Hydrography Committee

ICES CM 1997/C:3



REPORT OF THE

# WORKING GROUP ON OCEANIC HYDROGRAPHY

**Texel, The Netherlands**
**21–23 April 1997**

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International Council for the Exploration of the Sea

Conseil International pour l'Exploration de la Mer

Palægade 2–4 DK–1261 Copenhagen K Denmark

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# 1. Opening

Following the opening remarks by the Chairman, Johan van Bennekom of the Netherlands Institute of Ocean Sciences welcomed the WG members to Texel and to the Institute, and explained the local arrangements associated with the meeting. The agenda (Annex A) was discussed and modified to include additional presentations that are of interest to the WG, as well as to make allowances for members who could not join the meeting on the first day. List of participants is given in Annex B.

# 2. Review of Membership

The latest list of the WG members provided by the ICES Secretariat was reviewed by the attendees, and corrections and additions were made to provide addresses, telephone and FAX numbers and the e-mail addresses (Annex D). However, it was obvious that the Secretariat had not revised the member list to reflect the 1997 nominations from the member countries.

# 3. Remarks from the ICES Oceanographic Secretary

Due to the pressures and commitments the Oceanography Secretary was not able to attend the meeting. The following text was provided subsequent to the meeting at the request of the Working Group.

The Oceanography Secretary, Dooley, reported that the past year had seen a significant increase in the size of the data bank by almost 60,000 profiles. However there was a notable drop in the number of chemical data (nutrient and oxygen) received, largely because a number of the major sources of data had been concentrating on developing relational database systems for CTD data only. This in turn was resulting in the development of more robust quality control systems in support of CTD data which was in part producing data of higher quality. However this was also placing extra pressure on the data centre because of re-submissions of old, but newly quality-controlled data. Because of this the total amount of data received during the past years exceeded well over 100,000 profiles. Unfortunately, sources of data remained relatively static, with data being mainly acquired from government laboratories. University departments continue to be poor contributors, and this remains a major shortcoming in the usefulness of the databank. At the request of the EC-MAST, the data centre was asked to review the fraction of University data in the public domain, and this produced rather telling statistics. For example, in the case of the University of Bergen which is a rather prolific collector of oceanographic data, only 6% of the data collected since the 1960s have been made available. It is hoped that involvement in MAST Projects (see next paragraph) will help to nurture contacts with University departments and therefore improve data flow and enhance the overall quality of the Databank.

The Data Centre is currently contracted via EC MAST to manage the data sets of two major MAST projects, viz ESOP-II and VEINS, both of which are projects based on the oceanography of the Nordic Seas. The data centre also provides input to the TASC project and is responsible for the compilation of the ESOP-1 data set for subsequent merging with ESOP-II data. The data management structure for these projects is closely based on routine procedures which are being adapted to accommodate the broader range of parameters that are being collected, particularly in ESOP-II.

The Data Centre web-site continues to expand slowly, but its basic structure remains as described last year. The web-presence has resulted in a significant increase in the number of requests for data, with the balance shifting significantly from the provision of raw data to the provision of gridded products, especially the provision of statistics on varying space and time scales. It is expected that the more common types of requested products will be made available from the website.

The ICES Inventory of Oceanographic Activities, which was devised by the working group more that 15 years ago, continues to be produced on an annual basis. Many (>60 per year) requests for changes/additions reflect the continued interest in this product. However, because of changing commitments and priorities in the Secretariat it is likely that this and some other services may have to be discontinued soon.

## 4. Results from Standard Sections and Stations

Narayanan reported results from the NW Atlantic (Annex E). In general there have been warmer winter conditions. Air temperatures monitored at five sites have revealed normal or warmer than normal conditions. These temperatures seem to mark an end to the recent cooling trend. The warming appears well correlated with changes in the NAO. Less sea ice was produced due to weaker NW winds and warmer winter temperatures. A good index of climatic conditions is the area of sub-zero temperature water on the shelf. Standard sections off Seal Island, Bonavista and the Flemish Cap all reveal a warming trend, associated with possible freshening. Station 27 also reveals this trend. Rossby questioned whether density had been examined in order to describe changes in the dynamics of the upper ocean. Narayanan explained that geostrophic currents across the standard transects were computed, but showed considerable variability.

Malmberg presented results from Icelandic waters (Annex F). Conditions have been generally mild. Although salinities were low north and east of Iceland, this was not associated with cold temperatures as would normally be expected. Satellite imagery demonstrated SST features around Iceland very well. 1996 was not an ice year, but the salinity of the East Iceland Current was rather low. Malmberg noted that the NAO should be used with some caution in this area, since local variations in atmospheric pressure patterns were common.

No member from Denmark was present at the meeting. However, Buch from the Royal Danish Administration of Navigation and Hydrography provided a written report summarising the observations from west Greenland (Annex G). Consistent with the above-normal air temperatures at Nuuk/Godthaab, the upper layer temperatures in the west Greenland coastal waters were also above normal.

Hansen (Annex H) presented results from standard sections and stations around Faroe Islands. The decrease of salinity in the Atlantic water in the Faroe Bank Channel has now stabilised after beginning in the late 1980s and reaching a maximum rate in 1993/94. The temperature and salinity of this water is a good indicator of conditions in the North Atlantic Current. These changes have been associated with rather small changes in temperature. On the shelf temperatures have increased since the cold years 1993, 1994 and 1995.

Turrell presented results from the Faroe Shetland Channel (Annex I). Past CTD data has been recalibrated, hence values and time series presented may differ slightly from previously quoted values. There was a problem with some of the definitions used to derive indices from the five water masses observed within the Channel, hence they should be used with some caution. North Atlantic Water (NAW) at the shelf edge has demonstrated a warming since 1987. Salinity has shown great variability since the arrival of the salinity anomaly in the mid-1970s. This variability appears correlated with the NAO index. There may be an underlying increasing trend since the mid-1970s, with salinities now approaching 1960 values. In the so-called Modified North Atlantic Water there has been a cooling since 1960, unlike the general warming observed in NAW. There has been a recent enhanced freshening since 1991, with an underlying freshening trend evident since 1960. Salinities are beginning to approach values observed in the mid-1970 anomaly years. Salinity continues to decline in all intermediate and deep-water masses. In the North Sea, salinity has been variable, but well correlated with that of the NAW. The most Fair Isle Munken section shows extremely anomalous salinity in the Arctic Intermediate / North Icelandic Water, with a density distribution displaced towards the Faroese shelf.

Blindheim presented results from Norwegian sections in the Barents and Norwegian Seas (Annex J). The general trends in both temperature and salinity are decreasing. Temperatures in the Barents Sea have been above the long-term mean during 1989-1995, with warmest conditions in 1991/92. During 1996 temperatures fell to below the long term mean. The colder conditions are also reflected in the sea ice records, with relatively large ice coverage during the winter 1995-96. In the Norwegian Sea there was an increase in temperature and salinity between 1994 and 1995. From 1995 to 1996 all sections demonstrated cooling and freshening, with some local variability. In the North Sea relatively cold temperatures were found following the cold and dry winter of 1995/96. Time series in the Skagerrak reveal that deep-water renewal occurred in 1991 after a long period without deep water exchange. There was a further supply of deep water in the winter of 1996.

Osterhus reported on the oceanographic time series of Ocean Weather Station «Mike». The time series has not been updated since last year. However, considerable effort was made to quality control and analyse the existing long time series with the purpose of publishing the data on CD-ROM, and the results in refereed journals.

Lavín presented results from Spanish standard sections (Annex K). Air temperatures have closely followed changes in the NAO index. Results from the standard sections reveal a strong seasonal cycle, with evidence of regular upwelling. Winter salinities appear to be decreasing. There was evidence of a stronger poleward current during 1995/96. Nutrient records demonstrate peaks during the upwelling seasons. At 10m depth the warming that was evident from 1991-1995 has now stopped. Also the salinity decrease observed between 1991 and 1994 has now reversed. A correlation of salinity variability between two stations at 70m depth at La Coruna and Santander revealed a significant correlation with a lag of 60 days implying a poleward flow of 10 cm/s. Current meter data confirmed this mean transport.

Piechura presented results from the Barents Sea (Annex L). Conditions were very variable, with the intrusion of cold, fresh bottom water, termed Barents Polar Water (BPW). Variable mixing with Atlantic water was observed. Coldest temperatures were recorded in 1995. On the Svalbaard shelf water there was strong evidence of cold, dense bottom water cascading off the shelf.

Meinke presented results from the Greenland-UK trans-Atlantic section (Annex M). The differences between occupations in 1991 and 1995 were discussed, with particular reference to changes in the Labrador Sea Water. Implications to transport within intermediate waters of the North Atlantic were discussed. The volume budget of these intermediate waters did not appear at first to balance.

Further discussions took place on the standard section data. Rossby presented new Pathfinder SST images and noted these were extremely useful new products. Van Aken presented results from an analysis of altimeter data revealing patterns in eddy kinetic energy in the northeast Atlantic.

## 5. Report Format

During the 1996 WG meeting, it was decided that an overview of the status of the physical environment is to be prepared after the 1997 meeting, and presented at the annual science congress. Following the presentations on the standard sections and stations, the format and authorship of the overview report was discussed at length. The group recommended that one of the individuals who reported on the sections/stations together with a team he/she selected from the group be given the editorship of the overview report. Turrell from Scotland was nominated as the chairman for the editorial group for the 1997 and 1998 reports. Other members of the editorial group are Narayanan and Lavín.

An abstract was prepared for the ICES Annual Science Congress in Baltimore. It was also agreed that all relevant texts and figures associated with the presentations on standard sections and stations will be submitted to the Chairman before the end of May, so that preparation of the report and the overview paper can proceed in a timely fashion.

## 6. Progress in National and International Projects in North Atlantic

Bennekom presented results from his analysis of time series of temperature, salinity and nutrients collected from the Norwegian Sea (Annex N). He has added data from several cruises from the region to his time series of hydrographic properties of the deep water in the Norwegian Sea. By applying corrections for the standard water batches, as published by A. Mantyla, Bennekom was able to upgrade the quality of the deep salinities to a satisfactory level. The results show a constant salinity of 34.910 ($\pm$0.001) since 1981, indicative of a stagnant situation in the deep Norwegian Sea. It was hypothesized that such salinity characteristics are caused by the disappearance of deep convection in the Greenland Sea, a source for the flushing of Norwegian Sea deep layers. Osterhaus added that the concurrent change in temperature of the deep water in the Norwegian Sea, also presented by Bennekom, can be modelled with a simple model containing isopycnal mixing and a realistic geothermal heat flux, without any lateral exchange with the Greenland Sea. This stagnant scheme for the deep Norwegian Sea is further supported by the build-up of dissolved silica gradients and the reduction of the $^3$H concentration in accord with radioactive decay.

Van Aken presented results from an ongoing program to study the circulation in the Bay of Biscay and the role of currents and mixing in maintaining the observed distribution of temperature and salinity. An impressive mix of hydrography, moored current meters and WOCE-type surface drifters are being used. The boundary currents are eastward along the Spanish coast, and north along the shelf break west of France. The interior circulation is less clear and must await detailed analyses. The spreading north of Mediterranean waters to Cape Finisterre beyond which two regions of high salinities, straight north and east along the Spanish coast suggest two pathways of spreading, but the relative roles of advection and mixing need to be sorted out. The current meters at the depth of the salinity maximum indicate a northward flow along the slope, but the high eddy kinetic energies suggest significant mixing. In addition there is strong evidence for enhanced diapycnal mixing along the boundary by breaking internal waves.

Meincke summarised the German trans-Atlantic sections that will take place this summer along WOCE lines A1 and A2. The first crosses the subpolar gyre, and the second crosses the ocean at 48°N, just south of the Subpolar Front. These sections follow the same lines as the two taken during the International Geophysical Year (IGY) in the late 1950s. This will be the third occupation of the A1 and A2 lines respectively since 1993. Meincke also reported that a major WOCE symposium will be held in Halifax May 25-29, 1998. A North Atlantic WOCE workshop is also being planned.

Malmberg discussed the surface circulation around Iceland as observed with WOCE-type surface drifters. These have been most valuable in highlighting the variability of the surface flow underscoring the need for additional observations to obtain a more quantitative measure of the mean flow and eddy activity. More drifter studies are planned for this coming summer. A lively discussion took place about the nature of the surface flow along the southern and eastern coasts of Iceland, as well as along the Iceland-Faeroes ridge. In particular, the WG focused on how and/or what fraction of the warm waters from the North Atlantic Current/Subpolar Front make their way north into the Nordic Seas along 1) the Reykjanes Ridge, 2) west of Rockall Bank, and 3) through the Faeroes-Shetland Channel. These questions are expected to be resolved from the direct measurements of velocity in the North Atlantic WOCE.

Blindheim reported that Norway plans to continue repeat hydrographic sections along the Bear Island West and Svinoy sections. These sections were first taken in 1958 during the first IGY.

Meincke detailed the plans for the upcoming VEINS program "Variability of Exchange in the Nordic Seas" (Annex O). The immediate objective is to conduct a program of flux measurements between the Nordic Seas and the Arctic in the north, and the North Atlantic in the south with a view towards implementing a longer term system of critical measurements to understand low-frequency variability of the Nordic Seas. The program, scheduled to start this year, will be a three-year pilot program to monitor in- and outflows using a mixture of moored current meter and ADCP measurements and hydrographic surveys. As an integral part of the program, a concurrent modelling activity will provide the framework for the analysis and assimilation of the observations and their dynamical interpretation. Significantly, the model will rely heavily upon boundary flux and surface forcing conditions to understand the interior circulation and its variability. A significant objective of the modelling effort will be to identify the minimum (i.e. cost-effective) set of critical measurements needed to monitor the Nordic Seas and their variability on a long-term basis.

Dickson reported on activities to monitor the overflow and southward transport of Denmark Strait Overflow Waters along the East Greenland continental slope. A ten-year plan is envisaged with funding for the immediate years probable. Participation from Finland, Germany and the UK for current meter measurements is anticipated. Past current meter measurements indicate astonishingly steady southward velocities. Dickson emphasised the importance of determining the thickness and location of the overflow waters, otherwise it will be difficult to obtain a quantitative understanding of the low-frequency variability of the overflow waters.

An important challenge for the future is to better document and understand the role of the ocean in mitigating and/or controlling climate and its variability. A new international cooperative effort, CLIVAR, seeks to address these questions in a systematic way. Dickson discussed one particular aspect of low frequency variability, namely a hypothesis that thermal anomalies can be injected into the ocean at high latitudes, circulate around the North Atlantic and reappear at high latitudes to provide a kind of decadal locking oscillator mechanism. Although the feedback mechanism as such is highly conjectural at this point, increasing evidence shows with considerable confidence that perturbations injected into the Labrador Sea waters at its source appear some five years later in the western subtropical gyre at Bermuda documenting a definite pathway for water mass propagation, not merely wave propagation (which would require much less time).

Lavín reported on the multi-disciplinary program, CANIGO (Canary Islands Azores Gibraltar Observations), involving 45 partners and 12 countries, designed to understand the Canary-Azores-Gibraltar system and its interaction with the northeast Atlantic Ocean. CANIGO is implemented through four subprojects and the field work has already started. A comprehensive management plan has also been implemented to ensure coordination among the components and to assure timely delivery of the results.

Lavín also reported on a 3-year Spanish program in the Bay of Biscay, planned to commence in 1998. This program is primarily biological in nature, with emphasis on fluxes, especially carbon.

Hagen reported on the Baltic activities with emphasis on the MESODYN project. MESODYN program is a cooperative venture with institutes in Kaliningrad and Petersburg, and covers four areas, the Arkona and Bornholm Basins, the Stolpe furrow, and the east Gotland Basin. The research emphasis will be on a) vertical mixing and fluxes, b) oceanographic events and c) horizontal currents. The observation program is designed to provide fine resolution data for input into the numerical models.

## 7. Developments in GOOS

None of the members present at the meeting had sufficient information on GOOS to report on the progress of GOOS implementation. However, every one agreed that ICES is capable of providing considerable assistance in the data management component of GOOS. Narayanan reported that she has been asked to attend the IGOOS meeting in Paris this summer as one of the Canadian delegates, and volunteered to provide an overview at the next WG meeting.

## 8. NANSEN Project Report

Hansen reported progress towards the final publication of results from the north Atlantic-Norwegian Sea exchanges (NANSEN) project. Twelve papers from the 1991 theme session were now edited and on the point of submission for publication in the ICES Co-operative

Research Report series together with a synopsis of the aims and history of the project by Hansen, Osterhus, Dooley, Gould and Rickards.

## 9. Trans-Atlantic ADCP Survey Proposal

Rossby (US) informed the Working Group on behalf of his Norwegian colleague Osterhus about the status of the planning for a VOS-ADCP line between Fair Isle and Kap Farvel. Negotiations are underway with the Danish Royal Arctic Line, which operates the Greenland supply vessels at 3 weeks interval. The vessel under consideration is already equipped with a surface TS-recorder. The route is optimal for scientific reasons, since the data will support the monitoring of the upper limb of the global thermohaline conveyor belt circulation. A similar project along the New York-Bermuda line crossing the Gulf Stream has already proven to be highly successful. The Working Group appreciates this activity.

## 10. Oceanographic Instrumentation

Lundberg informed the WG about a revival of the use of underwater cables for transport measurements. After initial trials with a demobilized telephone cable between Sweden and the Island of VEN using Carbon/Copper electrodes, latest experiments with dedicated cables and more sensitive Silver/Silverchloride electrodes have resulted in useful measurements in the Skagerrak area. Present improvements concern the analysis of the data, in particular if a baroclinic structure of the flow field has to be considered.

Osterhous reported on experiments in cooperation with RD Instruments to use an acoustic Doppler Current profiler (ADCP) package to measure ambient noise, to determine wind speed and rainfall rate. Such measurements in the past utilised hydrophone packages, and not ADCPs. Report on the results of this experiment can be found on the RD Instruments' WWW home page.

## 11. Overview of Instrument Calibration Procedures and Quality Assurance

The successive inter-calibration exercises of ICES Marine Chemistry WG and later the QUASIMEME initiative (European Community (EC) Bureau of Reference) have been successful in achieving a progressive reduction in community error for nutrient analysis. However, QUASIMEME procedures are not adapted for use by seep-sea oceanographers. The WGOH invites Dr. David Wells to advise on how QUASIMEME might best meet the specialised needs of deep-sea oceanography.

The WG was also advised that new quality assurance (QA) literature was available in the form of the WOCE QA manual and a series of handbook on methods, protocols, archiving and QA that were currently being issued in support of EC MAST Programs Though aimed at specific projects, these have a general reference.

## 12. Satellite Altimetry in Circulation Studies

Availability of altimetry data on CD-roms was noted (van Aken) and a number of projects utilising this were mentioned. A combination of altimetry and moored bottom pressure or inverted echo-sounder has great potential in certain areas, especially slope regions (Rossby). During the discussion, a concern was raised that students are being less and less familiarised with observational techniques (as compared to modelling) which may have an significant impact on large programs in the upcoming years.

## 13. Ocean Climate Forecasting

The discussion initially focused on the Norwegian approach to forecasting which is a part of the annual environmental report of the Marine Research Institute in Bergen. This approach is mainly based upon statistical prediction supplemented by other information and each prediction is evaluated in next year's report. New initiatives at prediction of fisheries will require reliable prediction of environmental changes. There was some discussion as to how appropriate prediction schemes are at the present stage. Clearly, there is a demand (Dickson), but different oceanic systems have different predictability and the time for which prediction may be realistic varies from one region to another (van Aken). In Canada, the index from station 27 may be useful for prediction a few months ahead and the areal extent of 4°C water seems to be a good index for salmon (Narayanan). Cod growth is also strongly related to temperature and temperature may predict weight at age e.g. at the Faroes (Dickson).

