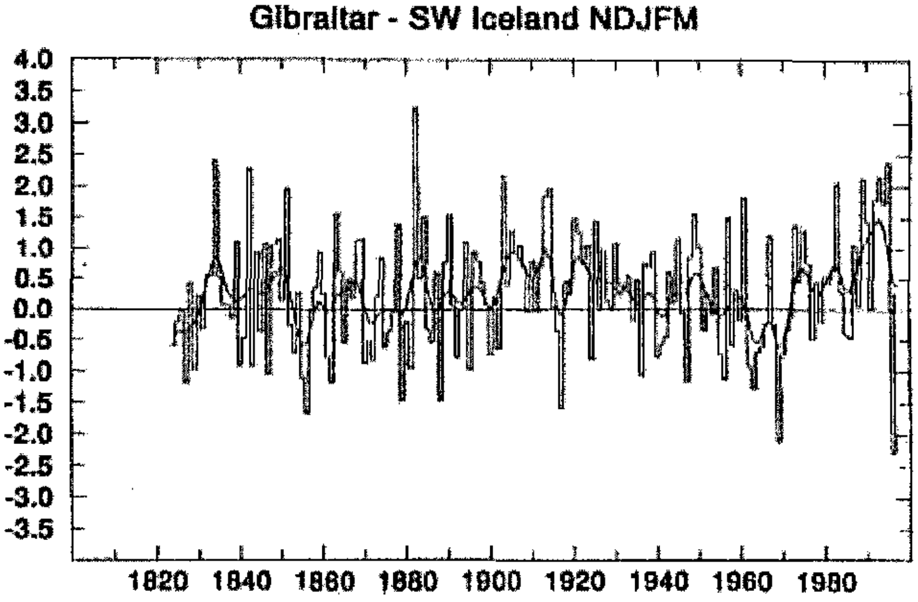


Figure 1

Fig.1 The winter (N D J F M) NAO-Index of Jones et al (1997), based on the atmospheric pressure records from Gibraltar and SW Iceland, which date back to 1823.

The general pattern of NAO variability shown in Figure 1 will be common to any version of the index: noisy interannual variations during the 19th C and early 20th C; the development of a more-extreme and more-decadal tendency thereafter, with the NAO swinging from its most extreme and persistent negative phase in the 1960s to its most extreme and persistent positive phase during the late-1980s-early 1990s; the rapid record decrease in the Index between the winters of 1994-95 and 1995-96; the recovery to positive values since then. Since the NAO is known to control or modify all three of the main parameters which drive ocean circulation--------- windspeed, latent and sensible heat flux (Cayan, 1992 a,b,c) and evaporation/ precipitation (Hurrell 1995a)------a knowledge of its past behaviour forms an essential context for the interpretation of hydrographic variability on Standard Sections (see below).

The general types of ocean response to NAO forcing are described elsewhere (e.g. Dickson et al in press). Here we concentrate on identifying the various ways in which the ocean appears to have responded to the abrupt but extreme interannual "flip" in the NAO between 1994/5 -1995/6. Figure 1 indicates just how anomalous was this change in a 176-year instrumented record, while Figure 2 confirms that both cells contributed. The justification for focusing on this particular event is simply that the ocean's responsiveness to it may indicate the potential for an equally-rapid recovery when high positive NAO conditions resume (Section 3, below).

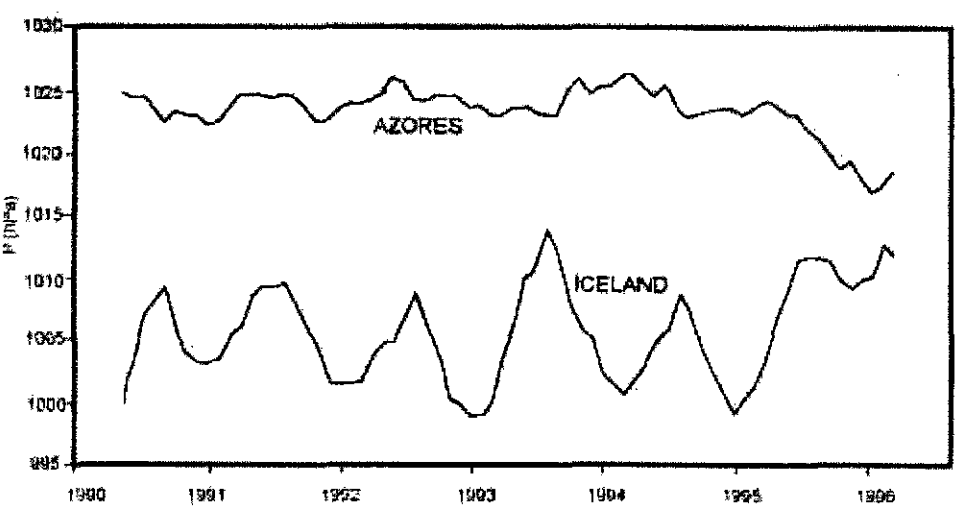


Figure 2

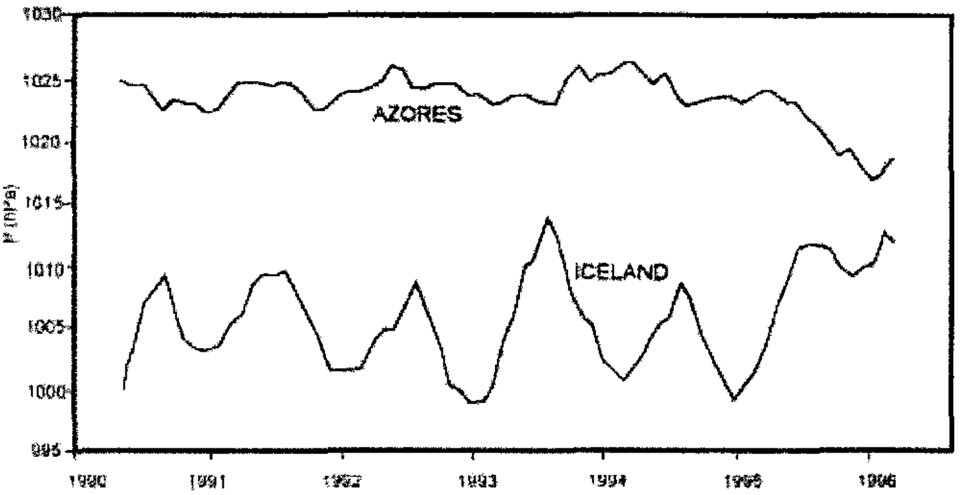


Figure 2

Fig. 2 Smoothed monthly mean air pressures demonstrating, that both the Iceland and the Azores pressure cells contributed to the strong interannual NAO-change 1994/95 – 1995/96.

2. Responsiveness of the Ocean to Abrupt Change in the NAO, 1994/95-1995/96

(a) Pan-Atlantic change in sea level. The 3-monthly means (M, A, M) of sea-surface height anomalies (SSHAs) for 1995 and 1996 show extreme changes in the latitude belts around 40N and 60N (Fig 3; Esselborn 1999). The SSHAs in the northern belt rose from near zero to +8cm approximately between 1995 and 1996 over both the North Atlantic Current (NAC) regime and the subpolar gyre. A closer analysis by Bersch et al (in press) and Esselborn (1999) shows that the SSHAs are largely of steric origin in the NAC regime, caused by warming (and thickening; see Figure 4) of the upper layers. The changes correspond in magnitude to the change in dynamic height estimated by hydrography on the WOCE A1E line. In the subpolar gyre, the SSHAs along this line were found to be due to a thickening of the fresh upper layers in the Irminger Sea. The (non-significant) difference between the SSHAs and the dynamic height anomalies (Esselborn 1999) is of the right sign to be explained by a deceleration of the cyclonic circulation, related to a decrease in wind forcing. These results are confirmed by the analysis of SSHAs and dynamic heights along the WOCE AX2 line between Iceland and Newfoundland due to Reverdin et al (submitted). Figure 5 also shows their time-dependence, with a significant height increase between 1995 and 1996, including a (non-significant) difference from 1996 onwards attributed to barotropic currents. The timing of the height increase corresponds to the arrival of warm and saline waters from the east, described below in Section (c).

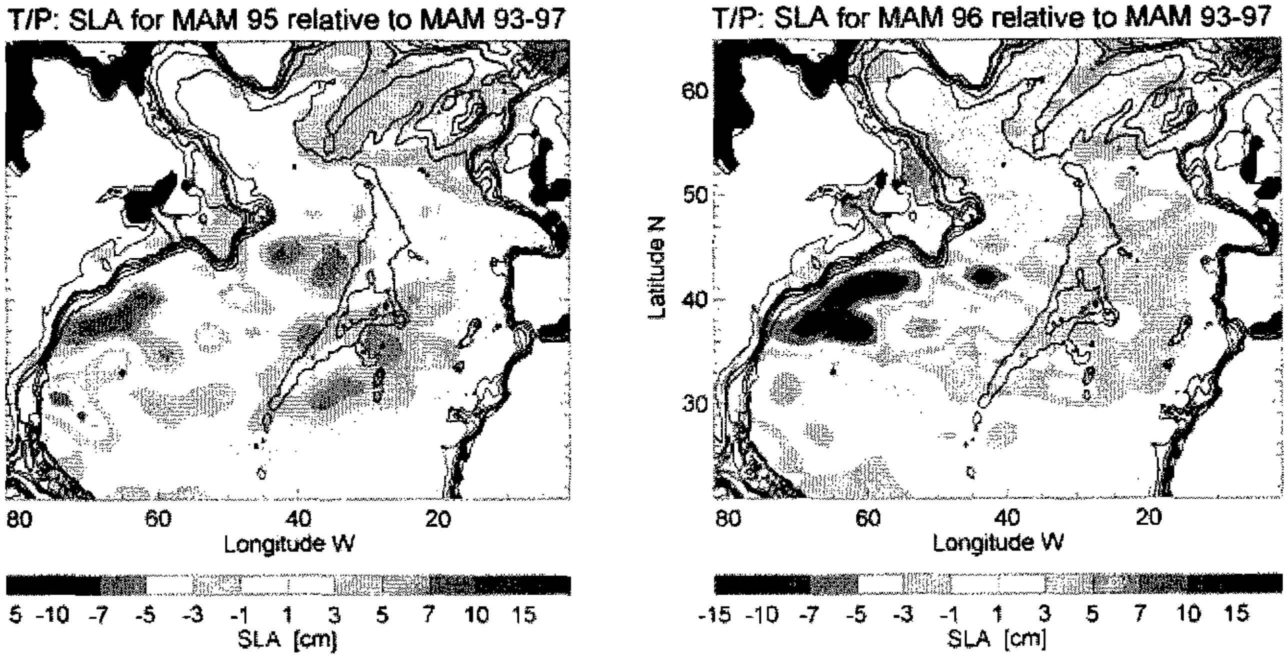


Fig. 3 Sea level height anomalies (SLA) from Topex/Poseidon altimetry for MAM 95 (left) and MAM 96 (right). The anomalies are referred to the MAM mean for the period 1993 to 1997 (S. Esselborn, 1999).

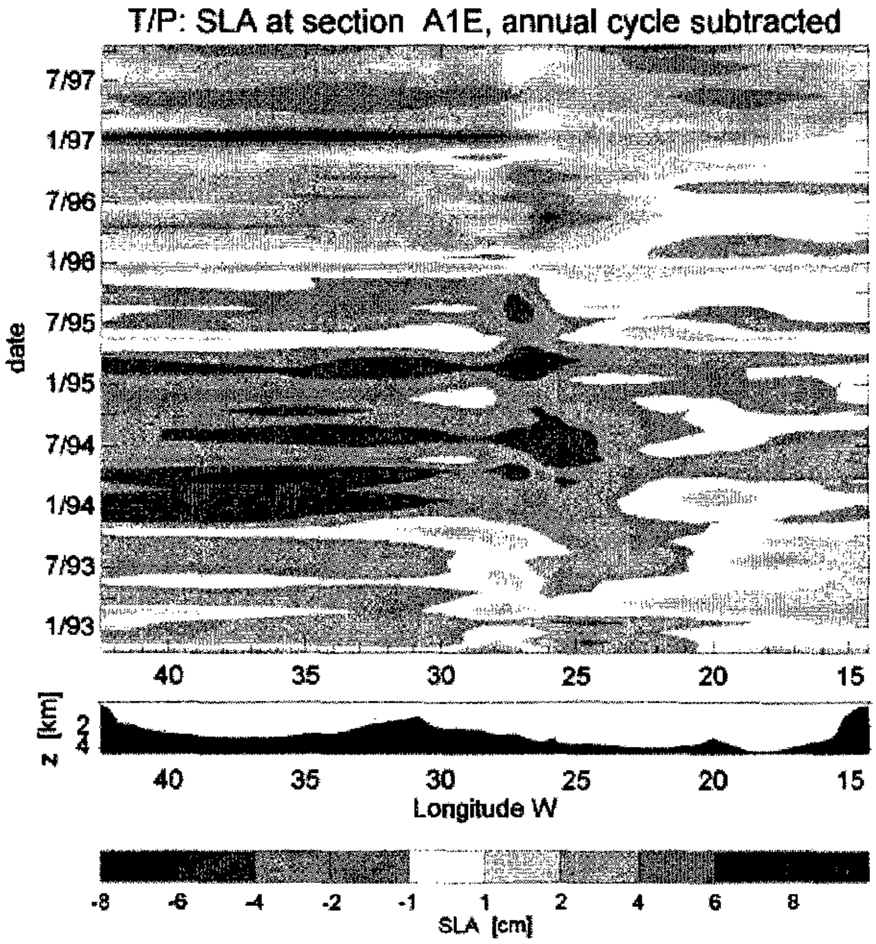


Figure 4

Fig. 4 Time series of sea level height anomalies along the WOCE A1E hydrographic line (see Fig.7). The anomalies are referred to the individual section mean (S. Esselborn, 1999).

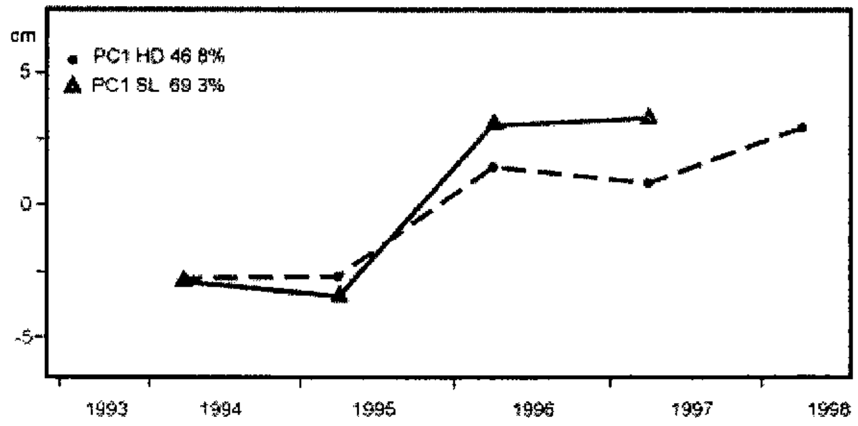


Figure 5

Fig. 5 Time series of the first principal components (PC1) of the dynamic height (HD) and the sea level height (SC) for the WOCE XBT-line AX-2 between Reykjavik and Flemish Cap (from Reverdin et al, subm.).

(b) The northward heat transport through 48N. Seven repeats of the WOCE A-2 Trans-Atlantic Hydrographic Section, worked between the English Channel and the Tail of the Banks, are available for the years 1957, 1982, 1993, 1994, 1996, 1997 and 1998. This section lies at 48N along the approximate line of zero windstress curl and is located south of the complex subpolar gyre system; the contribution to meridional heat transport on this section is mainly in the overturning (geostrophic) circulation component. Using the technique proposed by Bryan (1962) and applied by Dobroliubov et al (1996) to repeats of a hydrographic section along 36N, Lorbacher (1999) and Koltermann et al (in press) has estimated the total meridional heat flux through 48N as the sum of the fluxes carried by the barotropic, geostrophic and Ekman transport components of the circulation. In Figure 6, values for the 7 workings of this section are overlaid on Hurrell's (1995) version of the winter NAO Index. Though the few early values are not inconsistent with the long term trends in the NAO, the recent almost-annual dataset exhibits a short-term variability that appears to be a close reflection of the extreme interannual behaviour of the NAO Index since 1993. The meridional heat transport drops from 0.66 PW to 0.25PW following the record drop in the NAO Index between winter 1994-5 and 1995-6, and recovers equally rapidly to 0.57 PW in summer 1998 as the NAO returns to positive values. Though based as yet on a very short series, this dramatic behaviour may be a first indication that short term change in atmospheric forcing, however extreme, may be matched by an equally-rapid response in the large-scale ocean circulation.

Figure 6

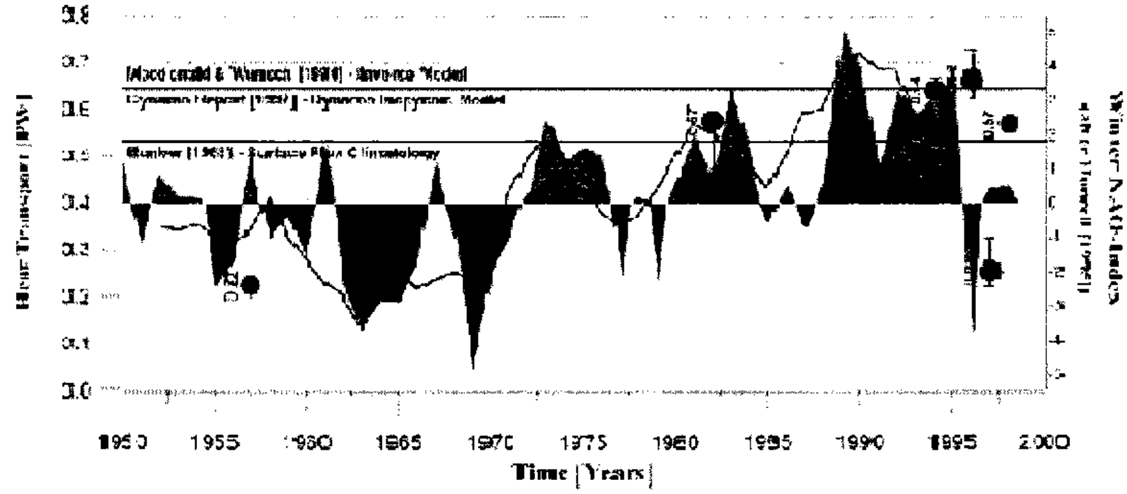


Fig. 6 The North Atlantic heat transport across 48°N (dots). Underlying are the Hurrell (1995) NAO-Index (coloured) and its five year running mean (line). Heat transport estimates based on models are also included (from Koltermann et al, 1999).

(c) The westward shift of the sub-Arctic front in mid-Atlantic. The sub-Arctic front in the northern North Atlantic is the boundary between the watermasses of the warm North Atlantic Current regime and the cold subpolar gyre. The location of the front is known to respond to atmospheric forcing, as demonstrated by Bersch et al (in press) for the WOCE A1E section (1991-97) between Ireland and Greenland, and by Reverdin et al (submitted) for the WOCE AX2 XBT line (1993-98) between Iceland and Newfoundland. More specifically, various data sets appear to show evidence of a westward shift of the front in the Iceland Basin during the abrupt and extreme switch in the winter NAO Index between 1995 and 1996. Until 1995 for example, the eastern limits of the subpolar gyre are located around 24°W on the A1E Section, as shown by the salinity distribution at 200m depth (Fig 7). After 1995 however (Fig 8), low salinity subpolar waters disappear from the waters east of the Reykjanes Ridge to be replaced by warm and saline waters of the North Atlantic Current. This westward shift is accompanied by a thickening of the SPMW on the A1E line from about 950m in NAO-positive years (1991-95) to 1050m in the NAO-negative extreme conditions of 1996 (Fig 9). The change in heat and salt content appear larger than can be explained by local fluxes, suggesting that advection is involved. The results of Reverdin et al set the time-of-arrival of warm, saline conditions on their meridional XBT line, SW of Iceland, as late 1995/early 1996, persisting until 1997/8. Experiments with the FLAME model at IFM Kiel appear to support this timing.

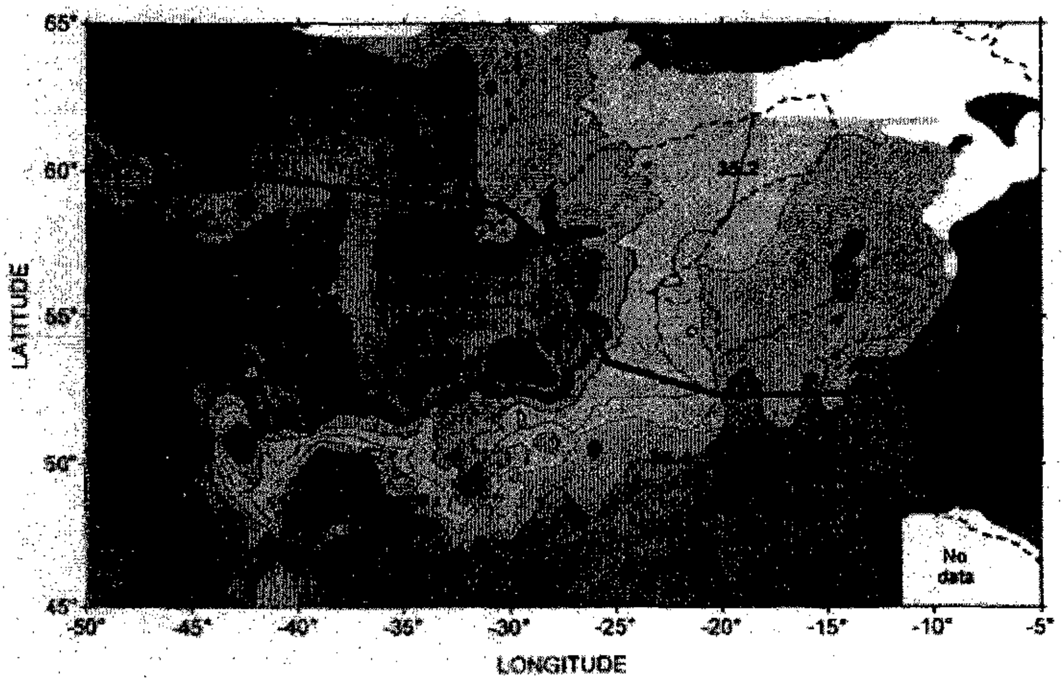


Figure 7

Fig. 7 The WOCE A1E hydrographic repeat section, superimposed onto the distribution of 200m-salinity which was derived post 1980-data (from Bersch et al, 1999).

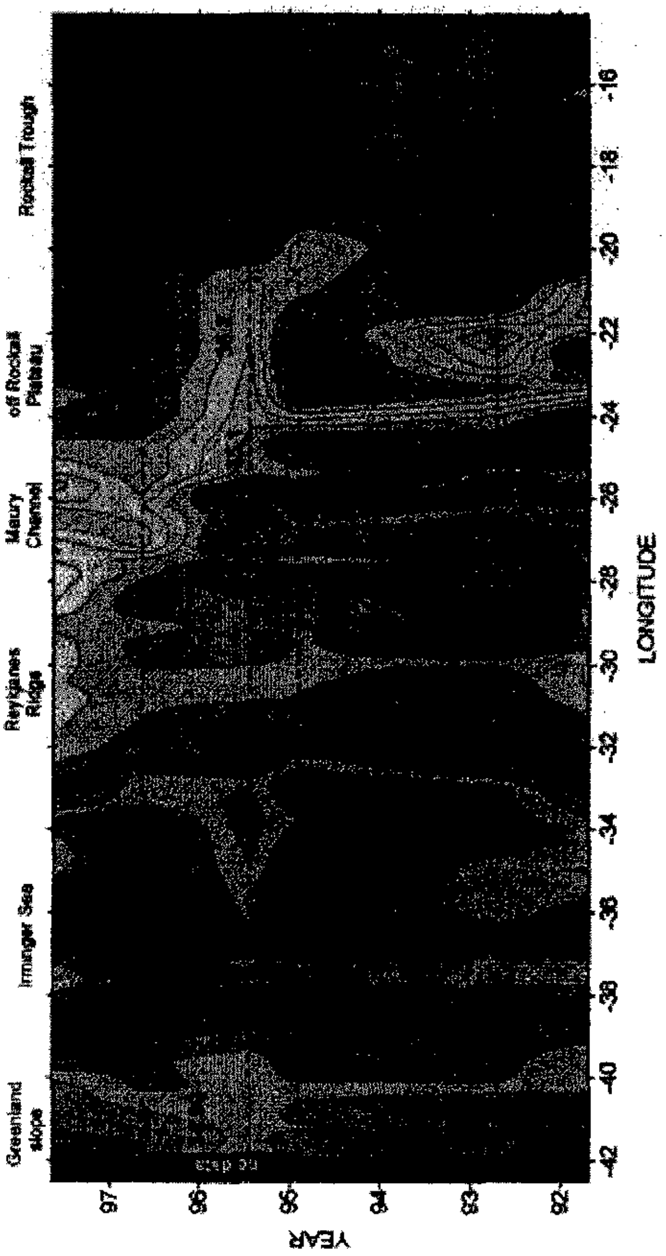


Figure 8

Fig. 8 Time and space development of the 0-500m salinity along the WOCE A1E-Section (from Bersch et al, 1999).

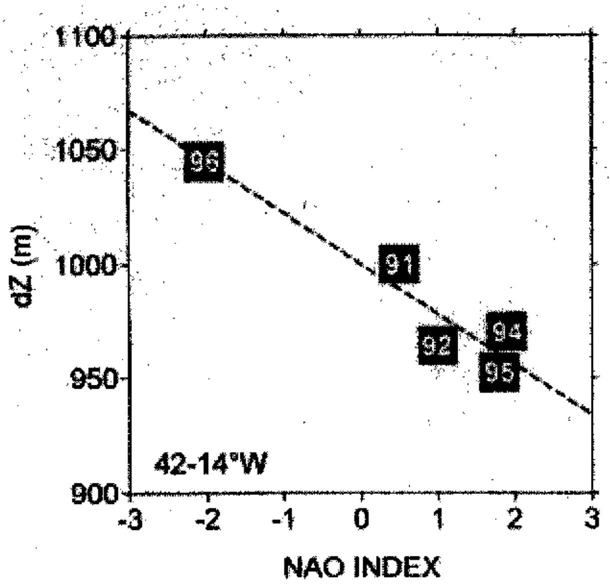
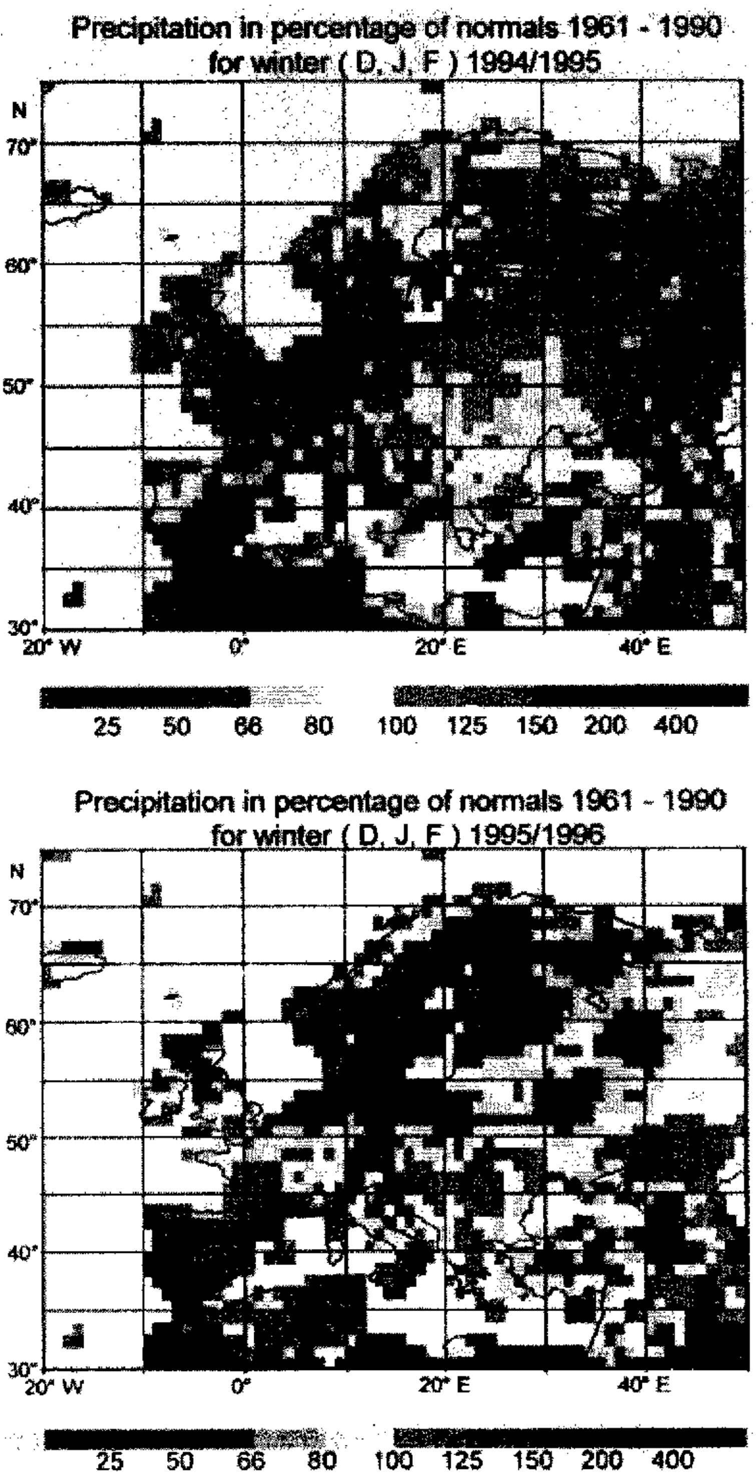


Fig. 9 The thickness of the Subpolar Mode Water layer (depth of the isopycnal 27.74 kg/m^3 along the WOCE A1E-Section in relation to the NAO-Index (from Bersch et al, 1999).

(d) Reversal of the precipitation regime over Europe. It is already well-established that the NAO exerts a significant control on the track, prevalence and intensity of Atlantic winter storms (Rogers, 1990, 1997; Hurrell 1995b). During the negative phase of the NAO, the centre of storm activity retracts southwestward to the American coast, but extends northeastwards into the Norwegian-Greenland Seas during the opposite high index phase. Hurrell (1995a) used composited ECMWF analyses to show that the axis of maximum moisture transport follows the storm activity in extending further to the north and east during NAO+; Hurrell and van Loon (1997) illustrate just such a pattern in showing the change in the pattern of Atlantic/European rainfall that corresponds to a unit deviation of the NAO index in winters, 1900-94; Dickson et al (in press) reconfigure the global precipitation data set of Xie and Arkin (1996) to show how the hemispheric precipitation pattern becomes focused on NW Europe and the Nordic Sea as NAO- gives way to NAO+. Now we use Figure 10, from the Global Precipitation Climatology Centre, Germany, to confirm that this general tendency was followed in the specific case of the large-amplitude decrease in the NAO Index between winter 1994-5 and winter 1995-6. As shown, the distribution of precipitation-anomalies (expressed as a percentage of the 1961-90 long term winter mean) shows a remarkable and almost complete reversal in pattern over Europe as far east as western Russia.


Precipitation in percentage of normals 1961 - 1990 for winter (D, J, F) 1994/1995

Precipitation in percentage of normals 1961 - 1990 for winter (D, J, F) 1995/1996

Figure 10

Fig. 10 Precipitation anomalies for the winters (D J F) 1994/95 and 1995/96 as referred to the 1961-1990 mean values (from Global Precipitation Climatology Center, Offenbach).

e) Ice flux through Fram Strait. With the NAO determining the longer-term variability of the atmospheric pressure distribution over the European Arctic and sub-Arctic Seas, the ice export through the western Fram Strait is expected to co-vary accordingly. This has been demonstrated by Dickson et al 1998, based on observations by Vinje et al 1998 and modelling by Hilmer et al (1998). From Figure 11, it is evident that the high values of the volume flux of ice observed during the winter of 1994-5, which exceeded the 1990-1996 period mean value by 64%, dropped sharply thereafter to 25% below the mean value in 1995-6 corresponding to the record winter-to-winter decrease in the NAO Index. According to Vinje et al, these changes largely reflect variations in the area flux of ice driven by the local pressure gradient and are only to a minor extent (+/- 10%) the result of changes in ice thickness that might be attributable to changes in source. Further south in the Greenland Sea, the excess fresh water from the 1994-5 peak in ice flux was found to spread east from the East Greenland Current (EGC) to enter the cyclonic circulation of the Greenland gyre. This behaviour is in marked contrast to an earlier maximum in ice and freshwater export during the late 1960's, which was transported south in a swollen East Greenland Current (EGC) without appreciable eastward spreading, eventually to pass through the Denmark Strait as the Great Salinity Anomaly (Dickson et al 1988). The different behaviour is tentatively ascribed to the changing convective conditions in the Greenland Sea between these two events. In the 1960s event, a strong windstress curl maintained an intense cyclonic circulation, a strong Greenland Sea "dome" and intense convection reaching to >3500m in the Greenland Sea, so that a strong front to the west of this convective cell acted to prevent an eastward spreading of the EGC. In the recent event, convective activity in the Greenland Sea was weak, the Greenland Sea "dome" had, to a large extent collapsed, and there was therefore no strong front to prevent an eastward spreading of freshwater from the East Greenland Current into the Greenland Sea. Once there, this fresh surface layer may well have acted as a further curb on an already-weak convective activity.

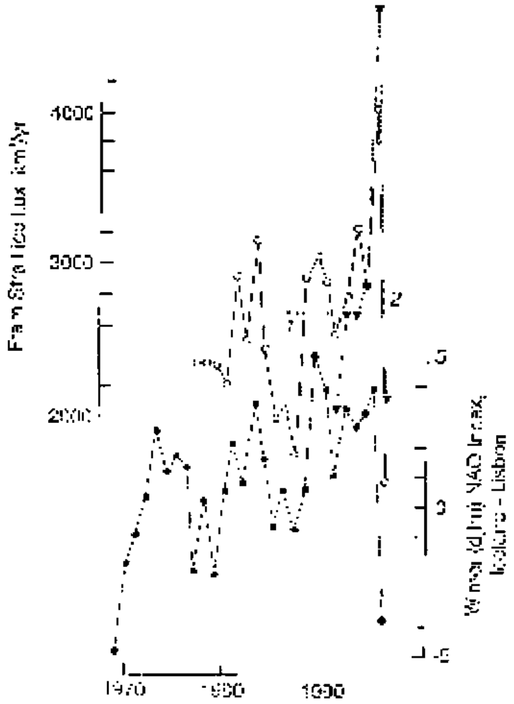


Fig. 11 Comparison of the winter NAO-Index (full dots, Hurrell, 1995) with the estimated (open circles) and measured (full triangles, Vinje et al, 1998) ice flux through Fram Strait (after Dickson et al, 1998).

(f) Cooling and cod recruitment in the North Sea. There is a strong positive correlation between the winter NAO Index and the surface temperature anomaly of the North Sea (Becker and Pauly, 1996). For the North Sea cod, which lies close to the southern limit of the species range, Planque and Fredou (in press) suggest an inverse relationship between NAO Index and cod recruitment. Thus the rapid extreme decrease in the NAO index from winter 1994/5 to winter 1995/6 can be expected to act in the sense of decreasing North Sea temperatures and increasing cod recruitment. Both of these changes appear to be evident in the record. If we use seasonal mean SST anomalies for the Felixstowe-Rotterdam route (sampled at nominal weekly intervals since 1970) as representative of the North Sea temperature trend, Figure 12 b will confirm that the peak positive values of the NAO Index in the early 1990s were accompanied by record warmth across the Southern Bight and that the reversal of the Index in 1996 was accompanied by a short-lived cooling from T' = +1°C to –1°C. The recruitment of North Sea cod, measured as the number of 1-year-olds but plotted against the year of hatching in Figure 12d (the graph is inverted; data from Anon 1999) appears to triple briefly in response before falling back to minimal levels in 1997-8.

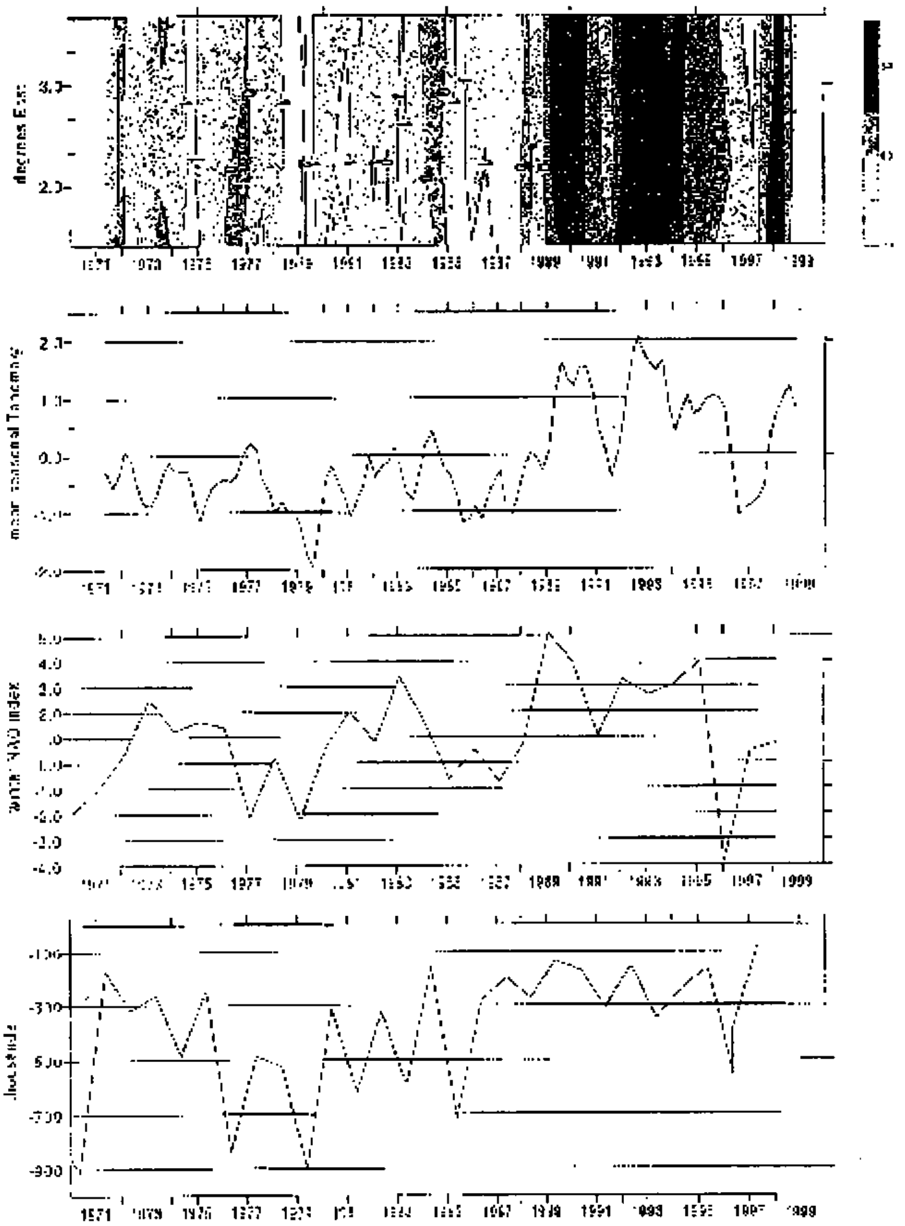


Fig. 12 a) SST anomaly distribution versus longitude on the Felixstowe-Rotterdam route, 1970-99, together with the variation of b) the seasonal mean SST anomaly for this route, c) the NAO Index (Hurrell, 1995a) and d) the recruitment to the North Sea cod stock estimated as numbers of 1-year-old fish (Anon 1999; graph inverted and numbers plotted against the year of spawning).

3. Responsiveness and Predictability

In these examples, we attempt to identify case studies in which the ocean's responsiveness is shown to be sufficiently rapid to match even an extreme short-term shift in the primary forcing------the abrupt change from the high positive state of the NAO in winter 1994-5 to possibly the most extreme NAO-negative state in the instrumental record in winter 1995-6 (see Figure 1). If so, then we may be justified in expecting the same responsiveness in these parameters as the NAO index returns to high positive values. Following its low value of -2.22 in winter 1995-6, the Gibraltar-SW Iceland Index of Jones et al (1997) has already shown a partial recovery to values of + 0.30 and + 0.92, respectively, in winters of 1996/7 and 1997/8, and in the case of the meridional ocean heat flux through 48N, Koltermann et al have already shown evidence of a return to high positive values in summer 1998 (Fig 6).

Since the values of the NAO Index for the early months of winter 1998-9 suggest that a high positive value is not unlikely (Table 1, below), these case studies of extreme interannual change may well prove to have a predictive value, suggesting a reversion to an NAO-positive type of response.