## 14. Second Decadal Symposium Proposal

The item on a «second decadal symposium» on time series of physical and chemical observations in the ocean and related biological investigations, along the lines of the Aland Symposium in 1991, was introduced by Dickson. The symposium aims to give decadal information on environmental conditions during the nineties in relation to longer observation periods, with emphasis on the ICES area in the north Atlantic, but not exclusively so. The WG members unanimously endorsed the proposal and put forward the suggestion that some long-term contributors of time series from the ICES community be honoured as well at this occasion, which is within the spirit of ICES and the Annales Biologiques.

It was decided to recommend to hold the symposium in Edinburgh, Scotland, in August 2001. The Chief Executives of the Marine Laboratory, Aberdeen and the CEFAS Laboratory, Lowestoft, has agreed to provide partial financial support for the event. The dates have been chosen so that the Symposium immediately precedes the Edinburgh International Festival and the main venue is expected to be the Royal Museum of Scotland, Chambers Street, with a Symposium Dinner, at participant's expense, in the main exhibition hall of the Museum.

The WG thanked Dickson and Meinke for volunteering to be the convenors of the symposium and Turrell and Drinkwater (Bedford Institute of Oceanography, Canada) for agreeing to act as the editors of the proceedings.

The WG discussed the possibility of NAFO participating in the Symposium, since NAFO has a keen interest in the north Atlantic, and through its environmental committee, does review the state of the ocean at annual and decadal time scales. Furthermore, many of the scientists who are involved in such studies in ICES are also participants in NAFO. The WG proposes to investigate this possibility further.

## 15. Any Other Business

Blindheim informed the WG that the 100th anniversary of the Kola Meridian Section will be in 1999, and that a special 1-day symposium is being planned to mark this event. The Knipovich Polar Research Institute of Marine Fisheries and Oceanography (PINRO) has offered to host the 1999 Oceanic Hydrography WG meeting if the meeting can be scheduled to commence the day after the symposium. Blindheim also offered to assist in making the travel arrangements for the members. The WG members were unanimous in their decision to accept the offer, and thanked Blindheim and the Russian colleagues for providing such an opportunity.

Rossby expressed an interest to be informed of research cruise plans in the ICES area for the upcoming years. He and his US colleagues are planning to conduct a very large drifter program in the north Atlantic, and are looking for opportunities to piggy-back on existing cruises. The WG agreed that it is a good idea to make such information available and requested the ICES Secretariat to investigate the possibility of posting the cruise schedules on the ICES WWW page, if it is not already available at any of the other sites in a consolidated form.

Narayanan reminded the WG members of the April 28th deadline for submitting abstracts to ICES. Ideas for theme sessions for 1999 and onwards were also discussed. The WG recommends four topics for the Theme Sessions for the upcoming years:

1. The Physical Environment of the *calanus finmarchicus*
2. The Aanderaa Current Meter: The contribution of Ivar Aanderaa to modern oceanography.
3. The use of ADCP in fisheries research
4. The shelf-edge, slope or Eastern boundary currents in the European margin.

The WG has identified potential convenors for the theme sessions. The Chairman was asked to contact them to confirm their acceptance.

The members felt that the mandate of the Oceanic Hydrography WG may be modified as a result of the new organizational structure. The WG supported Dickson's suggestion that Narayanan contact the new Chairman of the Oceanography Committee for the Terms-of-Reference of Oceanic Hydrography WG.

## 16. Place, Date and Topics of Next Meeting

The WG accepted an invitation from Lavín to have the 1998 meeting at Instituto Español de de Oceanografía, Santander, Spain, on 27, 28 and 29 April.

The following topics are proposed for the next meeting:

a) Update and review results from Standard Sections and Stations
b) Progress in national and international projects in north Atlantic WOCE, VEINS, CLIVAR/ACSYS, GLOBEC , OMEX, ESOP2, TASC, CANIGO, and others
c) Shelf-edge, slope or Eastern boundary currents
d) Assess the developments in GOOS

e) Review the progress of ships-of-opportunity vessel-mounted ADCP surveys
f) oceanographic instrumentation
g) Second Decadal Symposium

## 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 north Atlantic at the Annual Science Congress.

b) 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.

c) A number of programs are underway in the eastern Atlantic, Iberian Basin, Bay of Biscay, etc. This agenda item will provide an opportunity to review the results from these programs.

d) GOOS is still in design stage. Most ICES member countries will be formally involved, one way or another, in GOOS activities. 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 to the chairman.

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

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

g) This item is to review the progress on the second decadal symposium planning.

# Annex A: ICES Working Group on Oceanic Hydrography

**Texel, Netherlands, April 21-23, 1997**

Agenda

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# Annex B: List of Participants

| | |
|---|---|
| J. Blindheim | Norway |
| E. Hagen | Germany |
| H. Van Aken | Netherlands |
| A. J. van Bennekom | Netherlands |
| R. R. Dickson | UK |
| B. Hansen | Denmark |
| A. Lavín | Spain |
| S. Narayanan | Canada |
| P. Lundberg | Sweden |
| S. A. Malmberg | Iceland |
| J. Meincke | Germany |
| S. Osterhus | Norway |
| J. Piechura | Poland |
| T. Rossby | USA |
| W. Turrell | UK |

# Annex C: Recommendations

1) Working Group on Oceanic Hydrography recommends that a Symposium on «Hydrobiological Variability in the ICES Area, 1990–1999» be held in Edinburgh, Scotland on 8–10 August 2001, with Dr. R.R.Dickson of the CEFAS Laboratory, Lowestoft and Professor Jens Meincke of the Institut fur Meereskunde of the University of Hamburg as the Co-Convenors for the symposium.

   This will be the second in a series of such Symposia held to review the physical, chemical and biological changes of the decade and to set these changes into the context of longer-term variability; the first, on the decade of the 1980's, was held at Mariehamn in the Aland Islands in June 1991. These symposia were initiated by Council in 1987 as a means of continuing the essential purpose of the old Annales Biologiques series in recording the hydrobiological character of each decade across the ICES Area. As with the Mariehamn Symposium, the Proceedings will be published in the ICES Marine Science Symposium Series, with, Turrell and Drinkwater as Editors, and will form a Festschrift in honour of individuals who have maintained and supported the time-series on which the Symposium is based. The Chief Executives of the Marine Laboratory, Aberdeen and the CEFAS Laboratory, Lowestoft, is providing partial financial support for the event. The dates have been chosen so that the Symposium immediately precedes the Edinburgh International Festival and the main venue is expected to be the Royal Museum of Scotland, Chambers Street, with a Symposium Dinner, at participant's expense, in the main exhibition hall of the Museum.

2) The WG recommends that the following theme sessions be included in the ICES Annual Science Congress in the upcoming years.
   a) The Physical Environment of the calanus finmarchicus,
   b) The Aanderaa Current Meter: The contribution of Ivar Aanderaa (1940–1996) to modern oceanography,
   c) The use of ADCP in fisheries research,
   d) The shelf-edge, slope or Eastern boundary currents in the European margin.

3) The Working Group on Oceanic Hydrography will meet at Instituto Espanol de Oceanografia, Santander, Spain, on 27, 28 and 29th of April 1998 to:

a) Update and review results from Standard Sections and Stations
b) Progress in national and international projects in north Atlantic WOCE, VEINS, CLIVAR/ACSYS, GLOBEC , OMEX, ESOP2, TASC, CANIGO, and others
c) Shelf-edge, slope or Eastern boundary currents
d) Assess the developments in GOOS
e) Review the progress of ships-of-opportunity vessel-mounted ADCP surveys
f) oceanographic instrumentation
g) Second Decadal Symposium

# Annex D: Membership List

| Name | Address | POB | City | Country | Email | Telephone | Telefax |
|---|---|---|---|---|---|---|---|
| Dr H.M. van Aken | Netherlands Institute for Sea Research | P.O. Box 59 | 1790 AB Den Burg, Texel | The Netherlands | aken@nioz.nl | Tel.(31)-222-369416 | Fax (31)-222-319674 |
| Dr G. Becker | Bundesamt f. Seeschiffahrt und Hydrographie | Postfach 30 12 20 | 20305 Hamburg | Germany | gerd.becker@m2.hamburg.bsh.d400.de | | |
| Mr A.J. van Bennekom | Netherlands Institute for Sea Research | P.O. Box 59 | 1790 AB Den Burg, Texel | the Netherlands | bennekom@nioz.nl | Tel.(31)-222-369392 | Fax (31)-222-319674 |
| Dr J. Blindheim | Institute of Marine Research | P.O. Box 1870 Nordnes | 5024 Bergen | Norway | johan.blindheim@imr.no | Tel.(47)-55-238500 | Fax (47)-55-238584 |
| Dr E. Buch | Farvandsvæsenet Overgaden o. | Vandet 62b Postboks 1919 | 1023 Copenhagen K | Denmark | farvebu@unidhp.uni-c.dk | | |
| Ms H. Cavaco | IPIMAR | Avenida de Brasilia | 1400 Lisbon | Portugal | | | |
| M J. Citeau | ORSTOM | B.P. 1386 | Dakar | Sénégal | | | |
| Mr. E. Colbourne | Dept. of Fisheries & Oceans | P.O. Box 5667 | St-John's, NF A1C 5X1 | Canada | Eugene@pisces.nwafc.nf.ca | Tel. (709)-722-6106 Fax (709)-772-3207 | |
| Dr C. Afonso Dias | IPIMAR | Avenida de Brasilia | 1400 Lisbon | Portugal | | | |
| Dr R.R. Dickson | The Centre for Environment, Fisheries and Oceans | Aquaculture Science | Lowestoft NR33 OHT | Suffolk United Kingdom | r.r.dickson@cefas.co.uk | Tel.(44)-1502-524282 | Fax (44)-1502-513865 |

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|---|---|---|---|---|---|---|---|
| Dr. H. Dooley | ICES | Palaegade 2-4 | 1261 Copenhagen K | Denmark | harry@ices.dk | Tel.+45 33 15 42 25 | Fax +45 33 93 42 15 |
| Dr E. Fahrbach | Alfred-Wegener-Institut für Polar- und Meeresforschung | Columbusstrasse | 27668 Bremerhaven | Germany | | | |
| Prof A.F. Fiuza | University of Lisbon | Institute of Oceanography | Campo Grande | 1700 Lisbon Portugal | | | |
| Mr N. Gooding | Hydrographic Department AUNTON | Somerset | TA1 2DN | United Kingdom | **Error! Bookmark not defined.** | | |
| Dr W.J. Gould | Southampton Oceanography Centre | Waterfront Campus European Way | Southampton SO14 3ZH | United Kingdom | john.gould@soc.soton.ac.uk | | |
| Dr E. Hagen | Institut für Ostseeforschung | Seestrasse 15, 18119 | Warnemünde, | Germany | eberhard.hagen@io-warnemunde.de | Tel.(49)-3815197150 | Fax (49)-3815197440 |
| Dr B. Hansen | Fiskirannsóknarstovan | P.O. Box 3051 | Noatun, FR-110 Tórshavn | Faroe Islands Denmark | bogihan@frs.fo | Tel.298-15092 | Fax 298-18264 |
| Dr N.K. Højerslev | Geofysisk Afdeling | Juliane Mariesvej 30 | 2100 Copenhagen O | Denmark | nkh@gfy.ku.dk | | |
| Mr K.P. Koltermann | Bundesamt f. Seeschiffahrt und Hydrographie | Postfach 30 12 20 | 20305 Hamburg | Germany | Koltermann@bsh.d400.de | | |
| Ms A. Lavín | Instituto Español de Oceanografía, Laboratorio de Santander | Apdo 240 | 39080 Santander | Spain | alacia.lqavin@st.ieo.es | Tel.(34)-42-275033 | Fax (34)-42-275072 |

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|---|---|---|---|---|---|---|---|
| M C. Leroy | IFREMER | Rue de l'Ile d'Yeu BP 1105 | 44311 Nantes Cédex 03 | France | | | |
| Mr H. Loeng | Institute of Marine Research | P.O. Box 1870 | Nordnes, 5024 | Bergen Norway | harald.loeng@imr.no | | |
| Prof P. Lundberg | Fysisk Oceanografi/SMF | Stockholms Universitet | S-10691 Stockholm | Sweden | peter@misu.su.se | Tel.(46)-8-161735 | Fax (46)-8-157956 |
| Mr K. McClean | Hydrographic Department TAUNTON | Somerset TA1 2DN | | United Kingdom | | | |
| Dr S.A. Malmberg | Marine Research Institute | P.O. Box 1390 | Skulagata 4 | 121 Reykjavik Iceland | svam@hafro.is | Tel.(354)-552-0240 | Fax (354)-562-3790 |
| Prof J. Meincke | Institut für Meereskunde der Universität Hamburg | Troplowitzstrasse 7 | 22529 Hamburg | Germany | meincke@ifm.uni-hamburg.de | Tel.(49)-40-41235985 | Fax (49)-40-41234644 |
| Dr S. Narayanan | Marine Environmental Data Service | 200 Kent St. Station 1202 | Ottawa, Ontario | Canada KIA OE6 | Narayanan@ottmed.meds.dfo.ca | Tel. 613-990-0265 | Fax 613-993-4658 |
| Mr R. Oeberst | Institut für Ostseefischerei | An der Jägerbäk 2 | 18069 Rostock-Marienehe | Germany | | | |
| Prof J. Olafsson | Marine Research Institute | P.O. Box 1390, Skulagata 4 | 121 Reykjavik | Iceland | svam@hafro.is | Tel.(354)-552-0240 | Fax (354)-562-3790 |
| Mr S. Osterhus | University of Bergen Geophysical Institute | Allegaten 70 | 5007 Bergen | Norway | svein@regn.gfi.uib.no | | |
| Mme A. Pichon | EPSHOM SSH | B.P. 426 | 29275 Brest Cédex | France | | | |

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|---|---|---|---|---|---|---|---|
| Dr J. Piechura | Polish Academy of Sciences | Institute of Oceanology P.O. Box 6 | ul. Powstancow Warszawy 55 | 81-712 Sopot Poland | piechura@iopan.gda.pl | Tel.(48)-58-517281 ext.313 | Fax (48)-58-512130 |
| Dr M. Rhein | Institut für Meereskunde an der Universität Kiel | Düsternbrooker Weg 20 | 24105 Kiel | Germany | mrhein@ifm.uni-kiel.de | | |
| Prof T. Rossby | Graduate School of Oceanography | University of Rhode Island | Kingston R.I. 02881 | USA | tom@rafos.gso.uri.edu | Tel.(401)-874-6521 | Fax (401)-874-6728 |
| Mr M. Stein | Bundesforschunganstalt f. Fischerei | Institut für Seefischerei | Palmaille 9, 22767 Hamburg | Germany | | | |
| Dr W. Turrell | Marine Laboratory | P.O. Box 101, Victoria Road | Aberdeen AB11 9DB | United Kingdom | turrellb@marlab.ac.uk | Tel.(44)-0-1224-876544 | Fax (44)-0-1224-295511 |
| Mr J.P. Vitorino | Instituto Hidrografico | Rua das Trinas 49 | 1296 Lisbon | Portugal | | | |
| Mr W. Walczowski | Polish Academy of Sciences | Institute of Oceanology P.O. Box 68 | ul. Powstancow Warszawy 55 | 81-712 Sopot Poland | walczows@iopan.gda.pl | | |

# Annex E: Northwest Atlantic Sections

**Savi Narayanan, Marine Environmental Data Service**
**Fisheries and Oceans**
**1202-200 Kent St., Ottawa, Canada**

## Introduction

In the following, the meteorological and oceanographic conditions that prevailed in 1966 off the Canadian east coast have been described. The data presented here were collected by a number of researchers in Canada 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.

## 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 monthly air temperature anomalies at these sites relative to their 1961-90 mean (Fig. 2) clearly indicate the predominance of warmer-than-normal conditions in 1996. At all sites, the temperatures were either near normal or above during the winter months as well as towards the end of the year. The net effect was that the annual temperature anomalies at all sites were positive consistent with the moderating trend which began in 1994 (Fig. 3).

The oceanographic conditions in the north Atlantic is 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 westerly winds over the northern North Atlantic. Over the Labrador Shelf, 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 1996 was strongly negative, reversing the trend of very high positive anomalies of previous years.

The above normal air temperatures during the late fall of 1995 had the effect of slowing the ice formation. Ice advancement was slower and ice was more broken up than usual because of the warmer conditions for most of the winter and weaker northwest winds. Consequently, the total ice cover south of 55°N on the Labrador Shelf, frequently used as an index of the ice conditions in Newfoundland, was considerably lower in 1996 than the previous years (Fig. 5).

## Oceanographic Conditions

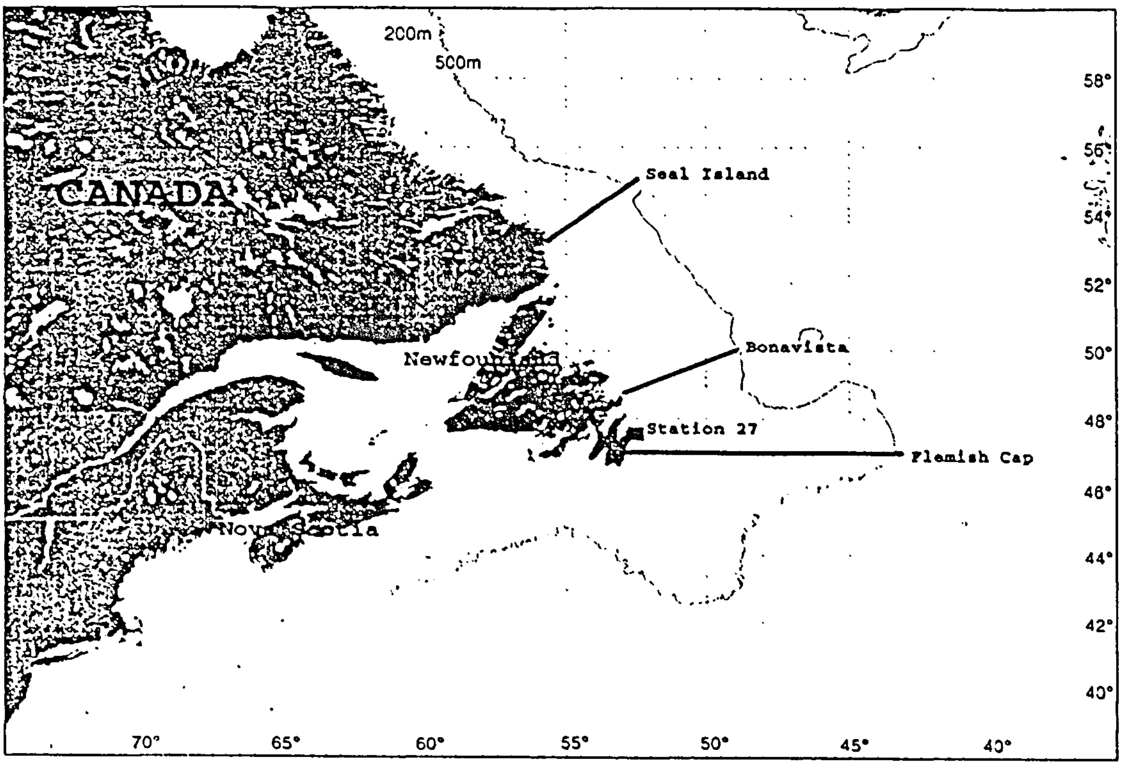
The area along cross-shelf transects off Newfoundland and Labrador, occupied by sub-zero temperature waters (referred to as the cold intermediate layer, or CIL), has been shown to be significantly correlated with the air temperatures and ice cover, and thus is an index of climate variability in the region. Recognizing 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 61-90 means. The anomalies from the three standard sections, Seal Island, Bonavista and Flemish Cap (Fig. 6) were all negative in 1996, thus continuing with the general warming trend.

The temperature and salinity transects from the three standard sections are given in Figs 7, 8, 9. On the southern Labrador Shelf (Seal Island), the upper layers were slightly colder and saltier, where as the intermediate and bottom layers were warmer and fresher than normal. On the Newfoundland Shelf (Bonavista) as well as on the Grand Banks (Flemish Cap), the conditions were similar in that except for a thin layer at the surface, the water was fresher and warmer than normal.

Data from the fixed stations off the Canadian East Coast confirm the continuation of the warming trend in the northwest Atlantic. At station 27 located off St. John's, Newfoundland (Fig. 10), the entire water column was warmer and fresher than normal for almost the whole year. The low pass filtered time series of temperature at standard depths (Fig. 11) clearly indicate that the doldrums of early 1990s is over and that the conditions are improving. The salinity anomalies on the other hand were considerably negative at the beginning of this decade, became near normal in 1993 and 94, but reversed to negative at most depths. The heat and salt contents in the water column as estimated by the vertically integrated temperatures and salinities at Station 27 also show similar trends (Fig. 12).

The deep-water temperatures on the Scotian Shelf have also been bound to have significant coherence at low frequencies horizontally from Laurentian Channel to mid-Atlantic Bight. Episodic intrusions of the warm slope water have been hypothesized as the primary source of this variability. The time series that has been assembled from Emerald Basin (Fig. 13) clearly indicate a number of such events, the recent one being at the end of 1991 when the bottom temperature increased from about 7° C to 10 ° C. Consequently, for the past 5 years, the bottom waters in the basin have been warmer than normal.

At Prince 5, a long term monitoring station in Bay of Fundy, the temperatures at both the surface and bottom were near normal and salinities well below normal (Fig. 14).



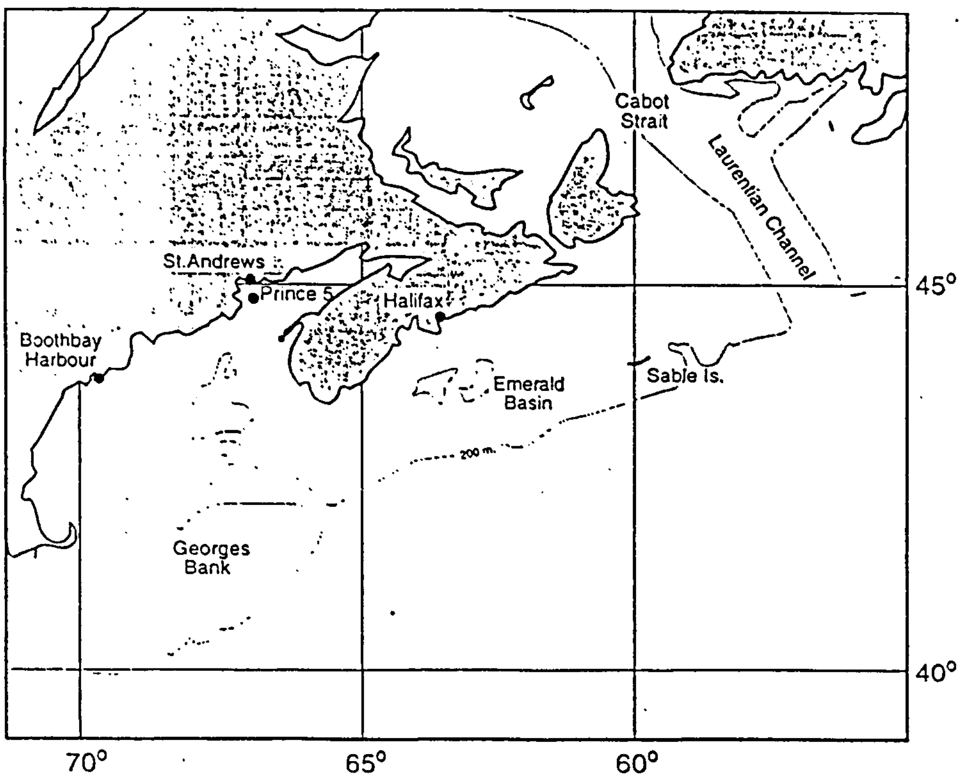
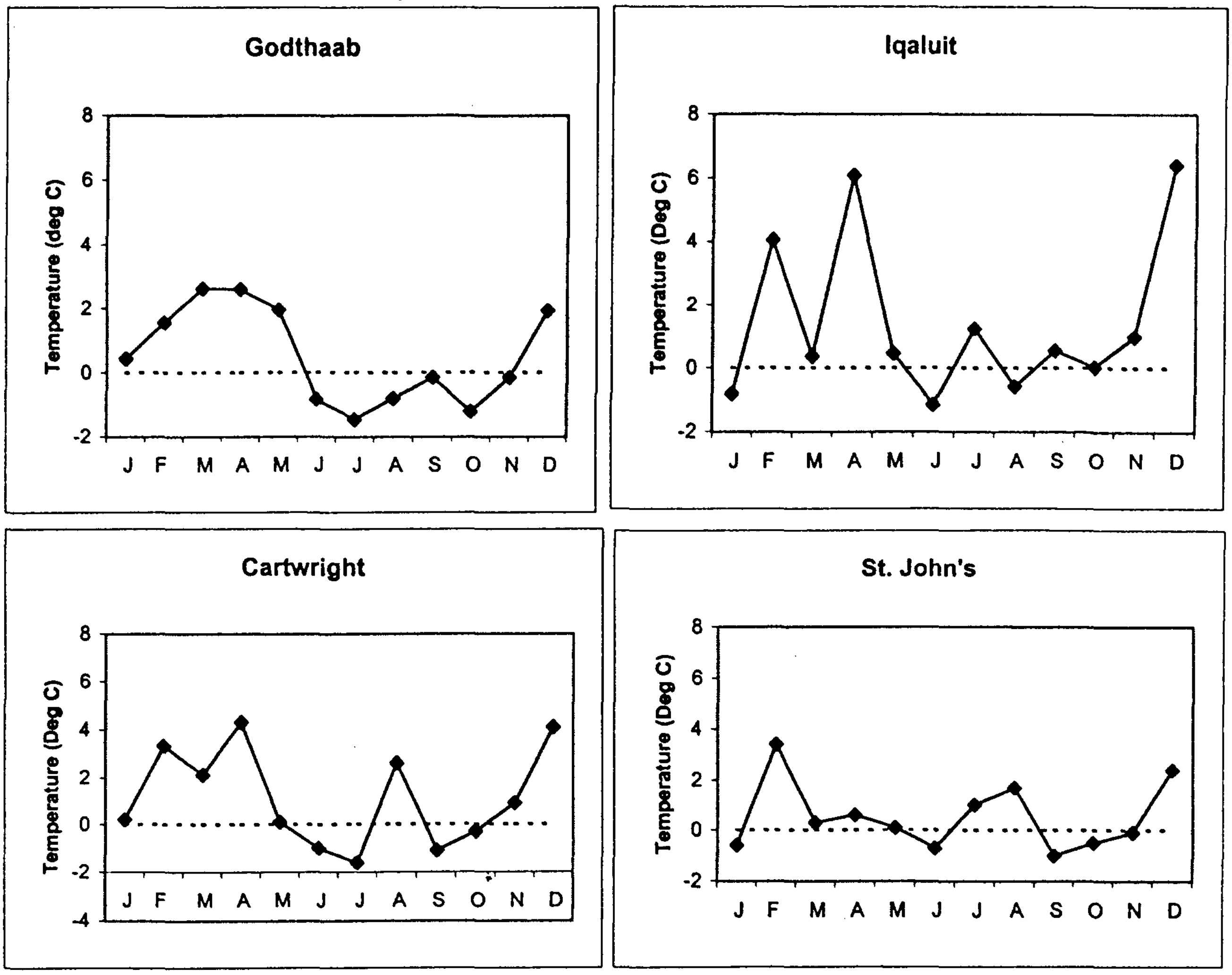




Fig. 1 Standard Stations and Sections - East Coast of Canada



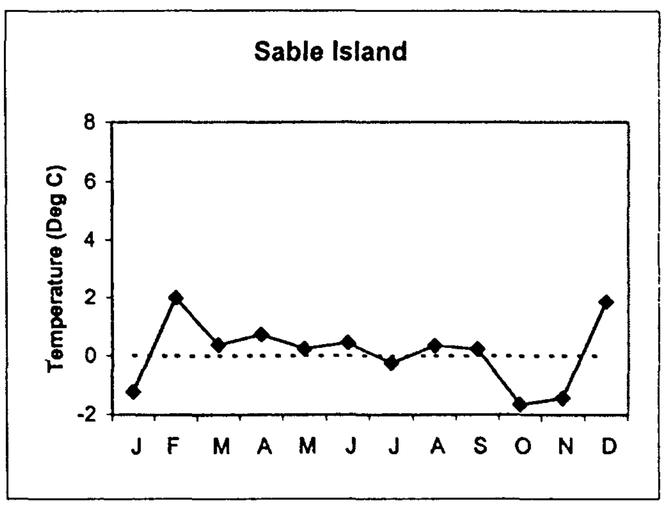
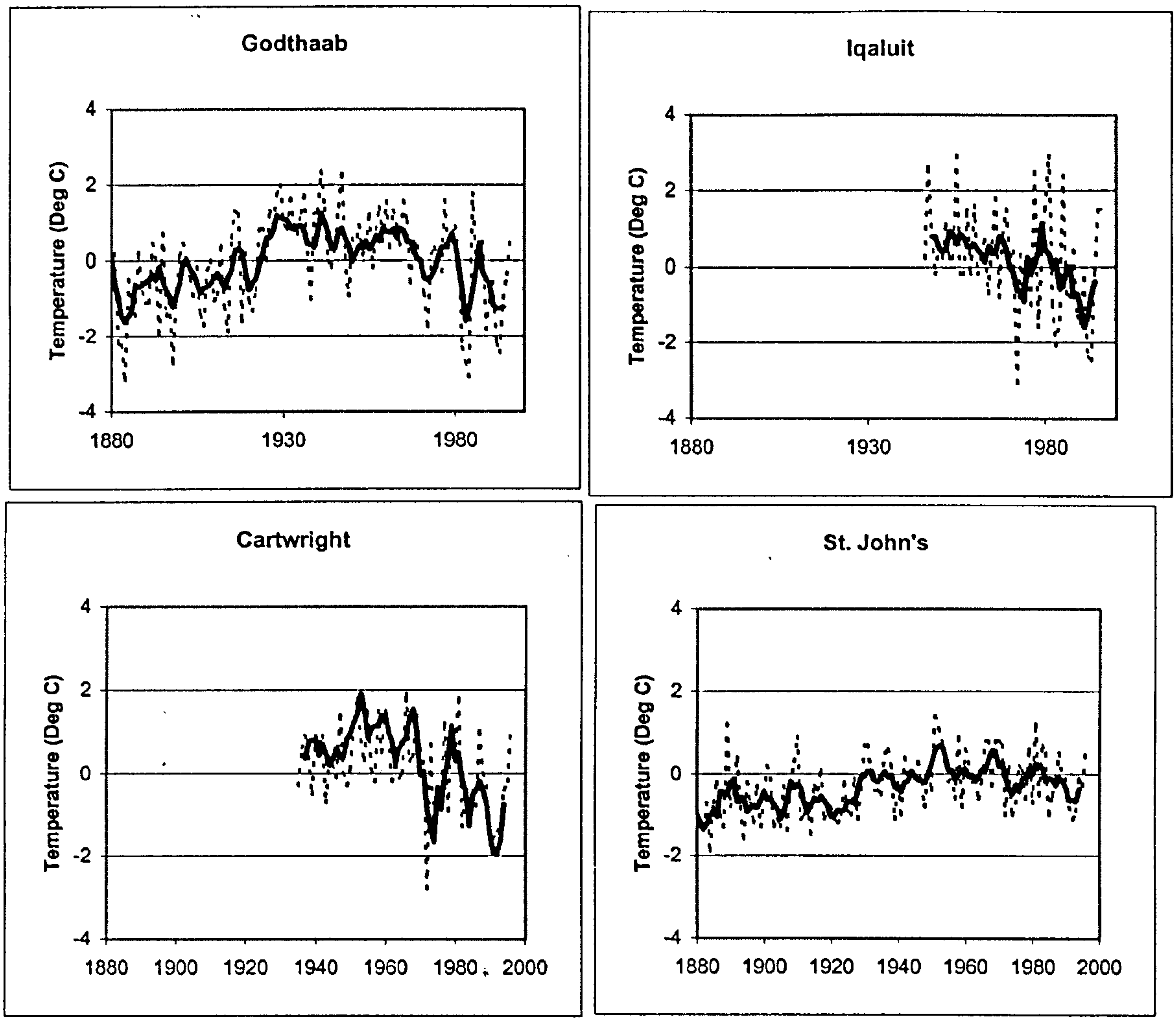




**Fig. 2 Monthly air temperature anomalies relative to 61-90 mean: 1996**



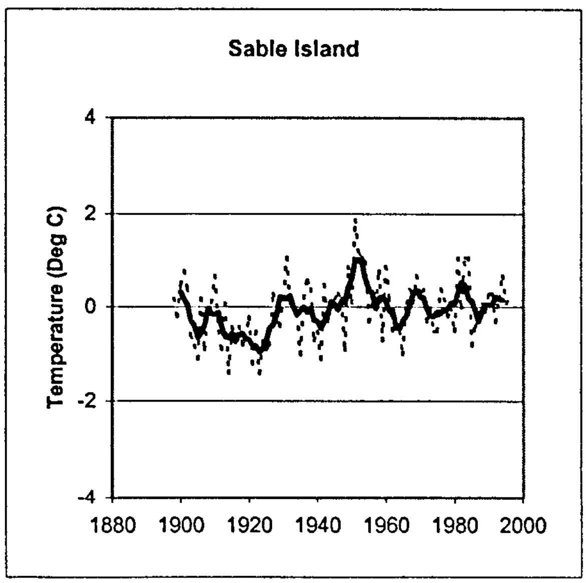
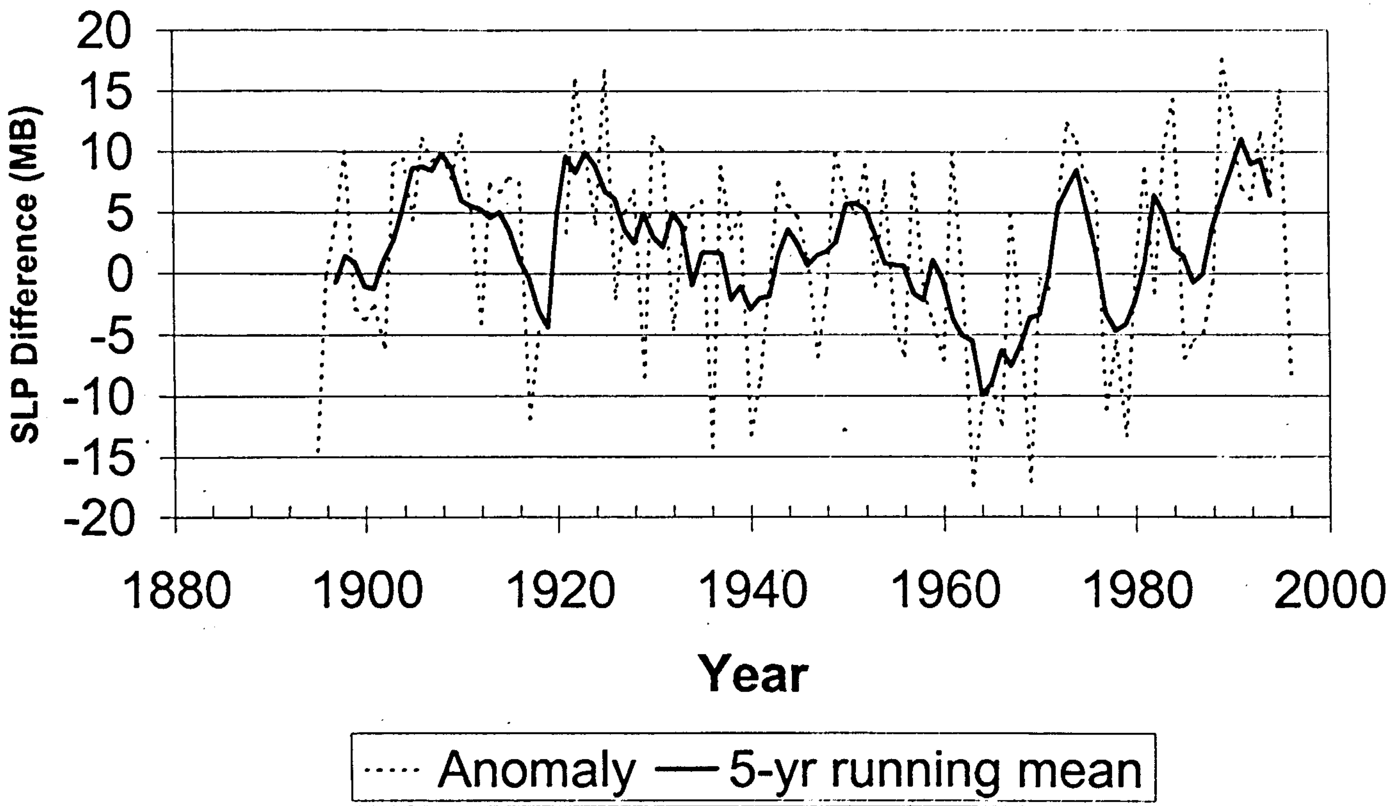




**Fig. 3** **Annual and 5-yr running means of air temperature anomalies at selected sites**

## Fig. 4 NAO Index Anomalies



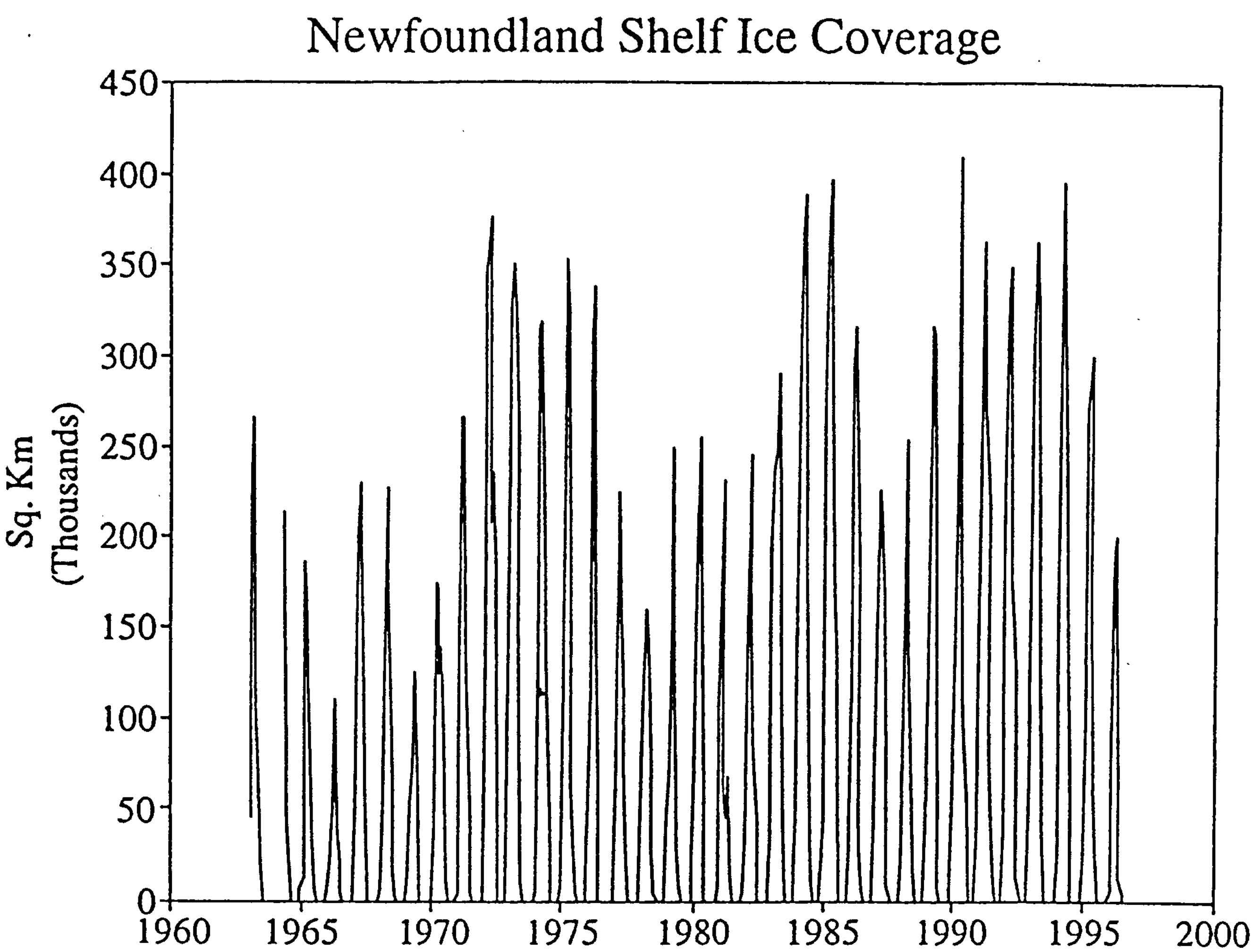



Fig. 5 Time series of the monthly mean ice area off Newfoundland and Labrador (between 45°N-55°N)