Table 1. Monthly values of the pressure difference Gibraltar-SW Iceland. (NAO Index of Jones et al 1996 and personal communication)

December 1998 = +2.12
January 1999 = +1.07

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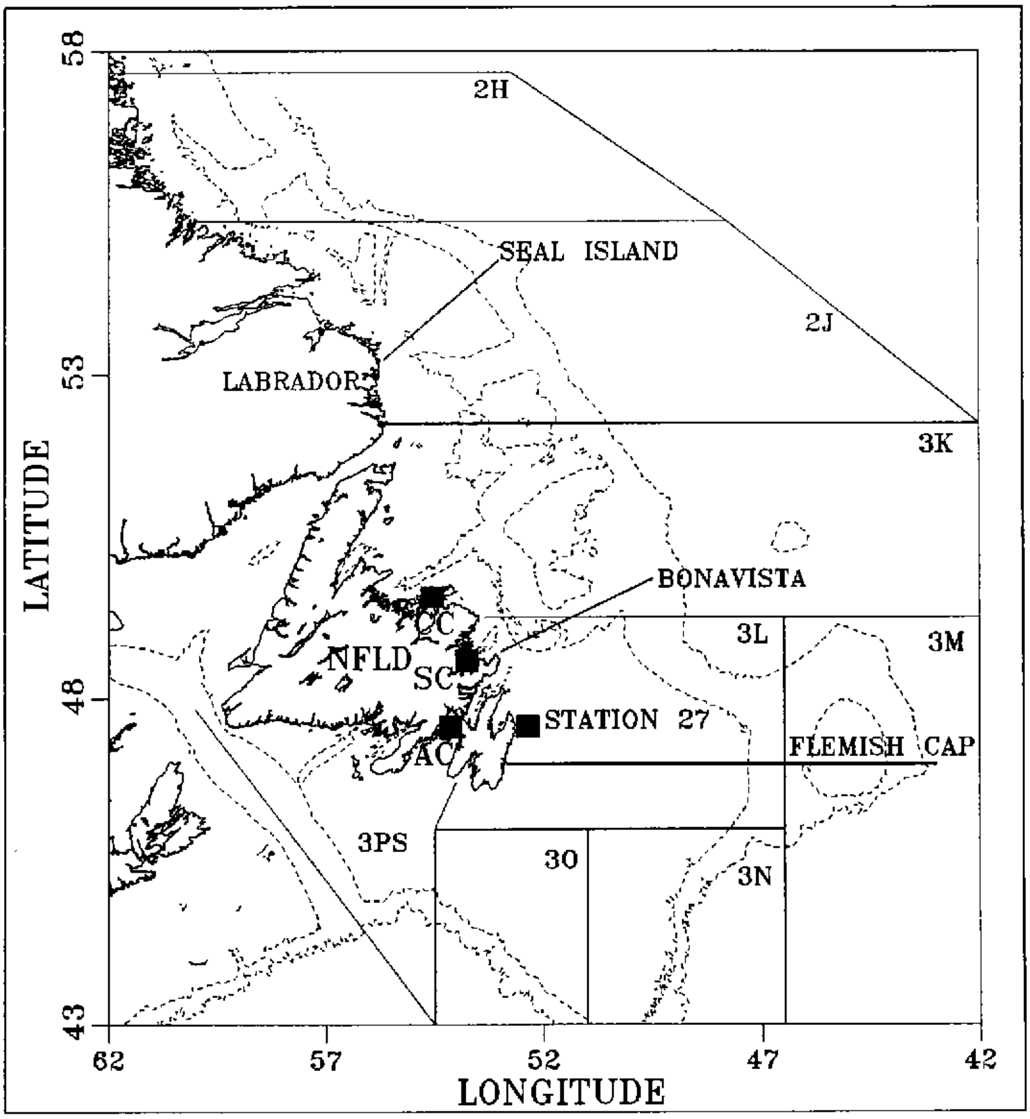
Annex G – Northwest Atlantic Sections

S. Narayanan, Marine Environmental Data Service, Ottawa, Canada

Introduction

In the following, the meteorological and oceanographic conditions that prevailed in 1998 off the Canadian East Coast have been described. The data presented here were collected by a number of researchers in Canada and Europe and compiled into time series for the standard sections and stations (Fig. 1). Colbourne in Newfoundland, and Drinkwater, Petrie, Prinsenberg and Peterson at Bedford Institute of Oceanography provided the time series and diagrams for this presentation.

Fig. 1 Map of the Newfoundland Region showing the standard sections and stations.



Meteorological Conditions

Air temperatures are monitored at Godthaab in Greenland, Iqaluit on Baffin Island, Cartwright on the Labrador Coast, St. John's in Newfoundland, and Sable Island on the Scotian Shelf. The data for these sites were obtained from: the Canadian Climate Summaries published by the Environment Canada (Canadian sites), and from the NOAA publication *Monthly Climatic Data for the World* (other sites). The monthly air temperature anomalies at these sites relative to their 1961-90 mean (Fig. 2) indicate warmer-than-normal conditions in most areas of the Northwest Atlantic for most of the year. The exception was at the northern regions, Godthaab and Iqualit: Godthaab experienced a colder than normal January while at Iqualit, January to March was colder than normal. The net effect was that the annual temperature anomalies throughout the Northwest Atlantic were higher than the 1997 values and warmer than the long-term normal by between 0.4°C to 1.5°C (Fig. 3).

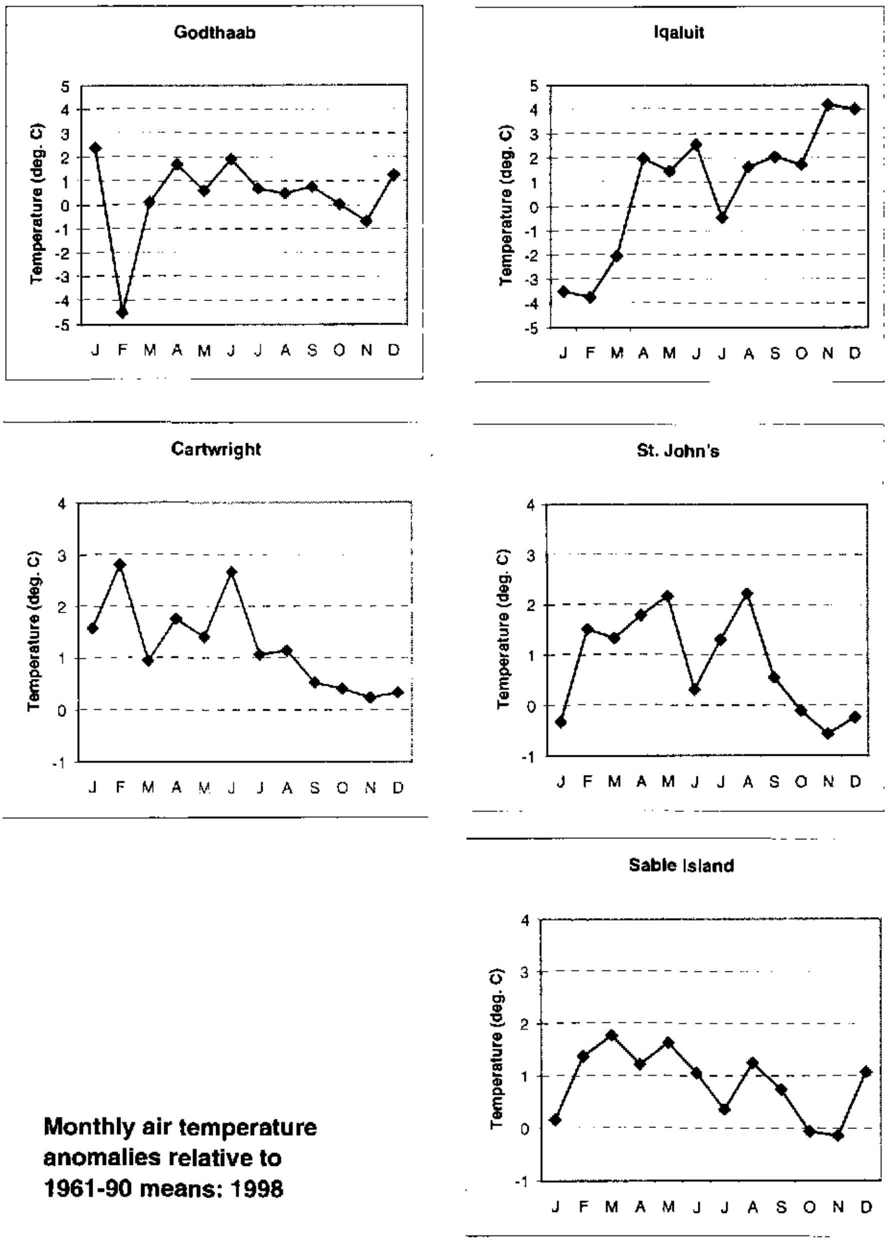


Fig.2 **Monthly air temperature anomalies relative to 1961-90 means: 1998**

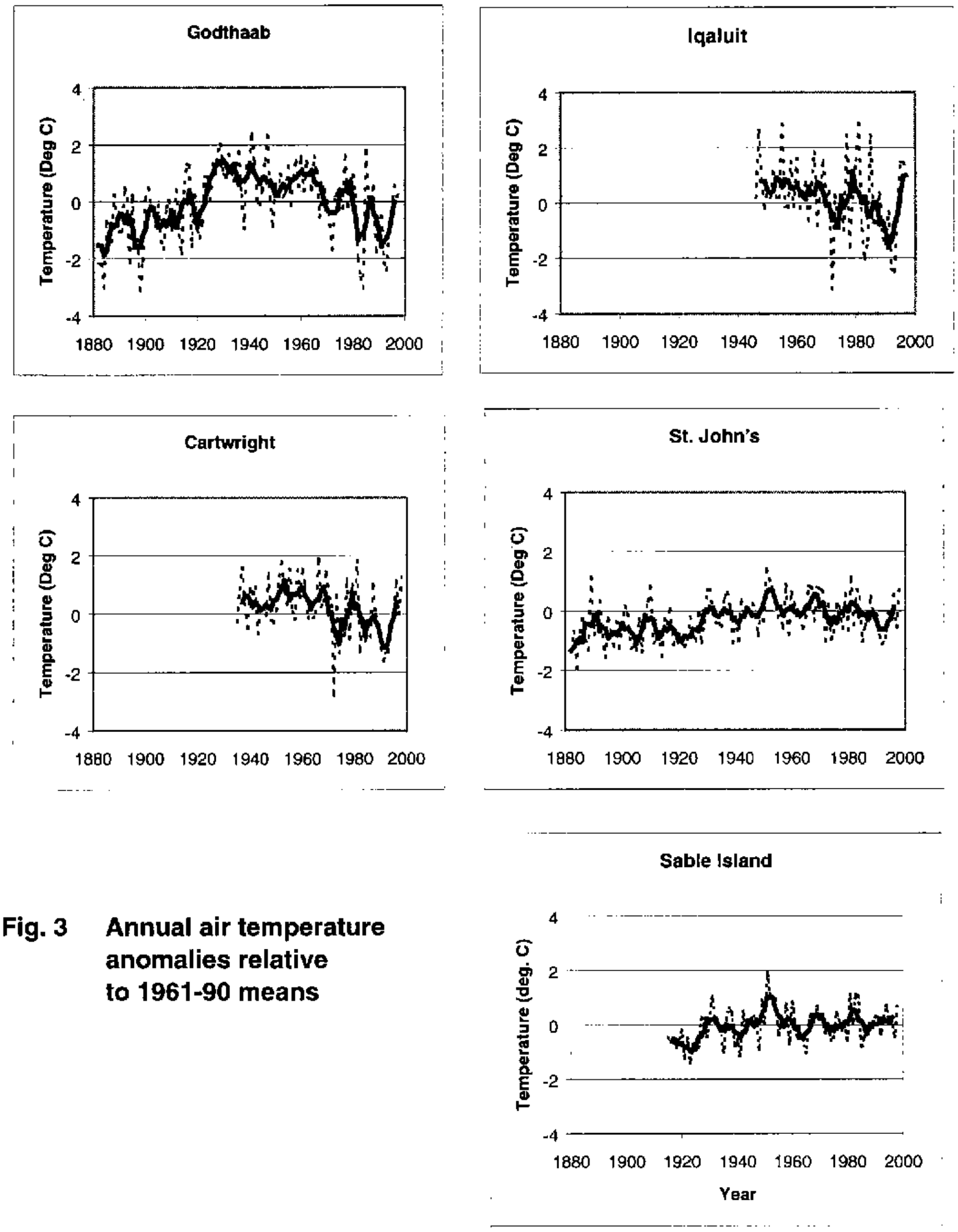
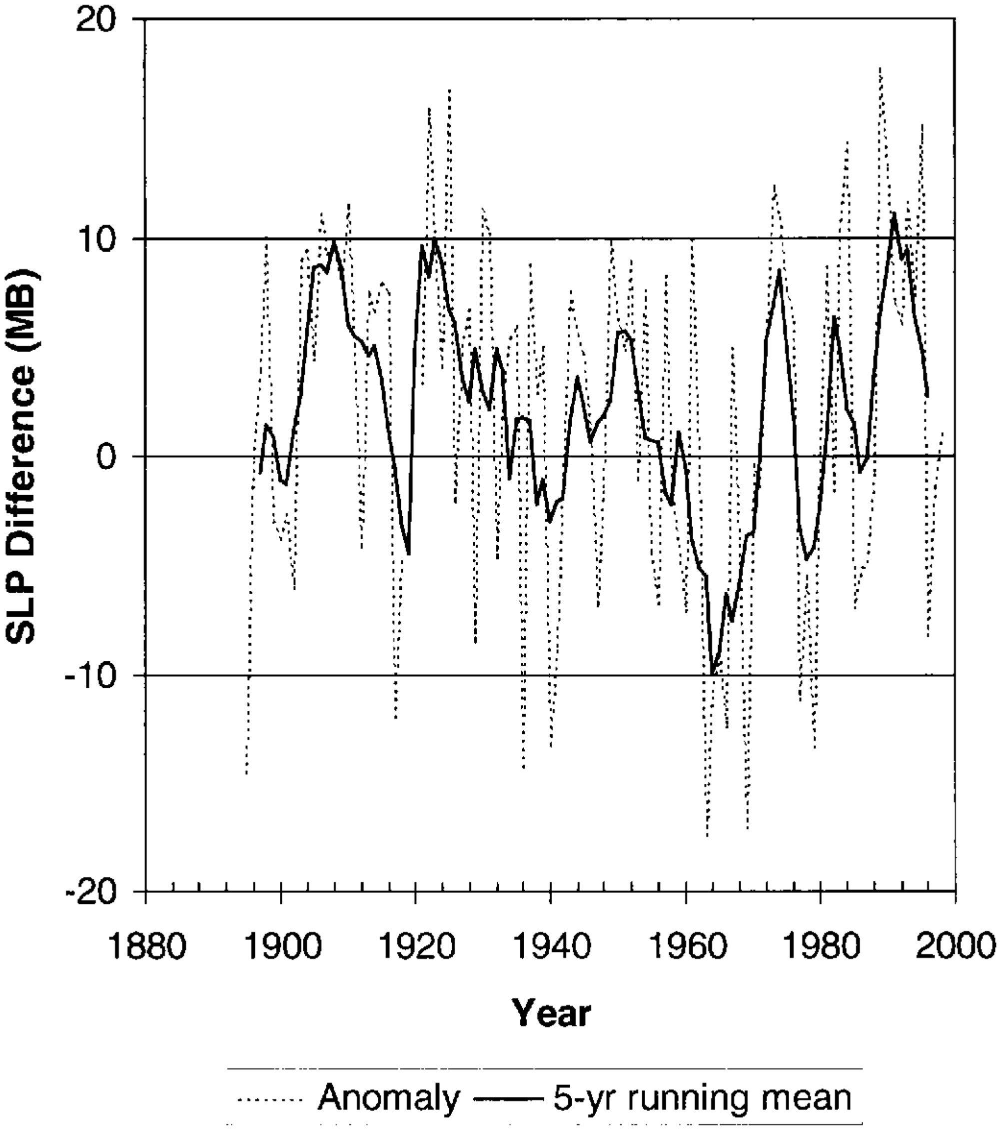


Fig. 3 Annual air temperature anomalies relative to 1961-90 means

The oceanographic conditions in the North Atlantic are closely linked with the large-scale atmospheric circulation. It has been shown that the difference between the winter sea level pressures between Azores and Iceland, referred to as the North Atlantic Oscillation (NAO) Index, is associated with the winter northwesterly winds over the Labrador Sea, where a negative NAO Index is associated with weak northwest winds, warm air temperatures, and limited ice cover. The annual NAO Index anomaly (Fig. 4) for 1998 was slightly above normal after two years of below normal values, but only slightly increased relative to 1997 value.

Fig. 4 NAO Index Anomalies



The above normal air temperatures at the northern locations during the fall of 1997 had the effect of slowing the ice formation up north and a delay in the arrival along the southern Labrador coast. Though ice formation may have increased in January, because of the warmer-than-normal air temperatures after March at all locations ice retreat was about 2 weeks earlier than normal (Fig. 5). Overall, it was a lighter than normal ice year.

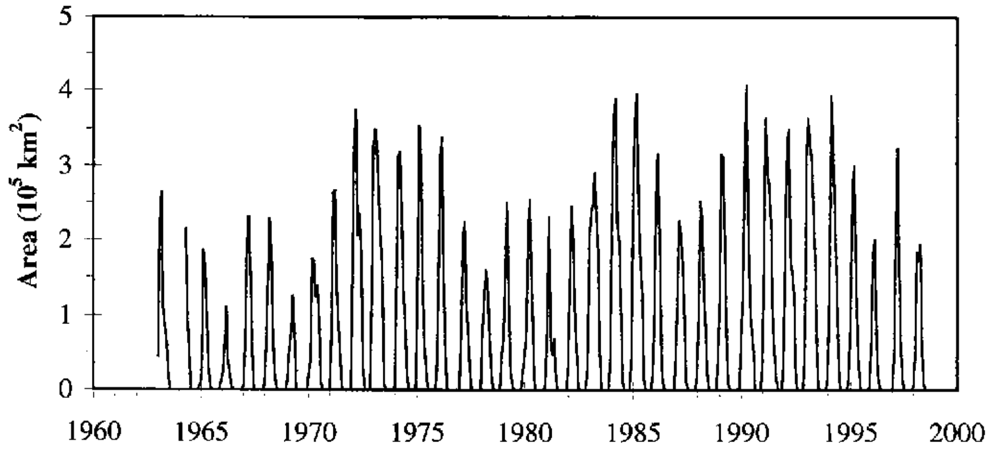


Fig. 5 Time series of the monthly mean ice area off Newfoundland and Southern Labrador (45° N to 55° N)

Oceanographic conditions

The area along cross-shelf transects off Newfoundland and Labrador (Fig. 1), occupied by sub-zero temperature waters (referred to as the Cold Intermediate Layer, or CIL), has been shown to be significantly correlated with the air temperatures and ice cover, and thus is an index of climate variability in the region. Recognising the usefulness of this index in monitoring the climate variability, the Department of Fisheries and Oceans occupies a series of cross-shelf transects in the July/August period of every year. The resulting temperature transects are used to derive the CIL areas and the anomalies relative to their 1961-1990 means (Fig. 6). The summer CIL area along the two northern transects increased slightly over the 1997 values but remained below normal. On the Grand Bank however, the 1998 CIL area was near normal, slightly less than the 1997 value. Overall, the amount of subzero water on the Canadian Continental Shelf was below normal, thus continuing with the general warm phase after the severe cold conditions of early 1990s.
Data from the fixed stations off the Canadian East Coast confirm the continuation of the warm phase in the Northwest Atlantic. At station 27 located off St. John's, Newfoundland (Fig. 1), the temperatures ranged from 0.3°C to 0.5°C above normal during winter and spring over most of the water column (Fig. 7a). The upper-layer salinities were slightly below normal during the first half of the year, particularly during the summer months (Fig. 7b). In spite of slightly colder-than-normal summer temperatures in the upper layers, which propagated down the water column, the bottom temperatures at Station 27 were above normal throughout the year and the vertically integrated temperature and upper-layer salinities at this site were near-normal (Fig. 8). Another index of the climatic variability on the Newfoundland shelf is the area covered by sub-zero °C water on the Grand Bank. This area has a significant inter-annual variability (Fig. 9) and has remained at that level, less than half of what was during the early 1990s.

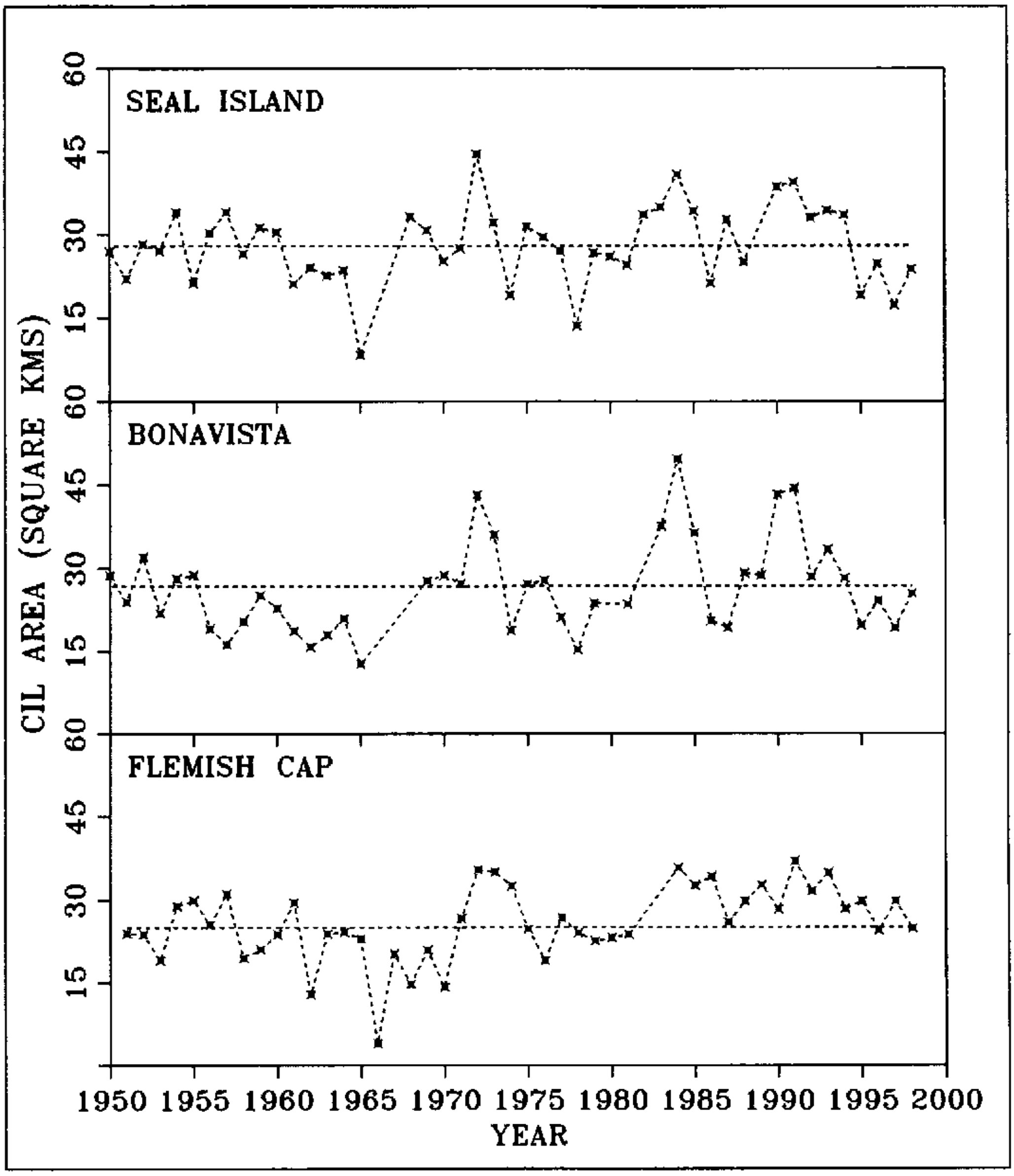


Fig. 6. Time series of Cold Intermediate Layer (CIL) areas of sub-zero °C water along standard transects across the Newfoundland Shelf during summer. The dashed lines represent the long-term (1961-1990) mean.

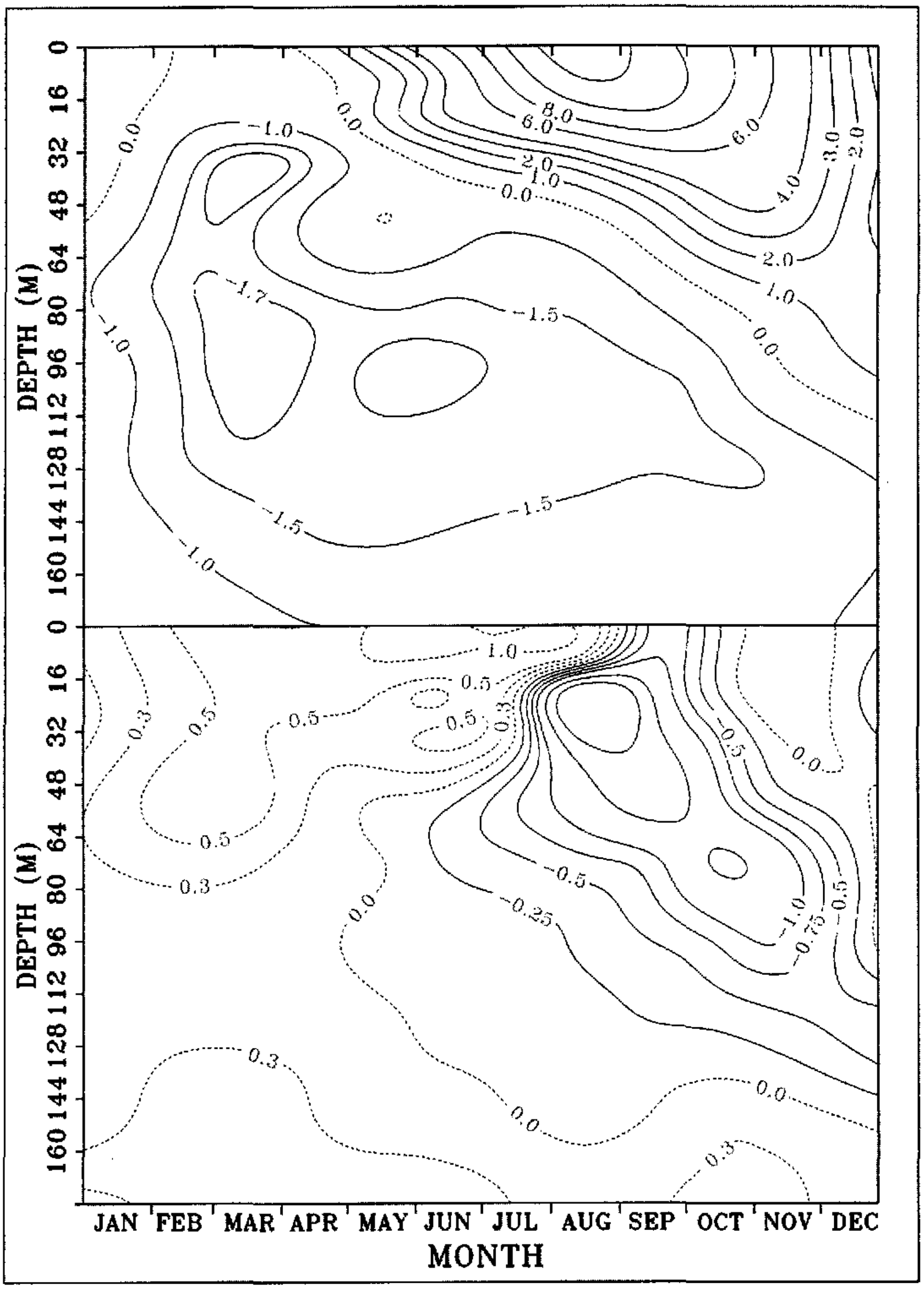


Fig. 7a Monthly temperatures (top panel) and anomalies (bottom panel) at Station 27 as a function of depth for 1998.

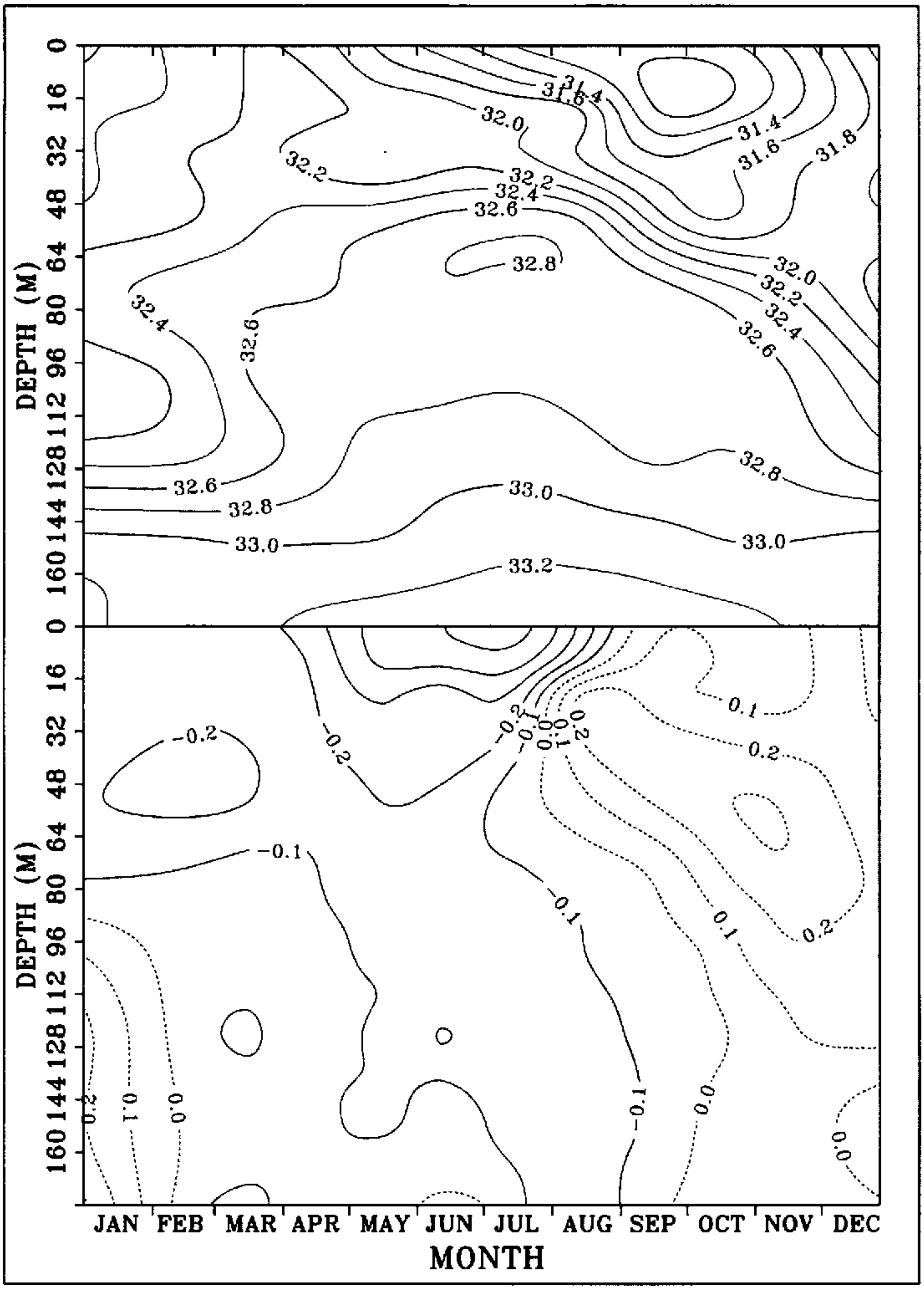


Fig. 7b Monthly salinity (top panel) and anomalies (bottom panel) at Station 27 as a function of depth for 1998.

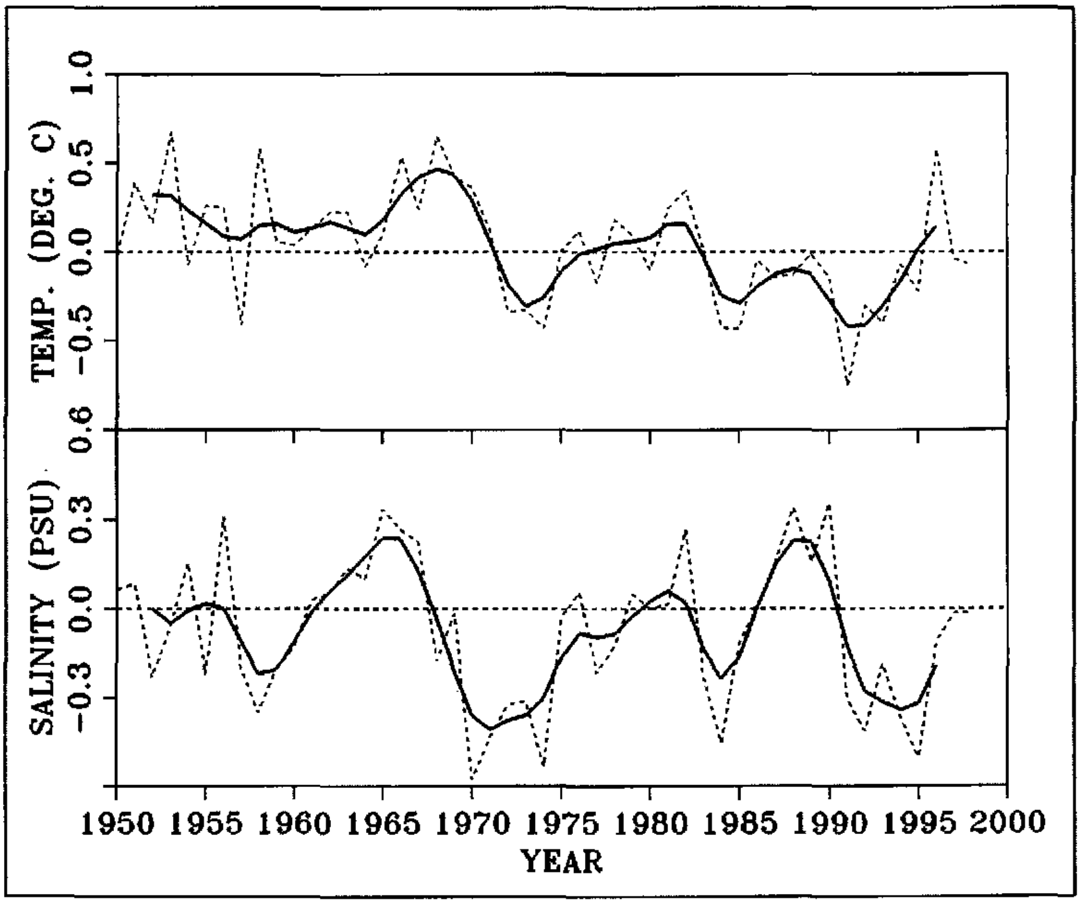


Fig. 8 Departures from normal depth averaged temperature and salinity off Newfoundland ,Canada, in the Northwest Atlantic. The dashed lines are the annual estimates and the heavy line represents the long-term trend.

Annex H – Icelandic Sections

Svend-Aage Malmberg, Marine Research Institute, Reykjavik, Iceland

Iceland is situated at the meeting place or fronts of warm and cold currents (Fig. 1), which meet in this area because of the geographical position, and the submarine ridges (Greenland-Scotland Ridge) which form a natural barrier against the main ocean currents around the country. To the south is the warm Irminger Current which is a branch of the North Atlantic Current (6°C to 8°C), and to the north are the cold East Greenland and East Icelandic Currents (-1°C to 2°C).

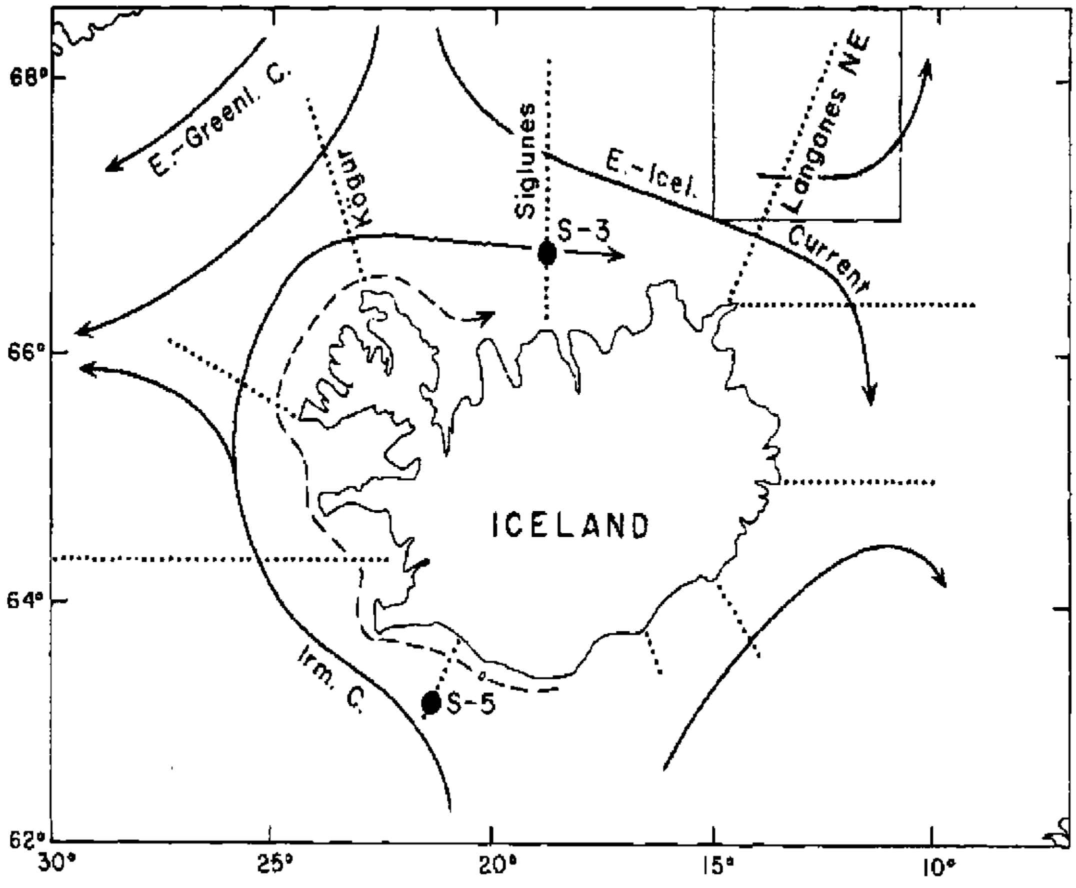


Fig. 1 Main currents and locations of standard hydro-biological sections in Icelandic waters. Selected areas and stations dealt with in this report are indicated.

There are also deep and bottom currents in the seas around Iceland, principally the overflow of deep cold water from the Nordic Seas and the Arctic Ocean south over the submarine ridges into the North Atlantic. The different hydrographic conditions in Icelandic waters are also reflected in the atmospheric or climatic conditions in and over the country and the surrounding seas, mainly through the Icelandic Low and the Greenland High. These conditions in the atmosphere and the ocean have their impact on biological conditions, expressed through the food chain in the waters including recruitment and abundance of commercial fish stocks.

The hydrographic conditions in Icelandic waters in 1998 revealed in general favourable temperatures and salinities. The salinity in the warm water from the south was higher since November 1997 than what was observed over the last decade and even before the so-called ice-years in Icelandic waters in the sixties (Fig.4). These conditions were evident in a moderate inflow of Atlantic Water into North Icelandic waters, where there is a surface low salinity layer in the upper 50-100 m in recent years (Figs 2-4). The warm Atlantic conditions in 1998 also seemed to spread westwards into the Irminger Sea towards Greenland. The East Icelandic Current, northeast and east of Iceland was further offshore with a limited southeastwards extension of temperatures below 0°C. The salinities were in general around 34.7 or even below the critical value for convection in the area (Fig. 4).

Following extremely cold conditions in Icelandic waters in 1995, temperatures rose again in 1996-97 and remained so in 1998 around Iceland. In 1998 the conditions improved further in the warm inflow from the south, the salinities rising even above the levels decades before. Despite this, a low saline surface layer was observed in North Icelandic waters in 1998, as since 1996, and in the East Icelandic Current salinities too were relatively low (<34.7).