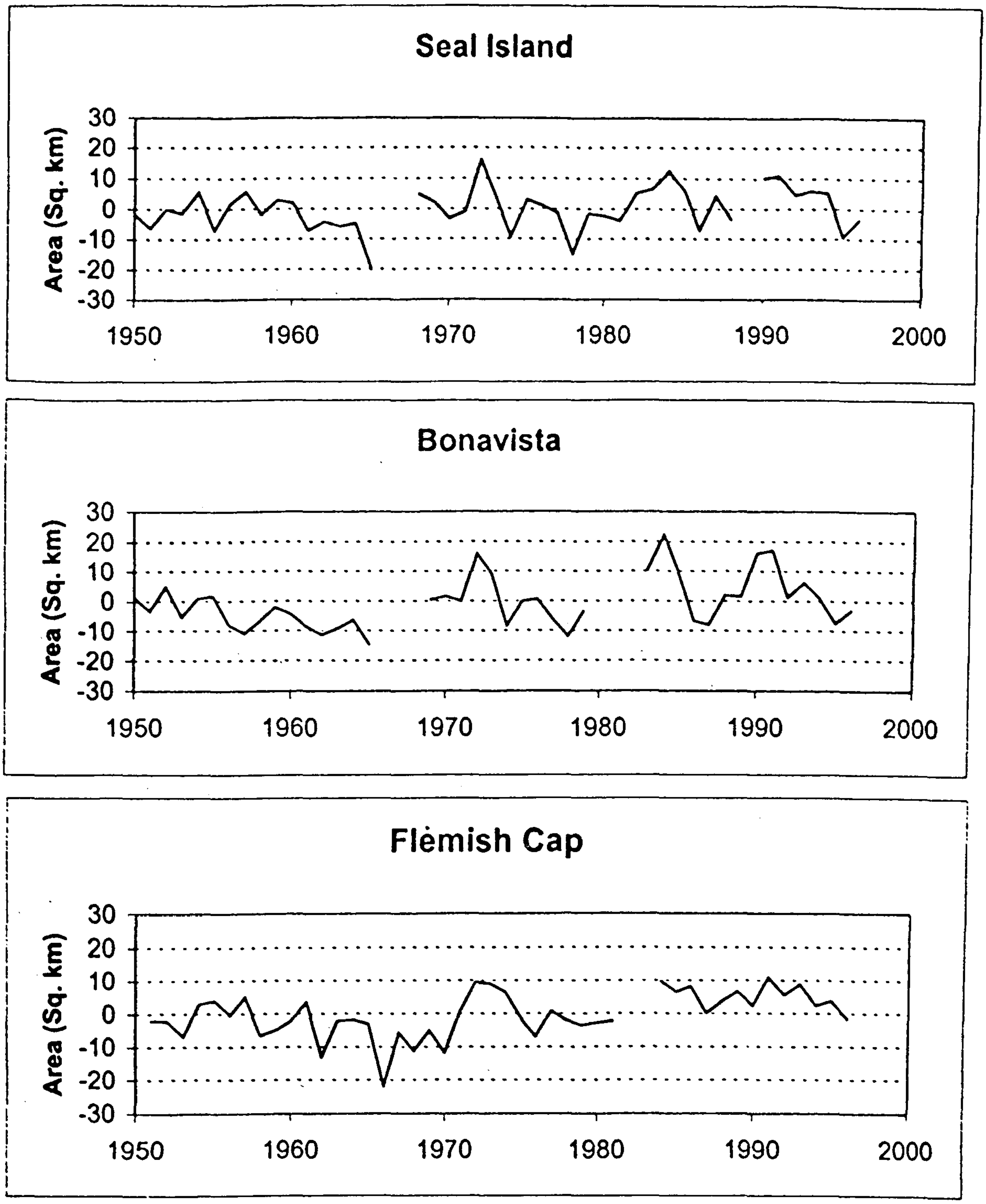



**Fig. 6 CIL area anomalies relative to 61-90 average**

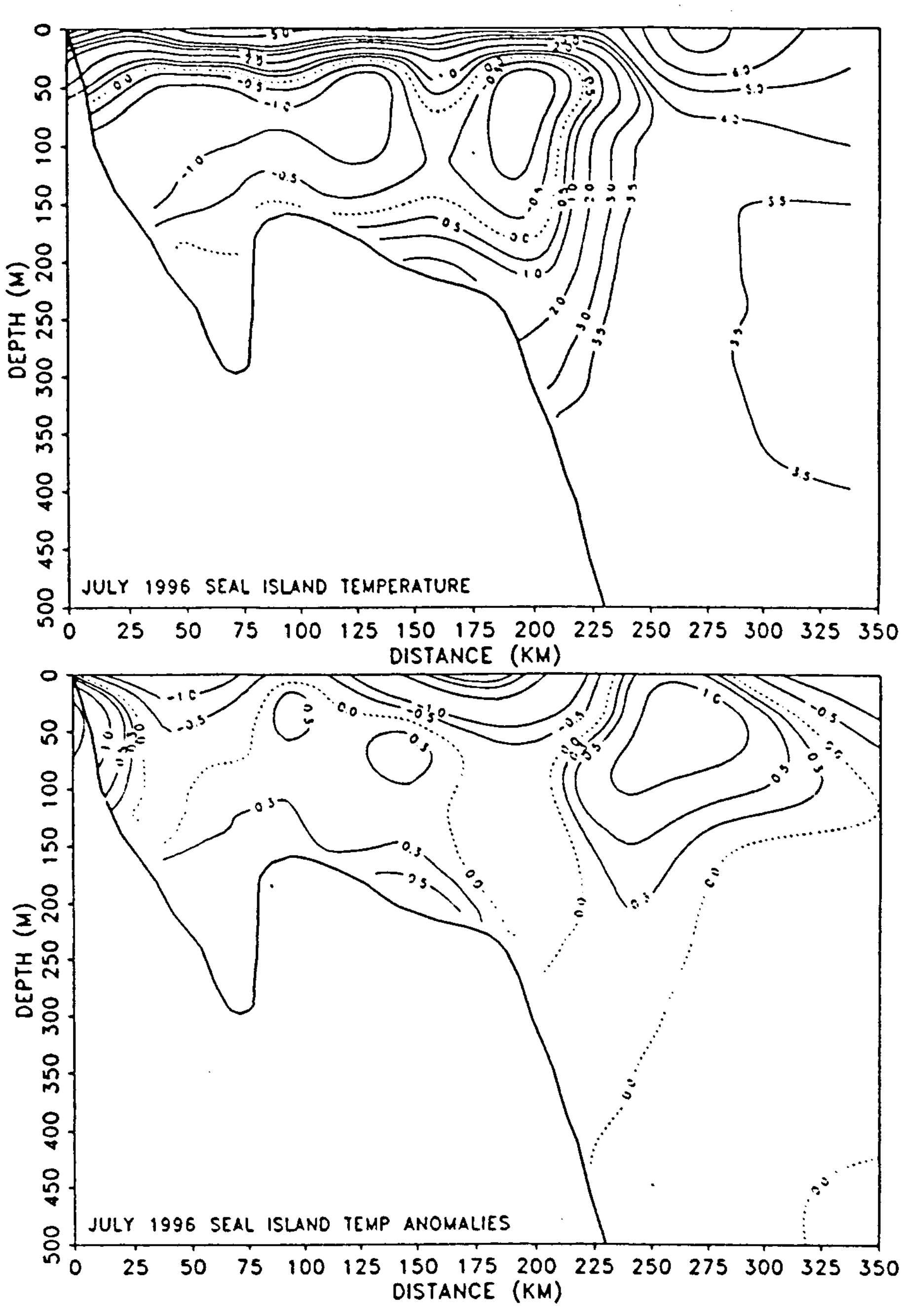



Fig. 7a The vertical distribution of temperature and temperature anomalies along the standard Seal Island transect for the summer (July) of 1996.

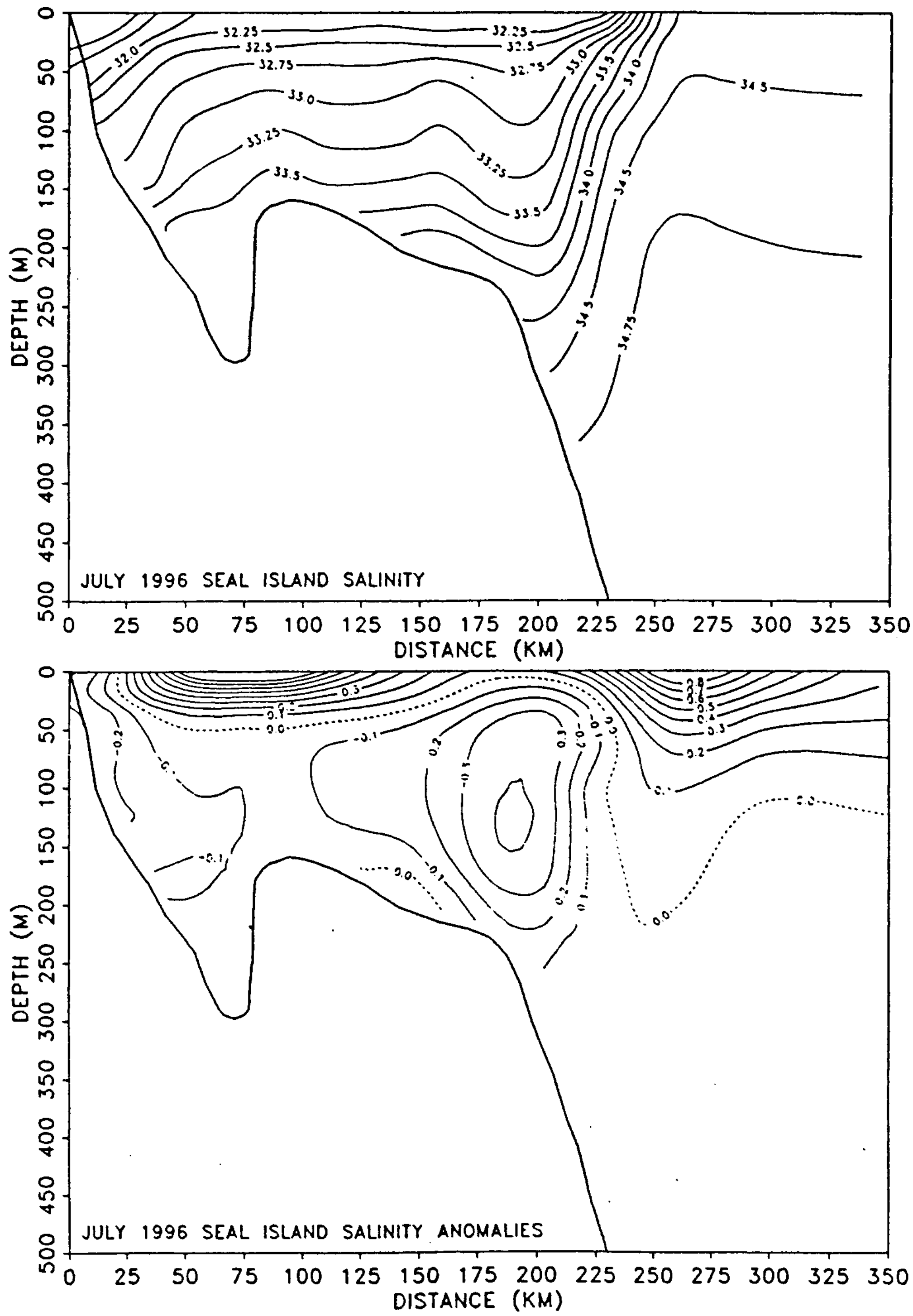



Fig. 7b The vertical distribution of salinity and salinity anomalies along the standard Seal Island transect for the summer (July) of 1996.

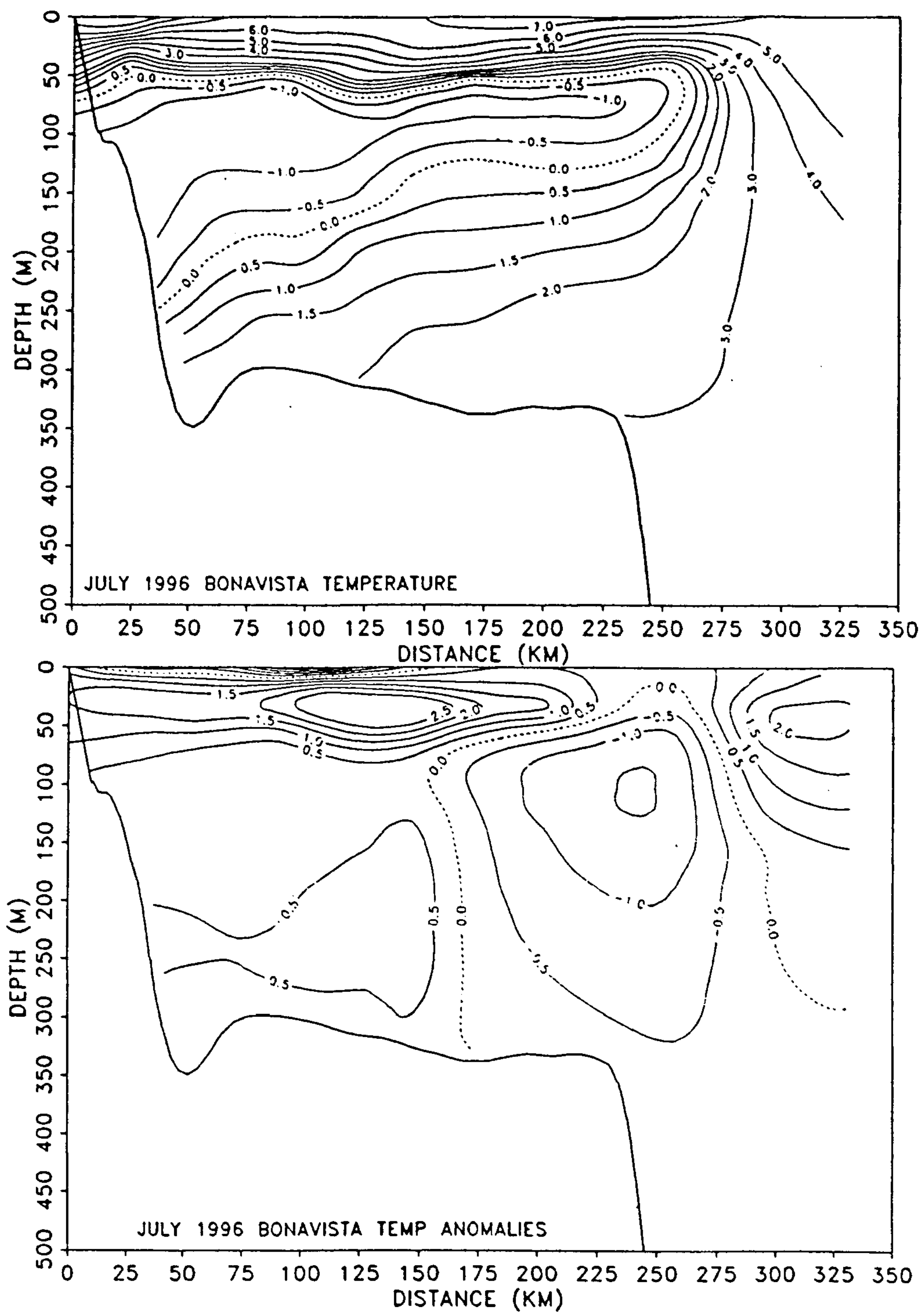



Fig. 8a The vertical distribution of temperature and temperature anomalies along the standard Bonavista transect for the summer (July) of 1996.

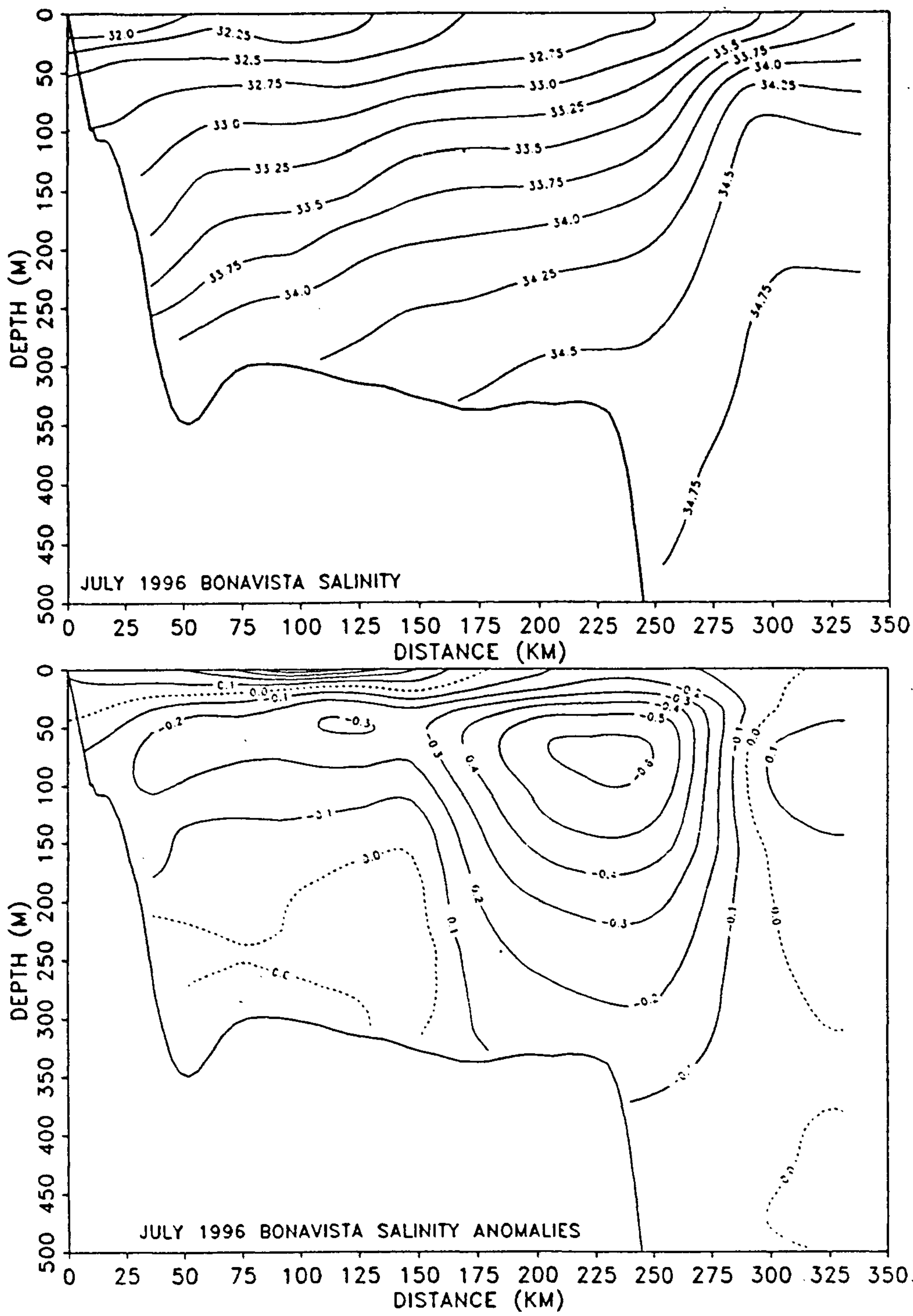



Fig. 8b The vertical distribution of salinity and salinity anomalies along the standard Bonavista transect for the summer (July) of 1996.

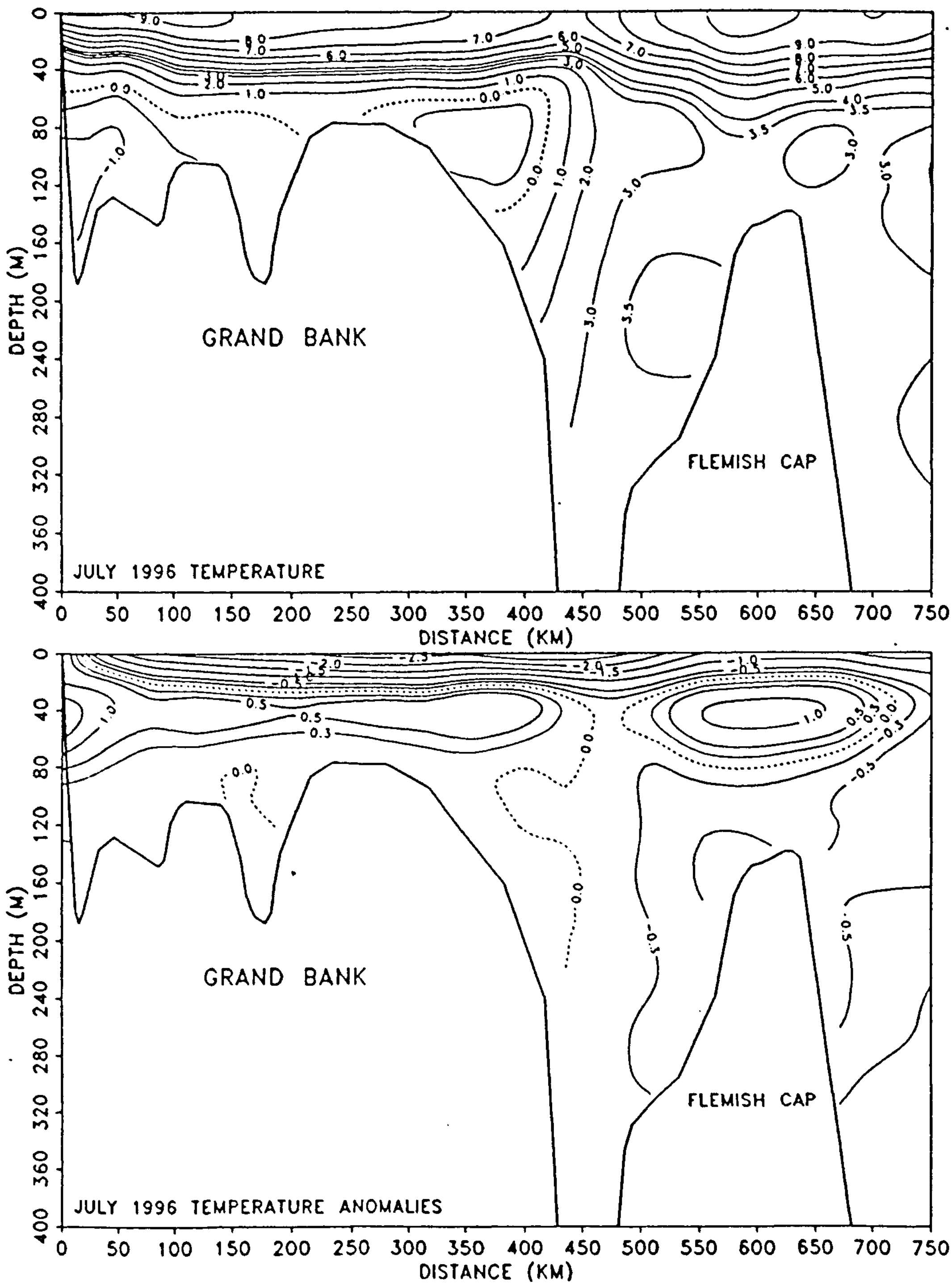
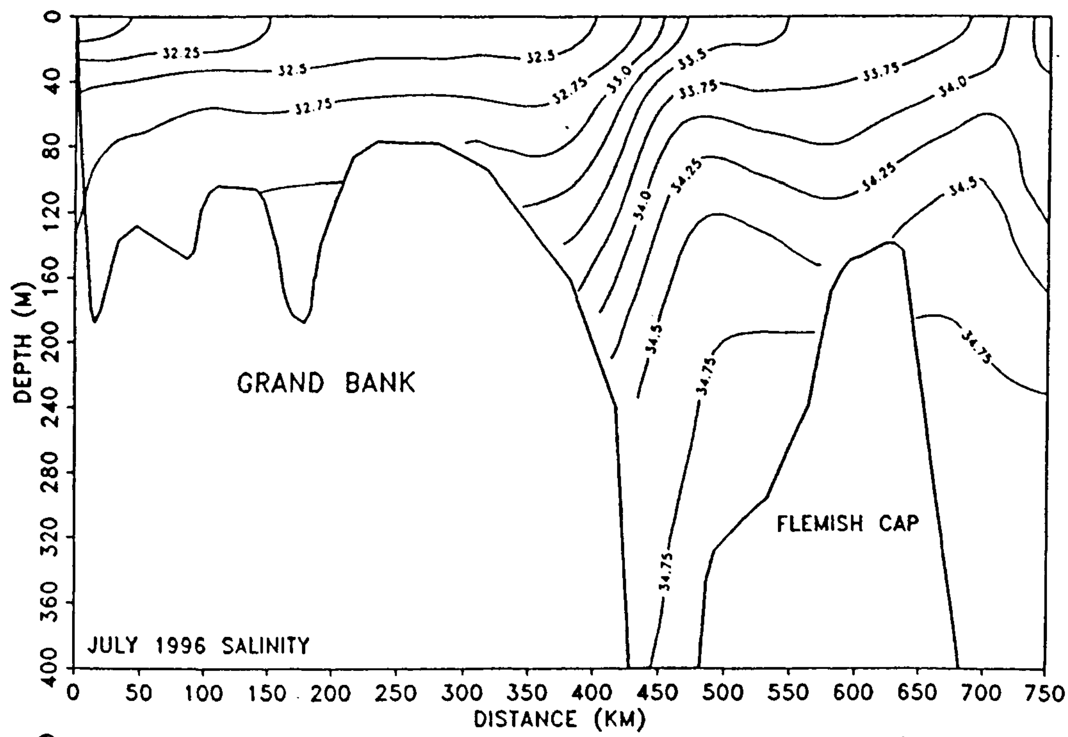



Fig. 9a The vertical distribution of temperature and temperature anomalies along the standard Flemish Cap transect for the summer (July) of 1996.



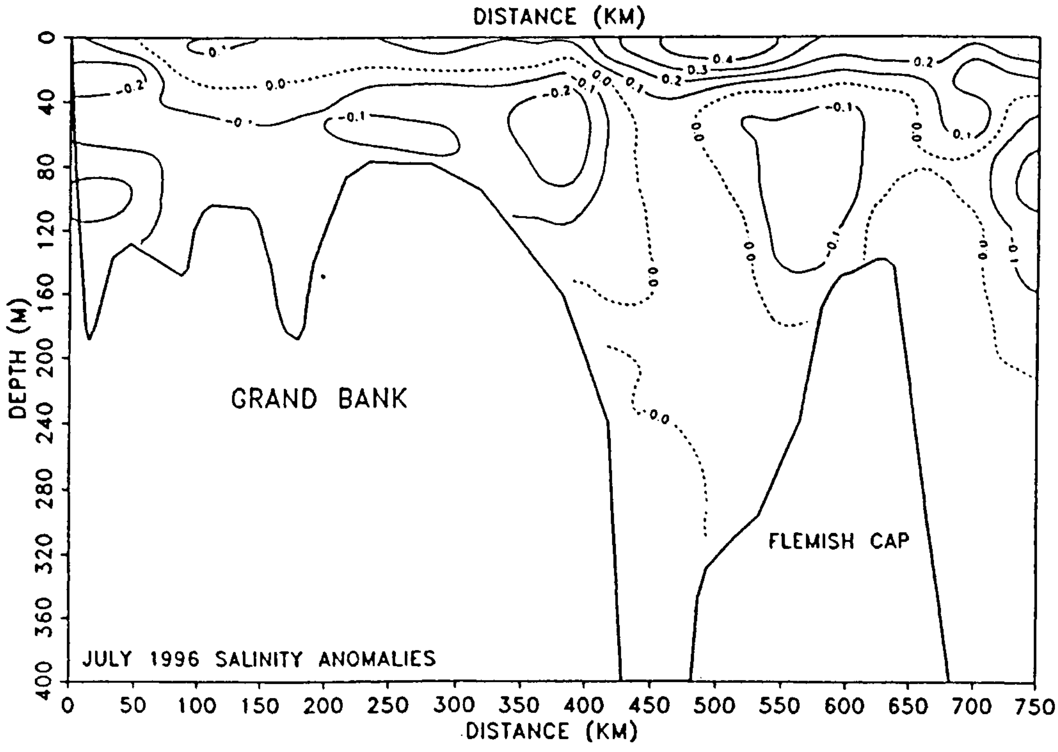




Fig. 9b The vertical distribution of salinity and salinity anomalies along the standard Flemish Cap transect for the summer (July) of 1996.

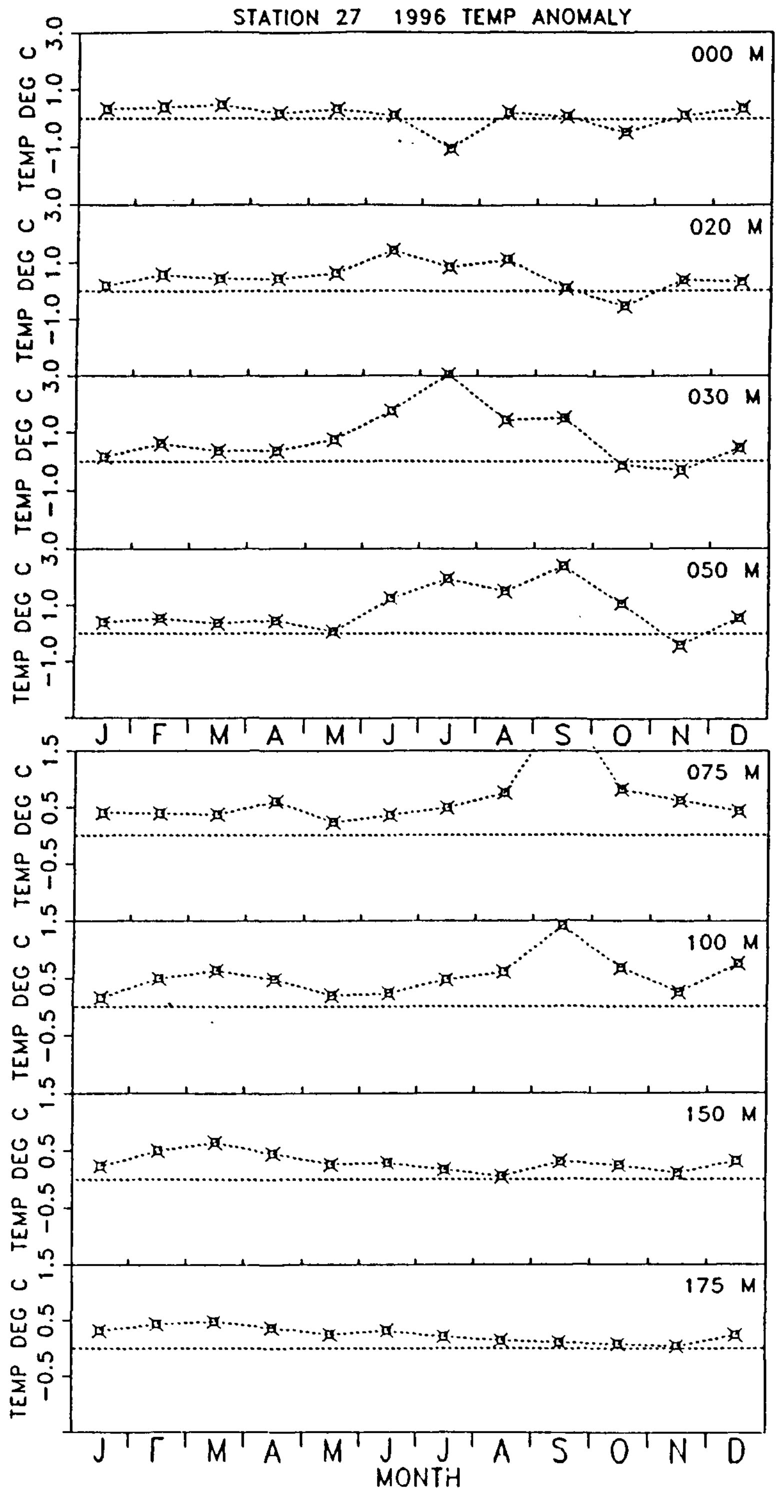



Fig. 10a Time series of the monthly temperature anomalies at Station 27 at standard depths during 1996.

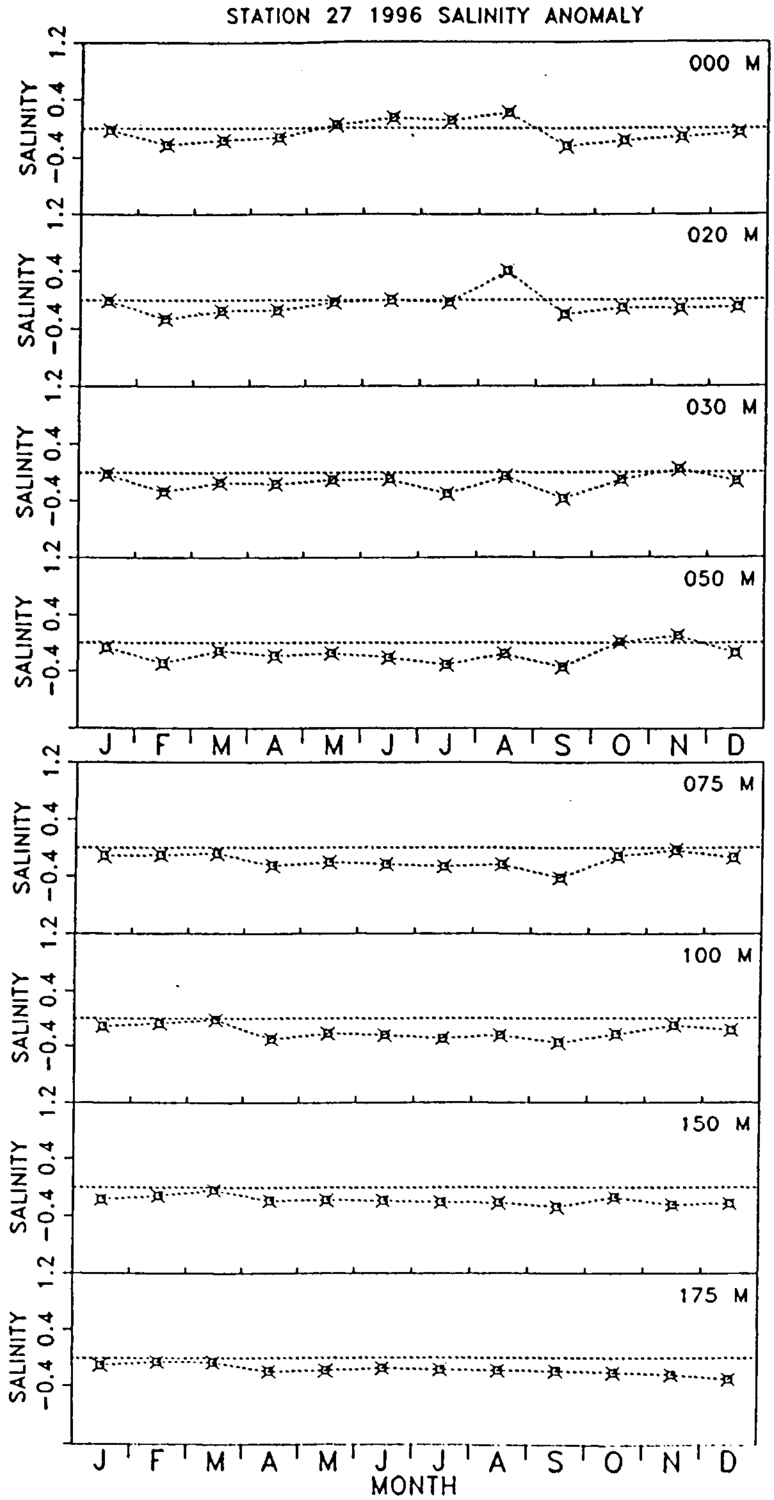



Fig. 10b Time series of the monthly anomalies at Station 27 at standard depths during 1996.