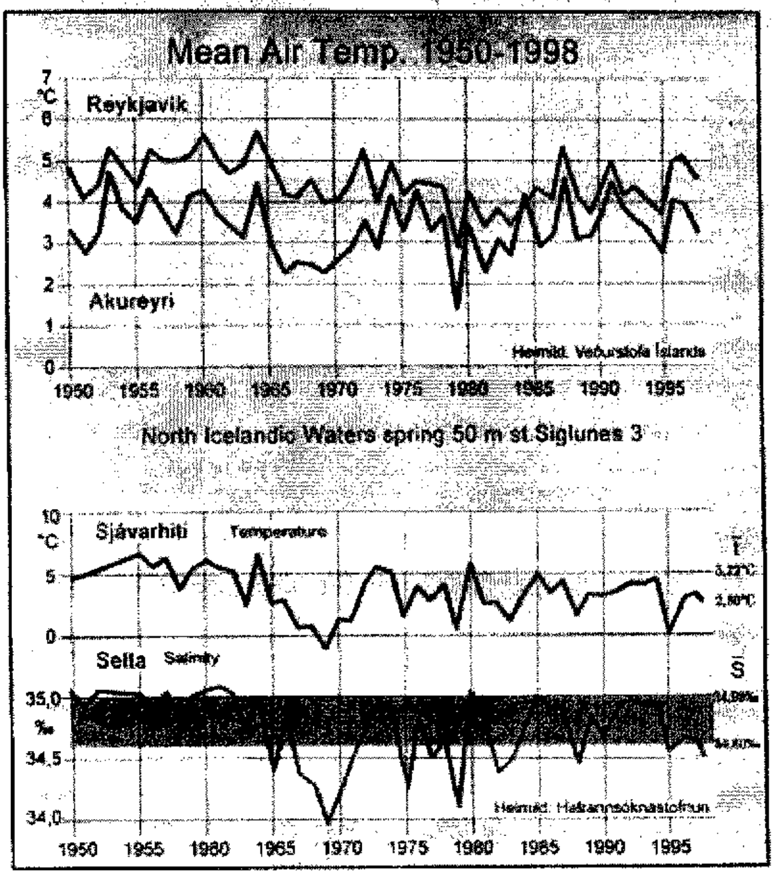


Fig. 2 a) Mean annual air temperature in Reykjavik and Akureyri 1950-1998.
b) Icelandic waters (S-3, see Fig. 1) in May/June 1950-1998

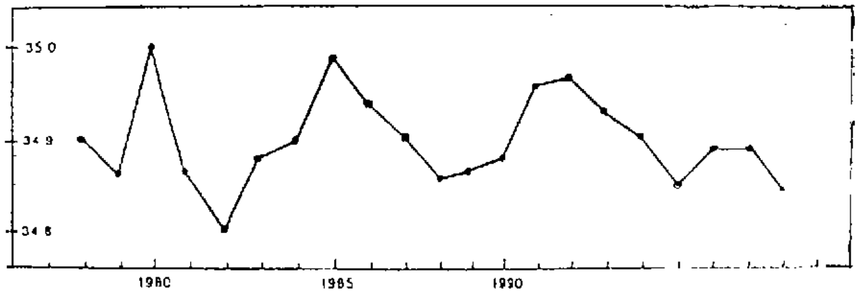


Fig. 3 Maximum salinity in near-surface or intermediate depths observed at a hydrographic station in North Icelandic waters (S-3, see Fig. 1) in May/June 1978-1998.

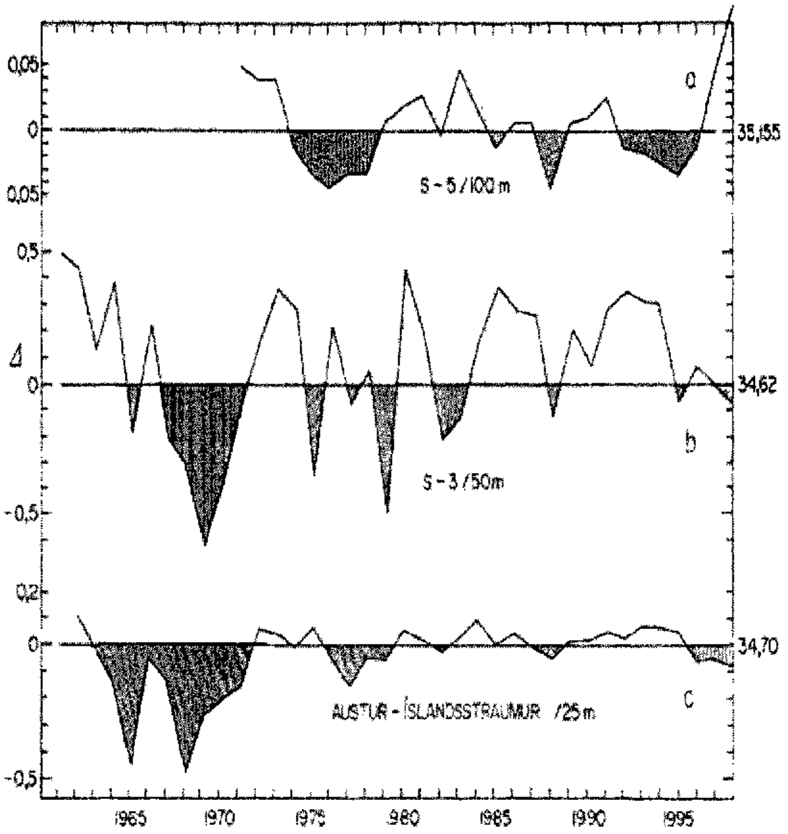


Fig. 4 Salinity deviations in spring at:
a) 100 m depth in Irminger Current south of Iceland (S-5) 1978-1998,
b) 50 m depth in North Icelandic waters (S-3) 1961-1998,
c) 25 m depth in the east Icelandic Current 1962-1998.

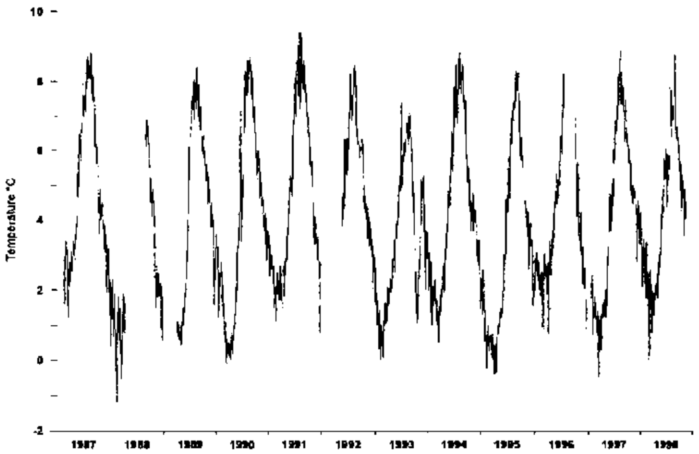


Fig. 5 Annual and seasonal variations in the sea-surface temperature at Grimsey, North Icelandic waters, 1987-1998.

Annex I/1 – Hydrographic Sections Occupied by the Netherlands: Bay of Biscay, Armorican slope

H.M. van Aken, NIOZ, Texel

In the Bay of Biscay, the Eastern North Atlantic Central Water (ENACW) in the permanent thermocline overlays the deep saline core of Mediterranean Overflow Water. Because of the positive correlation between Θ and S in the central water this results in a subsurface salinity minimum, indicating the lower boundary of ENACW. Since 1992 NIOZ (Texel) and RIVO (Ijmuiden) have carried out annual hydrographic surveys of the Bay of Biscay, including a line across the Armorican continental slope at 47°N, 5-7°W, which monitors the inter-annual variability of ENACW properties. Comparison of horizontal distributions of temperature and salinity for different years show that the data from the section are representative for a larger area, including the central Bay of Biscay.

Analysis of the Θ-S diagram of the section from the summer of 1998 (Figure 1) reveals that in the temperature interval from 10.0 to 12.5 the bulk of the salinity data can adequately described by a third order polynomial of Θ. This polynomial line is used a reference line to compare the 1998 data with previous years (Figure 2).

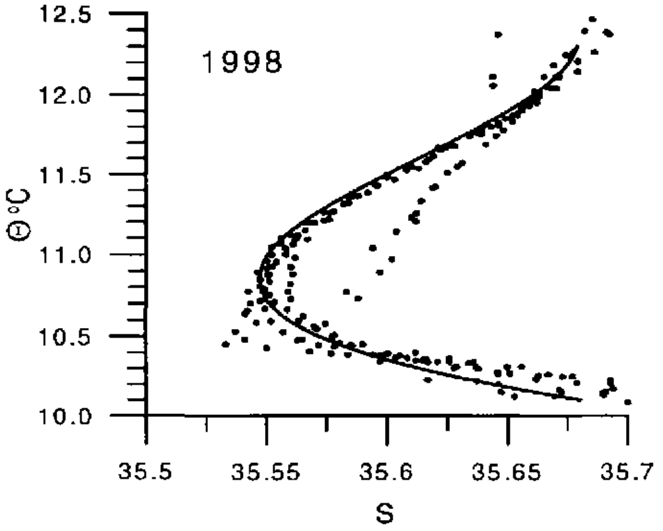


Figure 1. Potential temperature – salinity diagram for August 1998. The drawn line is S, expressed as a third order polynomial of Θ.

The 1998 water mass appears to be slightly more saline than in the previous years, especially at potential temperatures above 11.5°C. The hydrographic variation in ENACW since 1992 can be described as follows: In 1992 and 1993 the thermocline water mass was nearly 0.05 more saline (or ~0.5°C colder) than the 1998 water mass. In 1994 a freshening started, initially in the higher temperature range. After 1995 the salinity at Θ values of over 11.5°C increased (or the water cooled) whereas at lower temperatures the salinity decrease went on until 1996. Since then a slight salinity increase has been observed, continuing until 1998. The relatively high salinity data points from 1998 relative to the reference line originate from the upper slope, and probably reflect locally enhanced mixing.

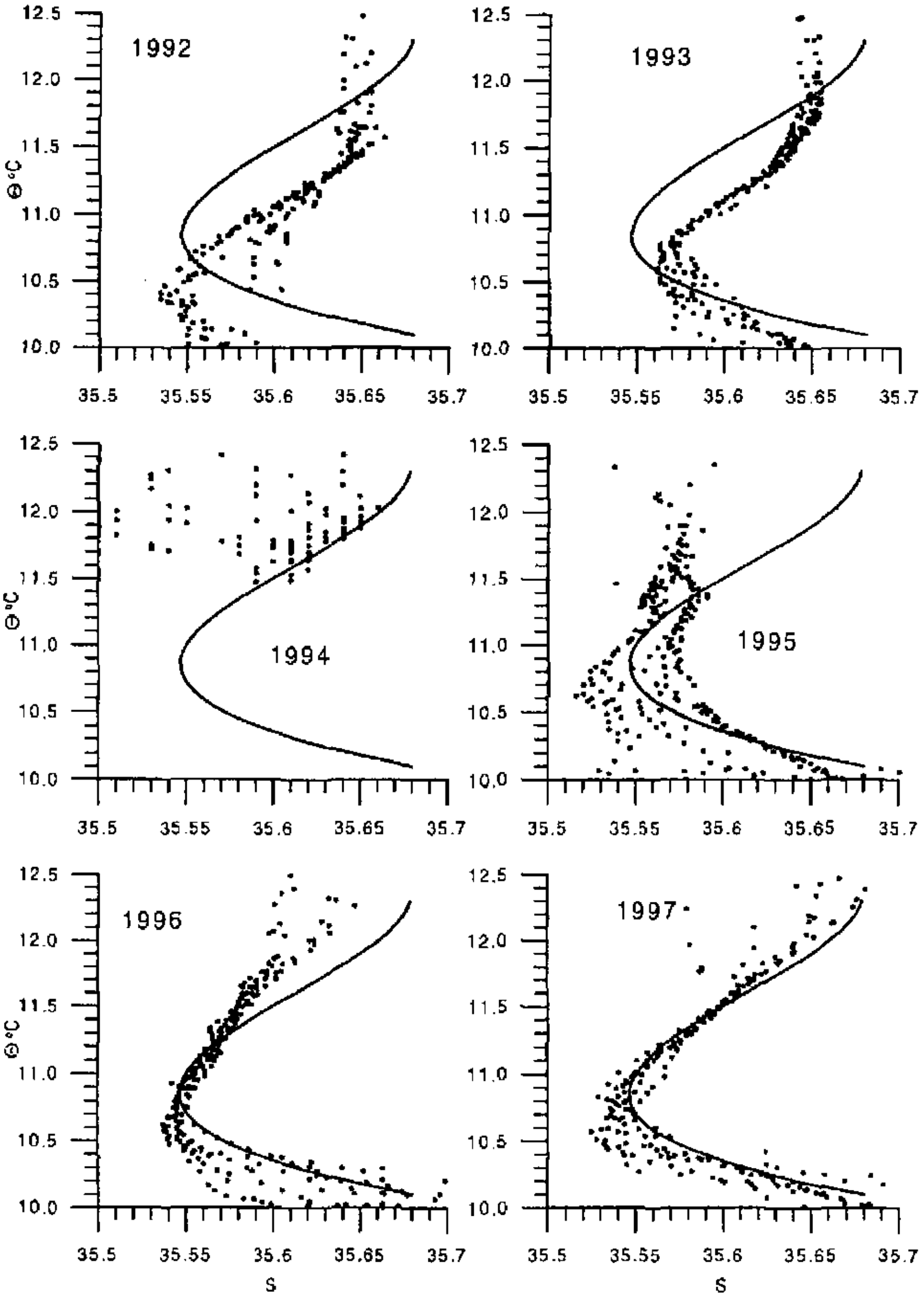


Figure 2. Potential temperature – salinity diagram for the summers (July-August) of 1992 to 1997. The 1994 survey was in November and reached only to a depth of 170 m. The drawn line is the polynomial reference line for 1998.

Annex I/2 –Time Series of Salinity Extremes in the Southern Bight of the North Sea

Follow-up Note to OWHG 1998 Discussion

By J. van Bennekom, Netherlands Institute for Sea Research

During the 1998 OWGH meeting at Santander, high salinities in the Southern Bight of the North Sea and the Channel, found in winter 1998 were mentioned (Annex L in the report of that meeting). To put these observations in a proper framework, regarding existing time series, more data have been assembled afterwards.

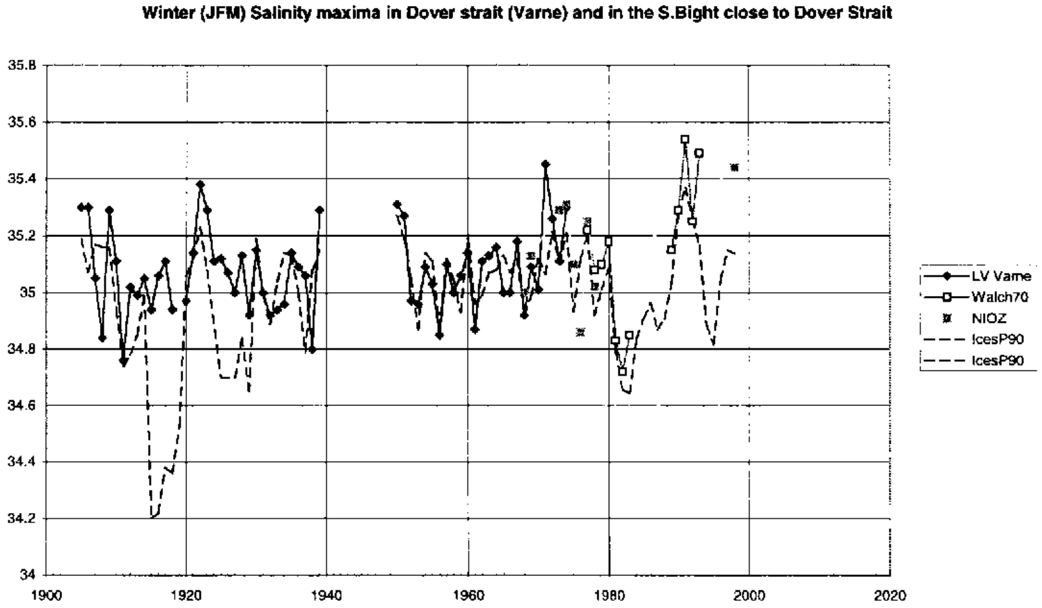


Figure 1 compiles salinity maxima in winter (JFM) for:

- Light vessel *Varne* in the middle of Dover Strait, 1905-1939 and 1950-1974
- Walch 70, middle Southern Bight, Courtesy North Sea Directorate, Rijkswaterstaat
- ICES data files, south of 52°30' N, except for the 10% highest values (P90) Courtesy of Harry Dooley, ICES Data Center.
- NIOZ observations near Dover Strait, 1968-1978 and 1998

Comments

Winter data was chosen to remove noise due to seasonal patterns; detailed analyses for some stations showed seasonal amplitudes of about 0.5 in salinity with maxima from January to March and minima in spring.

It was necessary to apply some selection criteria to the data set in ICES files; raw data show maxima up to 36.5 and in many years values above 36.

The dip from 1915-1919 was a "war effect". During this period the number of observations in the ICES files decreased to about one quarter in the previous and later years, while *Varne* continued to operate. Apparently, only observations were made at coastal stations, where salinity was always lower.

Availability of P 90 data after 1993 was uncertain. 1998 data ICES was incomplete.

It is noted:

- That the various time series are quite comparable (few exceptions)
- The 1998 high was not exceptional; 1991-1993 was even higher, as noted by Becker and Dooley, 1995; other highs in 1922 and - possibly - between 1940 and 1950. Low in 1982 stands out.
- There is no clear pattern, but it is noted that the year to year amplitude was small between 1952 and 1970 and much higher after 1980.

Annex J – Spanish Standard Sections

**A. Lavín and J. M. Cabanas, Instituto Español de Oceanografía,
Santander, Spain**

The Spanish Standard Sections cover the area of the shelf and shelf-break of the Eastern Atlantic and North Iberian Peninsula. There are 4 sections sampled monthly by the Instituto Español de Oceanografía situated in Santander (43.5°N, 3.78°W), Asturias (43.5°N, 6°W), La Coruña (43.4°N, 8.3°W) and Vigo (42.1°N, 9°W). The area is located between the eastern part of the subpolar and subtropical gyres. This region is affected by both gyres depending on the latitude and the general circulation in the North Atlantic.

The meteorological conditions to the north of the Iberian Peninsula (Santander Meteorological Centre) follow a warming tendency in the last period, mainly since the 80's (Figure 1). During 1998 the annual average air temperature was 14.8°C, 0.44°C higher than the mean (1961-1998) (Source: Instituto Nacional de Meteorología). The North Atlantic Oscillation (NAO) index is presented in the same figure. A correlation of 0.56 is found between both. On a monthly basis, winter presented temperatures between 1.5 and 2°C higher than the monthly mean (Figure 2). Despite having temperatures higher than the mean in the first term of 1998 and the higher NAO index indicating a warmer year, after April, the year was very normal, following the mean values of the time-series.

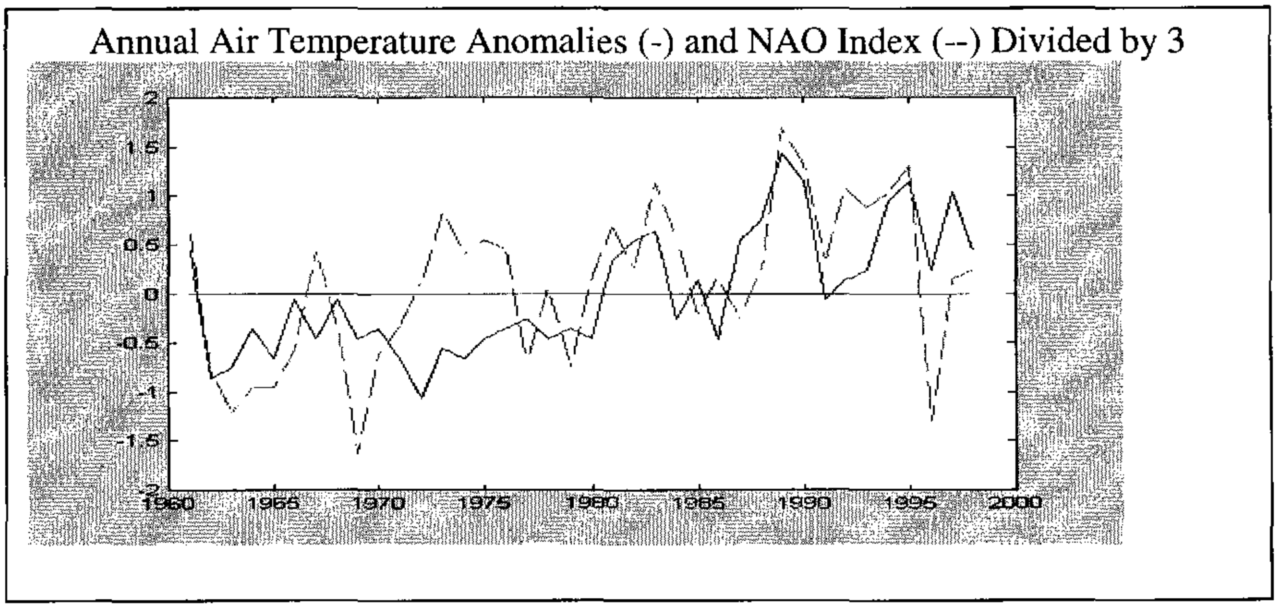

Annual Air Temperature Anomalies (-) and NAO Index (--) Divided by 3

Figure 1

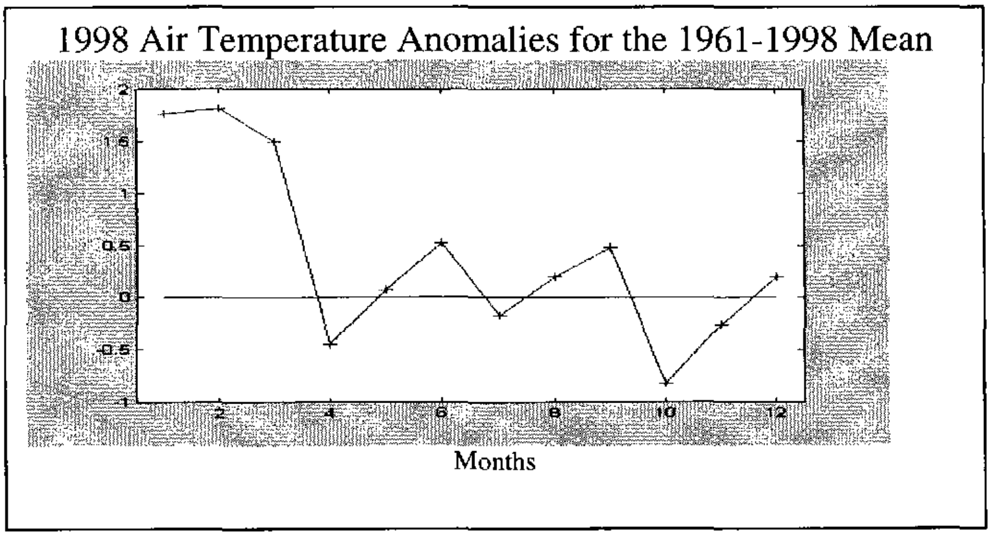

1998 Air Temperature Anomalies for the 1961-1998 Mean

Figure 2

Contours of temperature, salinity and nitrates over the shelf (110 m depth) in the Santander Section are presented in Figure 3. The seasonal cycle in temperature is clearly marked in the upper layers. Stratification develops between April-

May and October-November, and during the rest of the period the water column is mixed. Salinity contours show high salinity at the beginning of the winter due to the poleward current and sporadically in spring-summer due to seasonal upwelling events. Low salinity appears in autumn when the seasonal pycnocline is broken, in summer in the upper layers, due to the advection of warm surface water, and in spring, due to river overflow. In nitrate distributions, high values appear in the mixed period and, due to upwelling events, in the stratified part of the year.

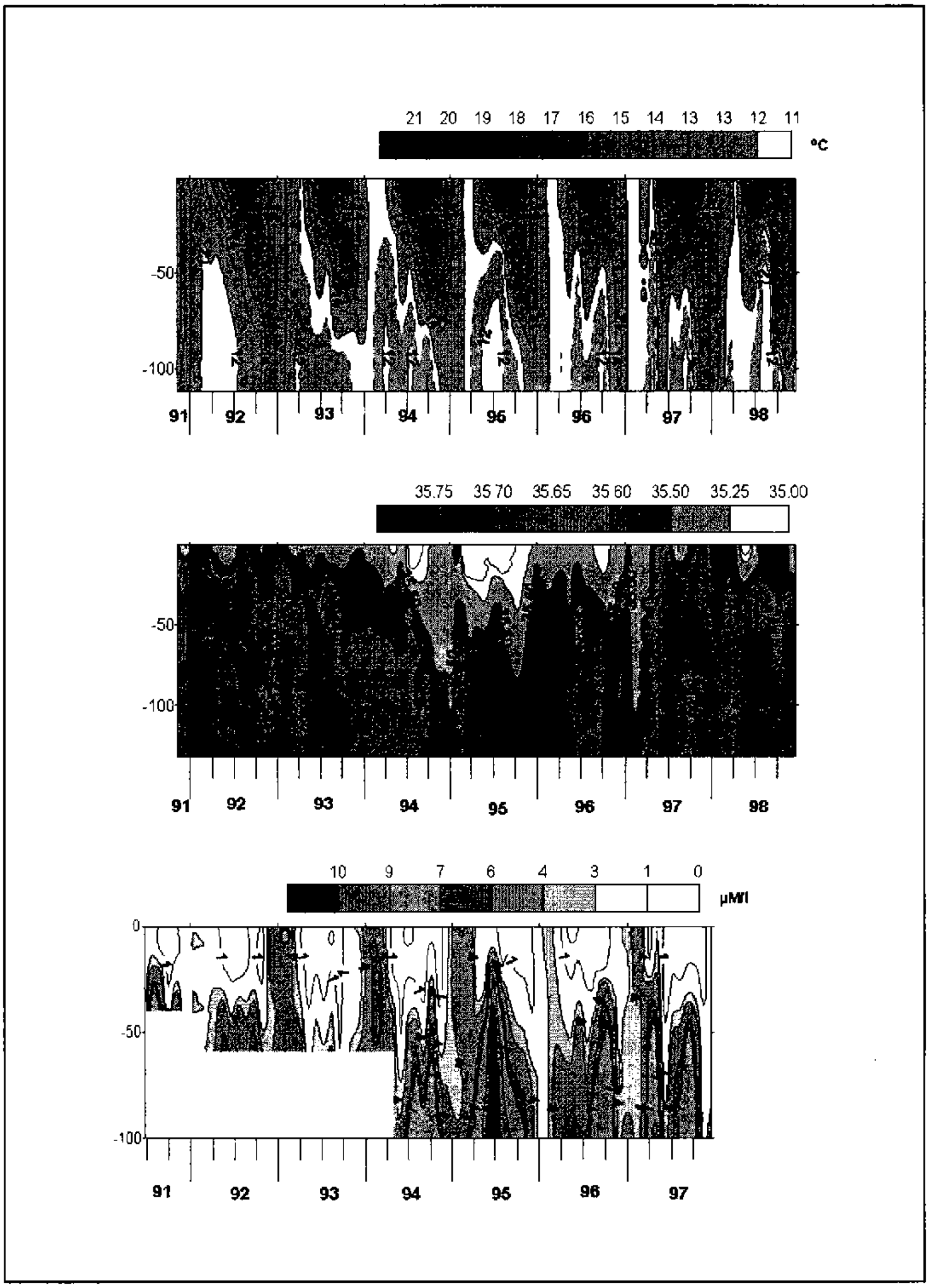


Figure 3

Sea temperature

Sea temperatures near the surface (10 m), at mid-depth (50 m) and at the bottom (100 m) show the following behaviour in relation to the time-series (Figure 4). 1998 summer surface temperature is lower than during the previous years, probably due to the lower heat transfer during those months as described above. At mid-depths, 1998 is one of the colder years of the series during summer (June, July and August) and the warmest year of the series in the autumn. The lower temperatures found at 50 m depth are due to the upwelling events that have occurred during summer.

1991-1998 Temperatures at 10 (-), 50 (--) and 100 m (..)

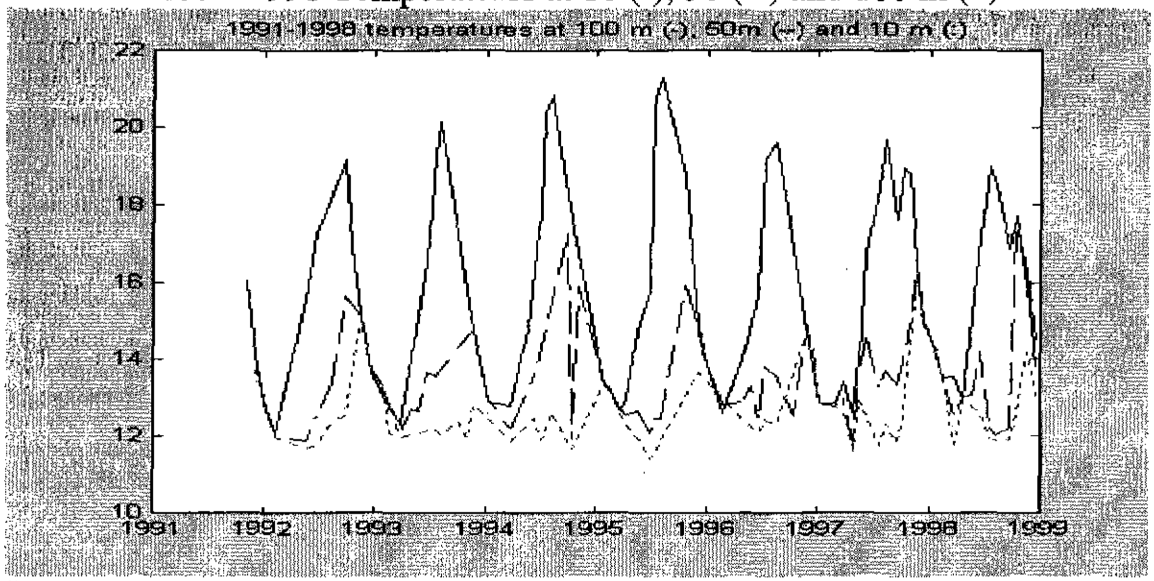


Figure 4

Comparing the parameter with the monthly mean (1991-1998), temperature throughout the water column shows similar behaviour, with higher temperatures in winter and autumn and lower in summer (Figure 5).

Seasonal Cycle of Temperature at 10 m (-), 50 m (--) and 100 m (..) and 1998 Values at 10 (+), 50 (*) and 100 m (o) Depth.

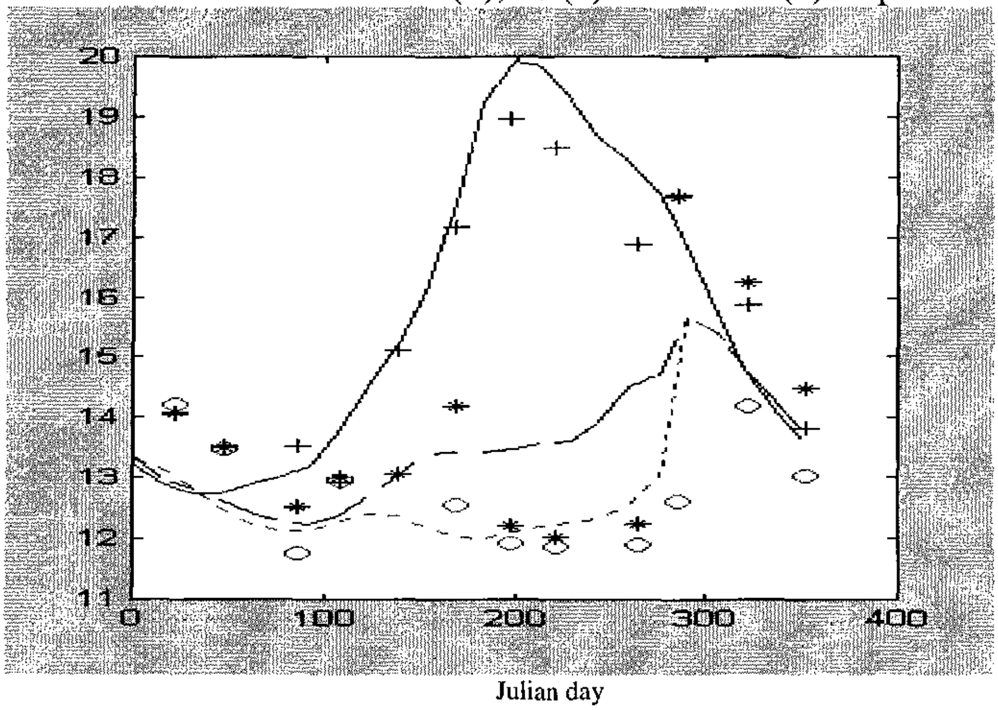


Figure 5

Temperature at 10 m. Monthly Values (1991-1998) and 12 Month Running Mean (--) and Mid-Year (June) Value (*)

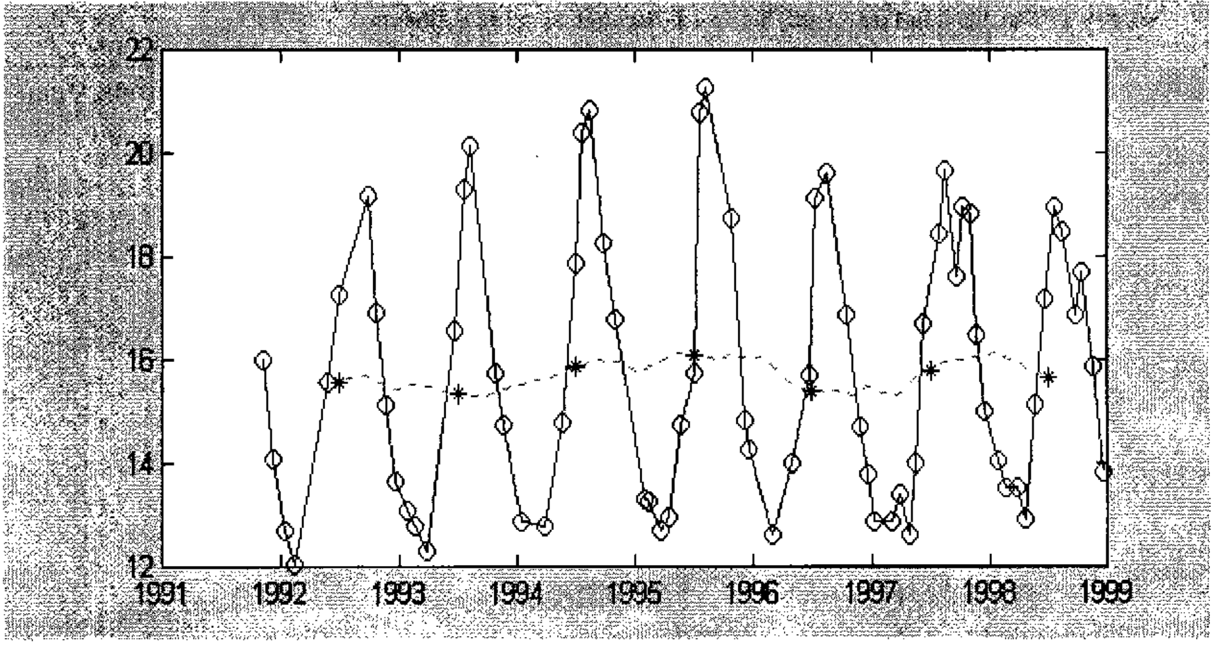


Figure 6

With regard to the annual running mean, the increase in mean values during the first part of 1997 kept going until the end of the year, but decreased during 1998. As a result of this, the warming tendency appearing between 1992 and 1997 has been reduced. The rate of warming between 1992 and 1998 amounts to 0.11°C/year at 10m depth. Studying which season contributes to a greater extent, winter mean values (January, February and March) present small variance and a linear trend of 0.17°C/year (Figure 7).: This trend is of great importance due to its statistical significance. As well, new water masses are formed during the winter, and once they are formed, their anomalies remain with the water mass. In summer, values have a great variance and we found a decreasing trend due to the colder last years (Figure 8)

Winter Trend

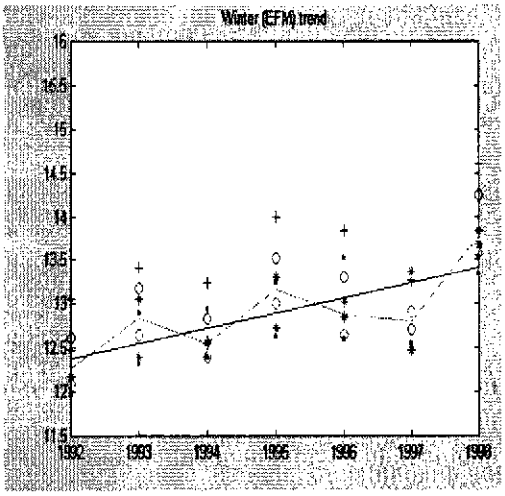


Figure 7

Summer Trend

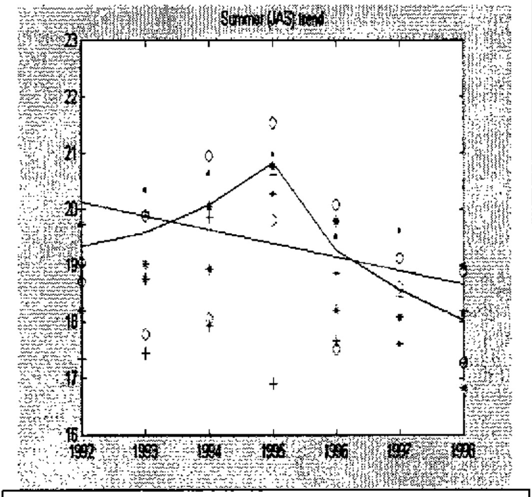


Figure 8

Salinity

Salinity variability during the year is presented in Figure 8 with annual mean values 1998 salinity values were high throughout the year and throughout the water column, with the exception of April and December, when high precipitation induced lower salinity in shallower waters. At 10 m depth, values are higher in winter and summer. Salinity at 50m depth has increased during 1998 though by a small amount.

Seasonal Cycle of Salinity at 10 m (-), 50 m (--) and 100 m (..) and 1998 Values

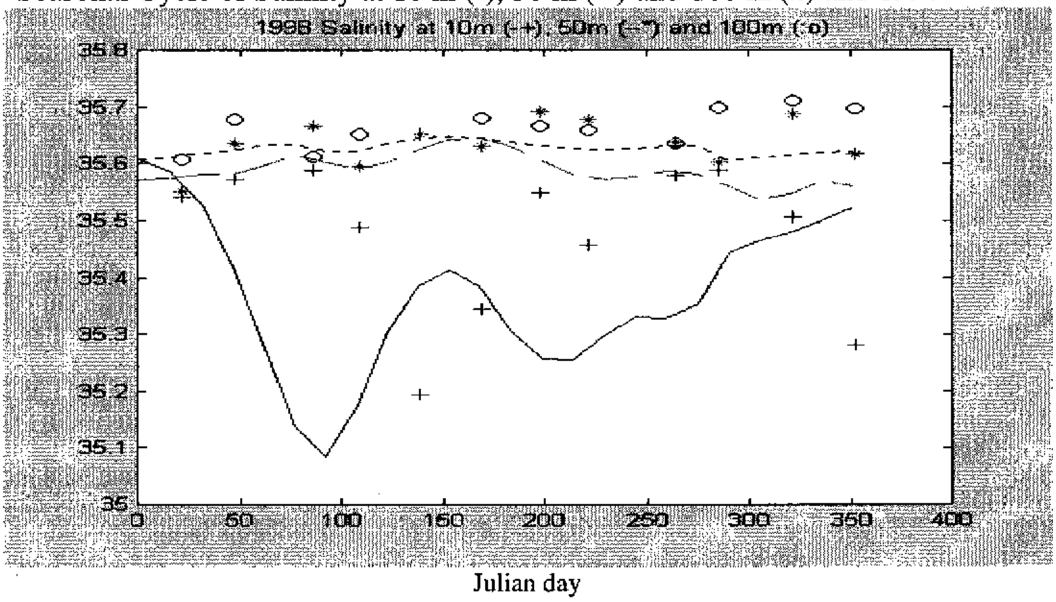


Figure 9

For the whole sampling period, salinity decreased from 1992 to 1995 and has increased since then, with a small rise in 1998.

Salinity at 50 m. Monthly Values (1991-1998) and 12 Month Running Mean (--) and Mid-Year (June) Value (*)

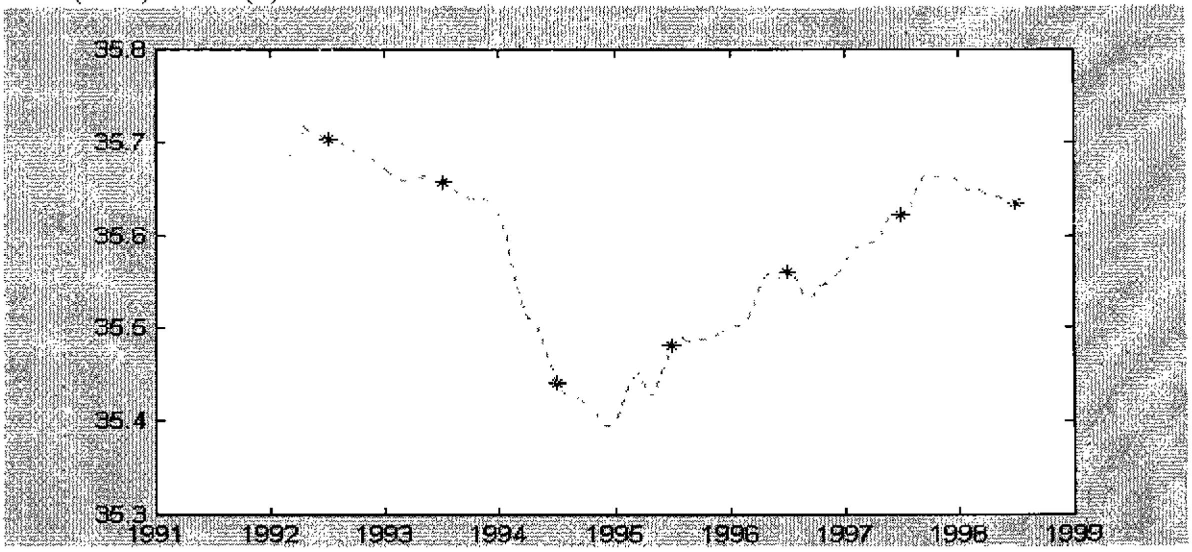


Figure 10

1998 EXTREME EVENTS

The high number of summer upwelling events are the cause of low temperature and high salinity mainly detected at 50 m depth.

The low temperature and high salinity found in the upper layers in summer seem to indicate that advection of warmer and fresher water from the south-eastern corner of the Bay of Biscay has diminished in recent years.

Vigo Standard Section

Contours of temperature, salinity and nitrates over the shelf (94 m depth) in the Vigo Section are presented in Figure 11 from 1994 to 1998. A seasonal cycle, marked by temperature in the upper layers, remains during the autumn and is usually interrupted by summer upwelling events. Stratification develops between April-May until October-November when warmer water covers the shelf. During the rest of the period the water column is mixed. Salinity contours show high salinity at the beginning of the winter in 1995 and 1996 due to the poleward current and sporadically in spring-summer due to seasonal upwelling events. The highest values were found during spring-summer 1997. Low salinity appears in autumn when the seasonal pycnocline is broken, and extends until spring, due to river overflow. On nitrate distributions, high values appear in the mixed period and, due to upwelling events, in the stratified part of the year. High nitrate concentrations show strong upwelling events as found in summer-autumn 1994 and 1995 and 1998.

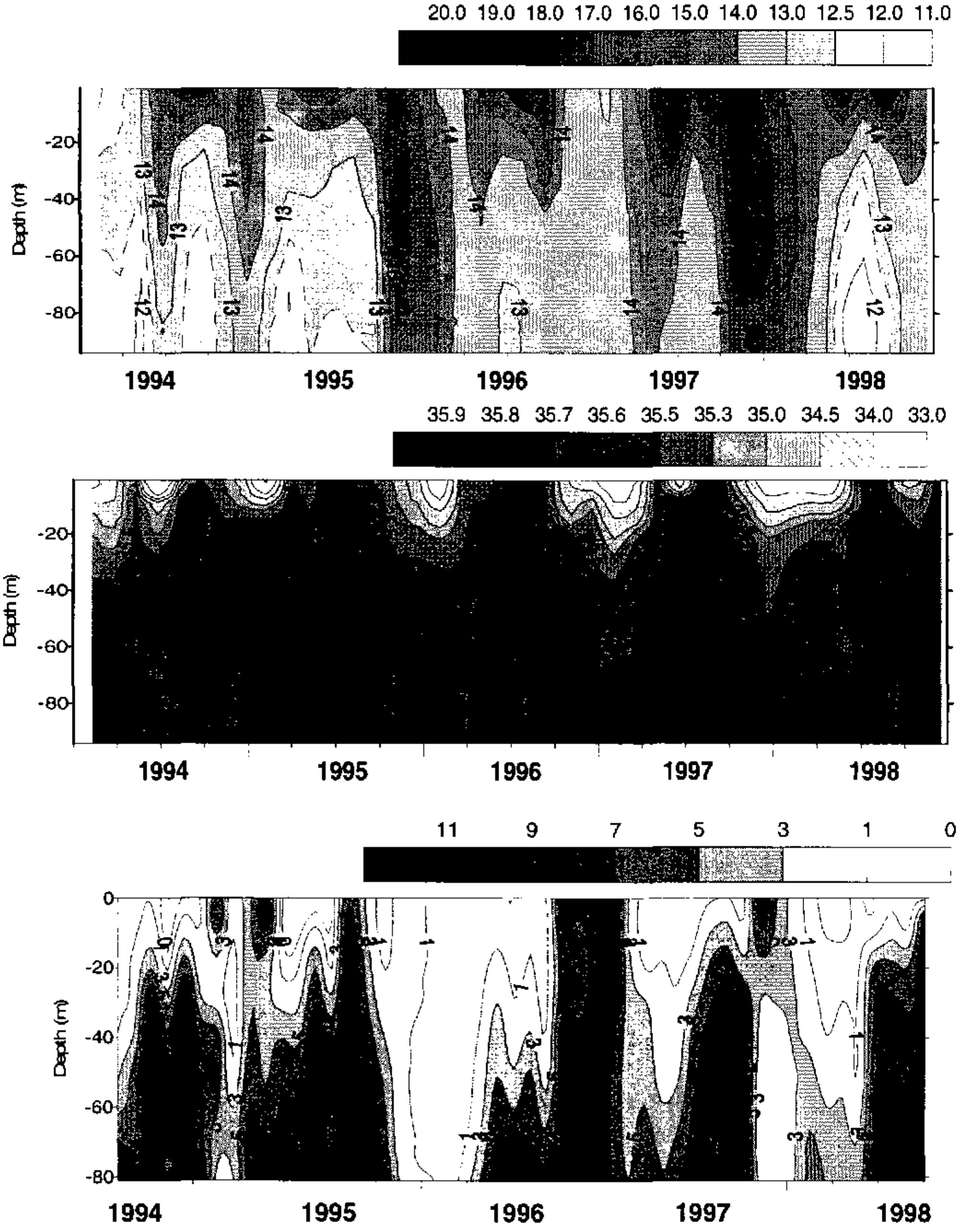


Figure 11

Annex K – Faroe-Shetland Standard Sections

Part 1. Faroe Bank Channel, Bogi Hanson

1. HYDROGRAPHIC DESCRIPTION

The Faroe Bank Channel (FBC) is in its upper layers filled with fairly homogeneous Atlantic Water (MNAW) which passes over the Iceland – Scotland Ridge into the Nordic Seas.

2. GENERAL 1998 SYNOPSIS

Since the mid-nineties temperature and salinity of the MNAW in the FBC have increased. In 1998 the increase in both parameters has stagnated, and especially salinity seems to have decreased again by the end of 1998.

3A.1. TEMPERATURE 1998

The temperature of the upper layer in the FBC seems to have been fairly high throughout 1998 .

4A.1. SALINITY 1998

Salinity of the upper layer in the FBC was high throughout 1998 as compared to the last decade, but a decrease is indicated for the latter half of the year

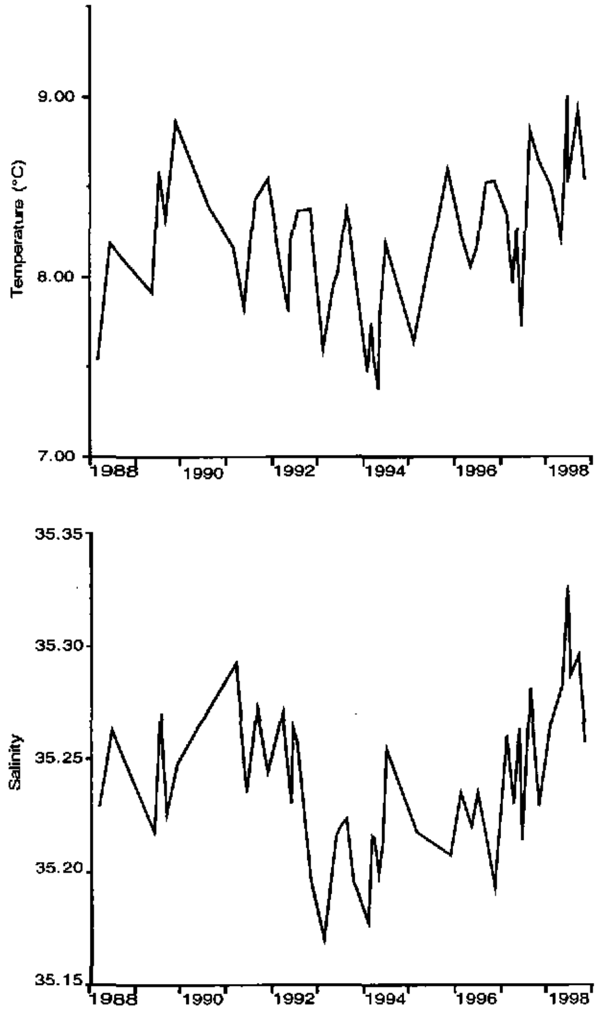


Figure 1: Average temperature and salinity of the 100-300 layer in the middle of the Faroe Bank Channel through the last decade based on CTD observations at two stations on the FBC Standard Section

Part 2. 1998/99 Results From The Scottish Standard Sections

W R Turrell, Marine Laboratory Aberdeen, Scotland

Introduction

The two Standard Faroe-Shetland Channel Sections [Nolso (Faroe) -Flugga (Scotland) and Fair Isle (Scotland) - Munken (Faroe)] have been occupied by the Marine Laboratory Aberdeen on two occasions since April 1998; October 1998 and December 1998. The North Sea JONSIS Section was occupied during the October 1998 survey (Figure 1).

The results presented here are based on the definitions of time series presented in the Scottish submission to the WGOH 1997 report. These definitions are not ideal, and are being further developed. However they may be used to give an indication of ocean climate change in the areas monitored by Scottish Standard Sections.

Summary of Results

Surface Waters

North Atlantic Water (NAW) at the Scottish shelf edge (Figure 2) has been warming since 1987 at a rate of O(0.5°C/decade). The survey in March 1998 found particularly high temperatures (the third highest recorded this century - Figure 2b), but the October 1998 survey showed a cooling. December 1998 indicated a warming trend again. The trend since 1987 is a recent more rapid warming imposed on a warming trend which commenced in 1966 and has continued at a rate of O(0.3°C/decade).

Salinity of NAW demonstrated an almost cyclically variability since the end of the low salinity anomaly (GSA) years in the late 1970s, with minima in the years 1977, 1987, 1994, and maxima in the years 1984 and 1990. This variability may be related to the NAO index. Since the minima of 1994, the salinity has constantly risen to the highest value since 1960. This rising trend continued through 1998. This variability has been imposed upon a more gradual overall salinity increase since the GSA period with salinities now exceeding 1950 values.

Modified North Atlantic Water (MNAW), at the Faroese edge, has demonstrated quite different trends to those of NAW (Figure 3). There has been a general cooling of MNAW since 1960 at a rate of O(0.3°C/decade). The rapid warming observed in the NAW since 1987 is certainly not observed in the MNAW. The extreme temperature (and salinity) anomaly calculated for the December 1998 survey should be used with some caution, and is not yet sufficient evidence to suggest a warming trend has commenced.

The salinity of MNAW has also behaved differently from that of NAW. Although the min-max-min-max-min cycle of 1977-1984-1987-1990-1994 is evident in MNAW salinities, it is less pronounced. More prominent is a continued freshening since 1991, which is part of a general freshening since 1960 at a rate of O(0.02/decade). While in 1997 salinities were thought to be approaching those values observed during the GSA period, the two surveys in 1998 suggest a reversal of the freshening trend (Figure 3b).

Intermediate Waters

The most significant change occurring within intermediate waters is the recovery following the dramatic freshening event recorded in the March 1997 survey, particularly within the Modified East Icelandic Water (MEIW - formerly referred to as NI/AIW) (See Table 2). A suggestion has been put forward that this may have been the result of the 1996 Icelandic Jökulhlaup, when 3.5 km^3 of freshwater was released from the southern coast of Iceland in 3 days, following volcanic activity beneath a glacier. When we consider evidence from the Faroese Standard Section north of the Faroes, some 670 km from the source, the salinity of the intermediate water reached a minimum 75 days after the event. This gives a mean transit speed of 10.3 cm s^{-1} (Figure 9). The salinity at the Faroe Shetland Channel Sections reached a minimum 103 days after the event. These sections lie 830 km from the source and hence this suggested a slightly faster transit speed of 8.5 cm s^{-1}. This event may well represent a model for processes associated with deglaciation. Sixteen similar events have occurred since 1934, and we hope to study these events in more detail using numerical models.

Bottom Water

Salinity of Faroe Shetland Channel Bottom Water (FSCBW) showed a slight increase during 1998, although values are still well below those in the period before the freshening commenced in the mid-1970s. Temperatures remained rather low, and hence the warming seen at similar depths at OWS Mike is not a persistent feature presently in the bottom waters of the Channel.

North Sea

In the North Sea the salinity variability in the past has been well correlated with that of NAW, with a possible 1 year lag. Certainly the min-max-min-max-min cycle since 1977 is very evident, in both salinity and temperature. During 1997 the salinity of mixed oceanic water flowing into the North Sea within the Fair Isle Current (Fair Isle Current Water - FICW) demonstrated the salinity rise seen in NAW since 1994 (Figure 7). The cool period previously noted in the mid-1990s was terminated by the onset of a rapid warming since 1994. The high temperatures observed in 1997 were not evident in the 1998 survey.

The properties of Cooled Atlantic Water (CAW), which typifies water lying within the central northern North Sea below the seasonal thermocline, may be more closely tied to those of NAW (Figure 8). Hence CAW demonstrates the gradual warming seen in NAW since 1970, and also exhibits the cyclic features seen in NAW and FICW since 1977. The freshening previously noted in CAW has stopped, and salinities are now increasing, again tracking those of NAW, but with an approximate 1 year lag. The very cool anomaly obtained from the single 1998 survey should be viewed with some caution.

Table 1. Characteristic θ and S of different surface water masses during 1995–1998. Values are anomalies after the seasonal cycle has been removed (See text for explanation).

	NAW		MNAW	
	θ (°C)	S	θ (°C)	S
Jun 96	0.64	0.055	-0.26	0.003
Oct 96	-0.23	0.069	-0.86	-0.028
Mar 97	0.26	0.030	-0.03	-0.060
May 97	n/a	n/a	n/a	n/a
Oct 97	-0.17	0.073	-0.94	-0.011
Mar 98	1.61	0.072	0.18	-0.037
Oct 98	-0.40	0.121	-0.77	0.031
Dec 98	0.62	0.108	2.06	0.210

Table 2. Characteristic θ and S of different intermediate water masses during 1995 - 1998. Values have been obtained manually from θS diagrams and not using the automated methods described above.

	MEIW (AI/NIW)				NSAIW			
	Nolso Flugga		Fair Isle Munken		Nolso Flugga		Fair Isle Munken	
	θ (°C)	S	θ (°C)	S	θ (°C)	S	θ (°C)	S
Jun 96	3.49	34.941	3.42	34.903	0.05	34.892	-0.04	34.892
Oct 96	3.17	34.898	3.02	34.933	-0.12	34.888	0.13	34.887
Mar 97	2.82	34.857	3.28	34.847	-0.29	34.889	-0.55	34.899
Oct 97	2.27	34.866	2.31	34.869	-0.27	34.885	-0.30	34.891
Mar 98	1.64	34.887	2.33	34.896	-0.25	34.887	0.21	34.884
Oct 98	n/a	n/a	2.51	34.910	n/a	n/a	0.21	34.887
Dec 98	n/a	n/a	2.71	34.928	n/a	n/a	-0.04	34.896

Table 3. Characteristic θ and S at three pressure levels during 1995–1998. Values have been obtained using the automated methods described above.

	800 dbar		1000 dbar		1100 dbar	
	θ (°C)	S	θ (°C)	S	θ (°C)	S
Jun 96	-0.52	34.908	-0.76	34.916	-0.79	34.916
Oct 96	-0.61	34.904	-0.77	34.909	-0.79	34.911
Mar 97	-0.38	34.898	-0.70	34.906	-0.72	34.906
Oct 97	-0.60	34.901	-0.75	34.907	-0.70	34.907
Mar 98	-0.51	34.899	-0.74	34.907	-0.71	34.907
Oct 98	-0.64	34.902	-0.82	34.909	n/a	n/a
Dec 98	-0.55	34.906	-0.83	34.914	n/a	n/a

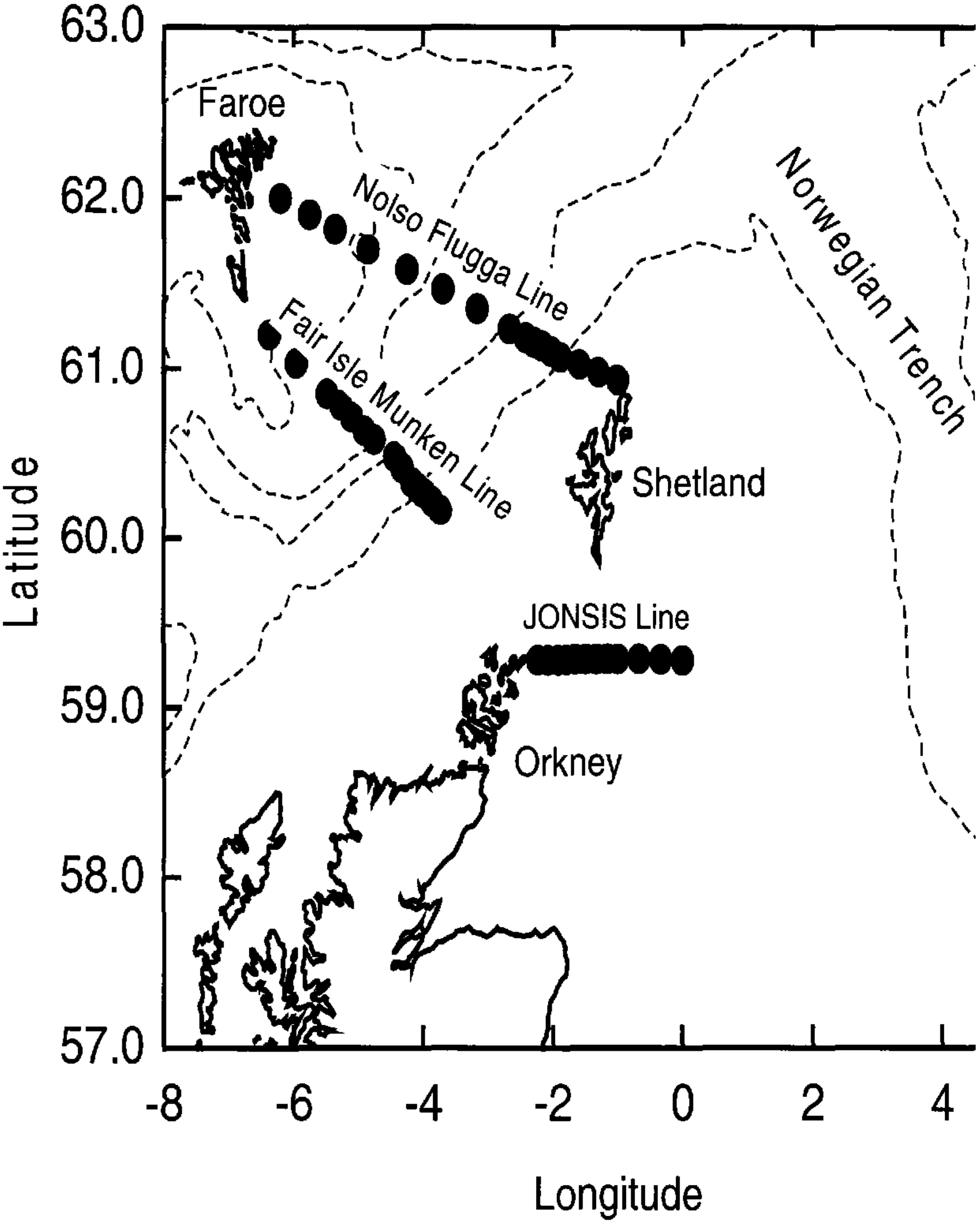

63.0
62.0
61.0
60.0
59.0
58.0
57.0
Latitude
-8
-6
-4
-2
0
2
4
Longitude
Faroe
Nolso Flugga Line
Fair Isle Munken Line
Norwegian Trench
Shetland
JONSIS Line
Orkney

Figure 1

Figure 2

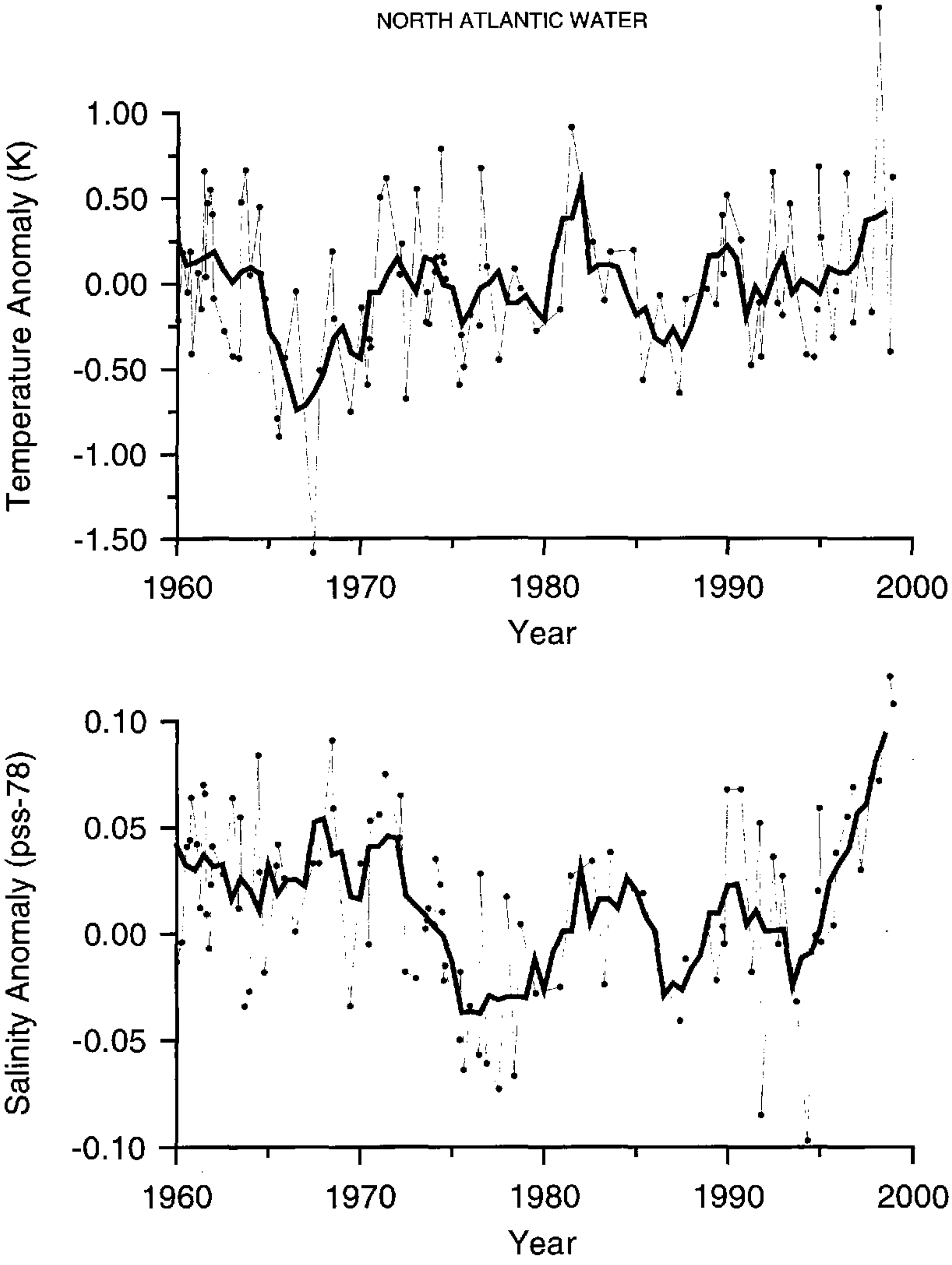

NORTH ATLANTIC WATER
Temperature Anomaly (K)
1.00
0.50
0.00
-0.50
-1.00
-1.50
1960
1970
1980
1990
2000
Year
Salinity Anomaly (pss-78)
0.10
0.05
0.00
-0.05
-0.10
1960
1970
1980
1990
2000
Year

Figure 2b

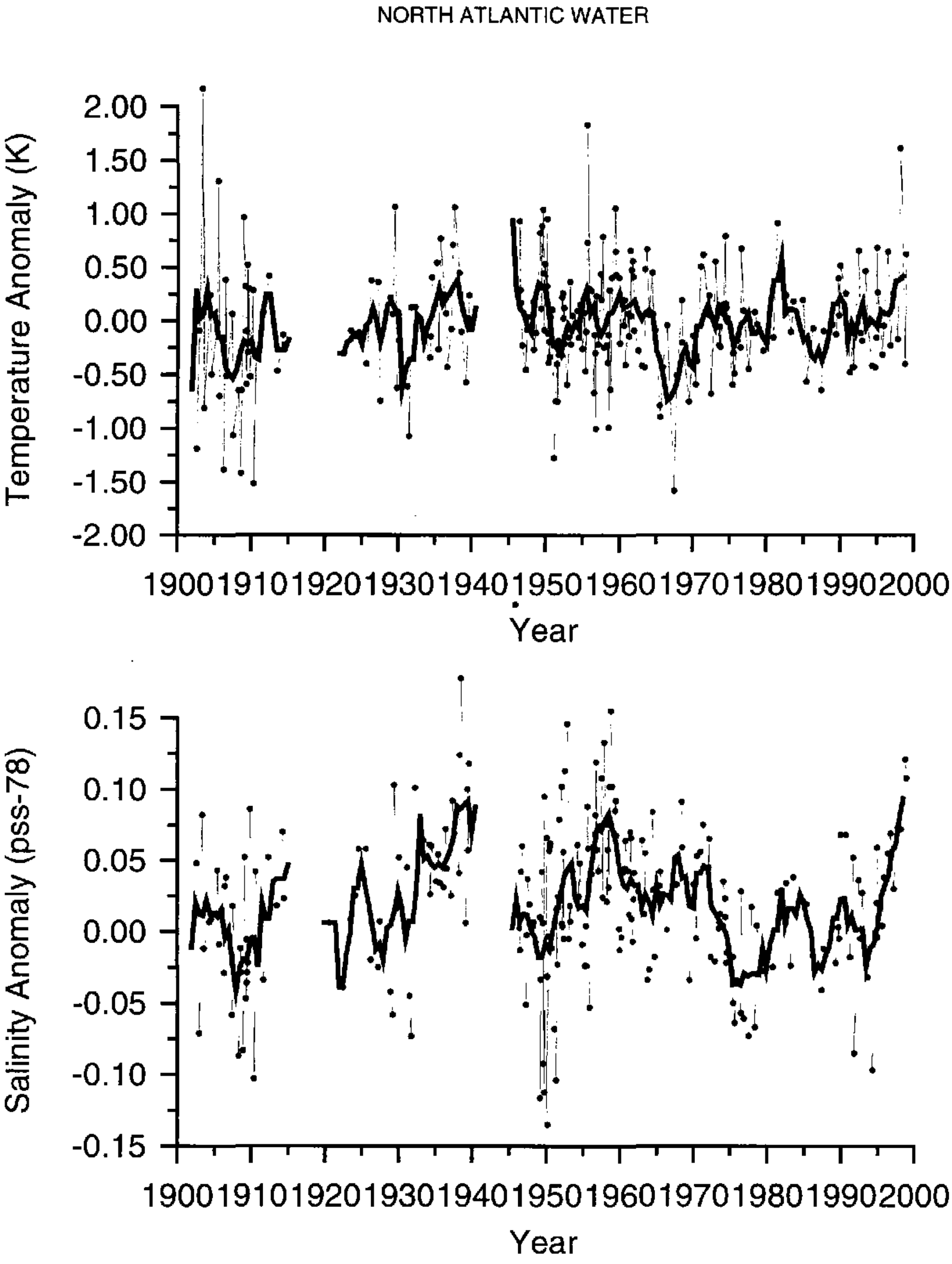
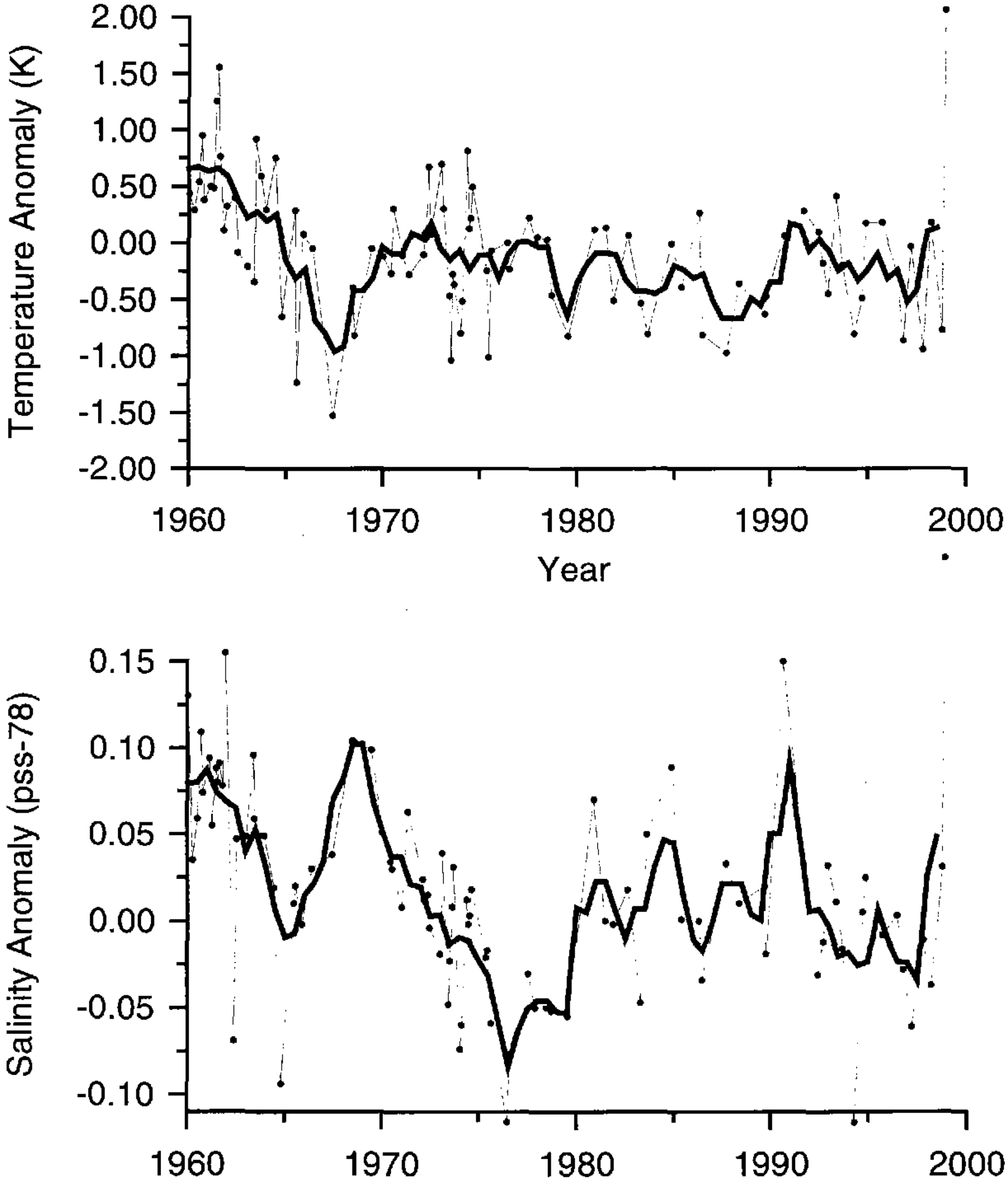

NORTH ATLANTIC WATER
Temperature Anomaly (K)
2.00
1.50
1.00
0.50
0.00
-0.50
-1.00
-1.50
-2.00
1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000
Year
Salinity Anomaly (pss-78)
0.15
0.10
0.05
0.00
-0.05
-0.10
-0.15
1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000
Year