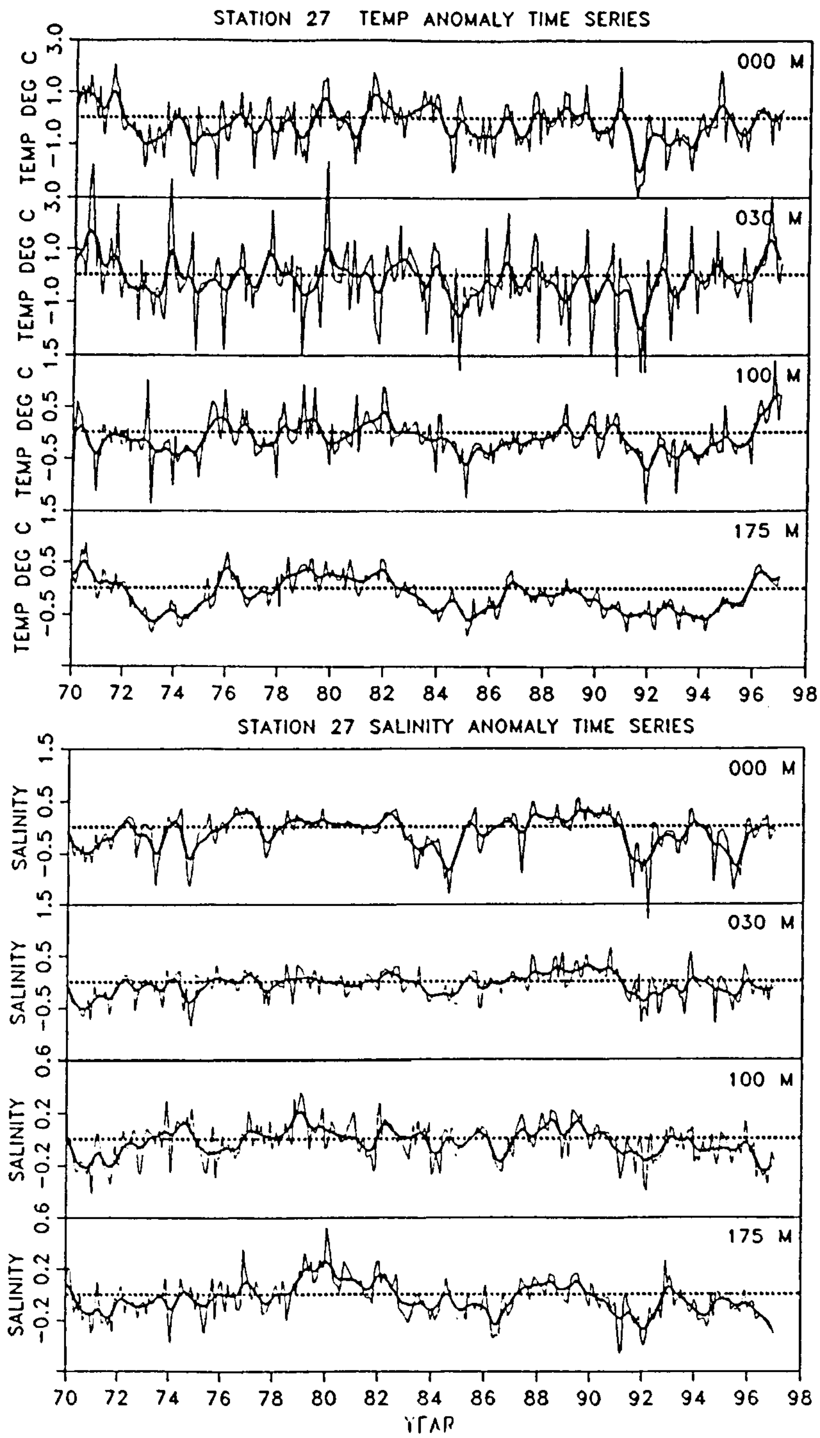



Fig. 11 Time series of monthly temperature and salinity anomalies at Station 27 at standard depths from 1970 to 1996. The heavy lines are the low-passed filtered time series.

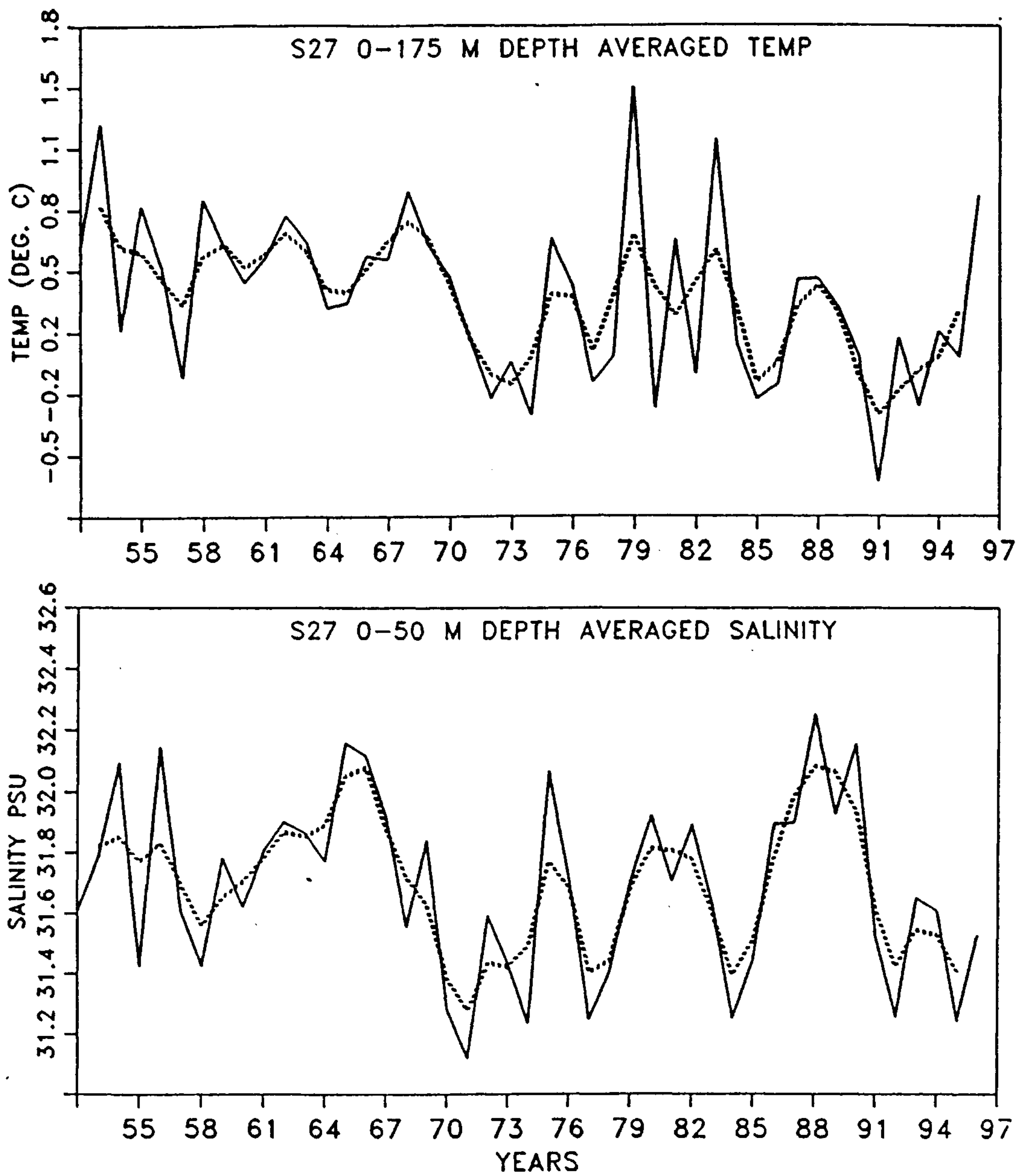



Fig. 12 Time series of the vertically averaged (0-176 m) Station 27 temperature and the vertically averaged (0-50 m) summer (July-Sept.) Station 27 salinity. The dashed lines are the three year running means.

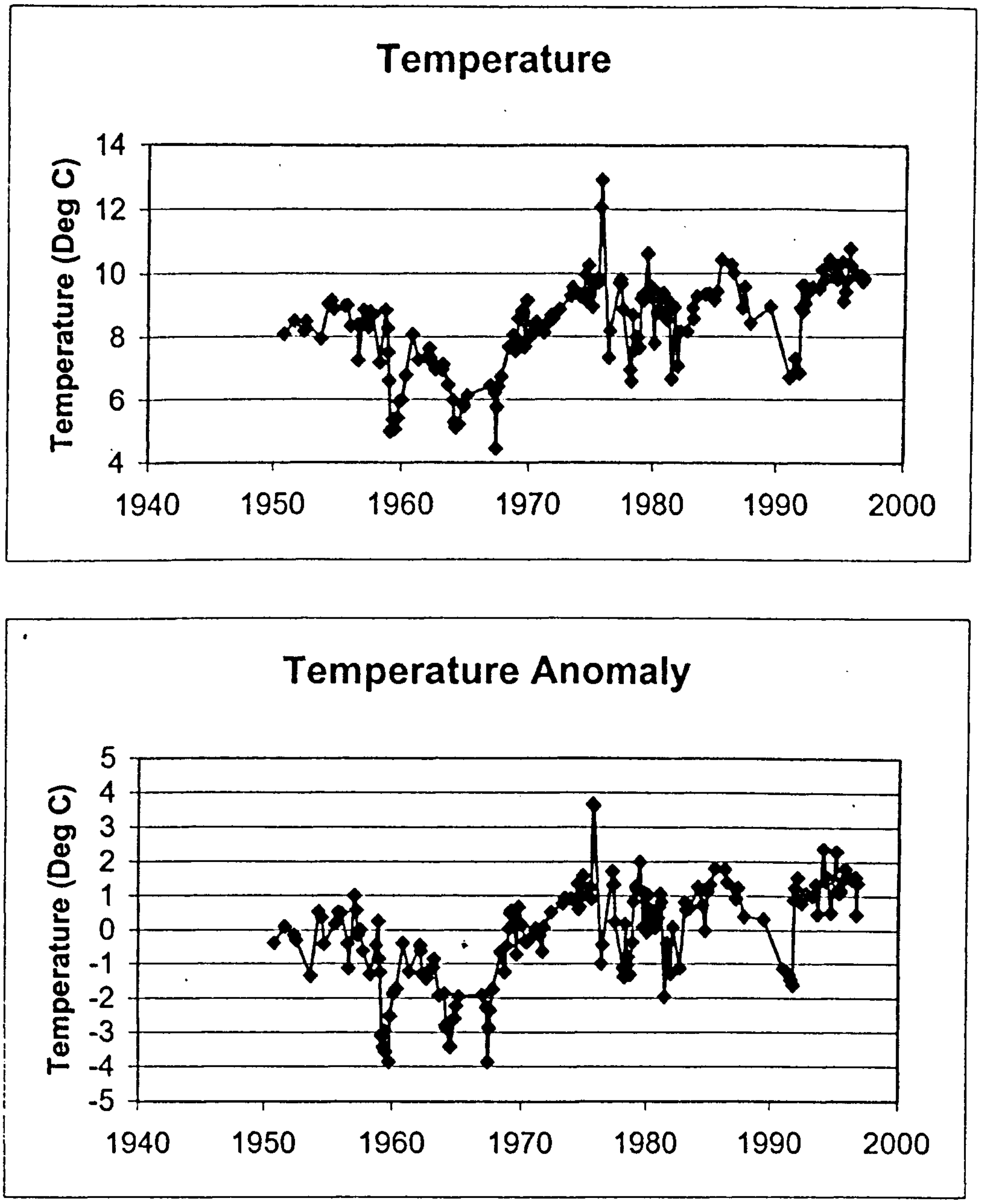



**Fig. 13 Emerald Basin, 250 M temperature and temperature anomaly**

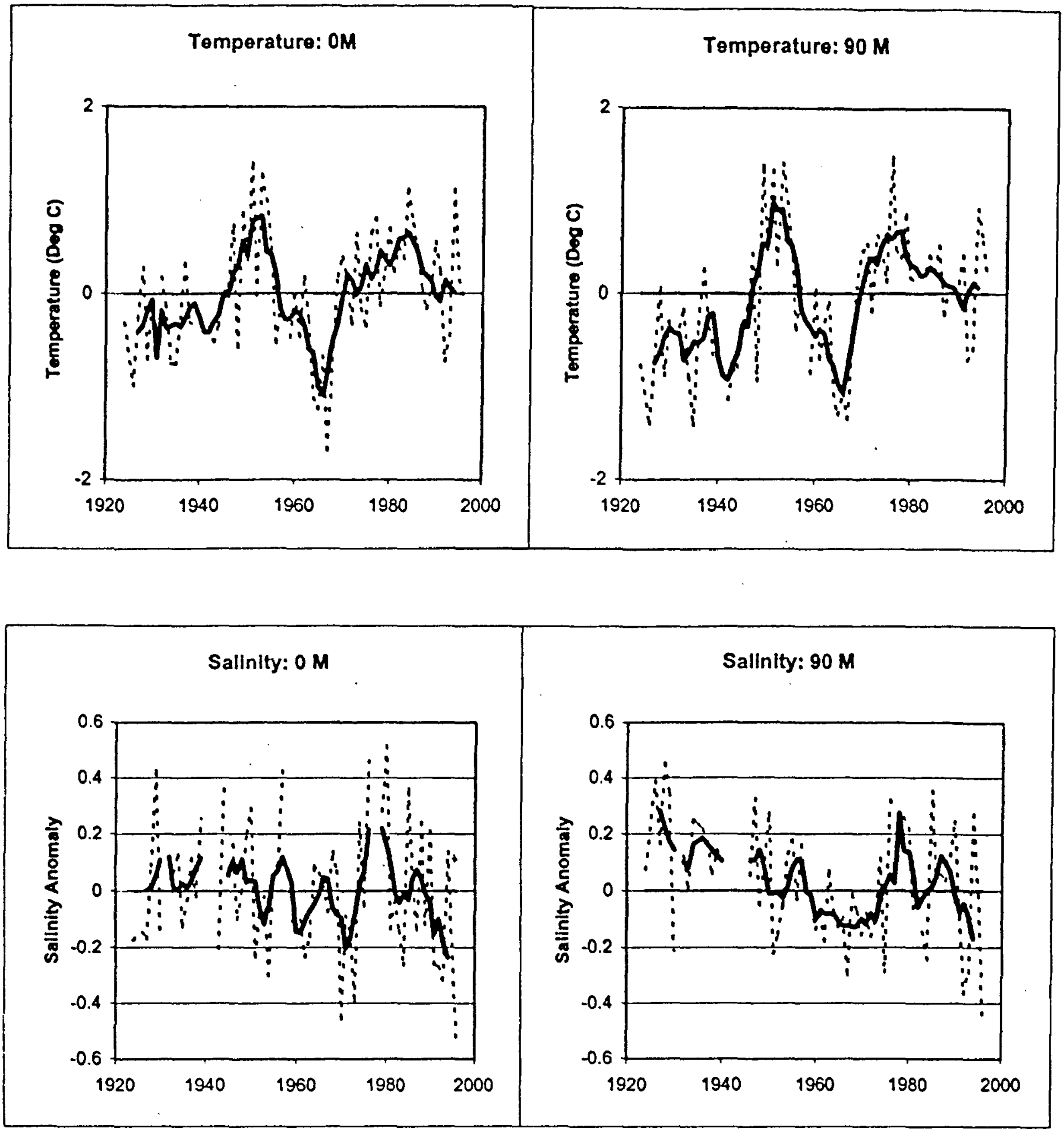



**Fig. 14 The annual and 5-yr running means of the temperature and salinitiy anomalies for Prince 5**

# Annex F:Results from Icelandic Waters

**Svend-Aage Malmberg, Marine Research Institute,**
**P. O. Box 1390, Skulagata 4, Reykjavik, Iceland**

## Introduction

The sea around Iceland is divided into various sectors, such as the Iceland Basin to the south, the Irminger Sea to the west, the Denmark Strait between Northwest Iceland and Greenland, and the Iceland and Norwegian Seas north and east of the country. These seas are all part of the Atlantic Ocean; the area south of the submarine ridges between Greenland and Scotland being part of the North Atlantic, while the area north of the ridges is part of the Nordic Seas.

Iceland is situated at the meeting place or fronts of warm and cold ocean currents, which meet at this point because of the geographical position and the submarine ridges, which form a natural barrier against the main ocean currents around the country. To the south these currents are warm (6-8°C; Irminger Current) and to the north the sea is cold (-1-2°C; East Greenland and East Icelandic Currents). At the continental shelf there is a coastal current which flows clockwise around the country and is created by the mixing of the ocean currents with fresh water from the land.

Finally, there are also deep and bottom currents in the sea around Iceland, principally the overflow of deep cold water from the Nordic Seas south over the submarine ridges into the North Atlantic.

## Hydrographic Conditions

### a) North Icelandic Waters 1924-1995

A selected hydrographic station in North Icelandic waters (S-3, Figs 1, 2) has been used to characterize the hydrographic conditions from year to year. At these stations, Atlantic water ($t>4°C$; $S>34,9$) dominated during the periods 1924-1964, 1972-1974, in 1980, 1984-1987 and 1991-1994. The late sixties as well as shorter periods thereafter (1975-1979, 1982, and 1988) were prominently characterized by Polar influence, frequently manifested by the appearance of sea ice and Polar water and by some biological consequences in North Icelandic waters. During the years 1981-1983, 1989-1990 and most severely in 1995 the hydro-biological conditions were extremely unfavorable and of neither Atlantic nor Polar character, but with a relatively homogenous water of an Arctic character ($t=0\text{-}3°C$; $S\sim34,8\text{-}34,9$). A continuous temperature recording in the sea at the island Gímsey in North Icelandic waters during the years 1987-1996 (Fig. 3) reveals the hydrographic conditions in North Icelandic waters as low winter/spring temperatures in 1988 and 1995 and relatively high temperatures in 1987 and 1991-1994 with an unusual interruption in fall 1993 when the Atlantic inflow into these waters was totally hampered for some time in the Denmark Strait area.

**b) South Icelandic Waters 1971-1996**

In the warm waters south of Iceland periods of relatively high and low salinities occur. Noteworthy were the low salinities observed in the mid-seventies (Great Salinity Anomaly), and again at least in 1988 and after 1992 (Fig. 2). Along with low salinities in the area low temperatures are also generally observed.

## Conditions in 1996 (Figs 4, 5)

Following extreme cold conditions in Icelandic waters in winter and spring 1995 temperatures rose again in winter 1995-1996 and remained in 1996 near the average all around Iceland, but salinities was rather low. Thus salinity in the East Icelandic Current was in spring below 34,7 indicating a polar character of the current (Fig. 2). In spring 1996 Atlantic water reached the Siglunes section in North Icelandic waters at depths below 100 m, but the surface waters were influenced by freshwater from land. During summer and fall a layer of low salinity polar water penetrated the surface waters north of Iceland. However, in the deeper layers Atlantic water had reached the Langanes section northeast of Iceland at that time. The nutrient concentrations in 1996, during the spring survey, were high in the waters all around Iceland except of the north coast where the spring bloom was over. The zooplankton biomass was high in these waters except off the south coast in 1996, though a downward trend is indicated by the long-time series both in South and North Icelandic waters. The Atlanto-Scandian herring was observed at the eastern and southern boundaries of the cold East Icelandic Current, in spring 1996 as in 1994 and 1995.

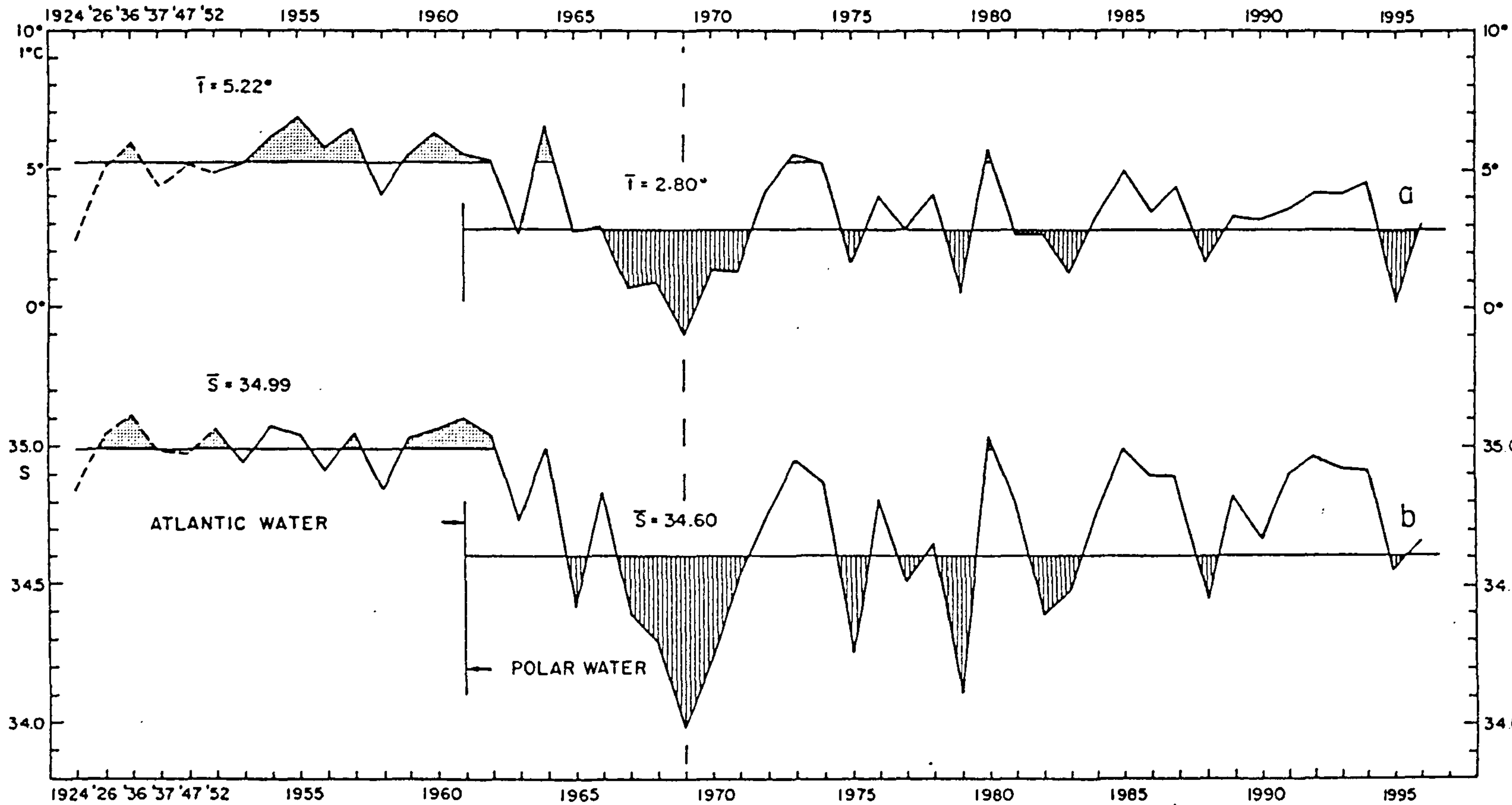



Fig. 1 Temperature and salinity at 50 m depths at the third station on the Siglunes section (see Fig. 4) in May-June 1924-1996.