Figure 3



MODIFIED NORTH ATLANTIC WATER

Figure 3b

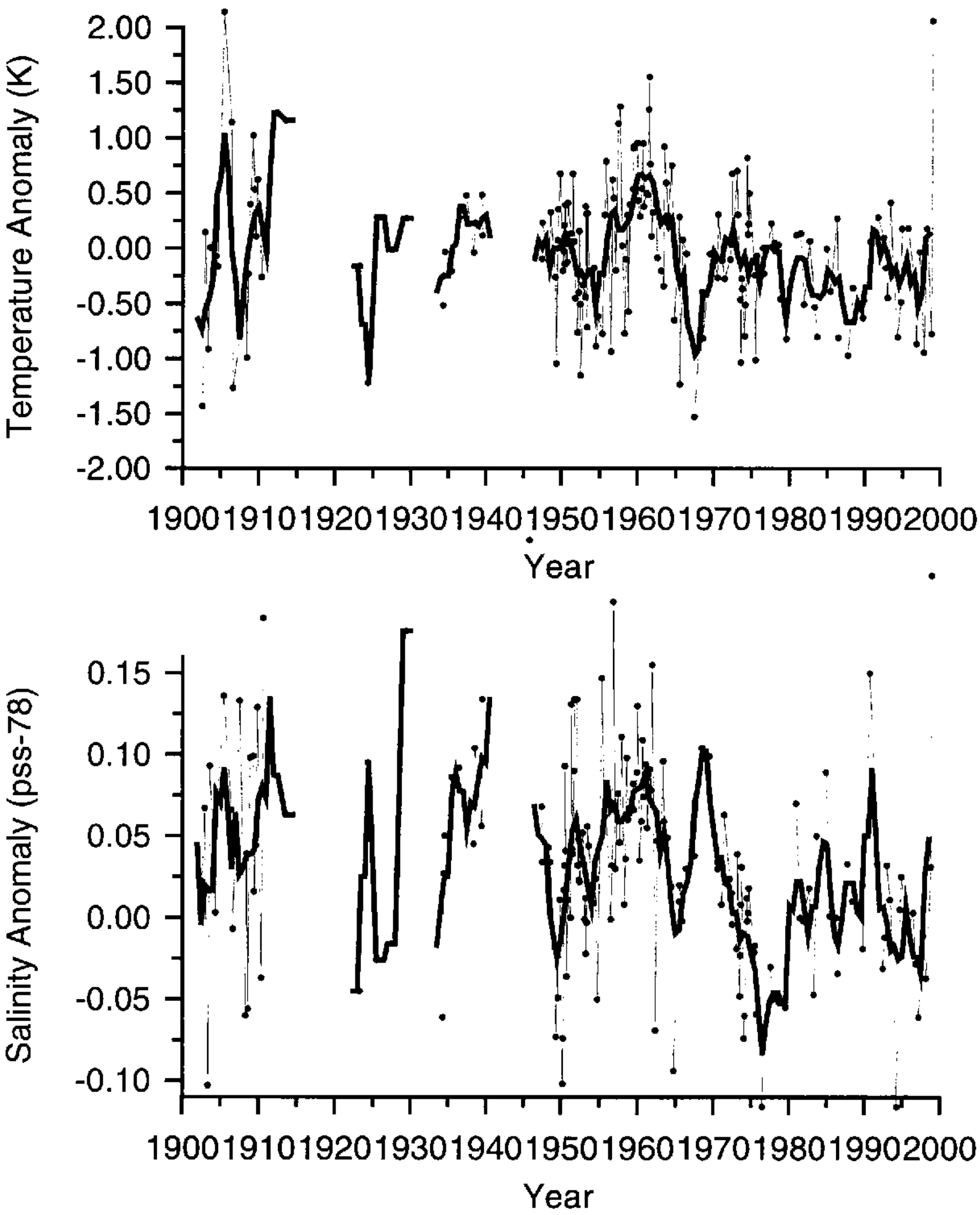

MODIFIED NORTH ATLANTIC WATER

Figure 4

FAROE SHETLAND CHANNEL BOTTOM WATER - 800 dbar

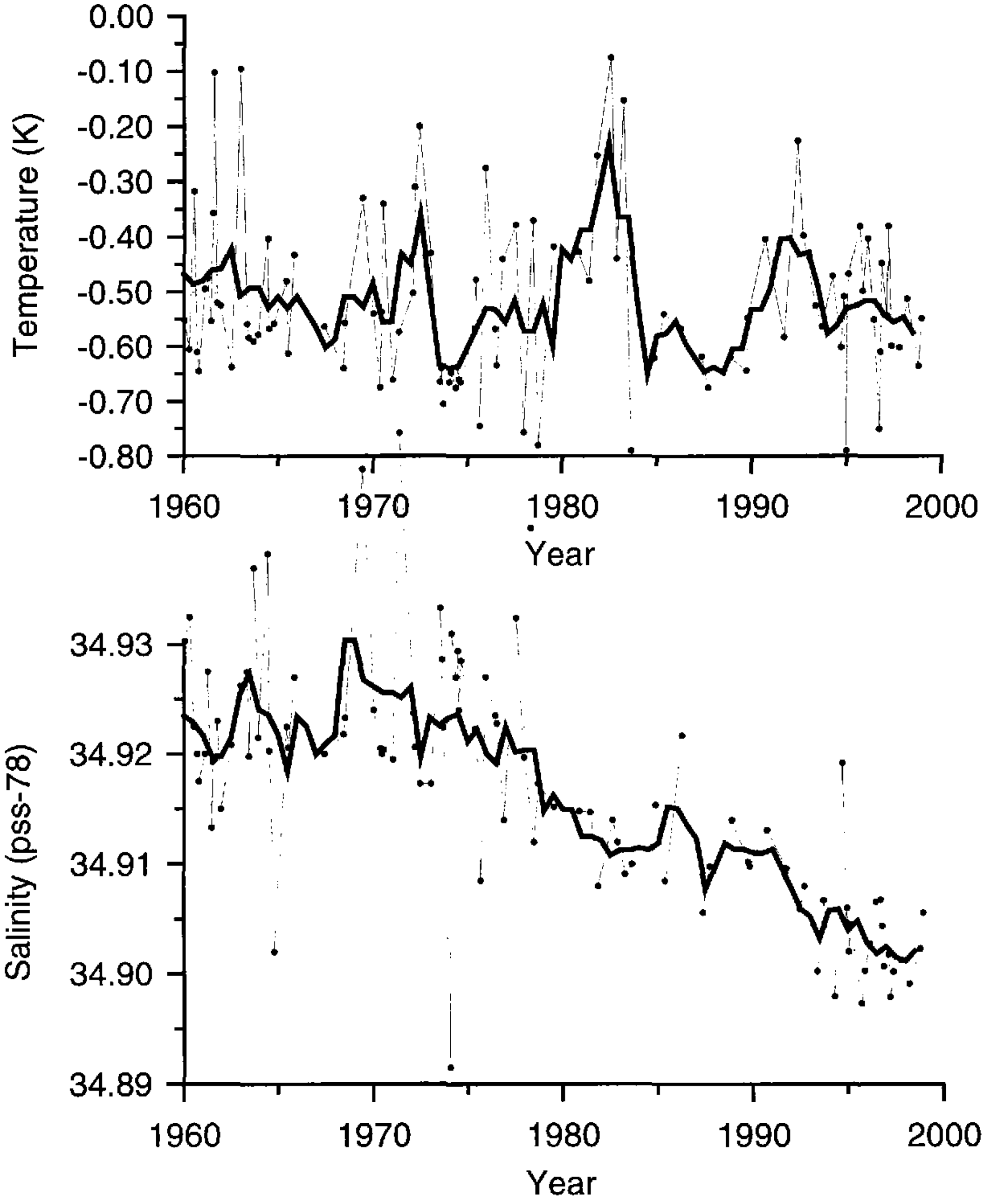


Figure 5

FAROE SHETLAND CHANNEL BOTTOM WATER - 1000 dbar

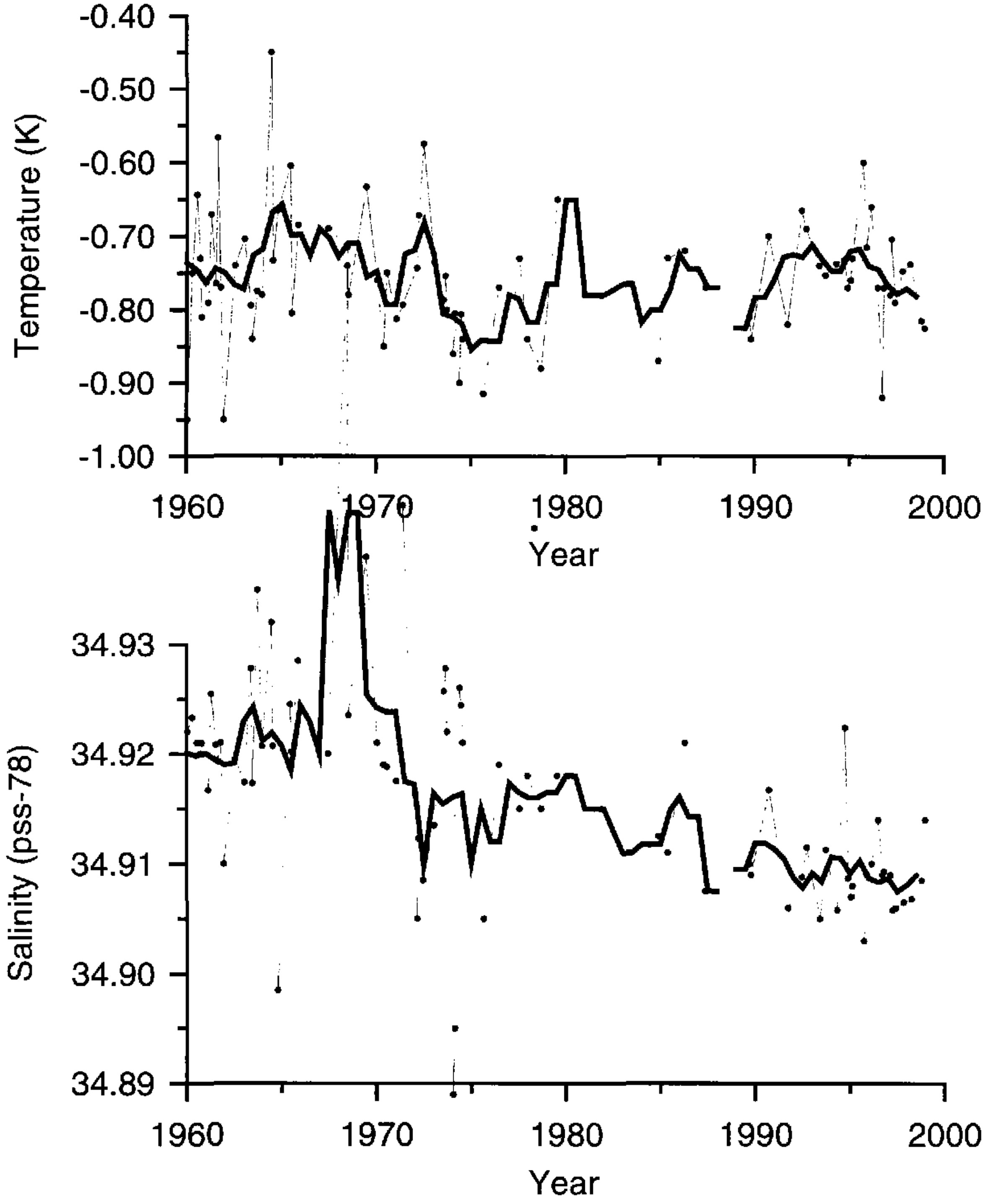


Figure 6

FAROE SHETLAND CHANNEL BOTTOM WATER - 1100 dbar

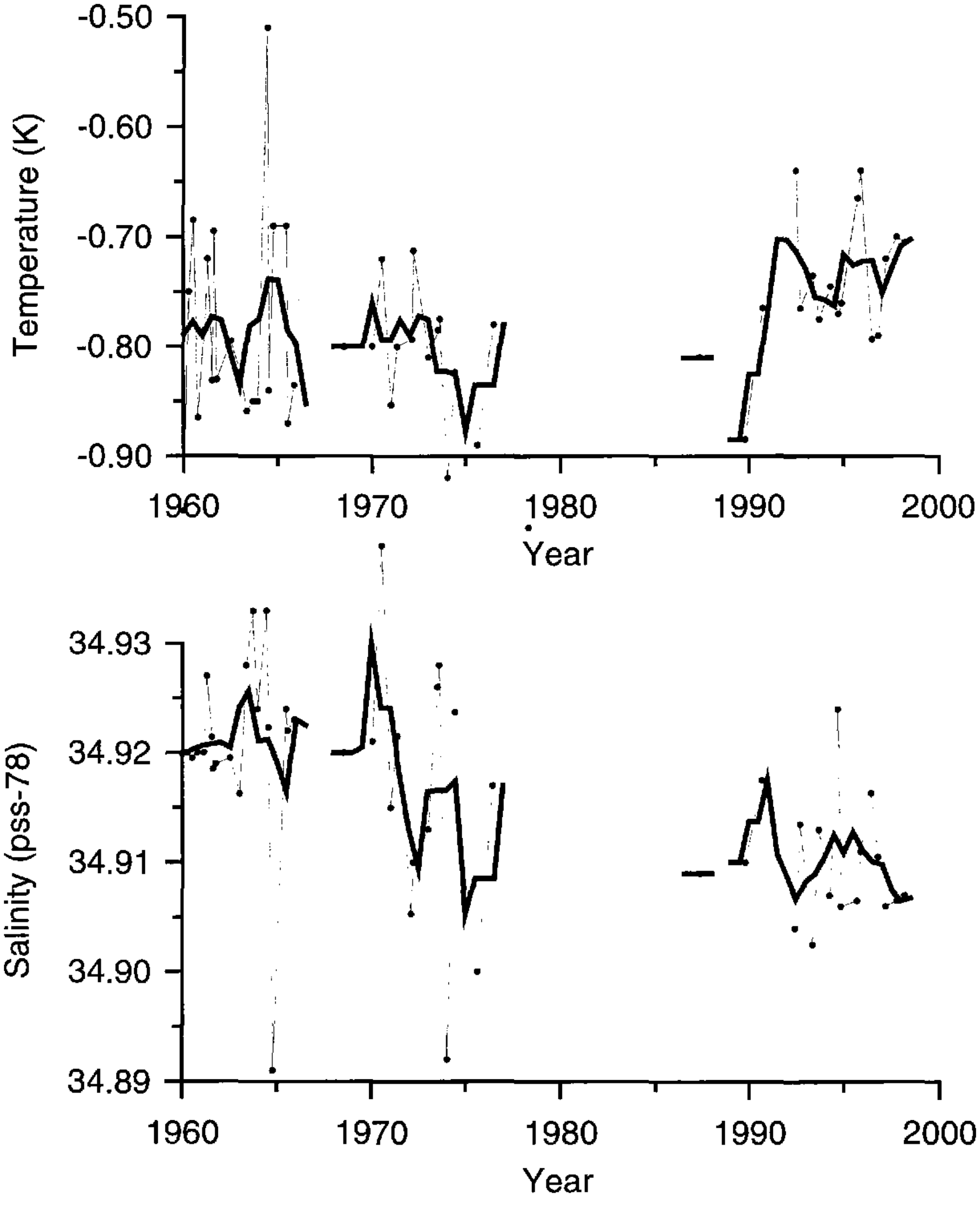


Figure 7

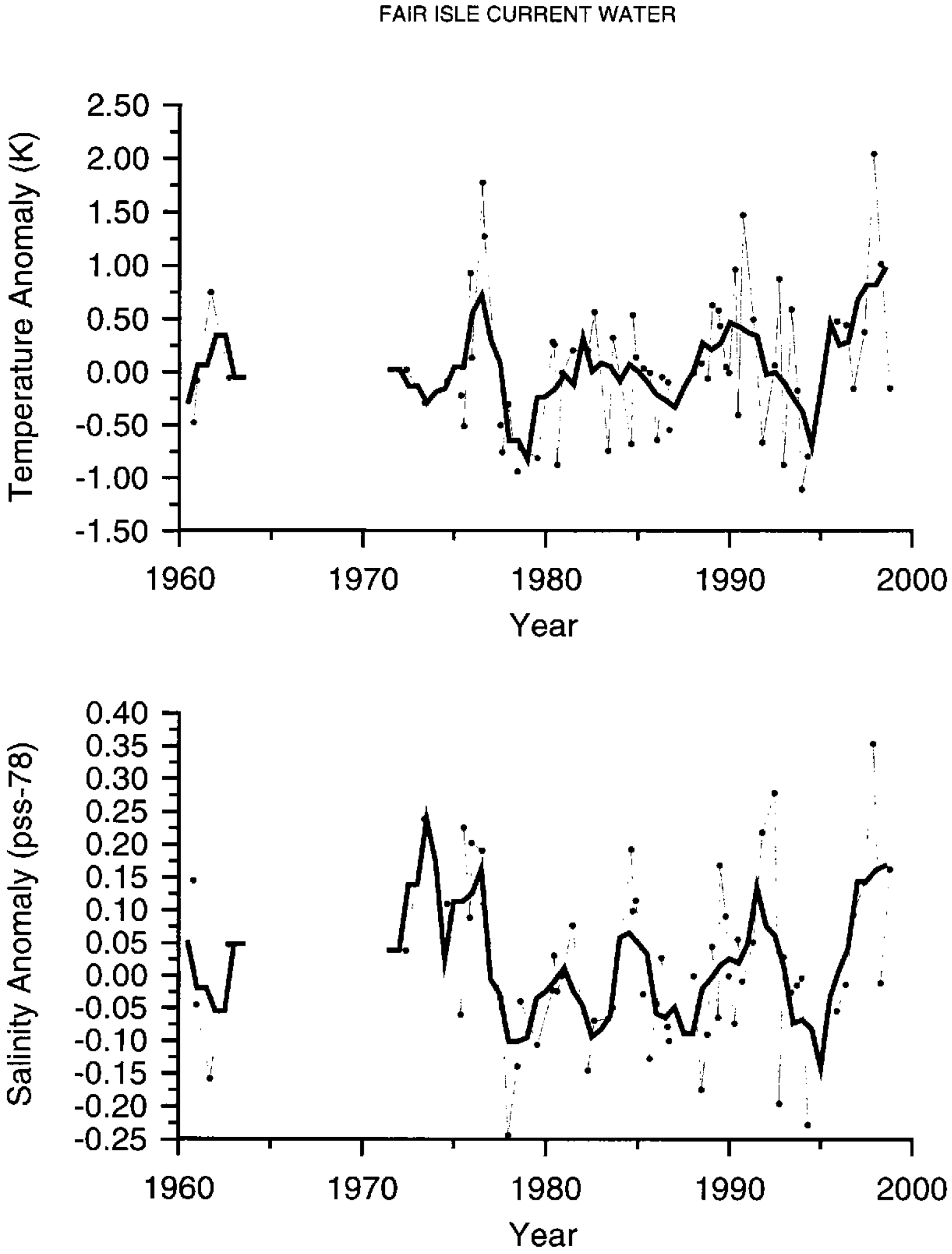

FAIR ISLE CURRENT WATER
Temperature Anomaly (K)
2.50
2.00
1.50
1.00
0.50
0.00
-0.50
-1.00
-1.50
1960
1970
1980
1990
2000
Year
Salinity Anomaly (pss-78)
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
-0.10
-0.15
-0.20
-0.25
1960
1970
1980
1990
2000
Year

Figure 8

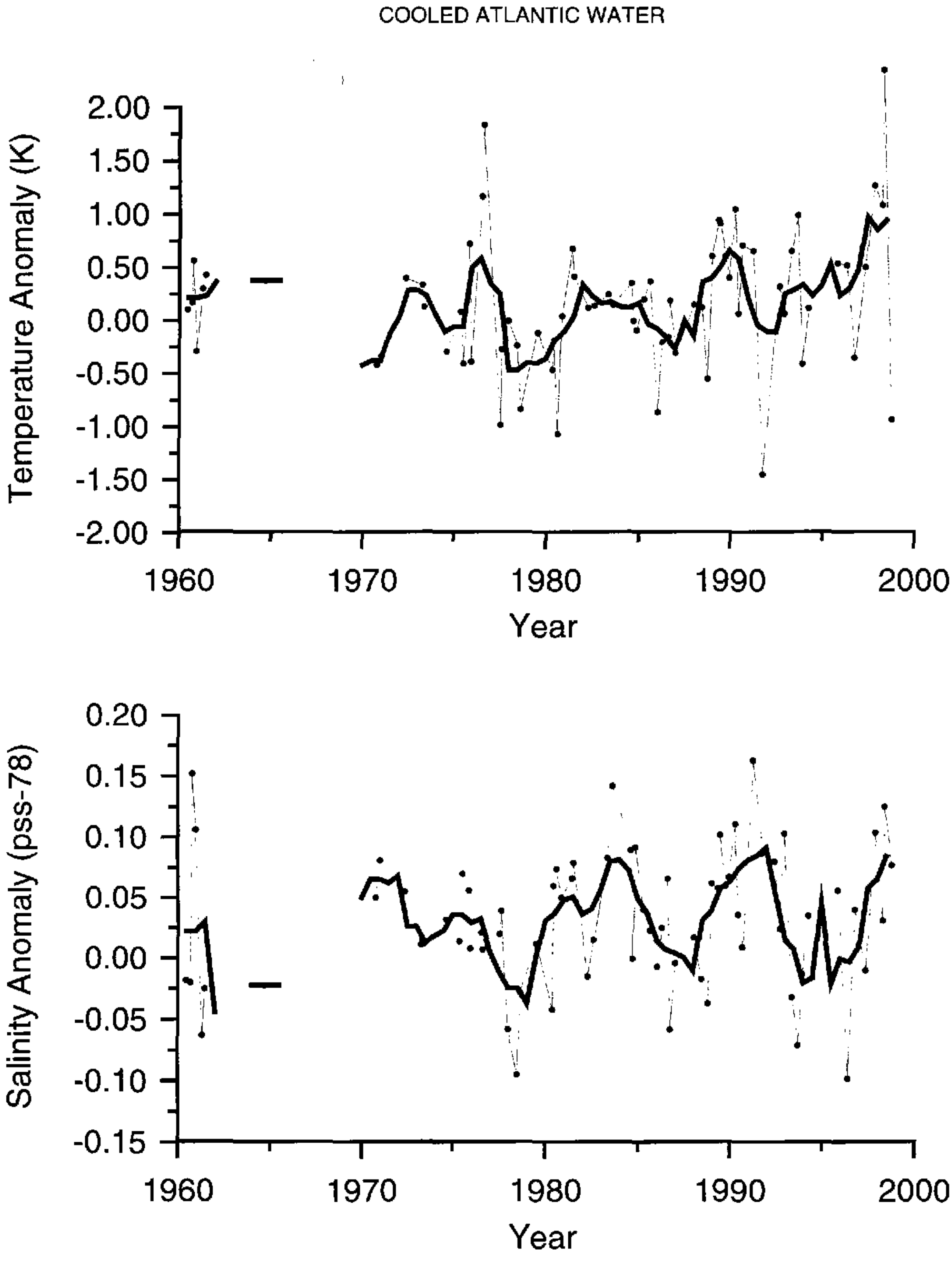
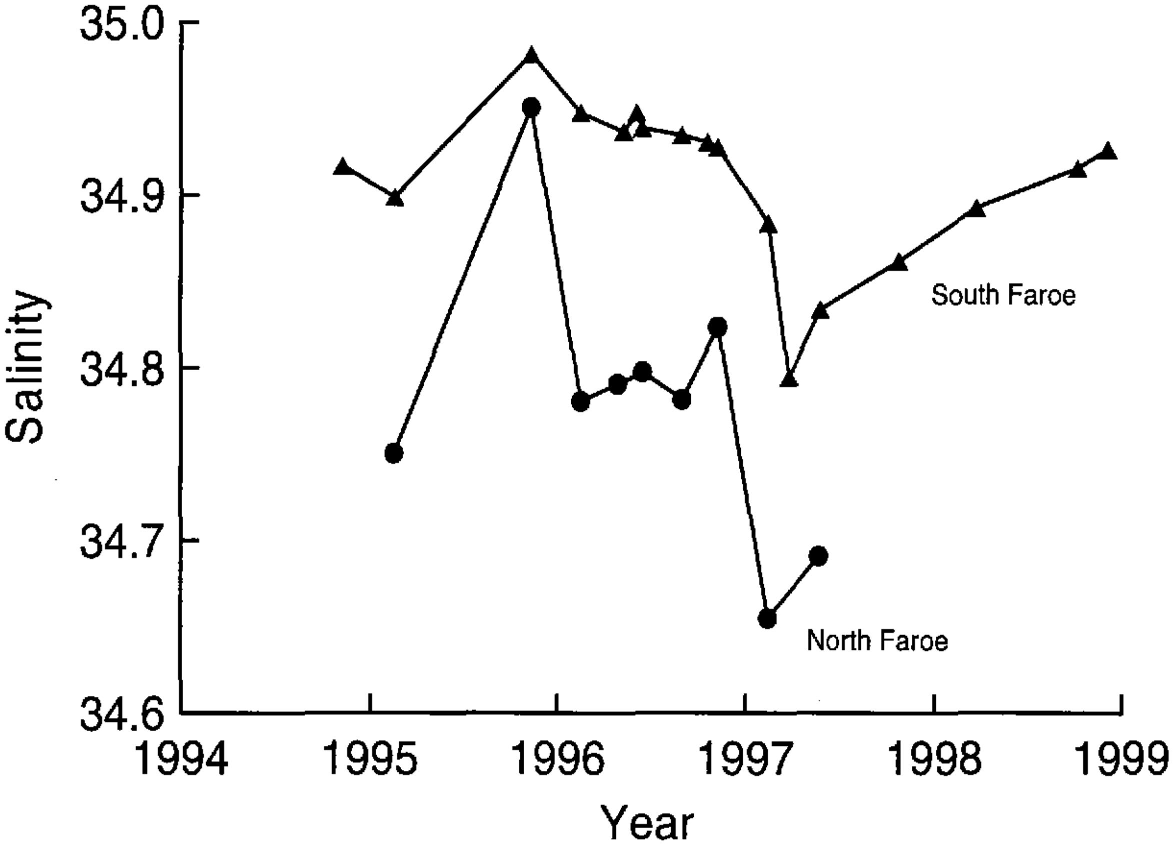

COOLED ATLANTIC WATER
Temperature Anomaly (K)
2.00
1.50
1.00
0.50
0.00
-0.50
-1.00
-1.50
-2.00
1960
1970
1980
1990
2000
Year
Salinity Anomaly (pss-78)
0.20
0.15
0.10
0.05
0.00
-0.05
-0.10
-0.15
1960
1970
1980
1990
2000
Year

Figure 9

Salinity of MEIW



Annex L – Rockall Trough Standard Sections

N. Penny Holliday, Southampton Oceanography Centre, UK

1. HYDROGRAPHIC DESCRIPTION

The Rockall Trough is situated west of the British Isles and separated from the Iceland Basin by the Hatton and Rockall Banks and from the Nordic Seas by the shallow (500m) Wyville-Thompson Ridge. It is one pathway by which warm North Atlantic Upper Water reaches the Norwegian Sea and is converted into cold dense overflow water as part of the thermohaline overturning in the North Atlantic. The upper water column is characterised by poleward moving Eastern North Atlantic Water (ENAW) which is warmer and saltier than the subpolar mode waters of the Iceland Basin, which also contribute to the Nordic Sea inflow. Below 1200m the deep Labrador Sea Water (LSW) is trapped by the shallowing topography to the north which prevents through flow but allows recirculation within the basin.

2. GENERAL 1998 SYNOPSIS

The occupation of the Anton Dohrn Seamount Standard Section in May revealed 1998 to be an extreme year in terms of the water mass properties and volume transports in the upper ocean. The ENAW was unusually warm and saline and moving through the region at a rapid pace, both in the Scottish shelf edge current and in the interior of the basin. The deep reservoir of LSW was observed to be continuing its slow cyclonic recirculation with gradually increasing salinity through vertical mixing.

3A.1 UPPER OCEAN SALINITY - 1998

The upper ocean salinity reached a high in 1998 with a maximum of 35.475 in the western Rockall Trough and the Scottish shelf edge current. The anomaly from the long-term seasonal mean was the highest seen in the time series (0.05).

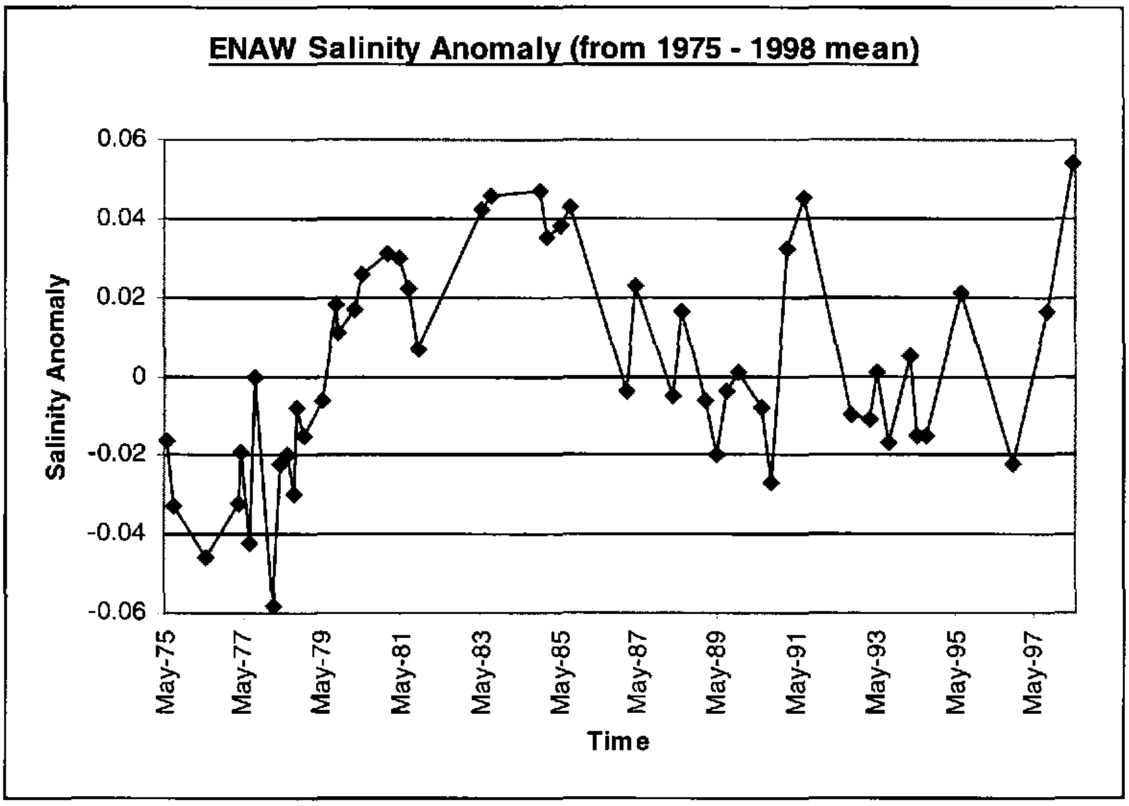


Figure 1. ENAW salinity anomaly (from 1975-1998 mean) on isopycnal 27.36 with seasonal cycle removed.

3A.2 UPPER OCEAN SALINITY - TREND

Since the low salinity period in the mid-1970's and the prolonged high salinity of the early 1980's, the anomaly pattern has fluctuated around a mid-point with a period of less than 5 years and with saline peaks in 1991 and 1998.

3B.1 DEEP SALINITY - 1998

The freshest water in core of the LSW was 34.940 in May 1998, continuing the recent trend of increasing salinity due to mixing with the ENAW and bottom water (Figure 2).

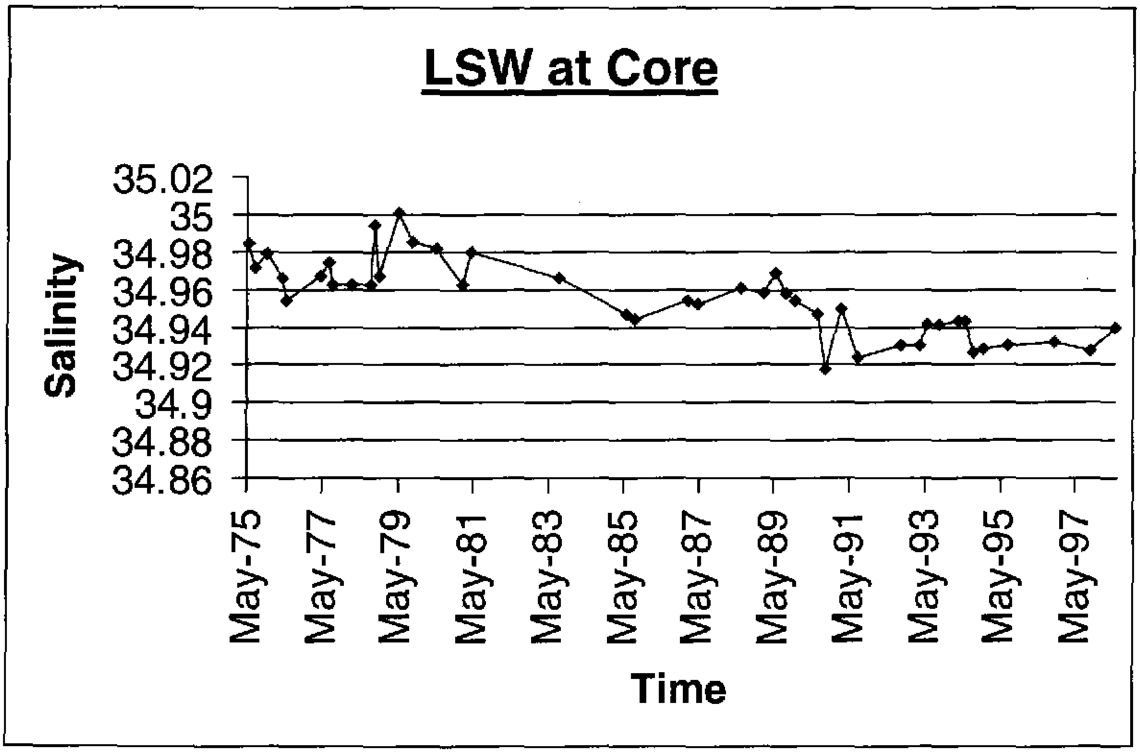


Figure 2. LSW at core (defined by PV minimum).

3B.2 DEEP SALINITY TREND

The LSW has experienced a mean freshening over the period of the time series as a result of two short-lived freshening events (1983-85 and 1990-91) separated by gradually increasing salinity.

4. 1998 EXTREME EVENTS

High baroclinic transport of nearly 8 Sv northward of unusually saline and warm ENAW in May 1998 means the throughflow of heat and salt was higher in 1998 than previous flux peak periods in 1980 and 1988-89.

Annex M – Norwegian and Barents Seas Sections

J. Blindheim and H. Loeng, Institute of Marine Research, Bergen, Norway

Barents Sea

The Barents Sea is a shelf sea, receiving an inflow of Atlantic Water from the west. The inflow demonstrate considerable seasonal and interannual fluctuations in water mass properties, particularly in heat content and consequently ice coverage.

After a period with high temperature in the first half of this decade, the temperature in the Barents Sea dropped to values slightly below the long term average over the whole area in 1996 and 1997 (except March 1997). From March 1998, the temperature in the western area increased to just above the average (Figure1), while the temperature in the eastern areas stayed below the average during 1998. The high temperature observed upstream in the Atlantic Current arrived at the western entrance of the Barents Sea between October 1998 and January 1999 when the temperature raised by more than half a degree. This increase was to a less degree also observed in the central part, while the temperature in the eastern part still stayed low. The increased temperature was also followed by increased salinity (Figure 2). The present temperature conditions are reflected in the ice conditions with little ice in the western area and severe ice conditions in the eastern areas of the Barents Sea.

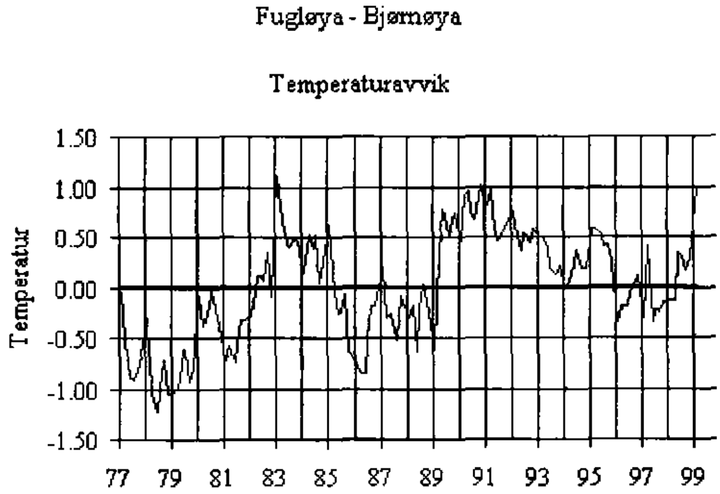


Figure 1: Temperature

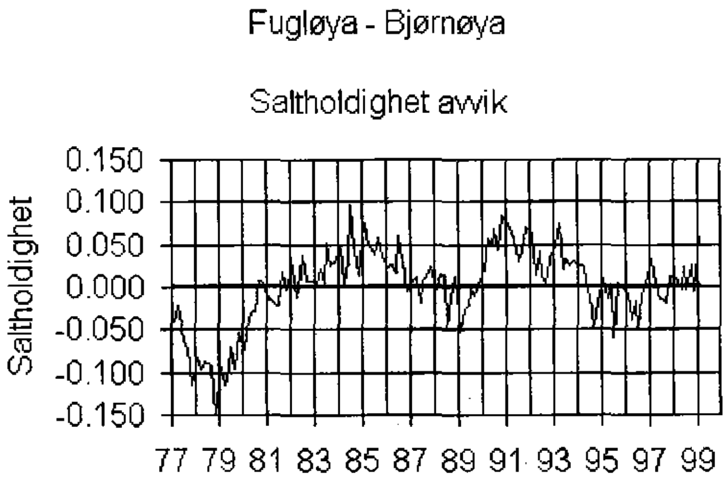


Figure 2: Salinity

Norwegian Sea

The considerable temperature increase in the southeastern Norwegian Sea during 1997 continued also in 1998. As a result, the 50 - 200 m mean off the shelf break was 1.5°C higher in August 1998 than in August 1996. This large temperature increase seems yet to have affected only the southeastern Norwegian Sea. A similar increase was observed off the Lofoten Islands, but it was less further west and further north temperatures have remained close to the mean since 1996. The general trend since the late 1970s is, however, a warming along the continental margin from the southeastern Norwegian Sea to Spitsbergen.

Although there has been a general increase in salinity in the southeastern Norwegian Sea since 1992, there was a decrease from 1997 to 1998. In most of the Norwegian Sea, salinities have been declining since the early 1980s. Probably, this is a result of persistent wind-driven supply of fresh water from the East Icelandic Current.

The central and northern Norwegian Sea has experienced an overall warming since 1978, probably due to mild winters and increased vertical stability associated with freshening of the surface waters. The multi-year variability is correlated with the wind forcing (NAO).

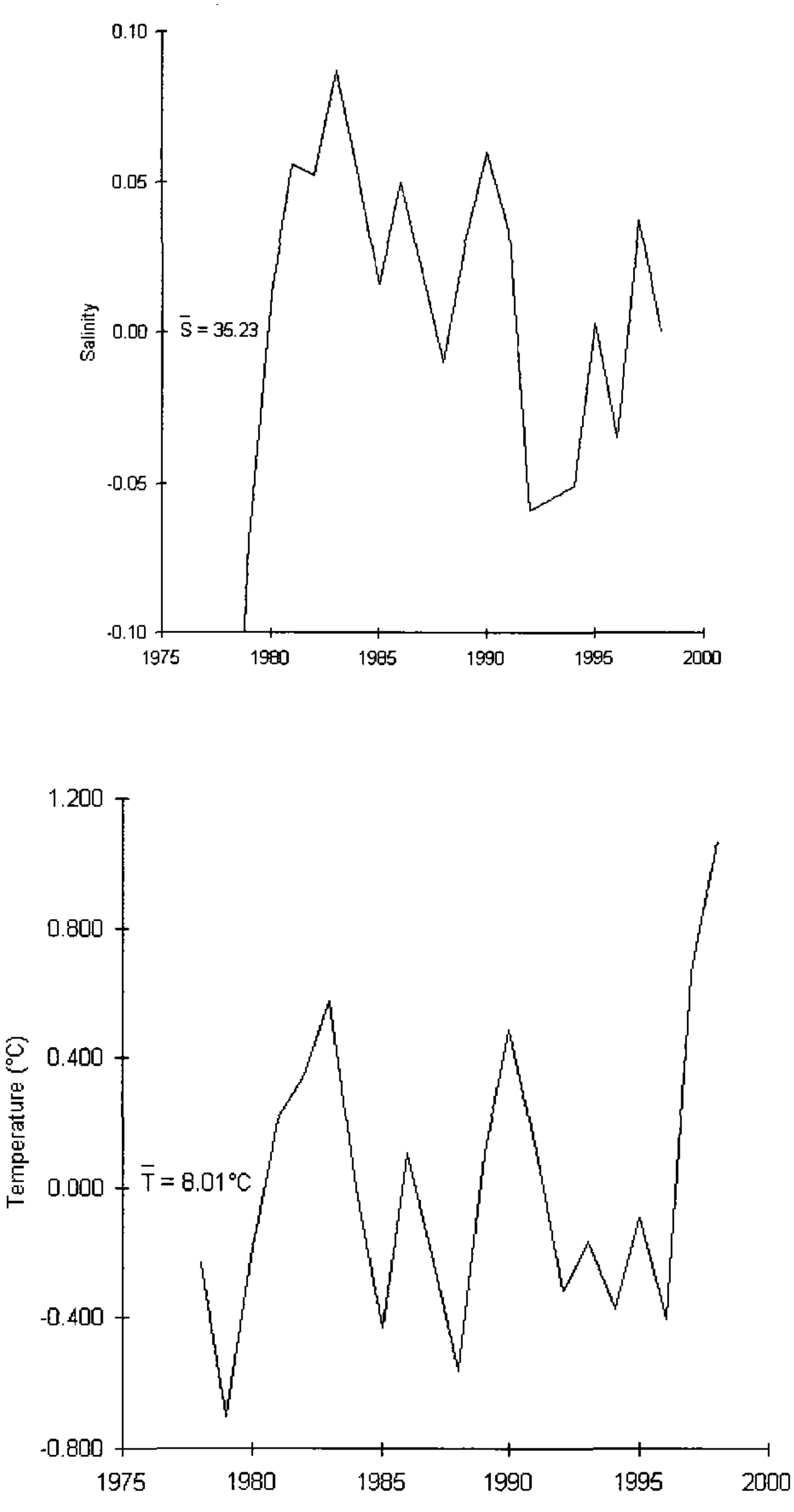


Figure 3. Temperature and salinity anomalies at the Svinøy Section in the Norwegian Sea.

Annex N – Russian Standard Sections

Hydrographic Conditions in the Barents and Norwegian Seas in 1998

V. Ozhigin, PINRO, Murmansk. Russia

PINRO carried out hydrographic observations only in the Barents and Norwegian Seas in 1998. These observations were made both along the standard sections and on an irregular grid. Station positions are shown in Fig. 1. Most stations were made by research vessels (crosses). The rest were made by research-fishing vessels (dots). The total number of stations was 1652.

The Barents Sea

Hydrographic conditions in the Barents Sea in 1998 were determined by low temperature in the southeastern sea and increased temperature in the western part of the sea. The temperature in the western Barents Sea was just above the long-term average for most of 1998. In the Kola Section (Fig. 2) temperature increased in comparison with 1997, but remained lower than the average. A significant increase of temperature occurred in December 1998 --February 1999. It is expected that the temperature increase will be temporary in the southern Barents Sea, and the year 1999 will be a moderately warm year.

The Norwegian Sea

The standard sections occupied by PINRO research vessels in the Norwegian Sea are shown in Fig. 3. These sections have been occupied in June of every year since 1959.

In 1998 the temperature in the 0-200 m layer of the Eastern Branch of the Norwegian Current increased in both Sections 6C and 7C in comparison with 1997, and was higher than normal (Fig. 3a). The temperature in the central Norwegian Sea (Fig. 3b) remained lower than the long-term average, but this trend was opposite (decreasing in Section 6C and increasing in Section 7C). The decreasing trend was probably caused by the influence of the East-Icelandic Current.

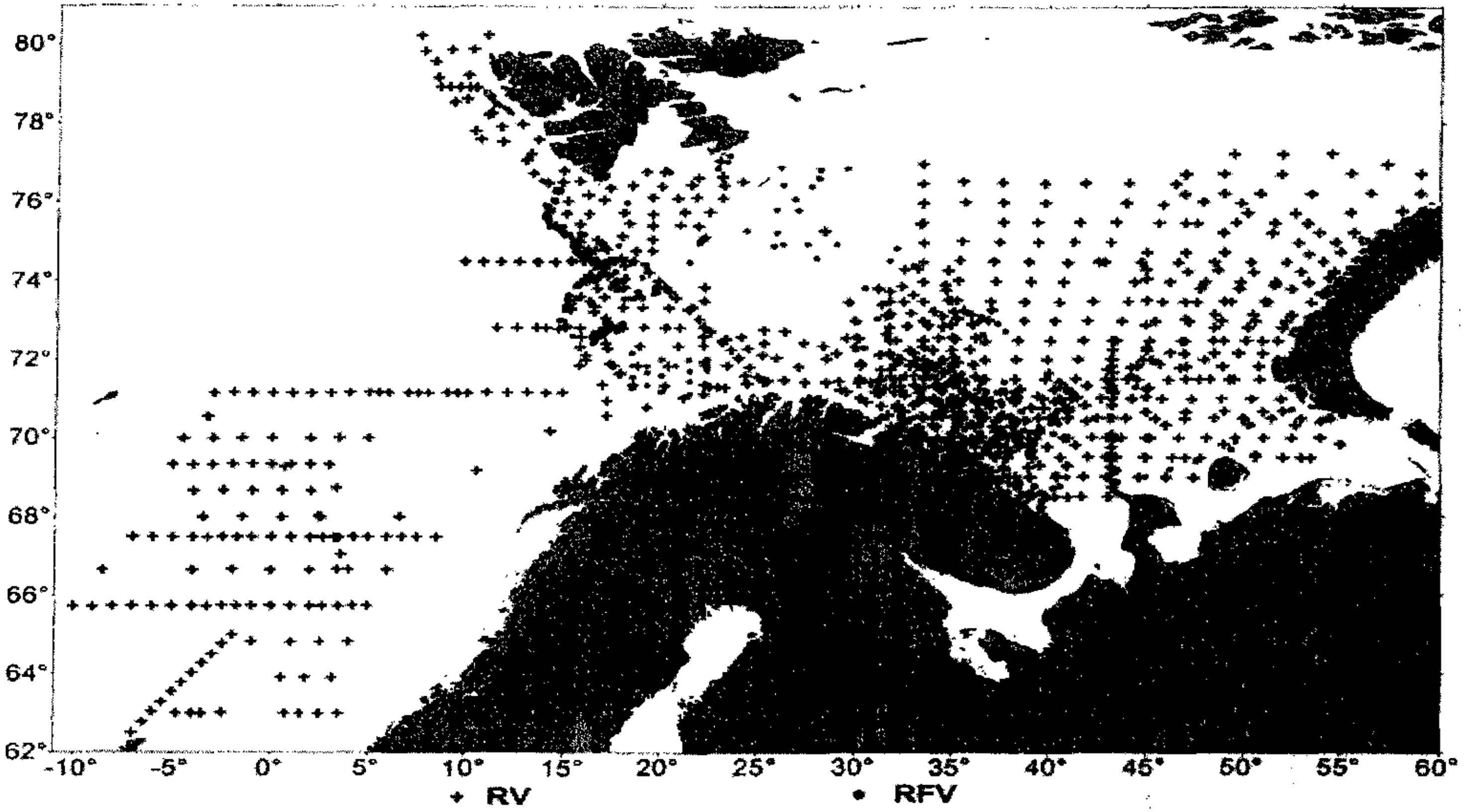
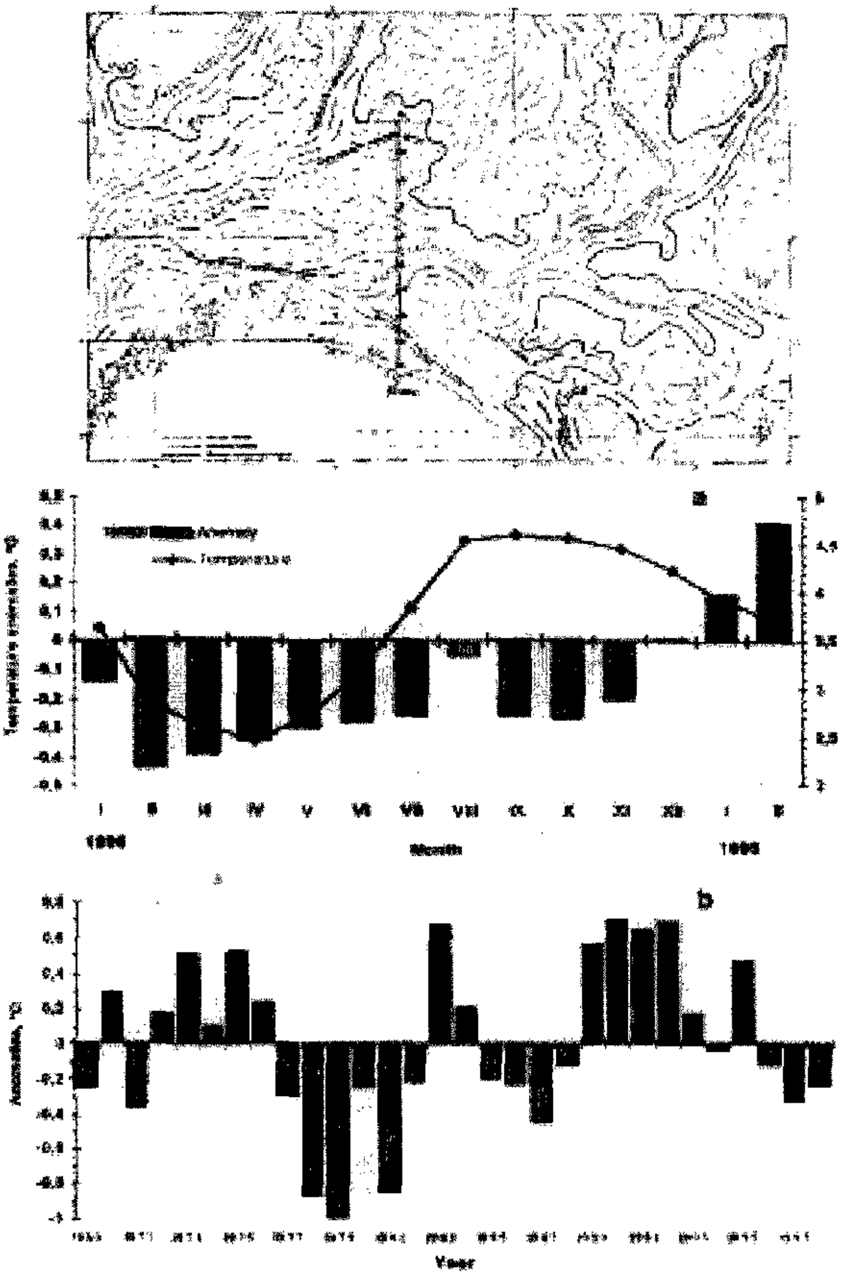


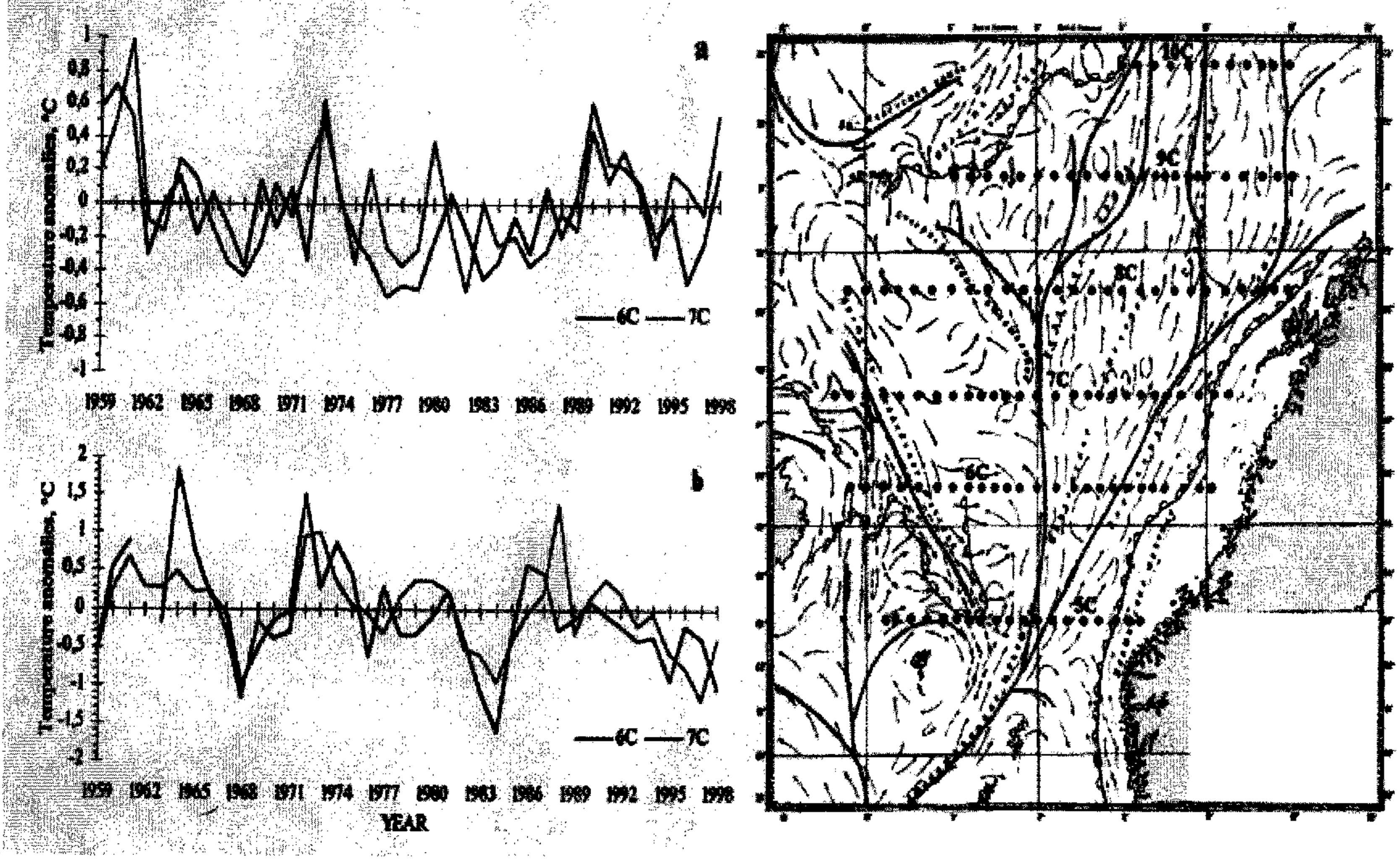
Chart of hydrographic stations made by PINRO in 1998 (1652 stations)



Mean monthly water temperature and its anomalies in the 0-200 m layer in 1998-1999 (a), the anomalies of annual mean temperature in the 0-200 m layer in the Murman Current Main Branch along **Kola Meridian** Section in 1969-1998 (b).

Positions of stations of the Kola Meridian Section are shown separately.

Temperature anomalies of Atlantic Waters of the Norwegian Current's East Branch (a) and Norwegian Sea mixed waters (b) in the 0 - 200 m layer in Sections 6C and 7C in June 1959 – 1998: Positions of oceanographic sections are shown separately on the pattern of the Norwegian Sea surface currents (Alekseev and Istoshin, 1956)



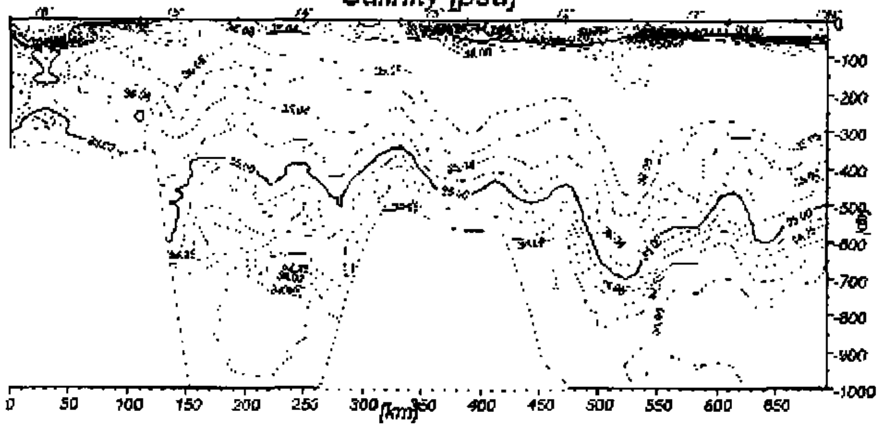
Annex O – Polish Contribution: Norwegian – Barents Sea opening

Jan Piechura, Institute of Oceanology, Sopot, Poland

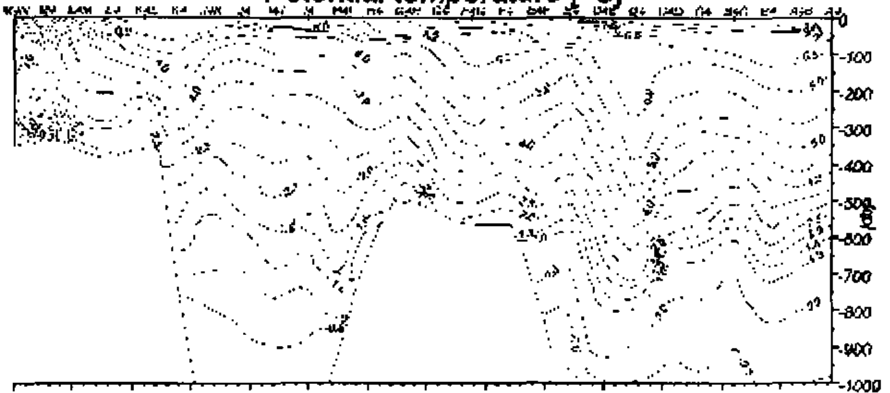
- **Hydrography:** One of the two main areas of intensive exchange processes between the Nordic Seas and the Arctic Ocean. The strong (3-5 Sv) Nordcap Current carries Atlantic Water to the Barents Sea, and somewhat weaker streams of Barents Sea Water and Polar Water come in the reverse direction.
- **1998 Synopsis:** Weather conditions during measurements (end of June) were very good (variable wind of low speed, 1-10°C air temperature). Area to the north of Bear Island was covered by drifting sea ice. Out going (towards the Barents Sea) geostrophic transport in the upper 1000 m layer was a bit over 3 Sv and was lower than in the previous year (4.4 Sv) and higher than the decadal mean. Dense winter water, of brine origin, $S = 34.99$, $t = -1.48°C$, $\gamma_t = 28,16$, was observed at one station on the continental slope in the 300-340 m layer.
- **Surface temperature:** From 8°C off the Norwegian Coast to 3°C in the Soerkapp region, mean value 6.92°C, which was higher than during last two years but lower than in summers of 1993 & 1995
- **Surface salinity:** From 34.40 in the Soerkapp area, 34.60 close to the Norwegian Coast to 35.04 in the Kveitehola Canyon. Mean surface salinity of 34.71 was low, lower than in any previous year except 1997 (34.69). Decreasing mean surface salinity has been observed since 1995.
- **Bottom temperature:** As not all measurements reached bottom, data from the 1000 to 1500 m layer are presented instead. In average, summer 1998 data showed low temperatures (-0.79°C). Temperatures here have remained low since 1996, the highest value (–0.69°C) was observed during summer 1995.
- **Bottom (layer 1000-1500 m) salinity:** In average, 34.93 was lower than 1993 & 1994, but a bit higher than 1995.
- **Depth Mean Temperature:** 1.68°C was the lowest observed, steadily decreasing since 1994.
- **Depth mean salinity:** 34.96, higher than 1997, but lower than 1993 – 1996. No extreme events were observed.

AREX'98 Transect 15°E

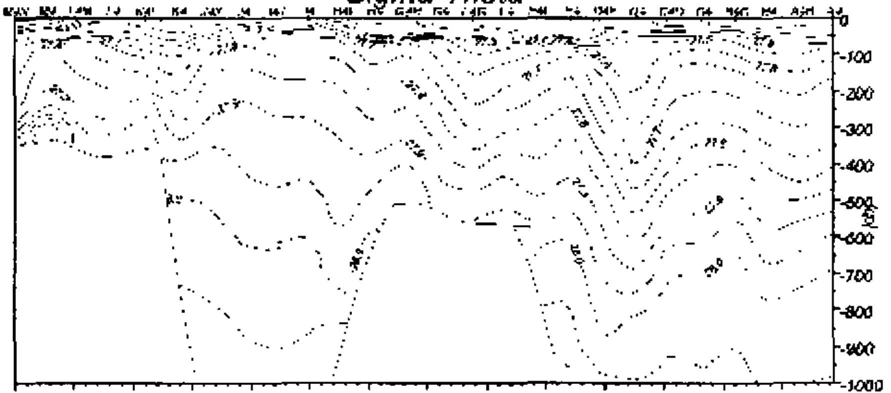
Salinity [psu]



Potential temperature [°C]



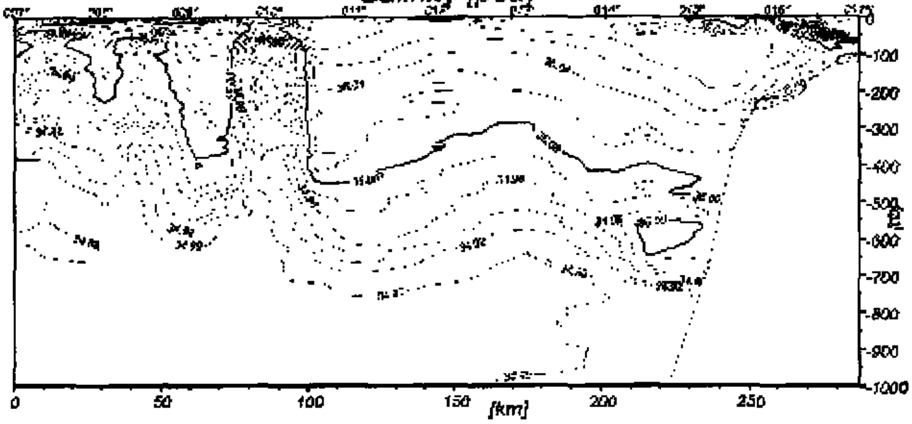
Sigma-Theta



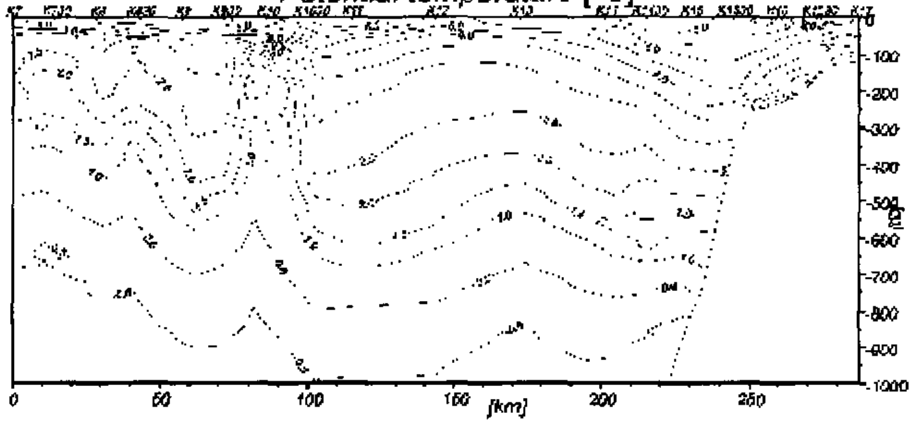
AREX'98 Narwegian-Atlantic Current

Transect 75°00'N

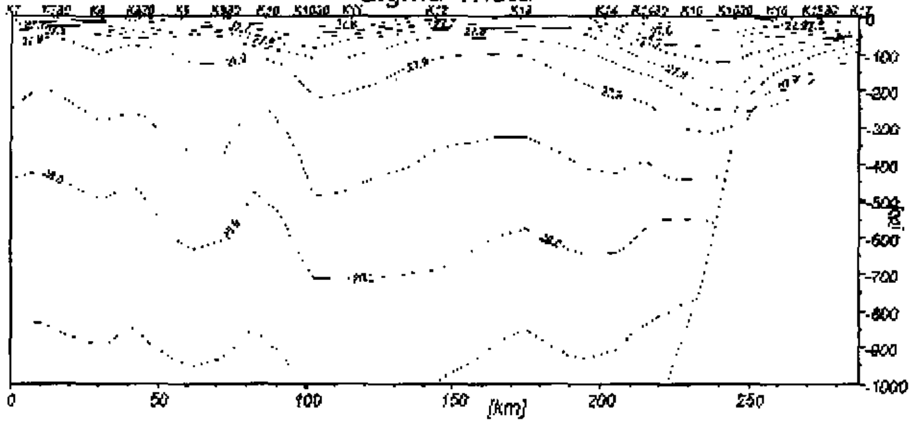
Salinity [psu]



Potential temperature [°C]

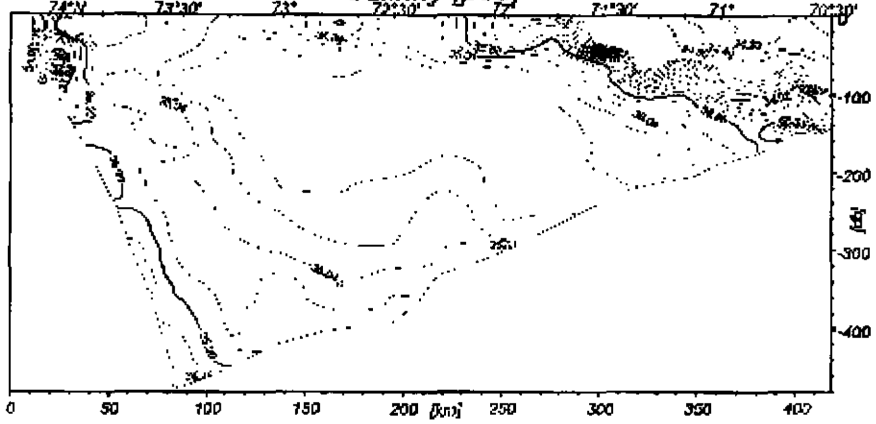


Sigma-Theta

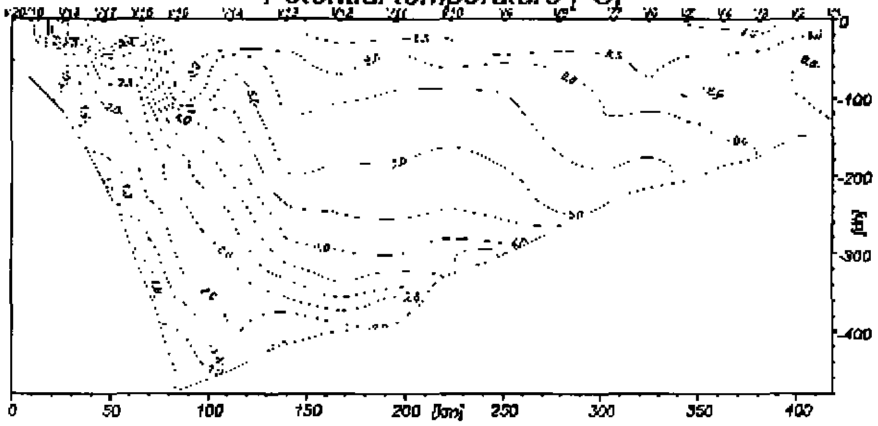


AREX'98 Transect 'V1'

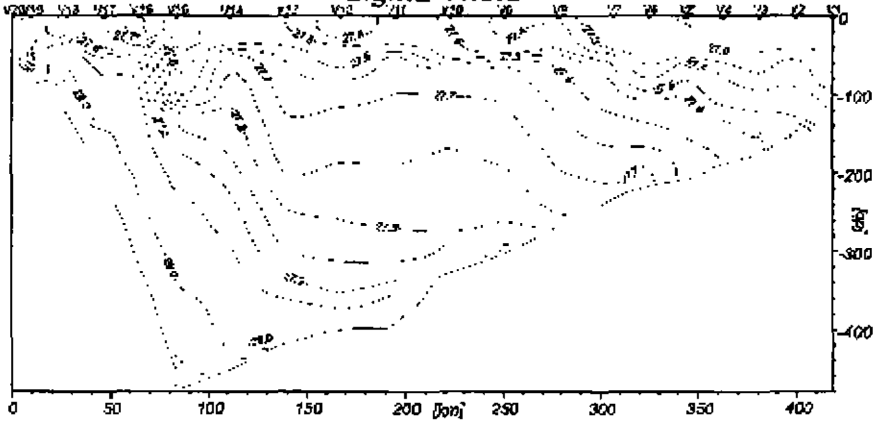
Salinity [psu]



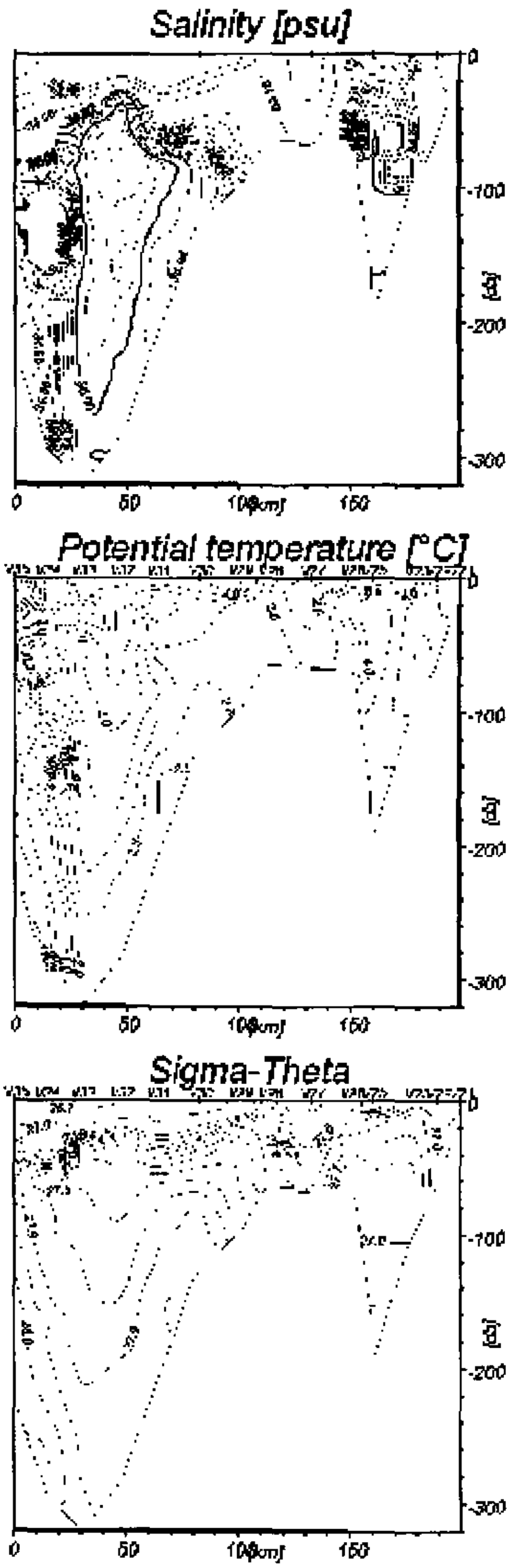
Potential temperature [°C]



Sigma-Theta



AREX'98 Transect 'V2'



Annex P – German Sections in the North Sea

G. Becker, Bundesamt F. Seeschiffahrt Und Hydrographie, Hamburg, Germany

1.Hydrographic Description

The semi-enclosed North Sea is situated on the European Continental Shelf. In the north it opens to the North Atlantic and in the south via the English Channel. The Baltic Sea supplies about 500 km^3/a low salinity water into the North Sea. The North Sea SST shows a pronounced annual cycle; the annual SST range increases from the Atlantic boundary in the north from about 4 K to about 16 K in the German Bight (southeastern corner). The SST interdecadal variability is connected with the North Atlantic Oscillation index variability via local air-sea interaction.

2.General 1998 Synopsis

In general, the 1998 North Sea showed no unusual oceanographic conditions. Temperature, salinity and summer stratification were found within the known variability.

3A.1 SST - 1998

In 1998 the amplitude of the North Sea area averaged SST annual cycle amounted to 4 K only, compared with 6 K in 1997. The 1997 positive SST anomaly persisted through the winter 1997/98 and continued until May 1998. In the second half of the year colder conditions prevailed.

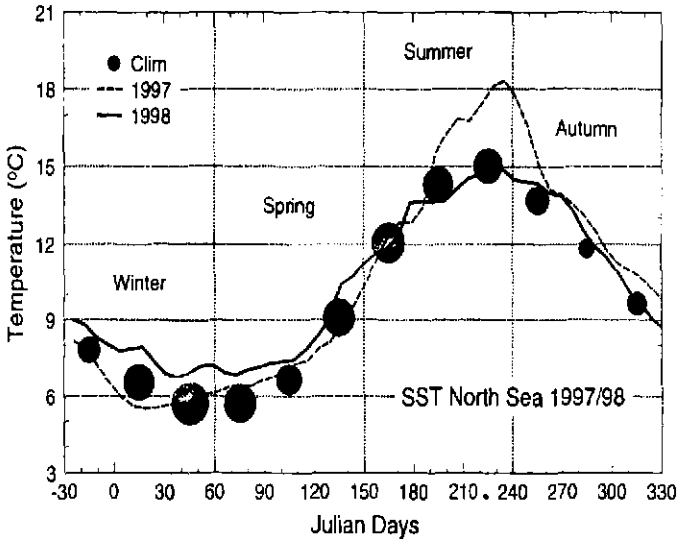


Figure 1. Weekly spatial mean SSTs of the North Sea 1997/98 and monthly climatology (1971-1993, radius = 1 standard deviation).

3A.2 SST – Trend

In the time series of the weekly North Sea SST maps since 1971 (28 years) the 1998 SST is on rank 5. In descending order the years 1990, 1989, 1995, 1997 were warmer than 1998.

Month	SST 71-93	StDev (s)	SST 1998	Rank	ΔSST	ΔSST/s	p-value	nG28
Dec	7.82	0.52	8.57	3	0.75	1.44	92.5	2.1
Jan	6.55	0.71	7.57	4	1.02	1.44	92.5	2.1
Feb	5.69	0.85	7.03	3	1.34	1.58	94.3	1.6
Mar	5.71	0.75	7.00	3	1.29	1.72	95.7	1.2
Apr	6.66	0.60	7.50	3	0.84	1.40	91.9	2.3
May	9.09	0.74	9.95	4	0.86	1.16	87.7	3.4
Jun	12.04	0.78	12.34	10	0.30	0.38	64.8	9.9
Jul	14.28	0.70	13.78	-8	-0.50	-0.71	23.9	6.7
Aug	15.02	0.68	14.72	-7	-0.30	-0.44	33.0	9.2
Sep	13.69	0.55	14.15	9	0.46	0.84	80.0	5.6
Oct	11.81	0.37	12.02	11	0.21	0.57	71.6	8.0
Nov	9.64	0.47	9.32	-8	-0.32	-0.68	24.8	7.0
Year	9.86	0.45	10.38	5	0.52	+1.16	87.7	3.4

Table 1: Spatio-temporal mean SSTs 1998 vs. 1971-93 North Sea climatology. p-values (%) give the area under the unit normal between – and DSST/s. nG28 is the expected average frequency within 28 yrs of warm/cold anomalies / DSST. Ranks within the 28 yr. record are from warmest to coldest (+) or vice versa (-).

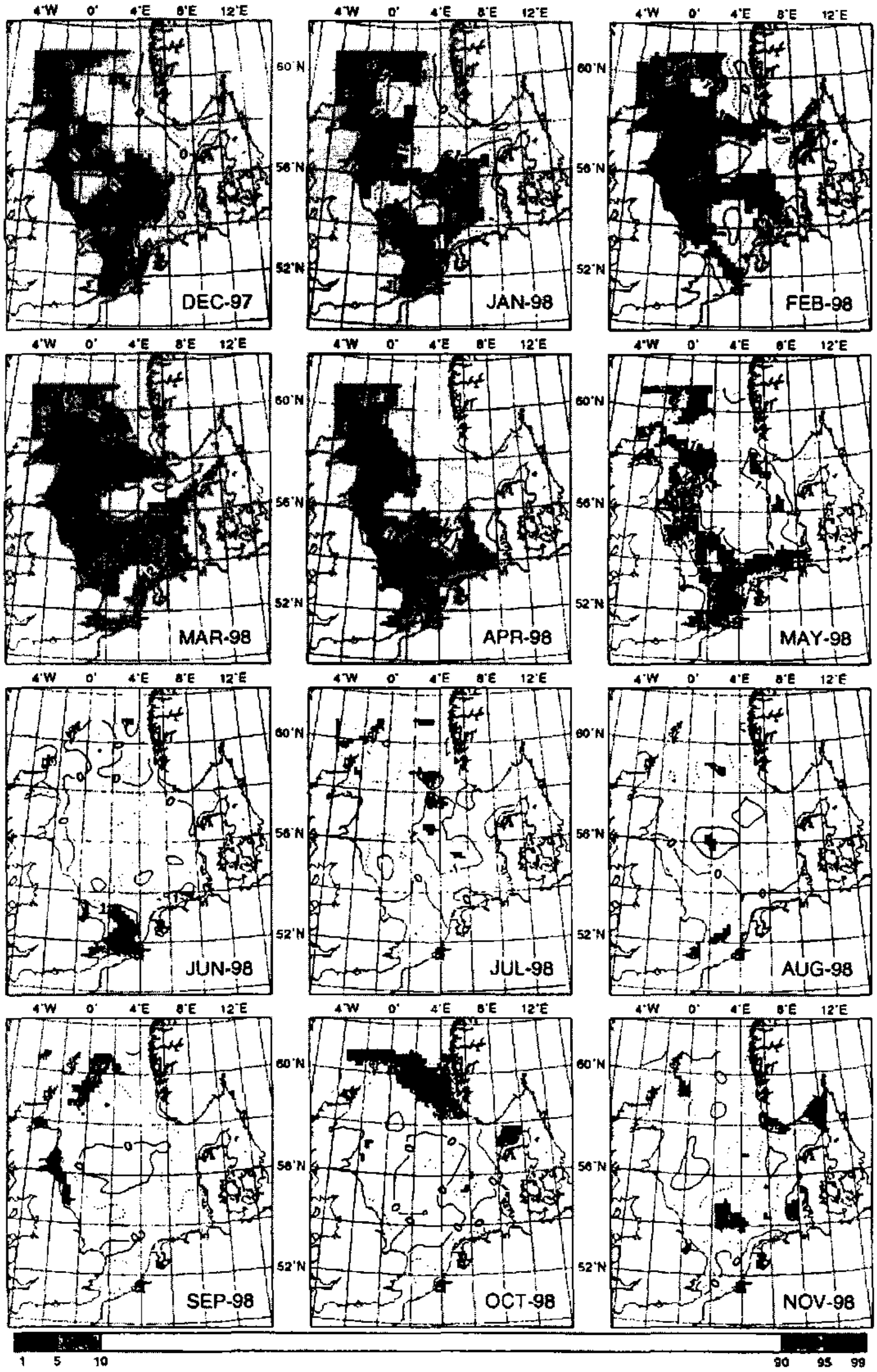

4°W
0°
4°E
8°E
12°E
60°N
56°N
52°N
DEC-97
JAN-98
FEB-98
MAR-98
APR-98
MAY-98
JUN-98
JUL-98
AUG-98
SEP-98
OCT-98
NOV-98
1
5
10
90
95
99

Figure 2.

Annex Q – Danish Observations – West Greenland 1998

E. Buch, Denmark

1. Introduction

Extreme climatic conditions have been experienced at many localities all over the world in 1997 and 1998. Many of the extreme signals can be related to the strong El Niño event in 1997, which is clearly reflected as high positive temperature anomalies in the Pacific Ocean off Peru in South America, Fig. 1.

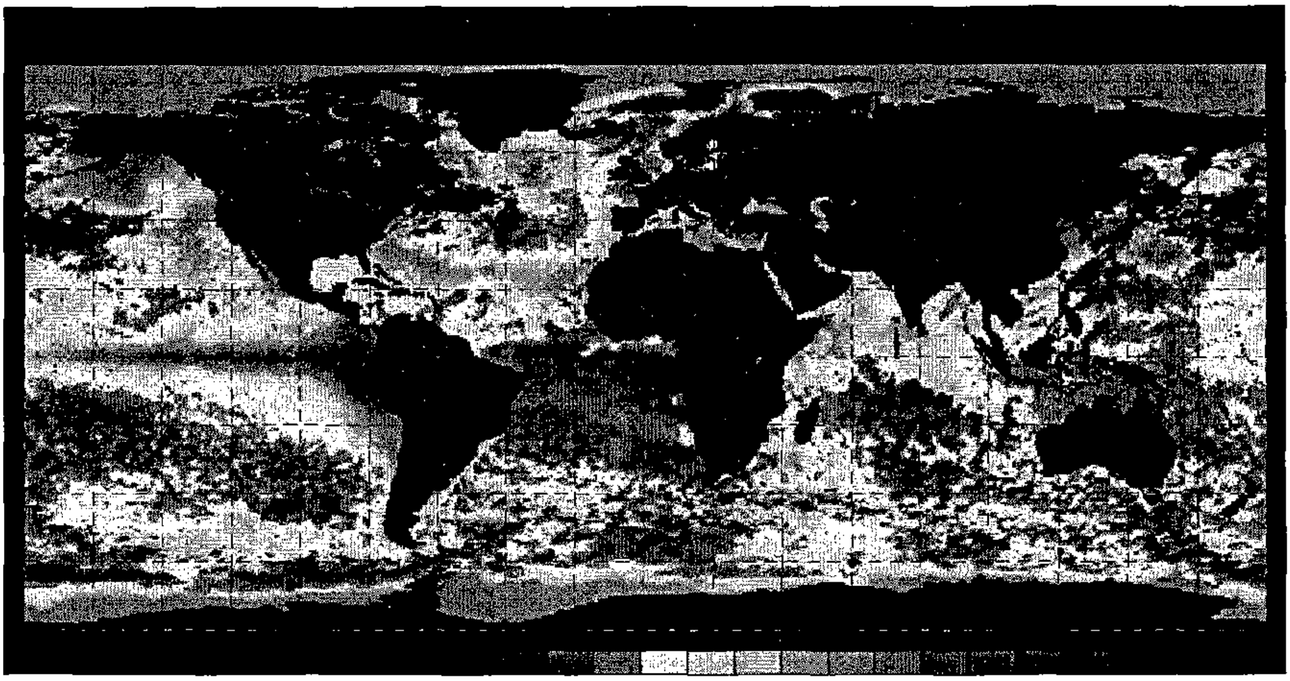


Fig. 1. Ocean surface temperature anomalies June 28, 1997, observed from satellite.

Fig. 1 reveals positive temperature anomalies in some parts of the North Atlantic especially in the Irminger Sea and the southern part of Davis Strait. The Davis Strait observations confirm the measurements performed by the author on behalf the Greenland Institute of Natural Resources in late June 1997, which also showed temperatures slightly higher than normal as far north as the Frederikshaab Section (62oN).

In 1998 the ocean surface temperature conditions were markedly different, Fig.2.

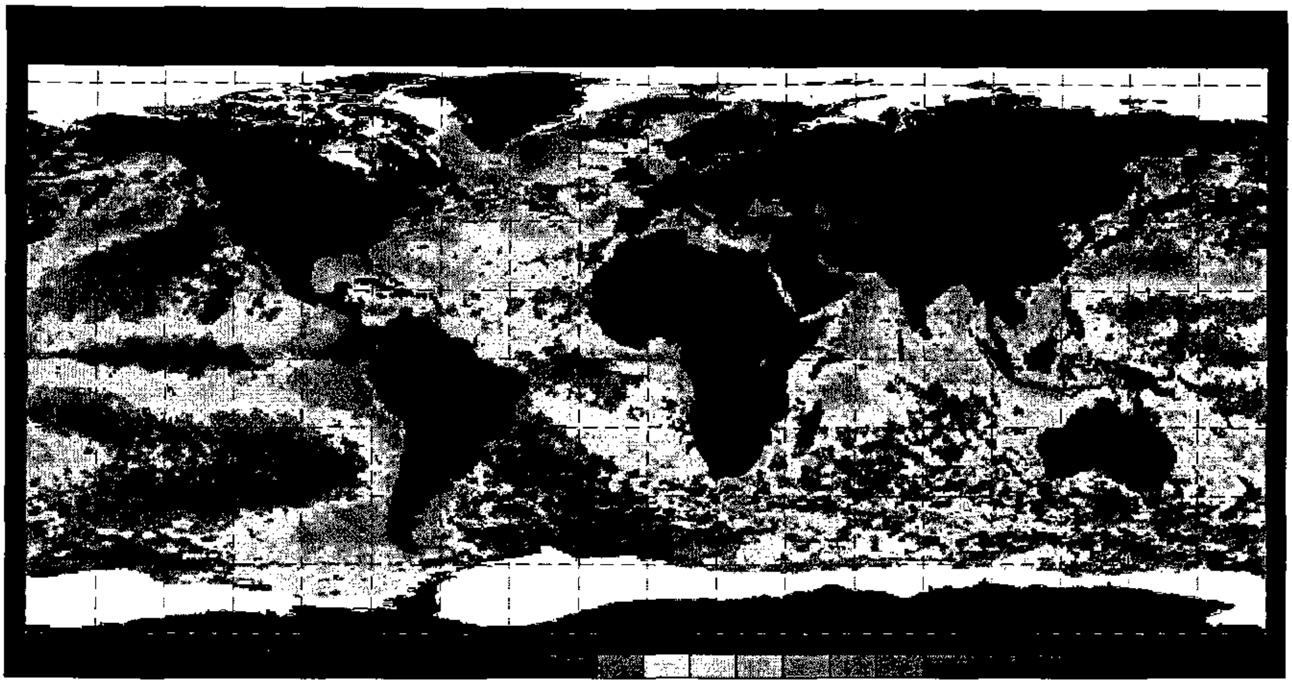


Fig.2. Ocean surface temperature anomalies June 27, 1998, observed from satellite

The El Niño signal in the Pacific Ocean has almost disappeared, while the positive temperature signal in the North Atlantic has strengthened especially in the Irminger Sea and Davis Strait.

The present report focuses on results from the oceanographic measurements performed in late June early July 1998 on the NAFO Standard Sections off West Greenland. These measurements reveal - as can be seen below - some of the highest temperatures in the surface layer ever recorded since the Greenland Fisheries Research Institute (now the Greenland Institute of Natural Resources) started regular oceanographic observations in the area in 1950.

2. Measurements

The 1998 cruise was carried out according to the agreement between the Greenland Institute of Natural Resources and the Royal Danish Administration of Navigation and Hydrography during the period June 24 - July 8 onboard the Danish naval ship "TULUGAQ". Observations were performed on the following stations:

- Cape Farewell St. 2 - 5
- Cape Desolation St. 1 - 5
- Frederikshaab St. 1- 5
- Fylla Bank St. 1- 5
- Lille Hellefiske Bank St. 1 - 5
- Holsteinsborg St. 1 - 5

On each station the vertical distributions of temperature and salinity were measured from surface to bottom, except on stations with depths greater than 1000 m where 1000 m was the maximum depth of observation.

The cruise was blessed with favourable weather and ice conditions. "Vestice" was not present at the Holsteinsborg Section and only at the innermost station at the Cape Farewell Section was "Storis" observed in quantities preventing navigation to the station.

3. Data handling

Measurements of the vertical distribution of temperature and salinity were carried out using a SEABIRD SBE 9-01 CTD. For the purpose of calibration of the conductivity sensor of the CTD, water samples were taken at great depth on stations with depths greater than 500 m. The water samples were analysed after the cruise on a Guildline Portosal 8410 salinometer.

The CTD data were analysed using SEASOFT 4.217 software provided by SEABIRD.

All quality controlled data was stored in the Marine Database at the Royal Danish Administration of Navigation and Hydrography from which copies have been sent to ICES and MEDS.

4. Oceanographic conditions off West Greenland in 1998

The climatic conditions in the West Greenland area had, after the cold period 1989 - 1994, been relative mild in 1996 - 1997 as can be seen in Fig. 3 showing the anomaly of the annual mean air temperature at NUUK for the period 1873 to 1997. The anomaly is taken relative to the mean temperature for the whole period. The conditions during the first ten months of 1998 are similar to those observed in 1996-97.

As discussed by Buch (1997) the air temperatures over Greenland are closely coupled to the strength of the North Atlantic Oscillation (NAO), which refers to a meridional oscillation in the atmospheric mass with centres of action near the Iceland Low and the Azores High (van Loon and Rogers, 1978). A high NAO Index will therefore result in cold conditions in the Greenland area, while a low NAO Index value means relatively mild climatic conditions.

The NAO index has been high since 1980, the values observed in 1983, 1989 and in 1990 being the highest recorded since 1863, and these years were some of the coldest ever experienced in Greenland. In 1996, however, the NAO index shifted from high to low values and a milder climate are now present in the Greenland region.