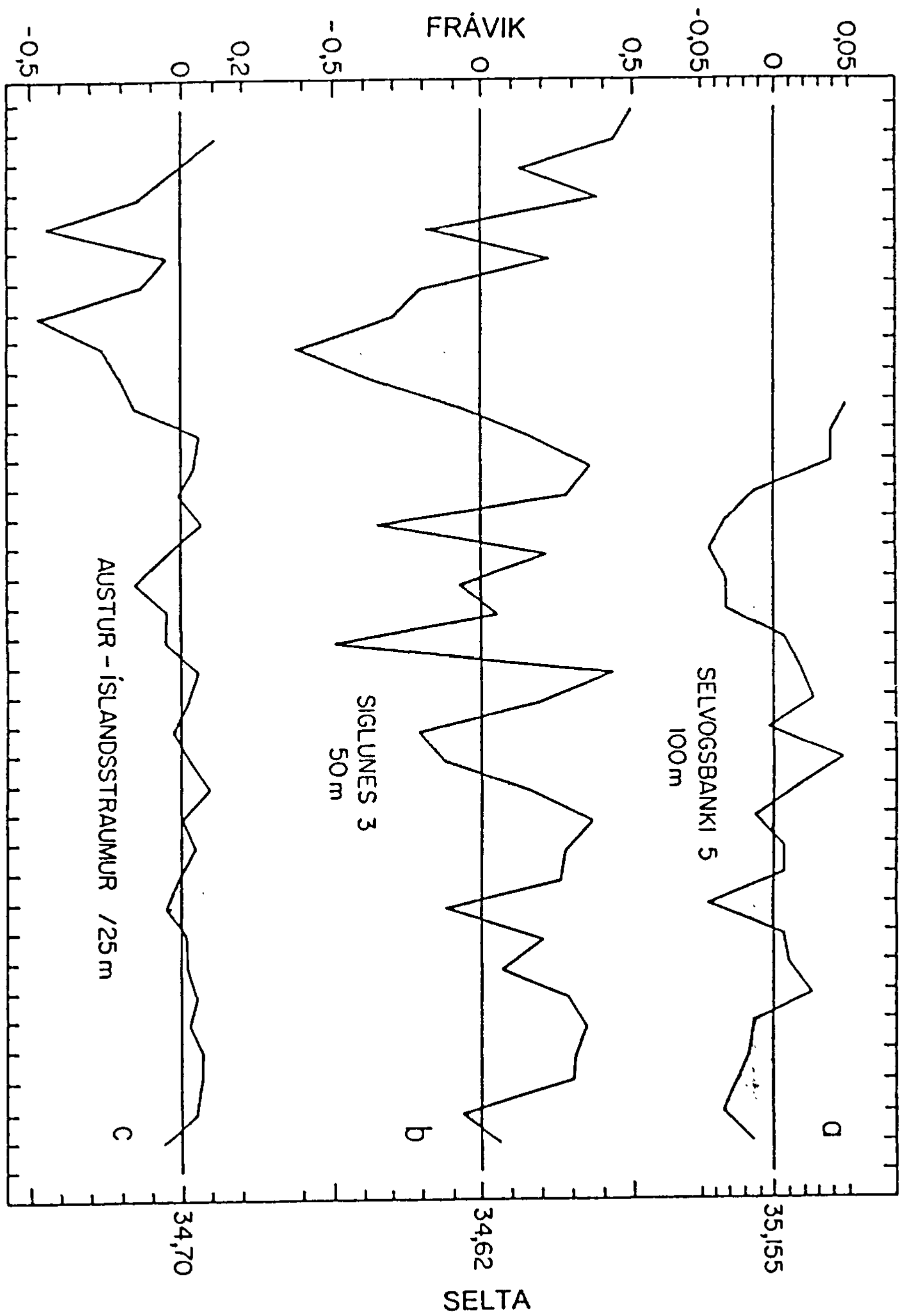



Fig. 2 Salinity deviations in spring at

a) 100 m depth in the Irminger Current south of Iceland (1971-1996);

b) 50 m depth in North Icelandic waters (1961-1996);

c) 25 m depth in the East Icelandic Current (1961-1996).

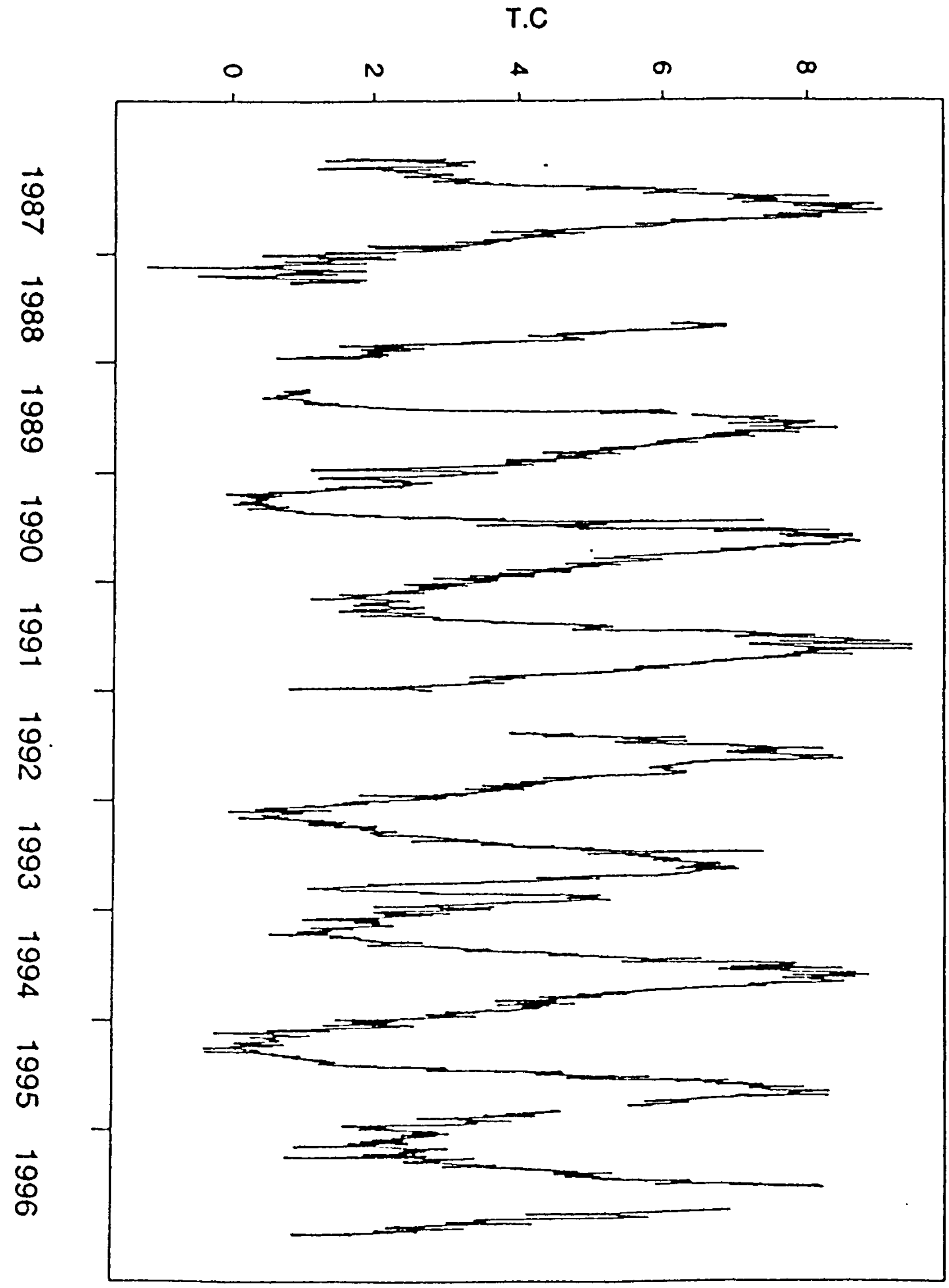



Fig. 3 Annual and seasonal variations in sea surface temperature (°C) at Grímsey, North Iceland, in 1987-1996.

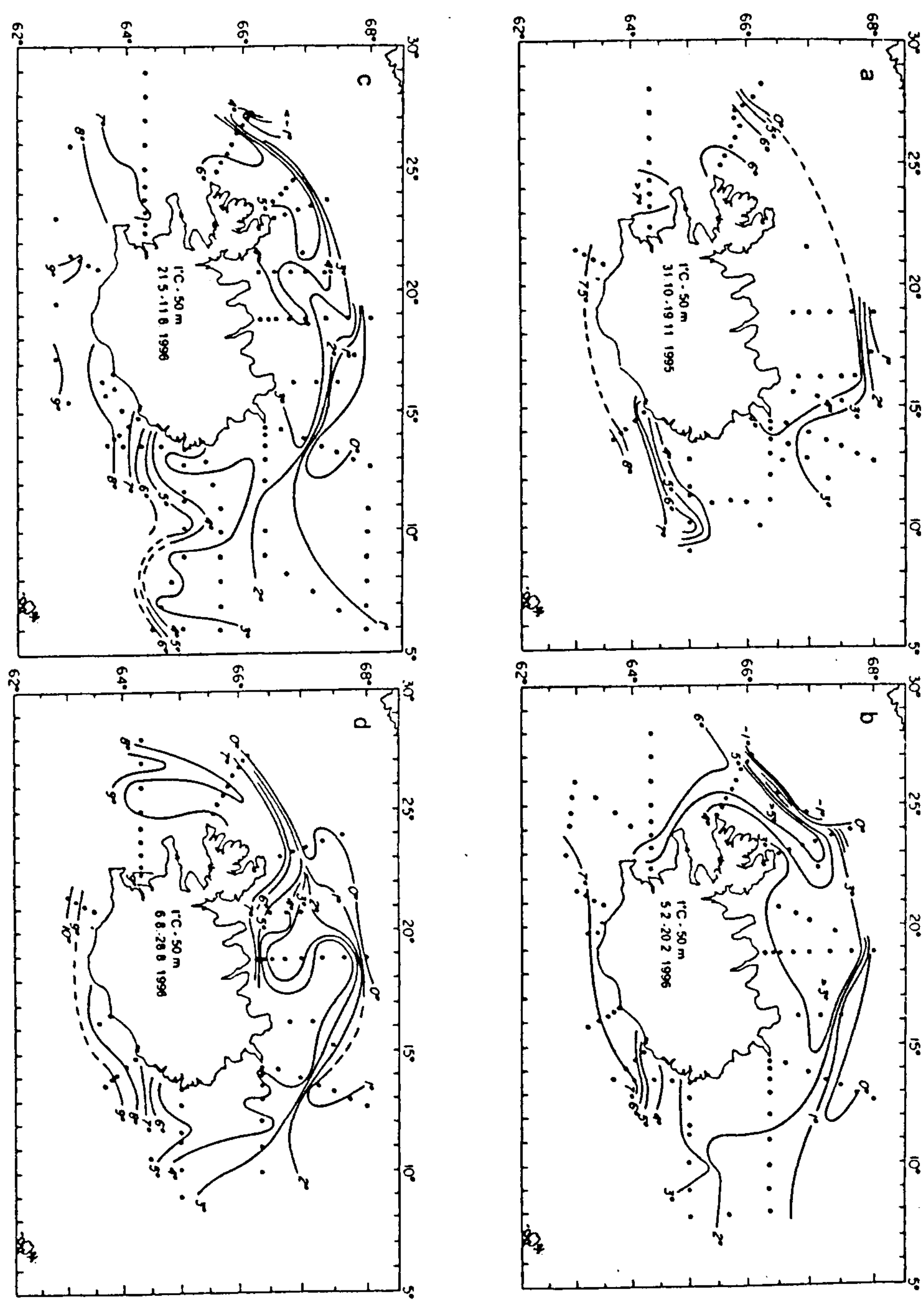


Fig. 4 Sea temperature (°C) at 50 m depth in Icelandic waters in
a) October/November 1995,
b) February 1996,
c) May/June 1996,
d) August 1996.

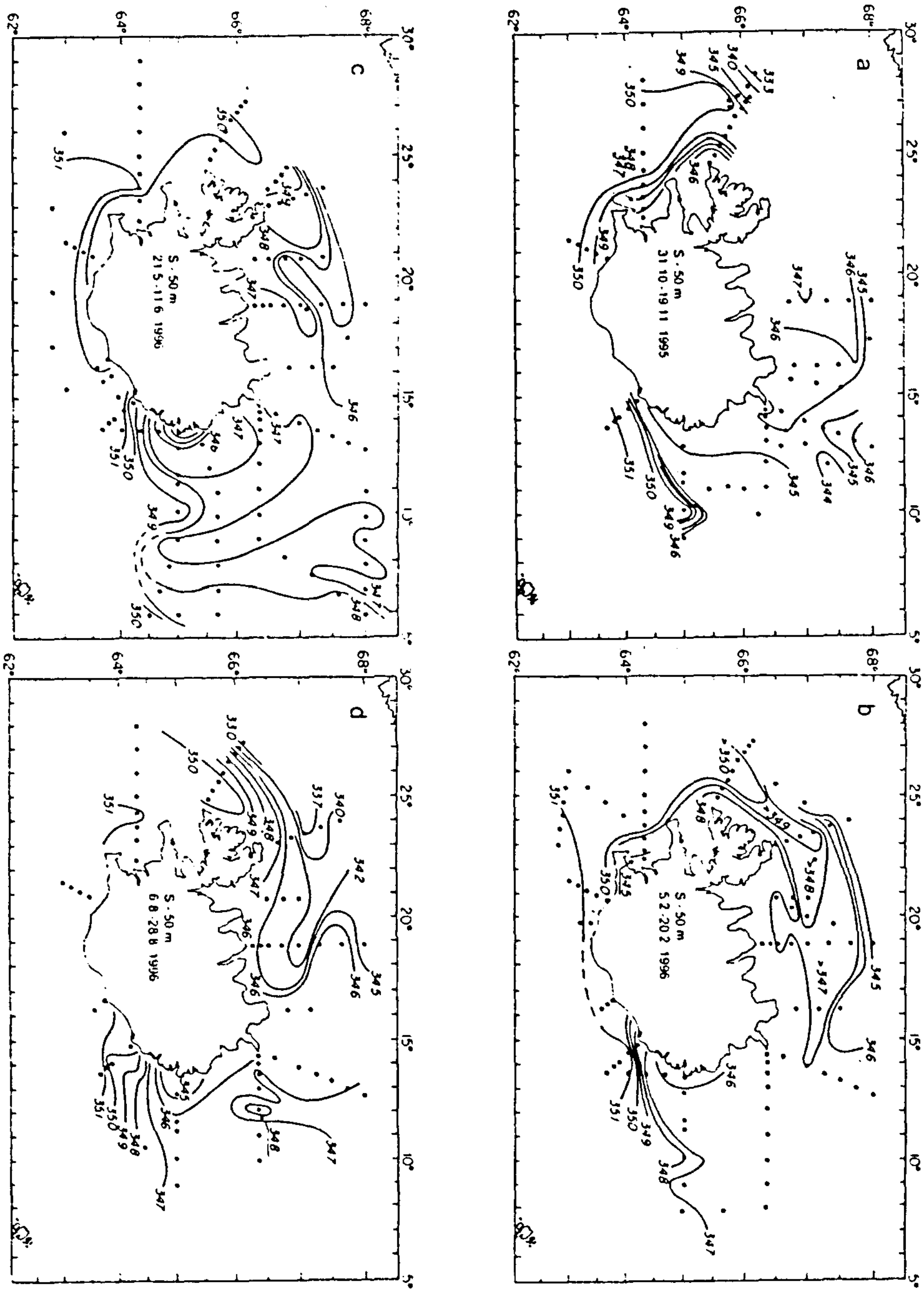



Fig. 5 Salinity (S) at 50 m dept in Icelandic waters in
a) October/November 1995,
b) February 1996,
c) May/June 1996,
d) August 1996.

# Annex G: West Greenland Sections

**Erik Buch, Farvandsvæsen et Overgaden o.**
**Vandet 62b Postboks 1919,**
**1023 Copenhagen K, Denmark**

The climatic conditions at Westgreenland has for most of the 1990'es been characterized by long periods with negative temperature anomalies in the atmosphere. Especially during wintertime this tendency has been very pronounced. I 1996 however slightly positive temeprature anomalies were experienced during wintertime while weak negative anomalies characterized the summer, Fig. 1.

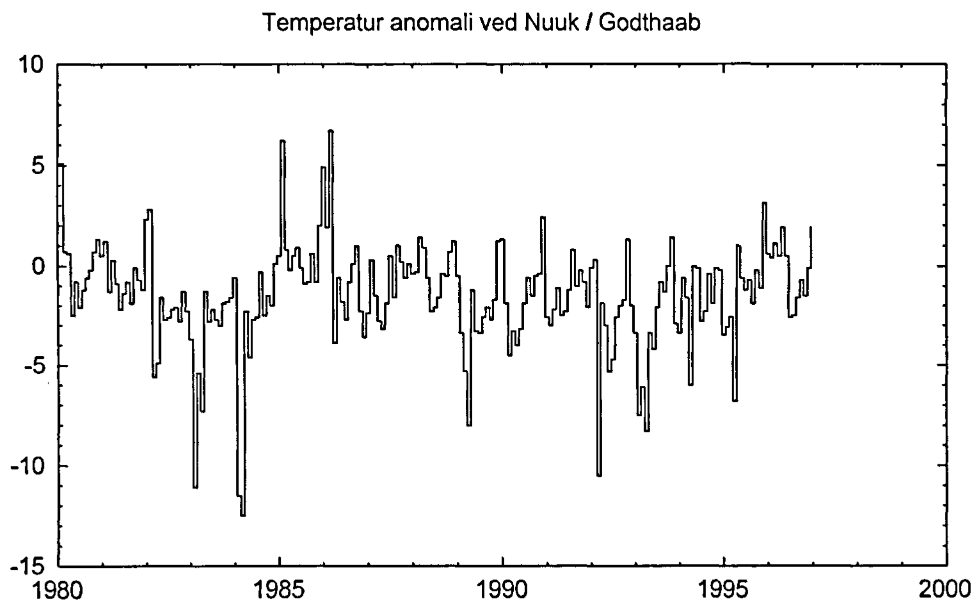



Fig.1 Monthly mean air temperature anomalies from Nuuk for the period 1980 to 1996

The Westgreenland Standard Sections were surveyed during the period 24 June - 6 July 1996.