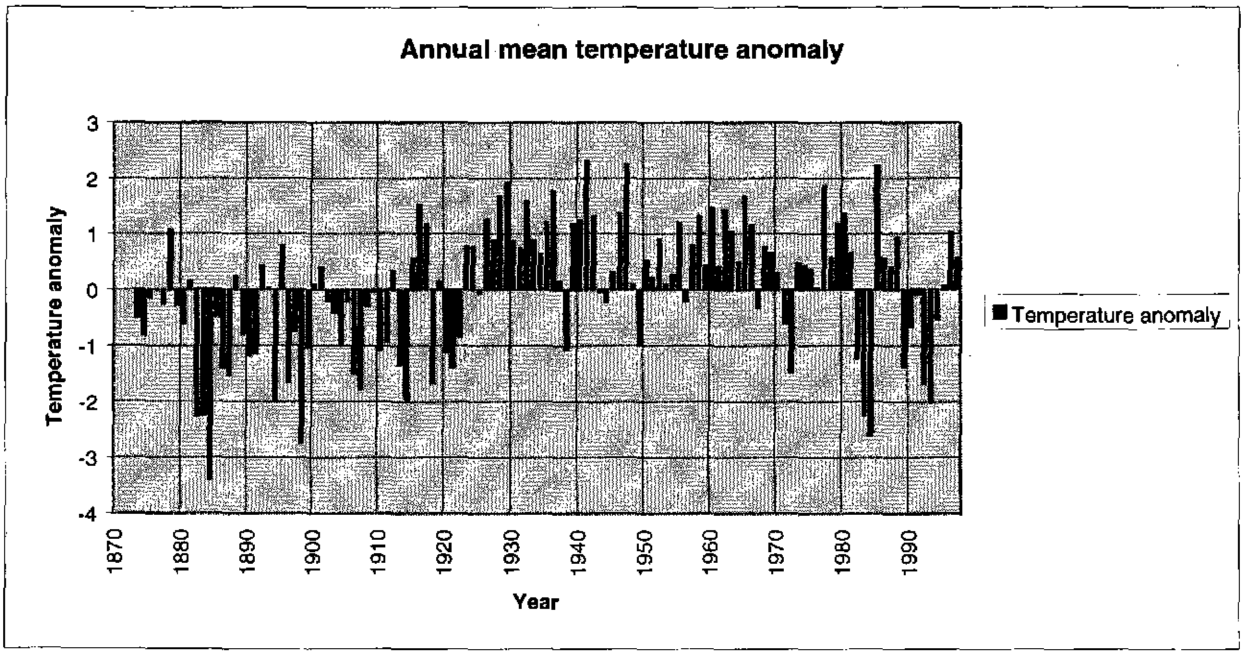


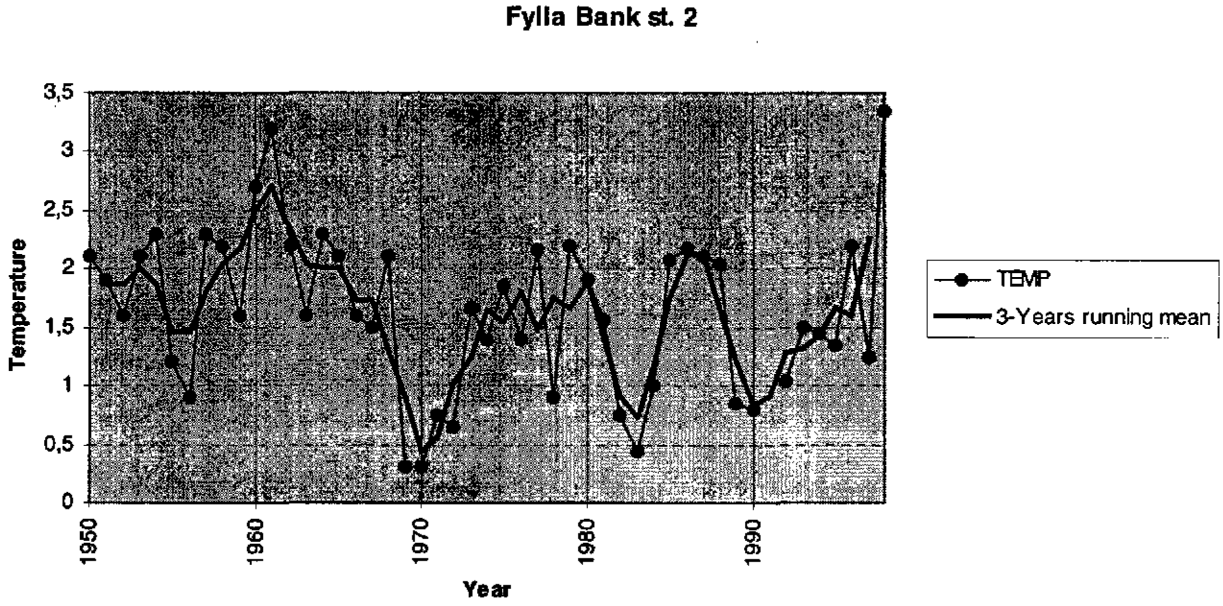
Fig. 3. *Anomaly in the annual mean air temperature observed at NUUK for the period 1873 to 1997. The anomaly is taken relative to the mean temperature for the whole period.*

The mean temperature and salinity on top of Fylla Bank in the middle of June, Fig. 4a, show that a remarkably low temperature was observed in 1997 although the atmospheric conditions were relatively warm, which could indicate a high inflow of Polar Water in 1997. Additionally relatively low salinities were observed in 1996 and 1997, indicating that the inflow of Polar Water had been above normal in these years.

In 1998 the oceanographic conditions were markedly different. The 1998 value of the Fylla Bank medio June temperature is the highest in the time series, the most recent value of similar size was observed in 1961. Additionally, salinity observations show that the 1998 mean salinity value on top of Fylla Bank (Fig.4b) was slightly above normal.

The surface temperatures and salinities observed during the 1998 cruise are shown in Figs. 5 and 6. The high temperature conditions are seen to occupy most of the area of investigation. Temperatures below 2°C were observed only close to the coast in the southern part (i.e. the area dominated by inflow of Polar Water and in the north-western part ,which was influenced by recent melting of westice. Water of Atlantic origin (T> 3°C; S> 34.5), are found at surface only at the outermost of the Cape Farewell Section).

a)



b)

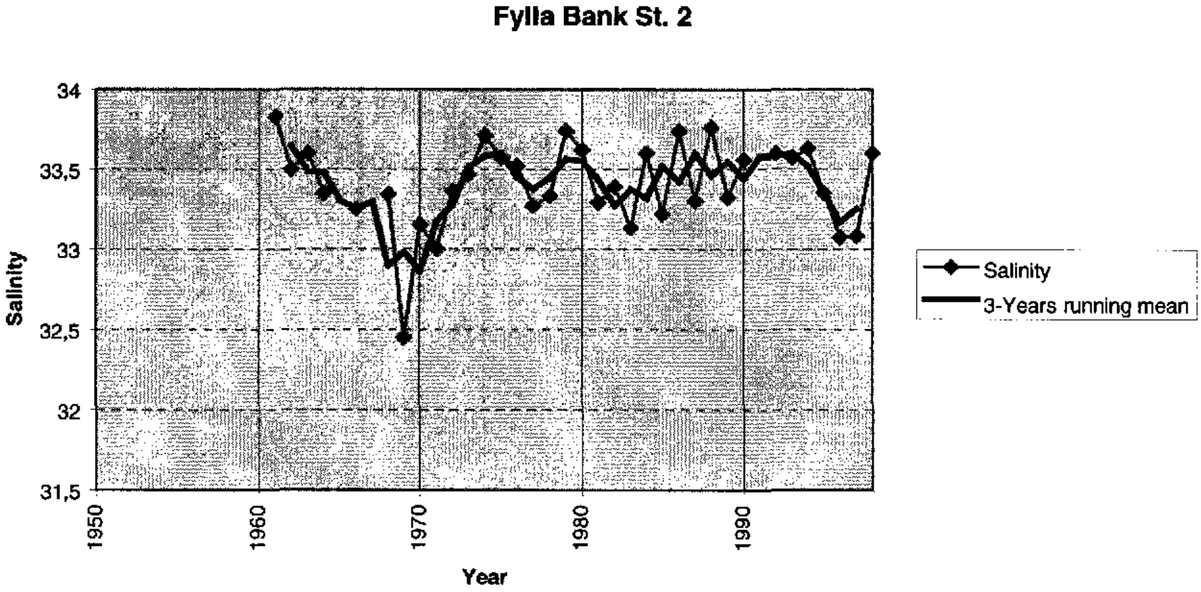


Fig. 4. *Time Series of*

a) mean temperature (observations and 3 year running mean)
b) mean salinity (observations and 3 year running mean)
on top of Fylla Bank (0 - 40 m) in the middle of June.

Fig. 5. *Surface temperature, June - July 1998*

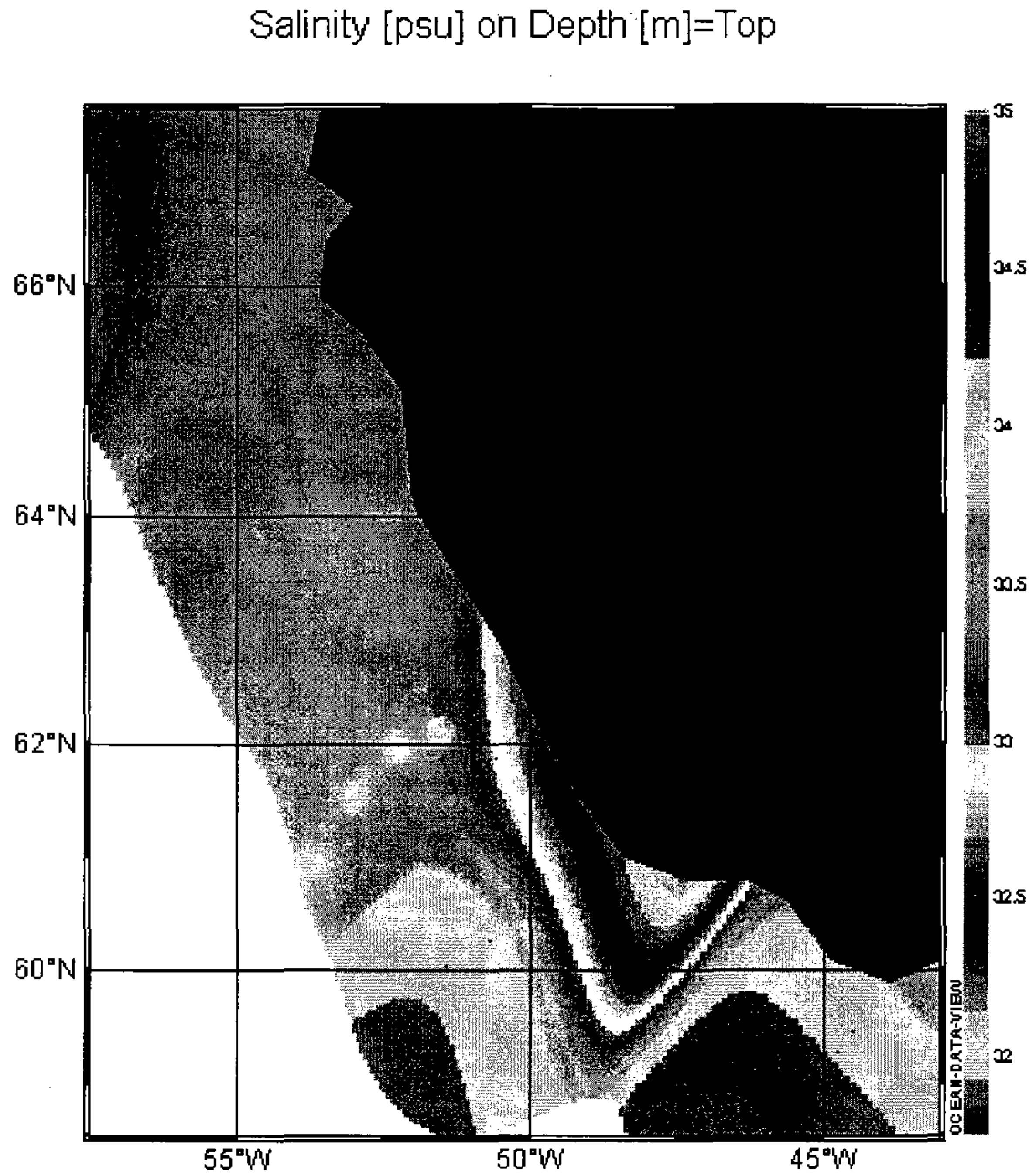


Fig. 6. *Surface salinity, June-July 1998*

The vertical distributions of temperature, salinity and density as well as TS-relations at the six observed sections are given in Figs. 7 - 12.

In the surface layer strong gradients between the cold, low-saline Polar Water and the warm, high-saline water of Atlantic origin were observed at the three southernmost sections. Further north the gradient was rather weak and the normally observed core of Polar Water just west of Fylla Bank at a depth of 50 - 150 m was absent in 1998.

Temperature and salinity observations at greater depth show that in 1998 an extremely high inflow of pure Irminger Water ($T \sim 4.5°C$, $S > 34.95$) took place. A tongue of Irminger Water was observed as far north as beyond the Frederikshaab Section, and salinity values even above 35.0 were observed at the Cape Farewell and Frederikshaab Sections. The centre of the core of inflowing Irminger Water was found at around 200 m depth at Cape Farewell, increasing to 400 m at the Frederikshaab Section. The TS-plots show that the Irminger Water ($S>34.95$) in 1998 had temperatures above 5°C - at some locations even above 6°C - meaning that the heat content of the Irminger Water was above normal, which can serve as an explanation to the high temperatures in the surface layer along the West Greenland Coast in 1998.

Modified Irminger Water ($34.88 < S < 34.95$) reached as far north as just south of the Fylla Bank Section and was present in great quantities at the three southernmost sections.

Sub-Atlantic Water ($3.5 < T < 4.5$; $34.5 < S < 34.88$) was observed at all six sections in 1998.

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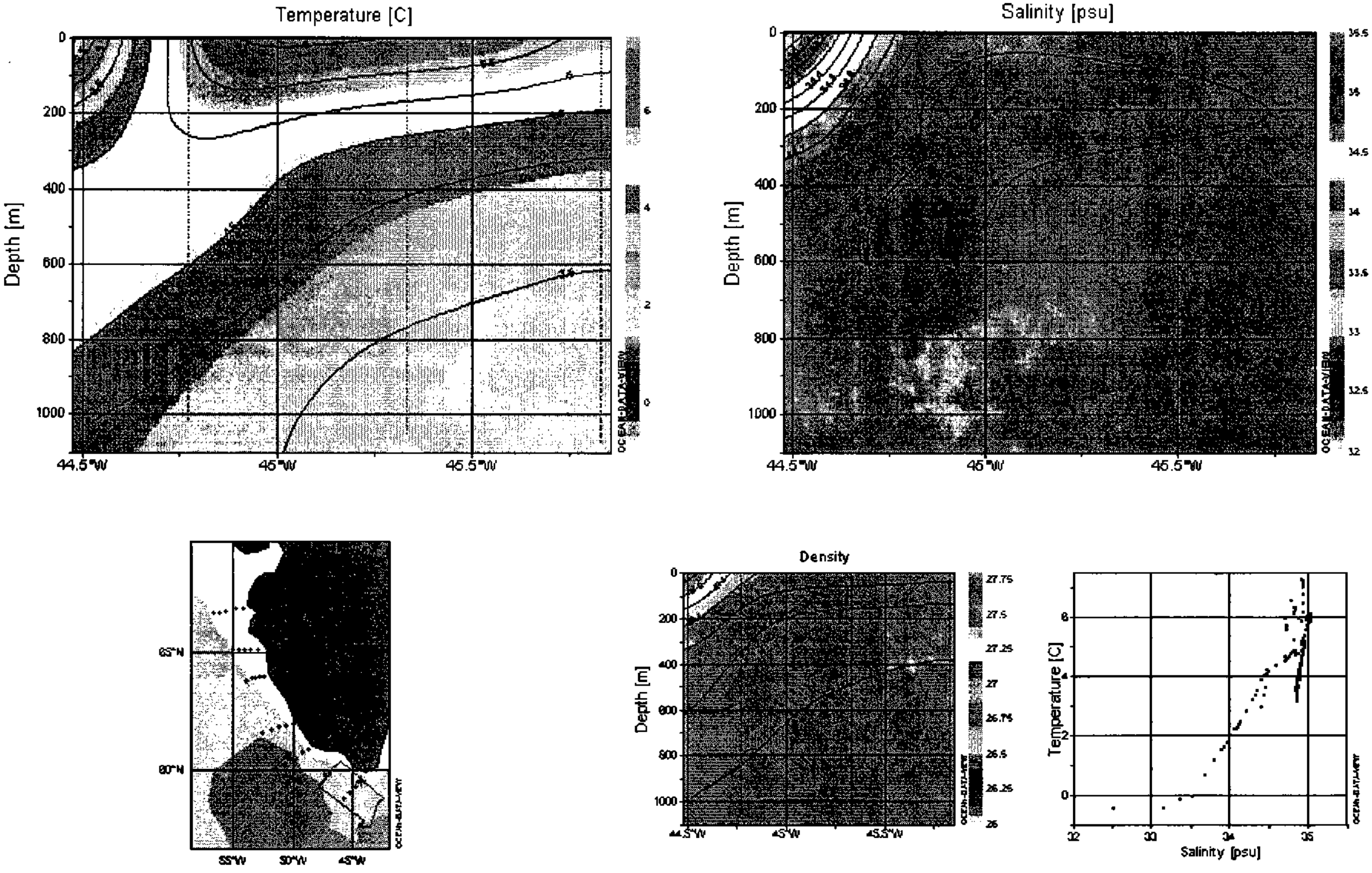

Fig. 7. *Vertical distribution of temperature, salinity and density at the Cape Farewell Section, July 4, 1998.*

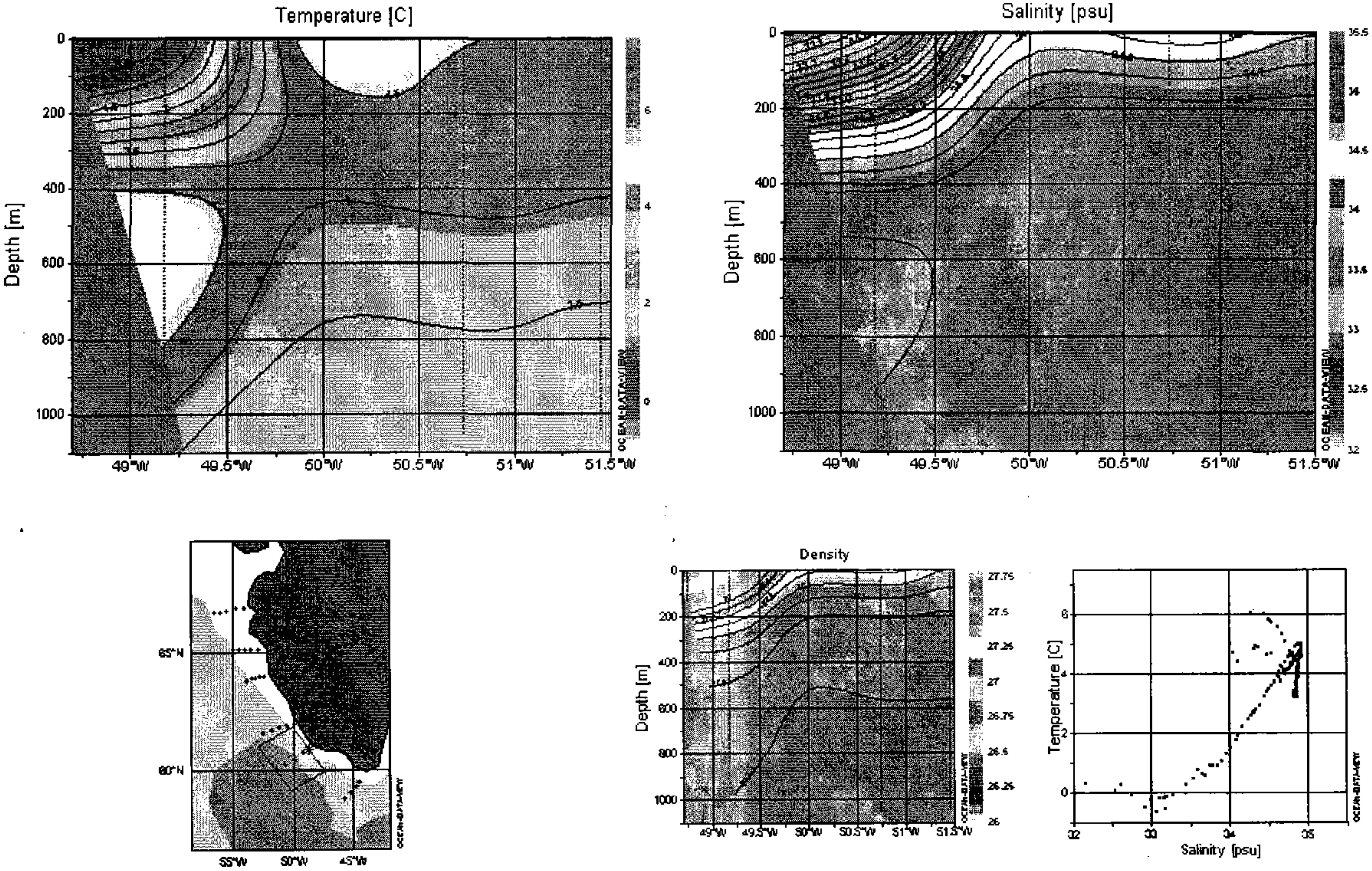

Fig. 8. *Vertical distribution of temperature, salinity and density at the Cape Desolation Section, June 30, 1998.*

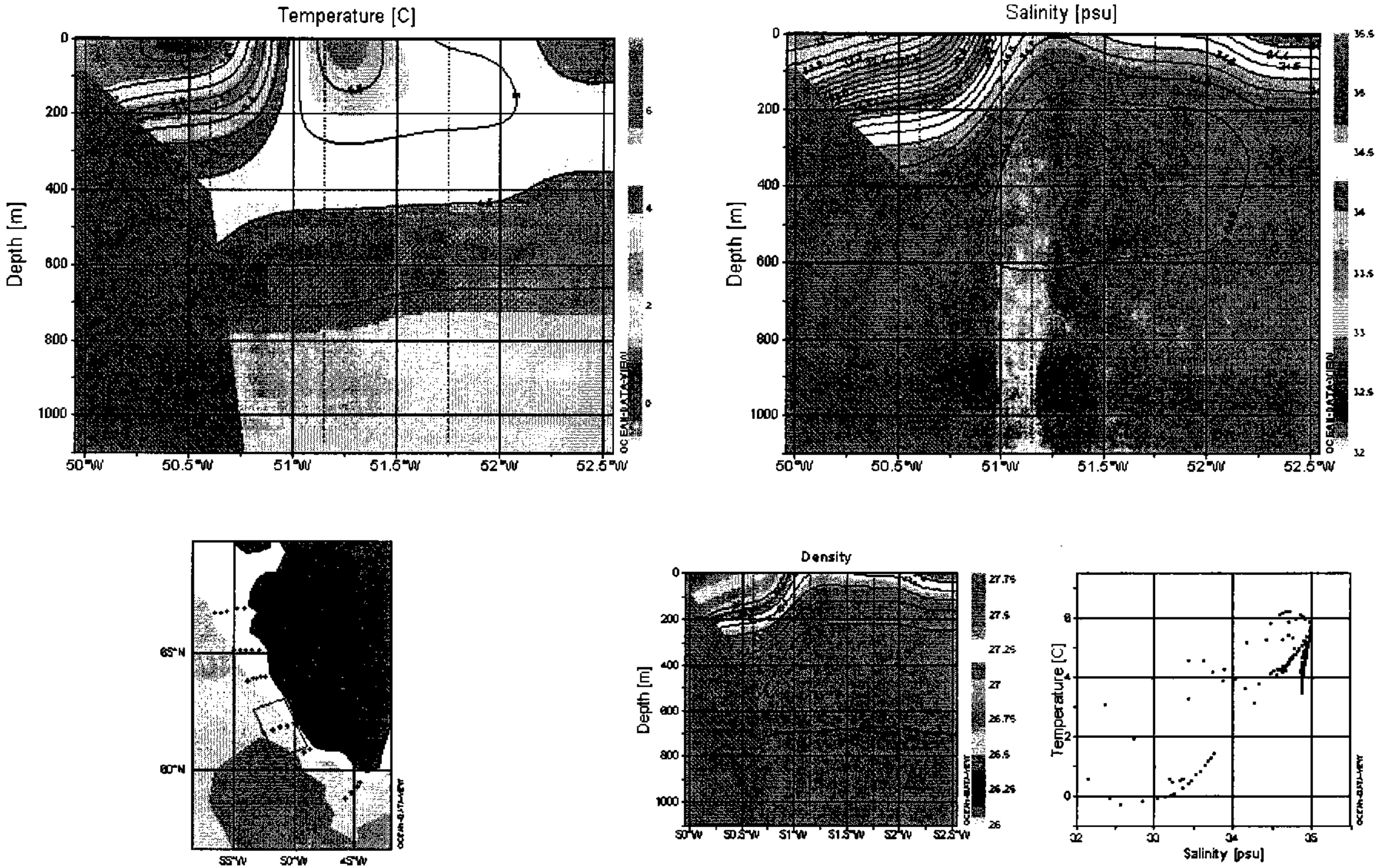

Fig. 9. *Vertical distribution of temperature, salinity and density at the Frederikshaab Section, June 29, 1998.*

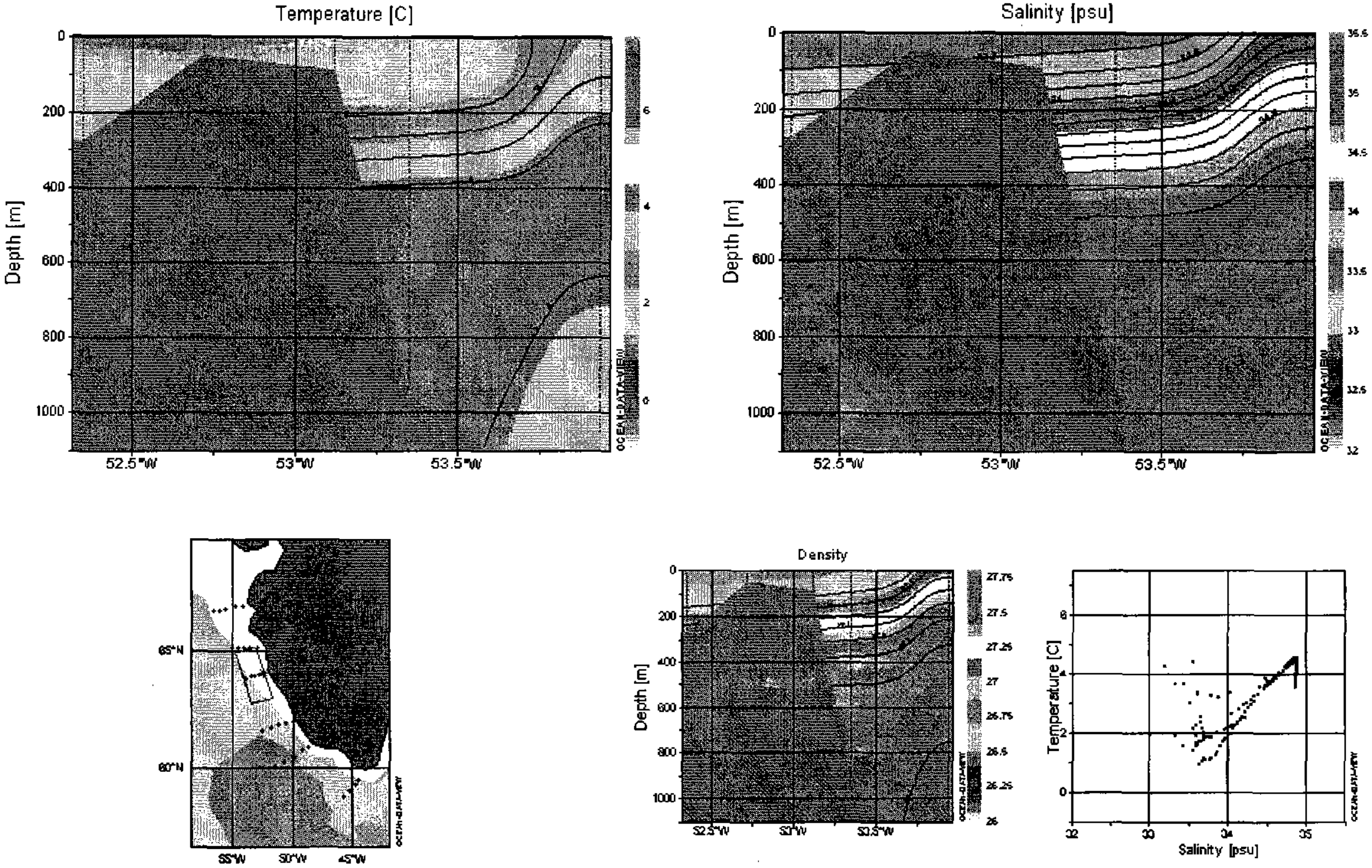

Fig. 10. *Vertical distribution of temperature, salinity and density at the Fylla Bank Section, June 26, 1998.*

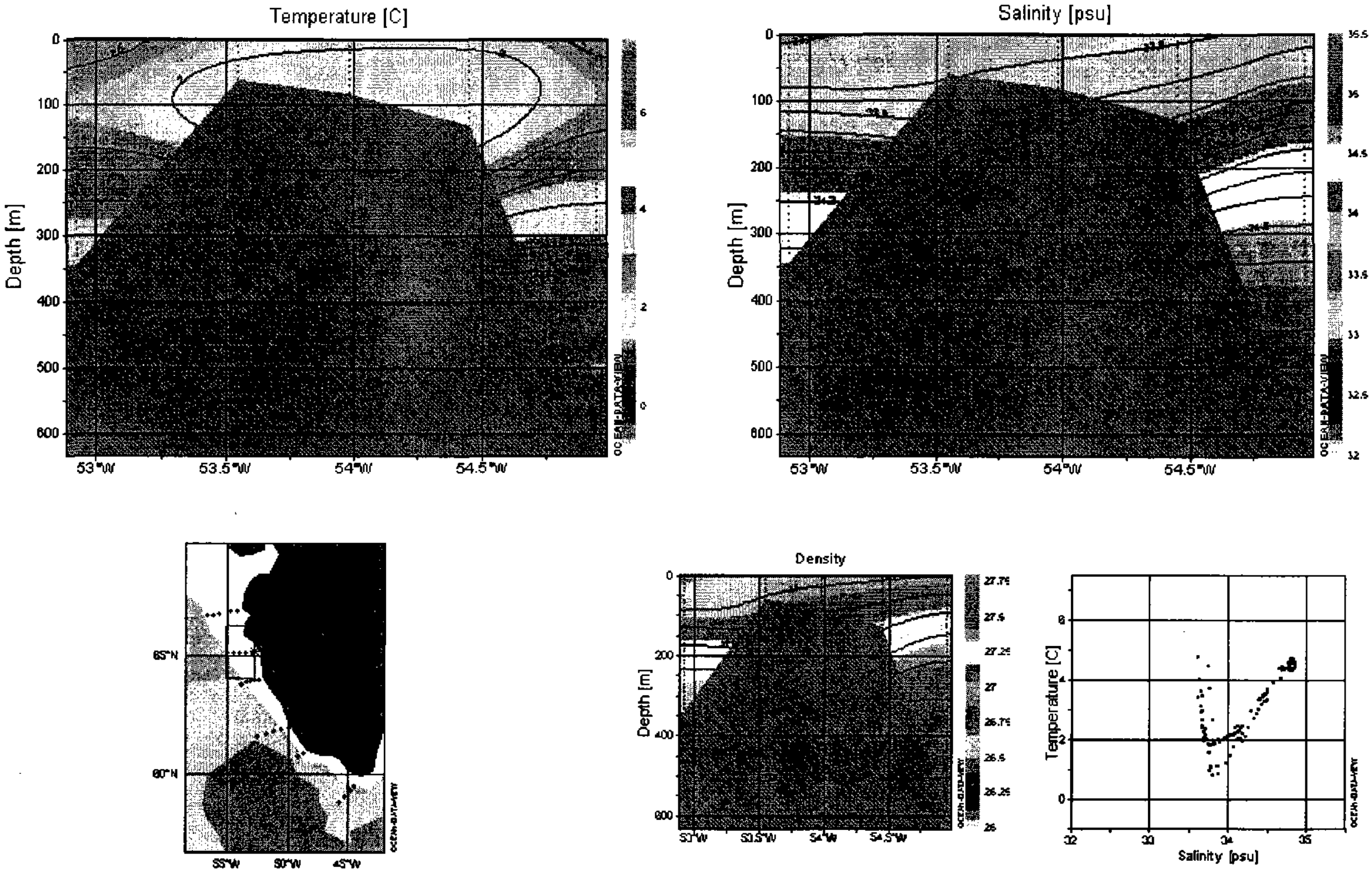

Fig. 11. *Vertical distribution of temperature, salinity and density at the Lille Hellefiske Bank Section, June 25, 1998.*

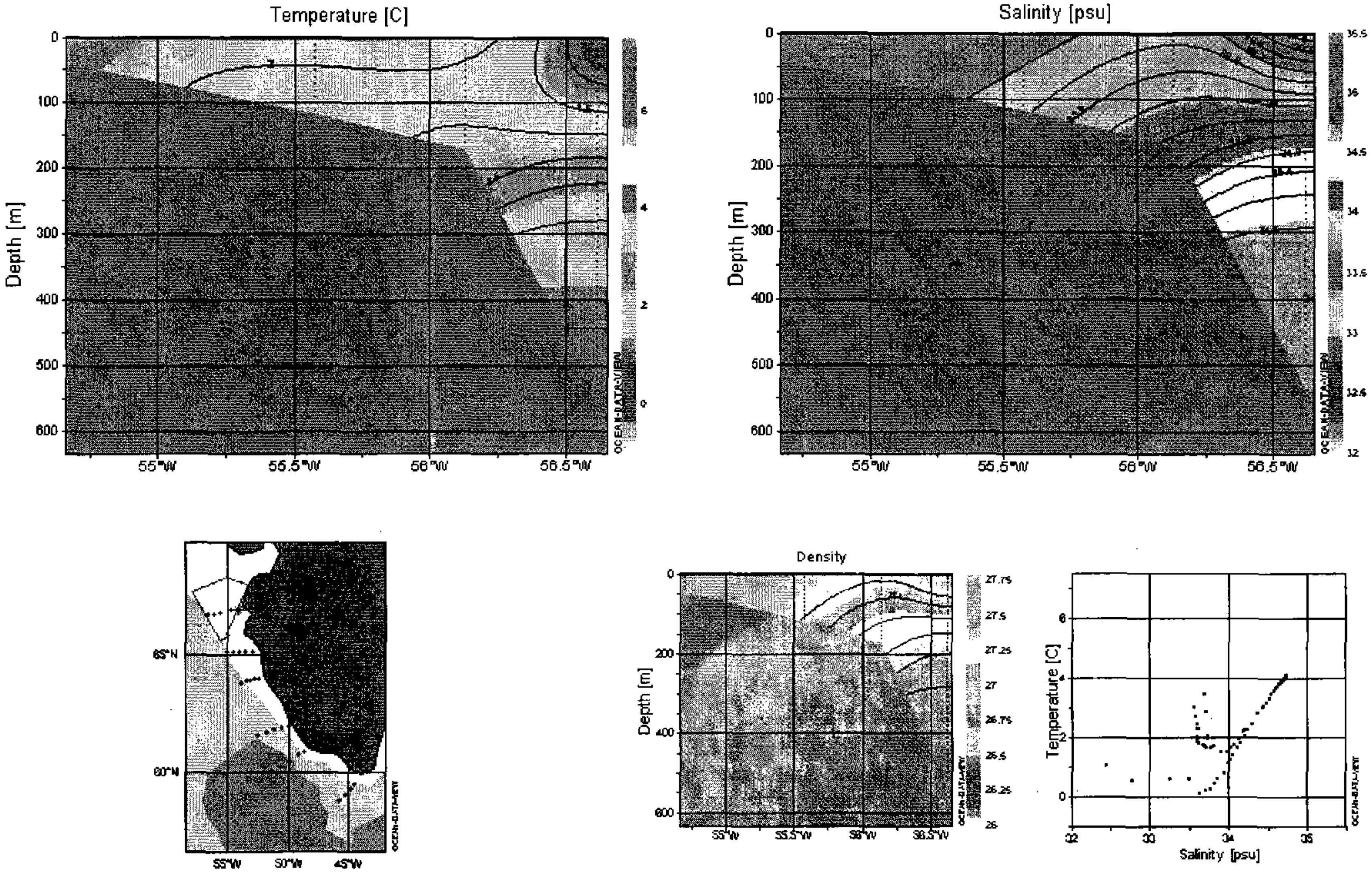

Fig. 12. *Vertical distribution of temperature, salinity and density at the Holsteinsborg Section, June 24 1998.*

Annex R – Baltic Observations Deep Water Changes in the Eastern Gotland Basin

E. Hagen and R. Feistel, Institute for Baltic Sea Research Warnemuende (IOW), Germany

A strong pycnocline (halocline) is observed in all deep Baltic basins permanently. It separates properties of intermediate water from those of the eastward spreading dense near-bottom current, which characterises inflow conditions. Stagnant conditions are frequently observed due to drastically relaxed intrusions of deep water. Such situations are determined by deep circulation patterns in different basin, which are dynamically independent of each other. Stagnant periods can last several years, Matthäus and Frank (1992). They may be interrupted only by strong inflows of dense water overwhelming the topographic sills to spread farther eastward from one deep basin via furrows and channels into the next deep basin. The Eastern Gotland Basin (EGB) reveals the largest volume capacity to store dense deep water for a certain time. This way, it plays a key role with respect to processes of water transformation for the whole Baltic proper.

Following the deepest pathway from south-west to north-east and starting in 1969, the hydrographic data set of the Baltic Monitoring Programme (BMP) involves irregularly distributed measurements not only in time but also in depth. Samples of Nansen bottles and CTDO-series show gaps between some days up to several months around UNESCO-standard depths. Data of neighbouring horizons are linearly interpolated to reconstruct time series for temperature (t), salinity (S), and dissolved oxygen (O_2) at 170 m depth at the central station of the EGB. The area under investigation and the position of BMP Station 271 are shown in Fig. 1. Equivalents of hydrogen sulfide have been expressed by negative values of dissolved oxygen according to Nehring and Francke (1981).

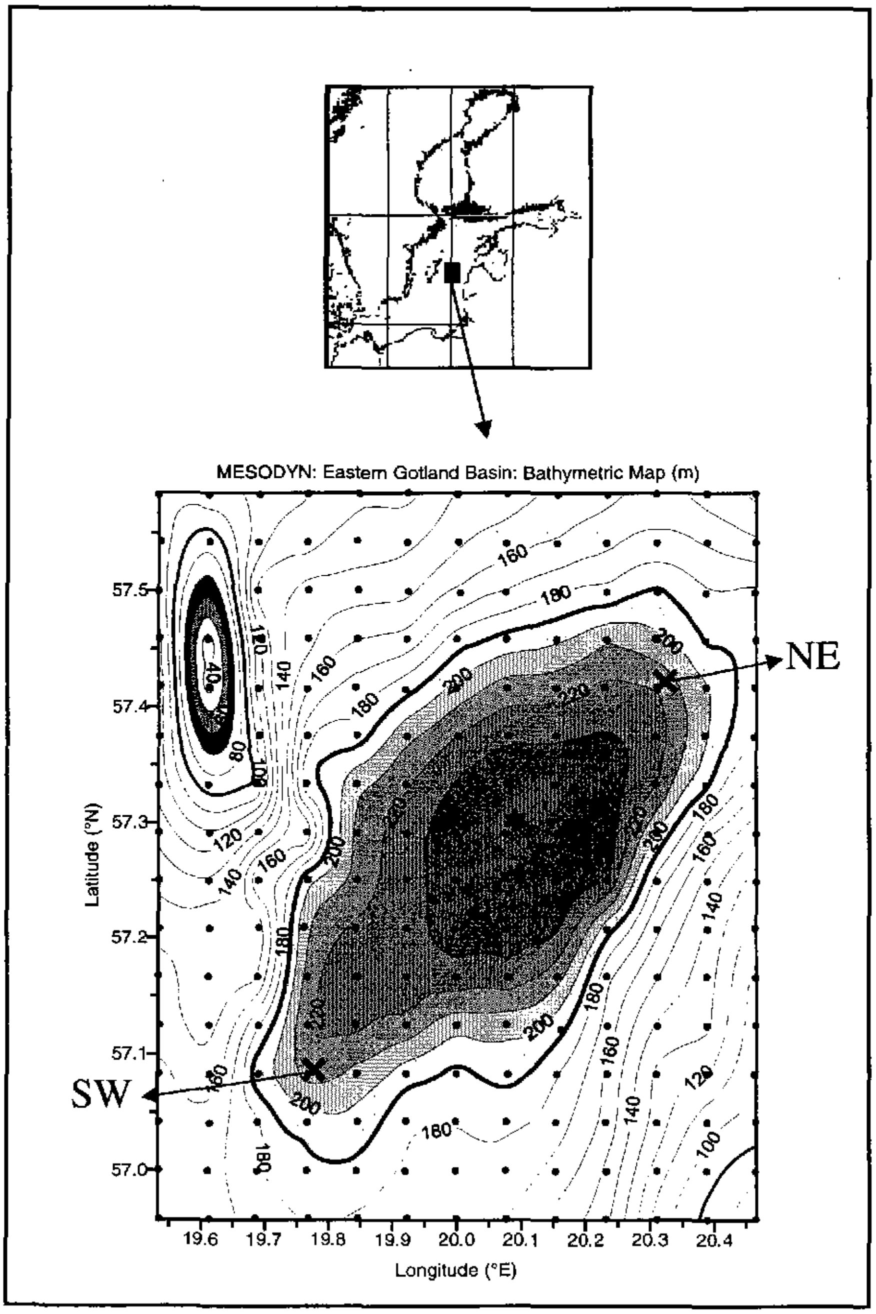

Fig.1 Area of investigation in the Eastern Gotland Basin with CTDO-stations (dots), the position of moored current meters (cross), and the position of the BMP-Station 271 (star) are shown above a bathymetric map (m), which resulted from echosounding depths with a station spacing of 2.5 n.m.

Two major inflows were reported from winters 1976/77 by Nehring and Francke (1981) and 1992/93 by Matthäus and Lass (1995). The last event led to an inflow of about 135 km^3. Relatively cold (3.5°C), highly saline (S>17), and well-oxygenated water (>8 ml/l) overflowed the Darss Sill in the western Baltic. This inflow event only lasted 21 days to fill up the Baltic with the volume transport of about 6.4 km^3. Subsequent anomalies of the sea level were larger than 0.7 m. In layers beneath the perennial halocline of the EGB, the content of dissolved oxygen reached peak concentrations of about 3.5 ml/l. At 170m depth, the stagnant period in between both inflow-events was accompanied by decreasing temperatures and salinities. This interim period lasted 16 years. During that time, relatively smoothed curves describe interannual changes not only in temperature and salinity but also in dissolved oxygen. The inflow event of the winter 1992/93 stopped this trend by the intrusion of saline and well oxygenated deep water. Thereafter anoxic conditions dominate again the deep water of the EGB. The situation was not changed significantly by the relatively weak inflow of warm, saline, but poorly oxygenated dense water, which could be observed in winter 1997/98.

According to Matthäus et al. (1998) there was an extremely warm summer in 1997. Two storms in September and the beginning October transported exceptionally warm and saline water across the sills into the Baltic deep basins. Among other things, this led to positive temperature anomalies of 3-4 K in the deep Bornholm Basin, which was filled with water of salinities larger than 15. Water with properties between 9-11°C and 14-15 in salinity crossed the Stolpe Furrow at the end of October. Within layers beneath the perennial pycnocline, temperatures reached levels insignificantly smaller than reported from the historical peak value of about 7°C in the winter 1976/77.

For the first time, half hourly and hourly sampled time series with lengths between 326 and 436 days temporally documented an inflow event by records of temperature and current within layers beneath 140m depth in the EGB during the winter 1997/98. Two moored strings were anchored at 220m water depth in the north-east (NE) and in the south-west (SW) above the topographic flanks of the EGB. . At 170m depth, current records reveal a mean cyclonic circulation of about 2.5 cm/s. Its direction points not into the north-west sector at the NE position, but into the south-east sector at the SW position. Such a rotation sense was earlier observed by current measurements with a total length of several weeks by Dietrich and Schott (1974) and Mittelstaedt (1996). Therefore, it seems to be that a cyclonic circulation of deep water with velocities of about 1-3 cm/s regularly determines the deep circulation in the EGB.

Temperature records indicated that the inflow period lasted 130 days at 170m depth above the eastern flank of the basin. Two hydrographic surveys with an eddy-resolving station grid provided snapshots in mass field patterns to characterise related pre-inflow and post-inflow situations spatially. The regular station spacing of 4.6 km sufficiently resolved the first mode baroclinic radius of deformation, which was found to be 11 km during 29 August- 4 September 1997, but 13 km during 19-24 April 1998. Detected vertical displacements of deep isopycnal surfaces between pre-inflow and post-inflow situations enabled an estimate of the net volume replacement by denser water. The changed volume between selected isopycnals and the sea bed was determined by numerical triangulation. Released mean vertical velocities in the order of 10^{-4} cm/s decreased with decreasing water depth and well reflected related changes in the bathymetric volume.

The inflow of at least 56 km^3 warm, saline, but poorly oxygenated deep water started above the eastern flank of the basin. Such a value lies in the order of monthly fresh water supply reported by Brogmus (1952). The water balance requires a previous outflow of Baltic near surface water of the same order. Concerning the detected inflow event, the volume transport of about 0.5 km^3/d completely filled up deep parts of the EGB. Here, the isobath of 190m depth completely seals the deepest parts of the basin. The resulting volume capacity is about 38 km^3. Half of that volume was filled by water denser than 1009.7 kg/m^3

The whole inflow period was accompanied by a linear trend of increasing temperatures within layers between 170m and 140m depth located beneath the permanent pycnocline over the topographic flanks of the deep basin. For example, this trend started at the nearly constant level of about 5°C at the end of the pre-inflow period (28 November, 1997) and ended at the nearly constant level of about 6°C at the end of the inflow period (6 May, 1998) at the NE position. Such a warming reflects the net inflow of warm, saline, and dense deep water. Consequently, deep isopycnal surfaces were displaced upward to produce a doming above the basin's centre during the post-inflow situation. Furthermore, the inflow situation was characterised by intensified currents. They accelerated by a factor of about two up to three. Released temporal fluctuations of the thermal field indicated quasi-periods of about 20 days. Such temporal fluctuations produced patterned structures in the mass field with diameters twice of the radius of deformation. In summary, it results the following scenario:

The first rotation cycle of relatively warm but dense deep water needed about 60 days to travel around the contour of the 220m isobath with a length of about 130km. It abruptly started above the eastern topographic flank of the basin (NE position) to form a rotating wedge-shaped frontal zone following closed bathymetric contours. The deep frontal zone propagated with an anticlockwise rotation around the basin and lifted lighter water of intermediate layers upwards. Associated vertical velocities indicated the order of 10^{-3} cm/s. For instance, a mean vertical velocity of $1.7*10^{-3}$ cm/s was able to fill parts of the basin deeper than 190m during 130 days. Mixing processes, which were released in the wake of this frontal zone, temporally and spatially merged properties of 'young deep water' with those of 'old deep water' as well as with those of upper layers, and mean upward velocities decreased by about one magnitude. Once the deepest parts of the basin were filled up, each next rotation cycle started with a temperature maximum at the thermal level produced by mixing and upward lifting of isopycnal surfaces in the wake of previous rotation cycles.

Concerning volume transports discussed, another topographic volume capacity provided other exchange rates of deep water. The bathymetric map used for the survey results from three hydrographic surveys. At each station, the vertically integrated profile of the sound velocity was used to determine the water depth. For instance, the bottom topography proposed by Seifert and Kayser (1995) underestimates the volume beneath 190m depth by about 45% in the EGB. Such coarse topographies are frequently used in numerical circulation models. Therefore, resulting rates of deep water exchange will be overestimated and the corresponding residence time of deep water will be too short, at least in the EGB. We urgently need exact topographic data for all deep basins to understand quantitatively the renewal of deep water. The volume capacity of deep basins essentially determines residence times of dense water and exchange rates for water mass transformation acting on different temporal scales.

By analysing time series of sea level data, Samuelsson and Stigebrandt (1996) concluded that wind produced dynamics dominate all circulation patterns in the Baltic Sea on time scales shorter than about one month. In order to get a hint about the origin of such 20 day fluctuations, we additionally analysed daily winds and daily differences in the air pressure observed at different stations in vicinity of the EGB during the 130 days lasting inflow period. Results are not shown here. They are objective for further studies. However, all estimated power spectra show an accumulation of energy for periods of about 20 days. According to Krauss and Brügge (1991), the deep layer flow increases in contra-direction to the wind due to sea level inclinations in response to the wind forcing. So, the working hypothesis rose up that atmospheric forcing conditions, which temporally fluctuated over a much larger spatial scale, could be responsible for changing wind directions. This way, spatial changes in sea level anomalies modify internal pressure gradients. It results in pulsating deep cyclonic circulation in the EGB.

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Annex S – The Annual ICES Ocean Climate Status Summary

1998/1999

Prepared by the
Working Group on Oceanic Hydrography
Editor: Bill Turrell

The 1998/1999 ICES Annual Ocean Climate Status Summary

Summary

In general 1998 was a year in which ocean temperatures around the North Atlantic were warmer than the long term average, and most areas show a warming trend.

- West Greenland experienced warm sea temperatures and a mild climate for the area.

- In the Northwest Atlantic air temperatures were warmer than average. There was less winter sea ice, and the duration of ice cover was less than normal.

- Off Newfoundland, the warm period which commenced in 1996 following the NAO reversal, continued into 1998.

- Biologically favourable conditions were experienced in the waters around Iceland.

- In the Bay of Biscay the temperature was high in the winter of 1997/1998, followed by low temperatures in summer. The ongoing trend of increasing salinities in the upper layers since 1995 continued.

- Waters in the Northeast Atlantic, along the Northwest European shelf edge, in the North Sea and the Norwegian Sea were warmer and more saline than on average.

- Temperatures in the Barents Sea were close to average in the west and cold in the east. The temperature increased over the whole of the Barents Sea towards the end of 1998.

- The North Atlantic Oscillation (NAO) index continues to recover, becoming positive in the winter preceding 1998, from a remarkably low negative value in the winter preceding 1996. The 1995/1996 reversal of the NAO index interrupted a trend of increasingly positive values which commenced in 1988. Areas which responded to the 1996 reversal of the NAO index showed a return to high-NAO conditions in 1998/99.

Objective of the Second ICES Ocean Climate Summary

This, the second annual ICES Ocean Climate Summary, continues as a pilot study to develop further uses and dissemination of results from the ICES set of standard sections and stations - the ICES Ocean Observing System (I-OOS). The objective of this year's summary is to present a simplified version of national reports, in a non-technical manner, in order to set the oceanic climate context for the period 1998/1999. It is intended to be of use to managers of any aspect of the marine environment in the ICES area. In addition to the presentation of data, some expert interpretation has been added by the ICES Working Group on Oceanic Hydrography.

The North Atlantic Oscillation (NAO) Index

Since the NAO is known to control or modify three of the main parameters which drive the circulation in the ocean area covered by this climate summary (ie wind speed, air/sea heat exchange and evaporation/precipitation) a knowledge of its past and present behaviour forms an essential context for the interpretation of observed ocean climate change in 1998.

The NAO alternates between a "high index" pattern, characterised by strong mid-latitude westerly winds, and a "low index" pattern in which the westerly winds over the Atlantic are weakened. High index years are associated with warming in the southern North Atlantic, NW European shelf seas and cooling in the Labrador and Nordic Seas. Low index years generally show the reverse.

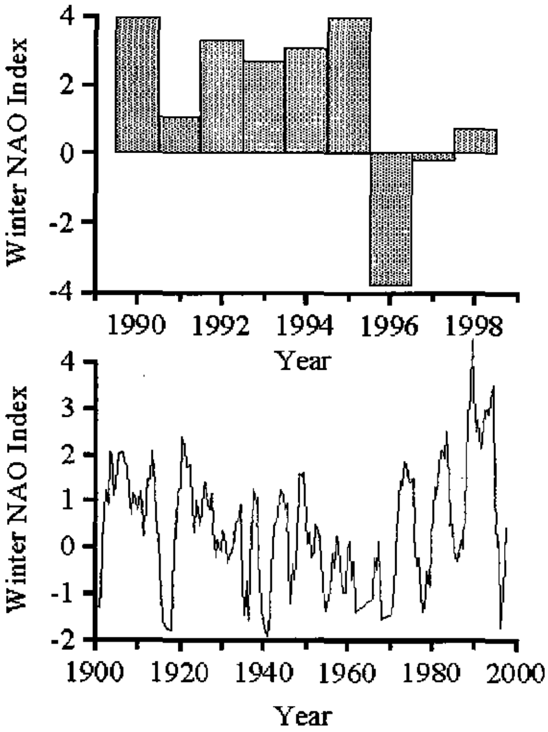

Figure 1. The winter NAO index in terms of the present decade (upper figure) and the present century (lower figure - a 2 year running mean has been applied).

Rapid Response of the Ocean to the 1995-1996 NAO Flip

The North Atlantic Oscillation (NAO) is the dominant recurrent mode of atmospheric behaviour in the North Atlantic sector accounting for more than one-third of the total variance in winter sea-level pressure; its variability also explains about one third of the variance in extra tropical Northern Hemisphere temperatures over the past 65 winters, so that in one way or another, NAO variability appears to be bound up with the long, slow trends of global change.

However the NAO may also demonstrate rapid and extreme changes embedded within the long term trend, and it now appears that the Atlantic may respond rapidly to these changes. Recently an abrupt change occurred from the high positive state of the NAO in the winter of 1994-5 to possibly the most extreme NAO-negative state in the instrumental record in the winter of 1995-6 (**Figure 1**).

A few examples of rapid changes associated with the NAO flip were; a large scale change in the pattern of sea level height over the Atlantic as a whole (with a complete reversal in the pattern between the spring months of 1995 and 1996); a reduction in the northward flux of heat into the northern North Atlantic; a sudden westward shift in the boundary between cold Arctic water and warmer Atlantic water in the centre of the North Atlantic; a reversal of the precipitation regime over Europe (from more than 150% of the average winter precipitation over most of northern Europe in the winter of 1994/95 to less than 60% of the average in the winter of 1995/96); a large increase in the flux of sea ice into the Greenland Sea and a rapid cooling in the North Sea (with an associated increase in Cod recruitment).

These changes reveal that the winter NAO index is a key predictor of environmental conditions in the ICES area, and that its variability must be considered when performing marine status assessments.

El Niño in 1998

Despite the rather average North Atlantic Oscillation (NAO) index for 1998, extreme climatic conditions were experienced at many localities all over the world in 1997 and 1998. Many of these extreme signals can be related to the strong El NIÀ event in 1997, which produced high positive temperature anomalies in the Pacific Ocean off Peru in South America.

In 1998 the ocean surface temperature conditions were markedly different compared to 1997 (**Figure 2**). The El NIÀ signal in the Pacific Ocean almost disappeared, while a positive temperature signal in the North Atlantic strengthened especially in the Irminger Sea and Davis Strait.

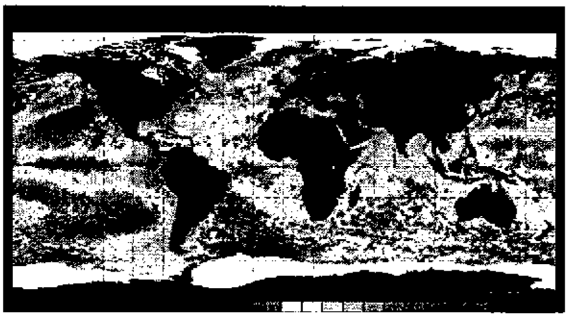

Figure 2. Ocean surface temperature anomalies June 27, 1998 revealing the disappearance of the strong 1997 El Niño event in the Pacific. The warmer than normal conditions (yellows and reds) throughout much of the area covered by this summary is evident.

There is presently no evidence of a causal connection between the El Niño Southern Oscillation (ENSO) phenomenon and the NAO. Both appear to respond quite independently of one another.

When we consider the NAO index for the present decade, and the present decade in the context of this century (**Figure 1**), the 1960s were generally low-index years while the 1990s are high index years. There was a major exception to this pattern occurring between the winter preceding 1995 and the winter preceding 1996, when the index flipped from being one of its most positive values to its most negative value this century. The index is now slowly rising from the extreme low, and the recovery continues during the winter preceding 1998. Thus 1998 has a relatively average, although positive, NAO index.

In the remainder of the ocean climate summary the descriptions will proceed in a clockwise manner around the North Atlantic, commencing in the waters west of Greenland. This follows the main circulation pattern of the North Atlantic (**Figure 3**).

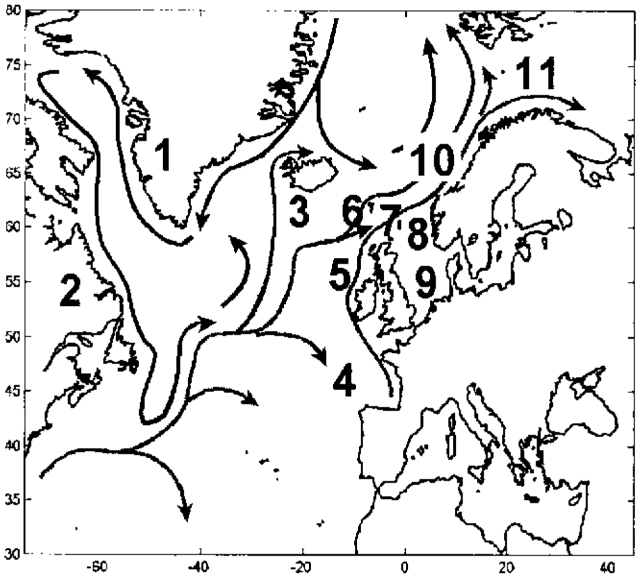

Figure 3. Schematic of the general circulation of the North Atlanticin relation to the numbered areas presented in the 1998/99 Annual ICES Ocean Climate Summary

Regional Descriptions

Area 1 - West Greenland

Greenland lies within the area which experiences cool conditions when the NAO index is high. Air temperatures during the period 1989 to 1994 were particularly cold. However, the reversal of the NAO in 1996 brought relatively mild conditions to the area, which persisted into 1998 (**Figure 4**).

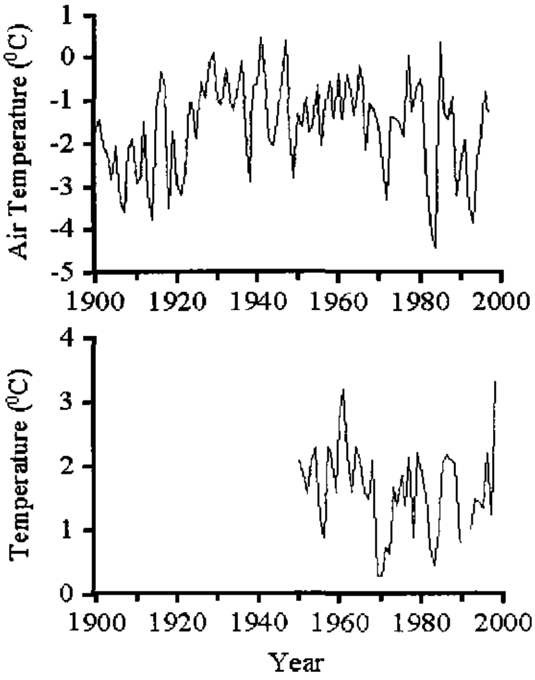

Figure 4. Upper Figure - Annual mean air temperature observed at NUUK, Greenland, for the period 1900 to 1997. Lower Figure - Mean summer (mid June) temperature on the top of the Fylla Bank (0-40m), west Greenland.

Changes in the ocean climate in the waters to the west of Greenland generally followed those of air temperature, except that in 1997 an inflow of cool, fresh Polar water resulted in cold temperatures. Oceanographic measurements performed in the summer of 1998 in the waters west of Greenland revealed some of the highest temperatures in the surface layer ever recorded since regular oceanographic observations began in the area in 1950 (**Figure 4**).

Area 2 - North West Atlantic

In a similar way to the W Greenland area, air temperatures during 1998 throughout the Northwest Atlantic warmed relative to 1997 and at some sites were warmer than the long-term (1961-1990) mean by up to 1.5 °C. Seasonally, during 1998 air temperatures in most areas of the Northwest Atlantic were above normal in at least 10 out of 12 months.

Sea ice on the Newfoundland and Labrador Shelves appeared late and left early resulting in a shorter duration of ice than normal during 1998. The areal extent of pack ice during 1998 was less than in 1997 and lower than average.

Off Newfoundland, the depth averaged water temperature ranged from a record low during 1991 (high NAO index in preceding winter), a near record high in 1996 (following the reversal in the preceding winter to the record low NAO index) and near the long-term mean in both 1997 and 1998 (following the recovery of the NAO index). The depth averaged summer salinity, which was below normal during most of the early 1990s returned to near normal values during 1997, and continued near normal during 1998.

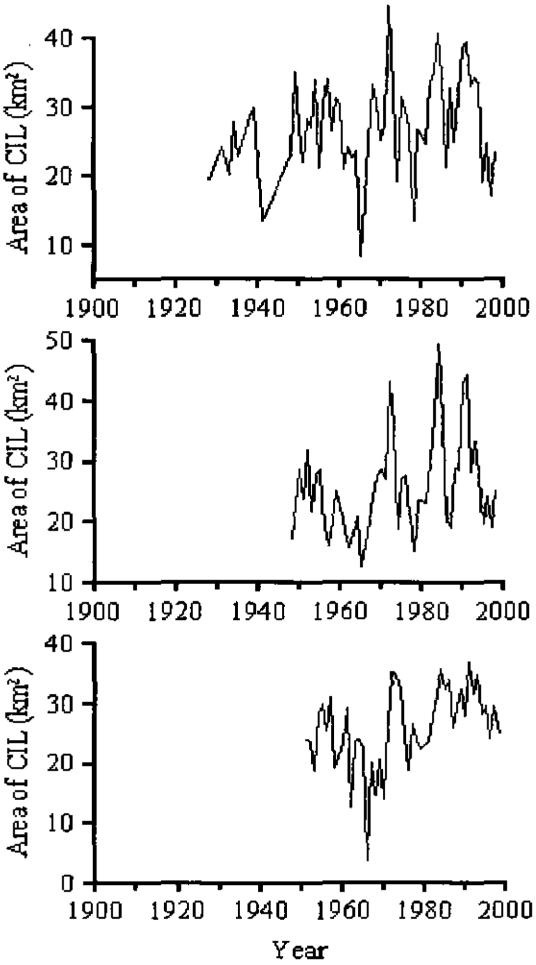

Figure 5. The area of the cold intermediate layer (CIL) of sub-zero °C water along standard transects across the Newfoundland Shelf during the summer. (Upper figure - Seal Island (Hamilton Bank), Centre - Bonavista, Lower - Flemish Cap (Grand Bank))

A very useful index of the general oceanic environmental conditions off the eastern Canadian continental shelf is the size of the cold intermediate layer (CIL) of sub-zero water trapped between the seasonally heated upper layer and the warmer shelf slope water. During the 1960s, when the NAO was well below normal and had the lowest value ever in this century, the area of CIL water was at a minimum, and during the high NAO years of the early 1990s, CIL areas reached high values. During 1998 the CIL areas off eastern Canada increased compared to 1997 values but were still below normal, continuing a trend established in 1995. Across the Grand Bank the CIL was normal during 1998, a decrease from 1997. (**Figure 5**)

Area 3 - Icelandic Waters

Iceland is situated at the meeting point of warm and cold currents on the Greenland-Scotland Ridge. To the south is the warm Irminger current and to the north the cold East Greenland and East Icelandic Currents. The ocean climate influences the air temperature to a great extent , and both impact biological conditions in the waters around Iceland.

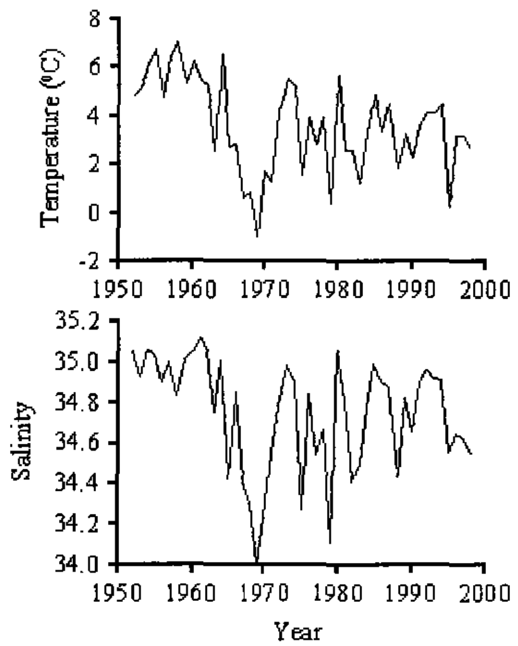

Figure 6. Temperature and salinity at station S3 on the Siglunes section north of Iceland

In general warmer than normal conditions were experienced in Icelandic waters during 1998. The salinity of the Atlantic water arriving from the south was also greater than normal, and salinities were generally at their greatest value since the ice-years of the 1960s. Warm, saline Atlantic conditions were also experienced in the Irminger Sea towards Greenland during 1998.

These mild conditions in the south and west follow extremely cold conditions in 1995. Conditions began to improve in 1996-97, and continued to do so in 1998. However, to the north of Iceland, a cool, low saline layer was evident in 1998 which has not been seen there since 1992 (**Figure 6**). Salinities in the East Icelandic Current were also relatively low (<34.7).

Area 4 - Bay of Biscay and Eastern Atlantic

The Bay of Biscay is located between the eastern part of the sub-polar gyre and the subtropical gyre. This region may be affected by both gyres depending on the latitude and the general circulation in the North Atlantic.

The annual mean air temperature over the Bay of Biscay followed the ongoing heating trend (**Figure 7**). For Santander an annual mean of 14.8°C was reported, 0.4°C above the 1961-1998 average.

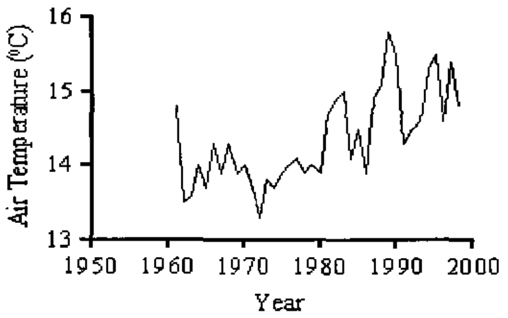

Figure 7. Annual mean air temperatures at Santander, northern Spain.

In the summer of 1998, strong upwelling was observed west of Galicia as well as in the southern Bay of Biscay, due to prevailing north-easterly winds. This was the cause of the low summer temperatures observed over the Spanish shelf. The cold summer temperatures contrast with the relatively high temperatures in the first three months of 1998. These resulted in the highest winter temperature since 1992 (13.8°C). The sea surface salinity in the Bay of Biscay continued to increase following the trend evident since the low salinity event in 1995. In the upper parts of the permanent thermocline a slight salinity increase relative to 1997 was observed. In the central Bay of Biscay, sea surface salinity was about 35.8

Area 5 - Rockall Trough

The Rockall Trough is situated west of the British Isles and separated from the Iceland Basin by the Hatton and Rockall Banks and from the Nordic Seas by the shallow (500m) Wyville-Thompson ridge. It is one pathway by which warm surface North Atlantic upper water reaches the Norwegian Sea.

In May 1998 the surface Atlantic water was unusually warm and saline. The upper ocean salinity reached a maximum for the 24 year record, exceeding values observed during the high salinity years of the 1980s, which themselves followed on from the low salinity period in the mid-1970s (**Figure 8**).

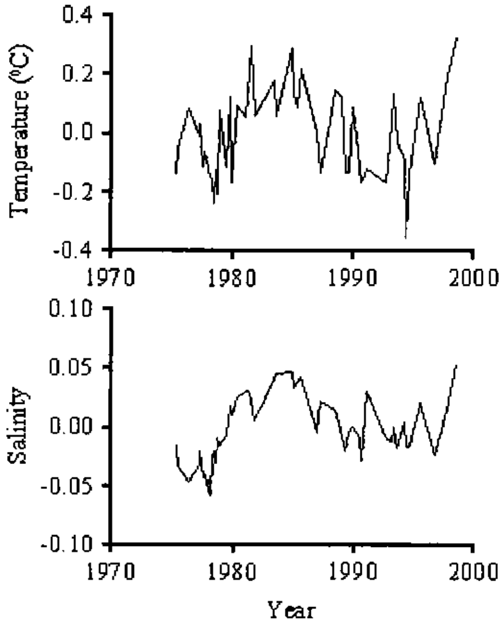

Figure 8. Temperature and salinity anomalies of surface Atlantic water in the Rockall Trough.

Area 6 - Faroe Bank Channel

The Faroe Bank Channel (FBC) receives an influx of Atlantic water which passes over the Iceland - Scotland Ridge into the Nordic Seas.

Since the mid-1990s, the temperature and salinity of the inflowing Atlantic water have increased, and this trend continued in 1998 (**Figure 9**), although there may have been a reversal of the trend in salinity during the latter half of the year.

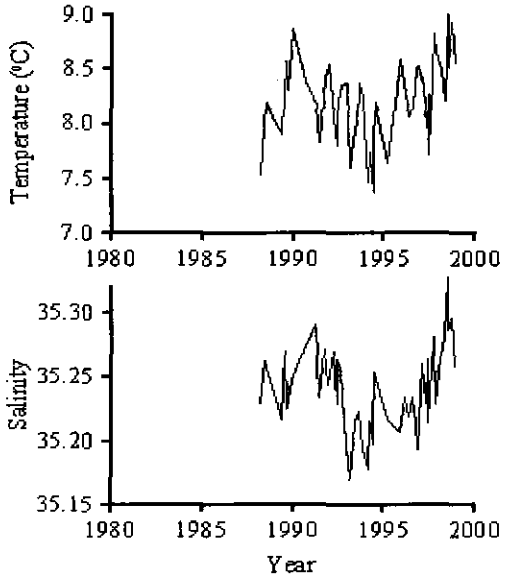

Figure 9. Temperature and salinity in the surface Atlantic waters entering the Faroe Bank Channel.

Area 7 - Northwest European Shelf Edge

Atlantic water lying at the northwest European shelf edge has been warming since 1987 at a rate of 0.5°C/decade. Particularly high temperatures (the third warmest recorded this century - **Figure 10**) were observed in the spring of 1998, but later in the year cooler temperatures were found. The salinity of the Atlantic water continued to rise during 1998, and the average values have reached a maximum for this century. This area did not show much response to the 1995/1996 flip in the NAO, but continues to reflect a response to the increasingly positive NAO.

Area 8 - Northern North Sea

The warm, salty conditions seen at the northwest European shelf edge were also experienced within the northern North Sea, continuing the trend of increasing annual mean temperatures and salinities during 1998. In the northwestern North Sea conditions were particularly mild during the first half of the year.

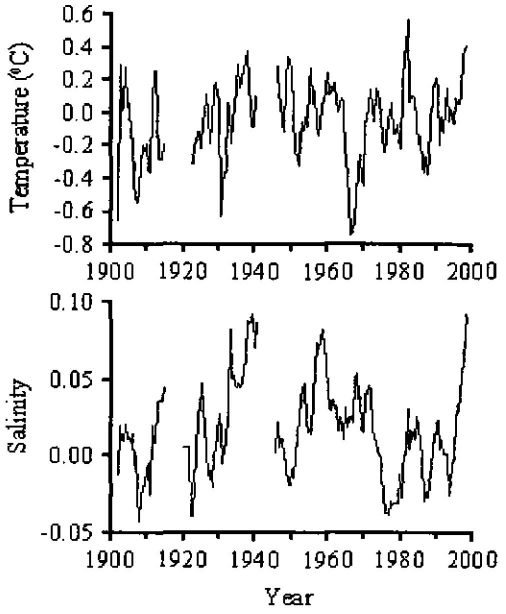

Figure 10. Temperature and salinity anomalies in the surface Atlantic waters lying along the northwest European shelf edge.

The warm and mild conditions are illustrated by the near-bed temperatures and salinities extracted from the January-March ICES International Bottom Trawl Survey (**Figure 11**).

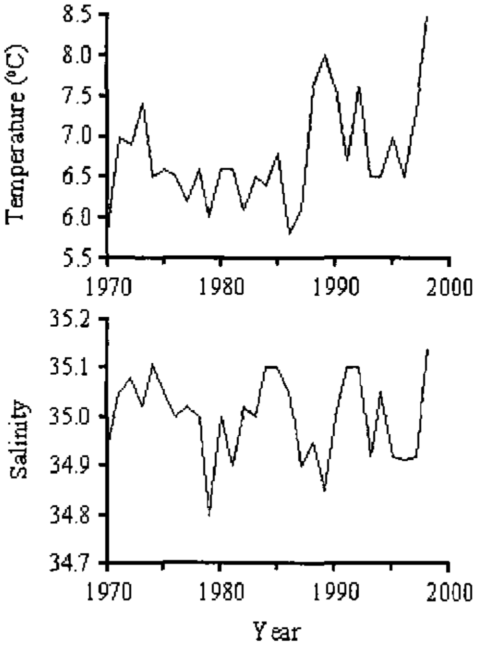

Figure 11. Temperature and salinity of near-bed water lying within the northern North Sea at 57° 30'N 0°E. The observations were performed during the ICES International Bottom Trawl Survey (See **Text Box - ICES IBTS**).

The ICES IBTS: A Source of Multi-Disciplinary Wide Area North Sea Observations

The ICES International Young Fish Survey (IYFS) in the North Sea has been undertaken during January/February in each year since about 1970. The name of the January-February IYFS became the IBTS Quarter 1 survey in 1993. IBTS is the International Bottom Trawl Survey. Most North Sea countries contribute to the survey.
The survey data is comprised of information on bottom trawl catches for 8 standard commercial fish species (herring, sprat, mackerel, cod, haddock, whiting, saithe and Norway pout), as well as catches of herring larvae.

The survey also includes station observations of hydrochemical measurements. Contour maps of temperature and salinity (and nutrients if available) drawn from data collected since the start of these annual surveys and other surveys during January and February can be viewed at:

www.ices.dk/ocean/project/datasets/iyfs.htm

Area 9 - Southern North Sea

From new data derived from a ferry run between Felixstowe and Rotterdam, it would appear that conditions in this area are quite closely linked to the NAO, although forcing may be local rather than due to oceanic forcing. Temperatures rose during 1998, continuing the recovery from the cool event during 1996, following the reversal of the NAO during the preceding winter.

Area 10 - Norwegian Sea

The considerable temperature increase observed in the south eastern Norwegian Sea during 1997 continued in 1998. As a result, the average temperature of surface water lying offshore from the shelf break was 1.5°C higher in August 1998 than in August 1996 (**Figure 12**). This large temperature increase seems to have only affected the south eastern Norwegian Sea. A smaller increase was observed off the Lofoten Islands, but further north temperatures have remained close to the mean since 1996. The general trend since the late 1970s is, however, a warming along the continental margin from the south eastern Norwegian Sea to Spitsbergen.

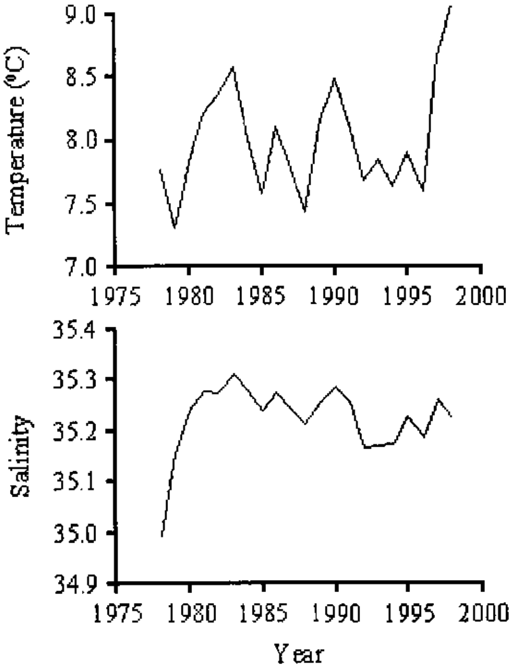

Figure 12. Temperature and salinity in the surface Atlantic waters in the southern Norwegian Sea (Svinøy Section).

Although there has been a general increase in salinity in the south eastern Norwegian Sea since 1992, there was a decrease from 1997 to 1998. In most of the remainder of the Norwegian Sea salinities have been declining since the early 1980s. This is probably a result of persistent wind driven supply of relatively fresh water from the East Icelandic Current.

Area 11 - Barents Sea

The Barents Sea is a shelf sea, receiving an inflow of Atlantic water from the west. The inflow demonstrates considerable seasonal and interannual fluctuations in strength and water mass properties, particularly in heat content and consequently ice coverage.

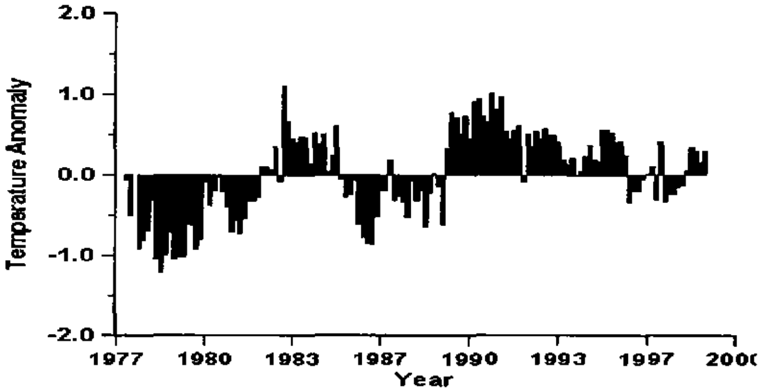

Figure 13. Temperature anomalies in the section between Norway and Bear Island

The Kola Section Centenary

The International Conference on Exploration of the Sea, held in June 1899 in Stockholm, recommended that observations along a standard section running north from the Kola Fjord (along 33° 30' E) and into the Barents Sea should be carried out.

Thus the Murman Fishery Research Expedition led by N.M.Knipovich occupied the Kola Section for the first time in 1900. The research vessel *"Andrey Pervozvanny"*, specially built and well equipped for that time, was used. The aim of the Expedition was to assess fish resources and possibilities for an all-year-round fishery in the southern Barents Sea. The Expedition was completed in 1908, and the Kola Section was then not occupied until 1921. The next gap in observations was caused bythe World War Two. The Section has been occupied most frequently since the middle of the 1950s with often more than 10 surveys each year (See **Figure 14**). By the Centennial year in 1999 the Kola Section had been surveyed 945 times.

Data collected along this section are used to study environmental variability and its impact on biota in the Barents Sea. They are also used as a basis to evaluate climatic variability in the area and estimate its role in fish stock fluctuations. Temperature and salinity time-series from the Kola Section are among the longest and most valuable for fisheries scientists, oceanographers and climatologists.

The Knipovich Polar Research Institute of Marine Fisheries and Oceanography (PINRO) held a symposium on April 12, 1999 in Murmansk (Russia) to celebrate the Kola Section centenary. The ICES WGOH was invited to participate in this symposium where seven papers were presented by Russian scientists, and five papers were given by members of the Working Group.

After a period with high temperature in the first half of this decade, the temperatures in the Barents Sea dropped to values slightly below the long term average over the whole area in 1996 and 1997 (except March 1997). From March 1998, the temperature in the western area increased to just above the average (**Figure 13**), while the temperature in the eastern areas stayed below the average during 1998 (**Figure 14**).

The high temperatures observed upstream in the Atlantic current arrived at the western entrance of the Barents Sea between October 1998 and January 1999 when the temperature rose by more than half a degree.

This increase was to a lesser extent observed in the central and eastern Barents Sea. The increased temperatures were also followed by increased salinity. The present temperature conditions is reflected in the ice conditions with little ice in the western area and severe ice conditions in the eastern areas of the Barents Sea.

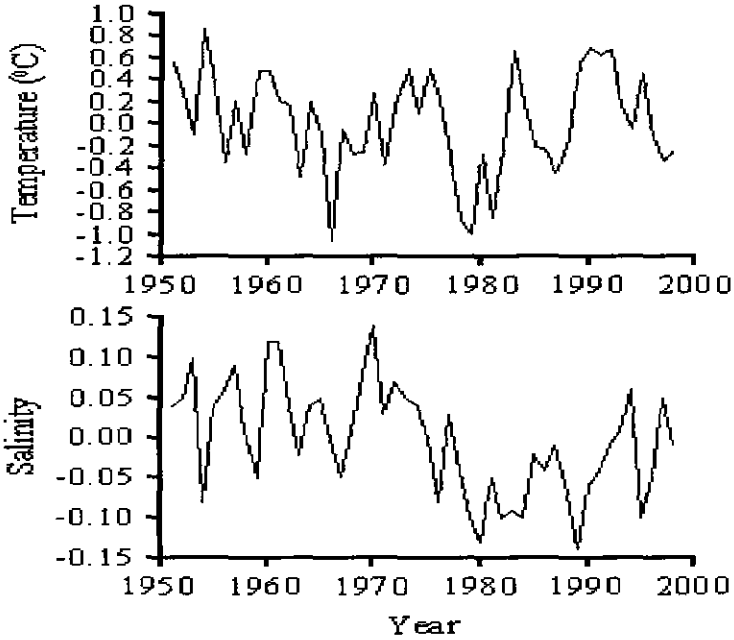

Figure 14. Temperature and salinity anomalies observed in the main currents along the historic Kola section (see **Text Box - The Kola Section Centenary**) in the eastern Barents Sea.

World Wide Web

The full report, including data and figures, upon which this status summary is based will be shortly available from the ICES Working Group on Oceanic Hydrography web page at:

http://www.ices.dk/committe/occ/ohyd.htm

This report also contains more detailed descriptions of changes to water masses in the ICES area, which may be of interest to oceanographers interested in inter-annual and decadal variability.

The ICES WGOH may be contacted at OHYD@ices.dk