The mild climate was reflected in the temperature conditions of the surface layer; Fig. 2.

The surface layer off Southwest Greenland was dominated by inflow of Atlantic water. Off Cape Farewell and Cape Desolation extraordinary high surface temperatures and salinities (T>7°C, S> 34.8 psu) were observed. Polar Water was only observed very close to coast.

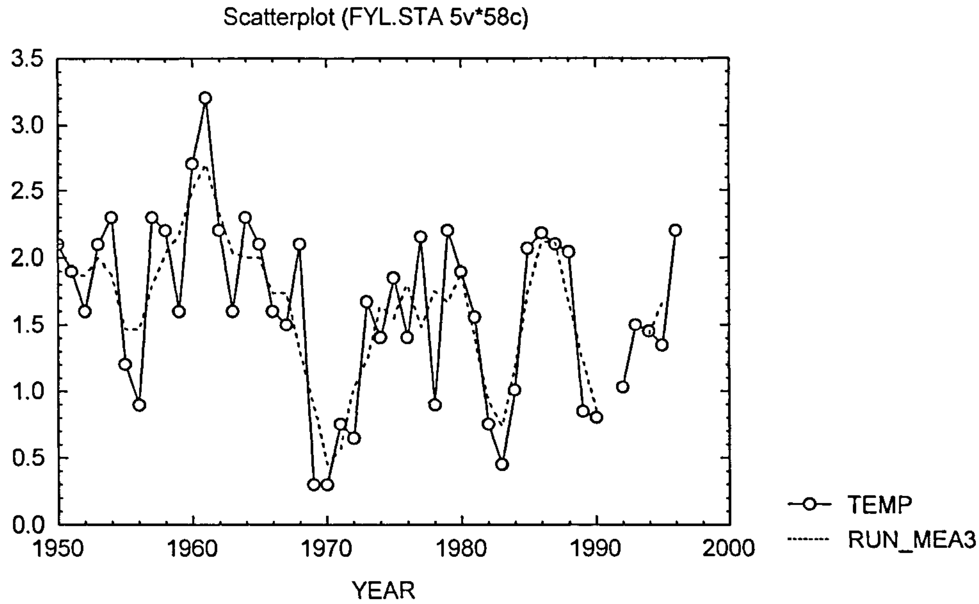



Fig.2. Mean Temperature on top of Fylla Bank, Medio June 1950-96

o-----o Observed values
\- - - - - 3 years running mean

The deeper layers were also dominated by inflow of water of Atlantic Origin, quite large volumes of water with temperatures above 5°C was observed. Pure Irminger Water (T>4.5°C, S>34.93 psu) was present at the three southernmost sections, while modified Irminger Water (T>4.5°C, 34.88<S<34.93) could be traced as far north as between the FyllaBand and the Sukkertop Bank sections. Subatlantic Water (3.5<T<4.5, 34.5<S<34.88) was in 1996 present on all sections.

# Annex H: The state of Faroese waters in 1996

**Bogi Hansen, Fiskirannsóknar stovan**
**P.O. Box 3051, Noatum, FR-110 Tórshavn**
**Faroe Islands, Denmark**

Figure 1 shows the four standard sections that are operated by the Faroese Fisheries Laboratory (Fiskirannsóknarstovan) and are usually occupied by CTD observations at least four times a year. The sections cover the Atlantic water inflow to the Nordic Seas between Iceland and Scotland. Since the end of the eighties, this water has freshened considerably and also become somewhat cooler. This is best illustrated by average characteristics for the 100 - 300 meter depth layer in the Faroe Bank Channel (white circle on Fig. 1), which is considered to represent water of generally pure Atlantic origin, deriving from the North Atlantic Current (Fig. 1).

Figure 2 shows observed salinity and "deseasoned" temperature for this layer during the last two decades. Since the mid-seventies ("Great") salinity anomaly, the salinity of this water increased and generally exceeded 35.25 until the decrease in the early nineties. Figure 2 includes CTD observations from 6 cruises in 1996 and one in February 1997. It appears that the salinity decrease has stagnated; but there is no clear evidence for increasing salinities again, although the observations from the latest years have not showed salinities as small as those observed in 1993 and 1994.

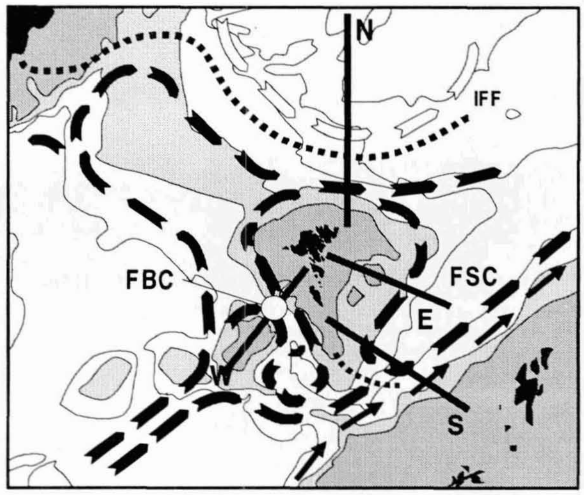



**Fig. 1.** The bottom topography around the Faroe Islands is indicated with the shallow areas shaded. The main flow in the upper layers is by arrows and the Iceland-Faroe Front by a dotted curve. The four standard sections (N, E, S and W) are shown by thick lines and the white circle indicates the area in the Faroe Bank Channel from which the data in Fig. 2 originate.

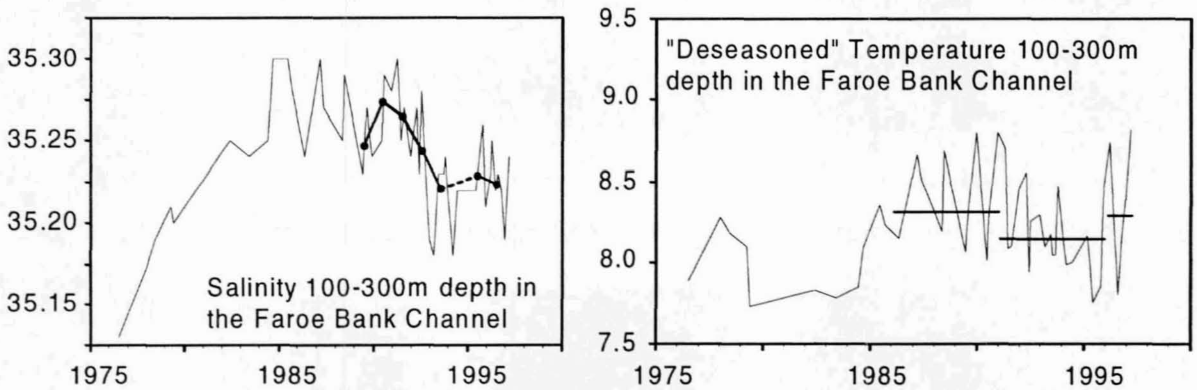



**Fig. 2.** Salinity (left) and temperature (right) averaged over the 100 - 300 m layer in the middle of the Faroe Bank Channel (white circle on Fig. 1) based upon CTD observations. Temperature has been "deseasoned" by subtracting the typical seasonal variation. Filled circles connected by bold lines on left graph show annual averages of salinity while thick horizontal lines on right graph show temperature over two 5-year periods and the period 1996 - Feb. 1997.

The observations of temperature in the 100 - 300 m layer of the Faroe Bank Channel (righthand graph on Fig. 2) make a fairly noisy time series even though the data in Fig. 2 have been "deseasoned". The five-year averages shown in figure 2 indicate that the 1991-95 period was slightly colder than the 1986-90 period while the average temperature for the 1996-97 observations had increased. The large variability reduces the significance of these conclusions. The coastal observations of sea surface temperature (Fig. 3), on the other hand, clearly indicate a warming of the waters on the shelf in 1996, but no analysis is available to establish how much, if any, of this is due to warming of the surrounding oceanic waters.

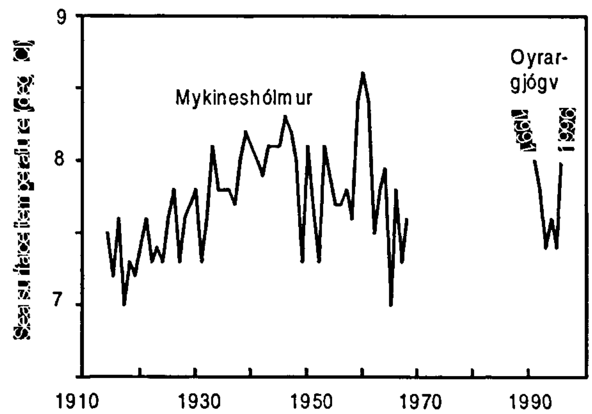



**Fig. 3.** Annually averaged coastal observations of sea surface temperature in the Faroes at two fairly close locations: Mykineshólmur 1914 - 1969 and Oyrargjógv 1991 - 1996.

# Annex I: Results from the Scottish Standard Sections

**Bill Turrell, Marine Laboratory**
**P.O. Box 101, Victoria Road,**
**Aberdeen, Scotland, AB11 9DB**

## 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 three occasions since April 1996; May/June 1996, October 1996 and March/April 1997. In addition the North Sea JONSIS section was also occupied during these surveys (Fig. 1).

The results presented here are based on the definitions of time series presented in a section below. 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 until April 1997.

## Summary of Results

*Surface Waters*

North Atlantic Water (NAW) at the Scottish shelf edge (Fig. 2) has been warming since 1987 at a rate of O(0.5°C/decade). This 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 has demonstrated great variability since the end of the low salinity anomaly (GSA) years in the late 1970s, and this variability may be related to the NAO index. There has possibly been a gradual overall salinity increase since the GSA period with salinities now approaching 1960 values. The most recent change is a more rapid rise at a rate of O(0.2/decade) since 1993.

Modified North Atlantic Water (MNAW) has demonstrated quite different changes compared to those of NAW (Fig. 3). There has been a general cooling of MNAW since 1960 at a rate of O(0.3°C/decade). Salinity has also decreased since 1960 at a rate of O(0.02/decade), with a more rapid decrease evident since 1991. Salinities are beginning to approach those values observed during the GSA period.

*Intermediate Waters*

Trends in temperature cannot be determined in intermediate waters using the present definitions, but salinity continues to decrease (Fig. 4). In the Arctic Intermediate / North Icelandic Water (AI/NIW) salinity has decreased at a rate of O(0.015/decade) since 1975. The salinity of Norwegians Sea Arctic Intermediate Water (NSAIW) also continues to decrease at a rate of O(0.02/decade). This decrease commenced in 1975 and is twice the rate of the decrease in the bottom water.

*Bottom Water*

Faroe Shetland Channel Bottom Water (FSCBW) again still demonstrates the salinity decline at a rate of O(0.01/decade). The warming observed at 1100 dbar which commenced in 1990 has now stopped (Figs 5 and 6).

In the North Sea the salinity variability in the past has been well correlated with that of NAW, with a possible 1 year lag. However, unlike NAW, the salinity of Fair Isle Current Water (FICW) has more recently demonstrated a differing trend, with FICW salinity decreasing since 1973, while NAW salinity is generally increasing (Fig. 7). Also unlike NAW, FICW demonstrated a cool episode in the mid 1990s which has now ended.

The properties of Cooled Atlantic Water (CAW) which typifies water lying within the central northern North Sea below the seasonal thermocline, are more closely tied to those of NAW (Fig. 8). Hence CAW does demonstrate the gradual warming seen in NAW since 1970, and the more recent salinity variability seen in NAW is reflected in that of CAW. One difference noted is that while the salinity of NAW has risen since 1993, CAW salinity has declined. This may imply reduced oceanic inflow to the North Sea presently.

*Dramatic Change in March 1997*

A final result of some note is the great change observed within the Fair Isle Munken line during the March/April 1997 cruise. Figure 9 shows the contoured sections of temperature along the two standard sections. These two lines were surveyed 4 days apart due to severe weather halting operations. The northerly Nolso - Flugga line was surveyed first (23-24 March 1997), followed by the Fair Isle Munken line (27-29 March 1997). As can be seen the isotherms in the southern section are displaced upwards against the Faroese slope. This implies an increased southerly transport against the slope. The θS characteristics of AI/NIW (Fig. 10) are significantly altered. NSIW is no longer marked as a salinity minimum. It is now represented as an inflection, but of lower temperature than in June 1996. AI/NIW is now seen as a salinity minimum, with salinities 0.12 less than in June 1996. This represents a significant reduction in intermediate water salinity. Its cause is not yet known, but may be connected with the increased southerly transport of intermediate water associated with the upward displacement of the Fair Isle Munken isotherms.

## Time Series Definitions

Time series from 5 characteristic water masses which occupy the Faroe Shetland Channel are presented in Figs 2 - 6 and for 2 North Sea water masses in Figs 7 and 8. The methods employed to define the water masses, and to derive the time series are described below. *Please note that these are preliminary definitions and may alter.*

Surface Waters:

*North Atlantic Water (NAW)* (Fig. 2) - The temperature and salinity at the standard pressure level which exhibits the maximum salinity within an individual survey of the most southeasterly two stations, on both standard sections, on the Scottish side of the Channel.

The criteria was designed to produce the characteristics of the North Atlantic water lying within the Slope Current at the Scottish shelf edge. North Atlantic Water is typified by a salinity maximum on a θ-S diagram. This water most probably originates west of the UK, in the Rockall Trough, and hence may be most closely related to North East Atlantic Water (NEAW).

*Modified North Atlantic Water (MNAW)* (Fig. 3) - The temperature and salinity at the standard depth which exhibits the maximum salinity within an individual survey of the first two stations, on both standard sections, on the Faroese side of the Channel.

These criteria were defined in order to characterise Modified North Atlantic Water, the water mass which composes much of the surface waters of the Channel, and encompasses the anti-cyclonic flow of warm, surface water around the Faroe plateau. These waters most probably originate in the sub-tropical gyre, west of Rockall, and hence may more closely follow conditions in areas influenced by the North Atlantic Current. This water again is identified on a θ-S diagram as a salinity maximum for waters on the Faroese side of the Channel.

*Removal of seasonal cycles*: As the surveys over the past century have been done at quite different times of the year, the effect of the seasonal cycle in the surface waters has been removed using the monthly mean t and S derived over the period 1960-1990. These means have been calculated for each individual station and at each standard pressure level, and subtracted from the individual observations resulting in plots of t and S anomaly from the mean seasonal cycle.

Intermediate Waters:

*Arctic Intermediate / North Icelandic Water (AI/NIW)* (Fig. 4) - The average salinity at standard pressures which exhibit potential temperatures in the range $3.5°C \leq \theta \leq 5.5°C$, at stations 7 - 10 along the standard sections. These stations lie between the centre of the Channel and the Faroese plateau.

This criteria is designed to examine the mean characteristics of water hugging the Faroese slope, whose characteristics fall within the stated potential temperature range on a θ-S curve. Within this range an inflection in the slope of the curve is generally observed, indicating the presence of AI/NIW formed North of Iceland and along the northern slopes of the Iceland - Faroe Ridge. The water circulates around Faroe, partly leaving the Faroe Shetland Channel through the Faroe Bank Channel, and partly recirculating back into the Norwegian Sea. The water which satisfies this criteria generally lies within the pressure range 300-400 dbar. The AI/NI temperature time series cannot be used due to the present definition employed.

*Norwegian Arctic Sea Intermediate Water (NSAIW)* (Fig. 4) - The salinity at the standard pressure which exhibits the minimum salinity within an individual survey of both standard sections, within the temperature range 0 K $\leq \theta \leq$ 1 K. Obviously the time series of temperature for this definition has little meaning.

This criteria is designed to examine the characteristics of the intermediate water mass created north of the Arctic front in the Iceland and Greenland Sea, which then subducts beneath the front forming a large salinity-minimum layer throughout the Norwegian Sea. The salinity minimum marking this water has not always been apparent due to changing properties of the water mass, but it has always been marked as a silicate minimum, and has been located between the stated temperatures.

Deep Waters:

*Standard Pressure Levels* (Figs 5-6) - Mean potential temperature and salinity at a standard pressure levels, averaged over all values on that pressure level recorded during an individual survey of both standard sections.

This method of deriving time series for the bottom waters in the Faroe Shetland Channel acknowledges that the characteristics of the water have changed considerably during the century, sometimes displaying the characteristics of true Norwegian Sea Deep water, while at other times being occupied by predominantly intermediate water.

North Sea Waters:

*Fair Isle Current Water (FICW)* (Fig. 7) - The mean temperature and salinity at all standard pressures, averaged over the first two stations at the west end (Scottish) of the JONSIS standard section.

This criteria captures the characteristics of water entering the North Sea through the Fair Isle Channel. This water originates west of Scotland, and is a mixture of coastal water and Atlantic water that has come onto the shelf from the Slope Current.

*Cooled Atlantic Water (CAW)* (Fig. 8) - The mean temperature and salinity at all standard pressures below 50 dbar, averaged over the first six stations at the east end (Norwegian) of the JONSIS standard section.

This criteria is designed to examine the characteristics of the cool dense lens of

Atlantic water which forms in the centre of the North Sea during the summer months. During period of vertical stratification in the northern North Sera, this water mass retains the characteristics of the mixed North Sea during the previous winter, until the dense lower layer is eventually eroded through autumnal wind mixing, and again takes on the properties of the northern North Sea as a whole. Thus it generally represents water of Atlantic origin, modified by mixture with North sea coastal waters to a varying extent.

*Removal of seasonal cycles*: As the surveys over the observational period have been done at quite different times of the year, the effect of the seasonal cycle in the surface waters has been removed using the monthly mean t and S derived over the period 1970-1990. These means have been calculated for each individual station and at each standard pressure level, and subtracted from the individual observations resulting in plots of t and S anomaly from the mean seasonal cycle.

All plots show individual cruise values, along with the results of applying a two year running mean filter.

**Table 1. Characteristic θ and S of different surface water masses during 1995 - 1997. Values are anomalies after the seasonal cycle has been removed (See text for explanation).**

| | NAW | | MNAW | | FICW | | CAW | |
|---|---|---|---|---|---|---|---|---|
| | θ (°C) | S | θ (°C) | S | θ (°C) | S | θ (°C) | S |
| Sep 95 | -0.32 | 0.004 | 0.18 | -0.008 | n/a | n/a | n/a | N/a |
| Nov 95 | -0.47 | 0.038 | n/a | n/a | 0.54 | 0.056 | 0.49 | -0.054 |
| Jun 96 | 0.64 | 0.055 | -0.26 | 0.003 | 0.52 | -0.098 | 0.45 | -0.013 |
| Oct 96 | -0.23 | 0.069 | -0.86 | -0.028 | -0.35 | 0.040 | -0.02 | 0.048 |
| Mar 97 | 0.26 | 0.030 | -0.03 | -0.060 | n/a | n/a | n/a | N/a |

**Table 2. Characteristic θ and S of different intermediate water masses during 1995 - 1997. Values have been obtained manually from θS diagrams and not using the automated methods described above.**

| | 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 |
| Sep 95 | 2.27 | 34.915 | 2.01 | 34.910 | 0.18 | 34.879 | 0.03 | 34.882 |
| Nov 95 | 1.93 | 34.901 | 1.64 | 34.895 | 0.32 | 34.875 | 0.18 | 34.883 |
| 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 |

**Table 3. Characteristic θ and S at three pressure levels during 1995 - 1997. 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 |
| Sep 95 | -0.38 | 34.897 | -0.60 | 34.903 | -0.67 | 34.907 |
| Nov 95 | -0.42 | 34.899 | -0.72 | 34.910 | -0.64 | 34.911 |
| 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 |

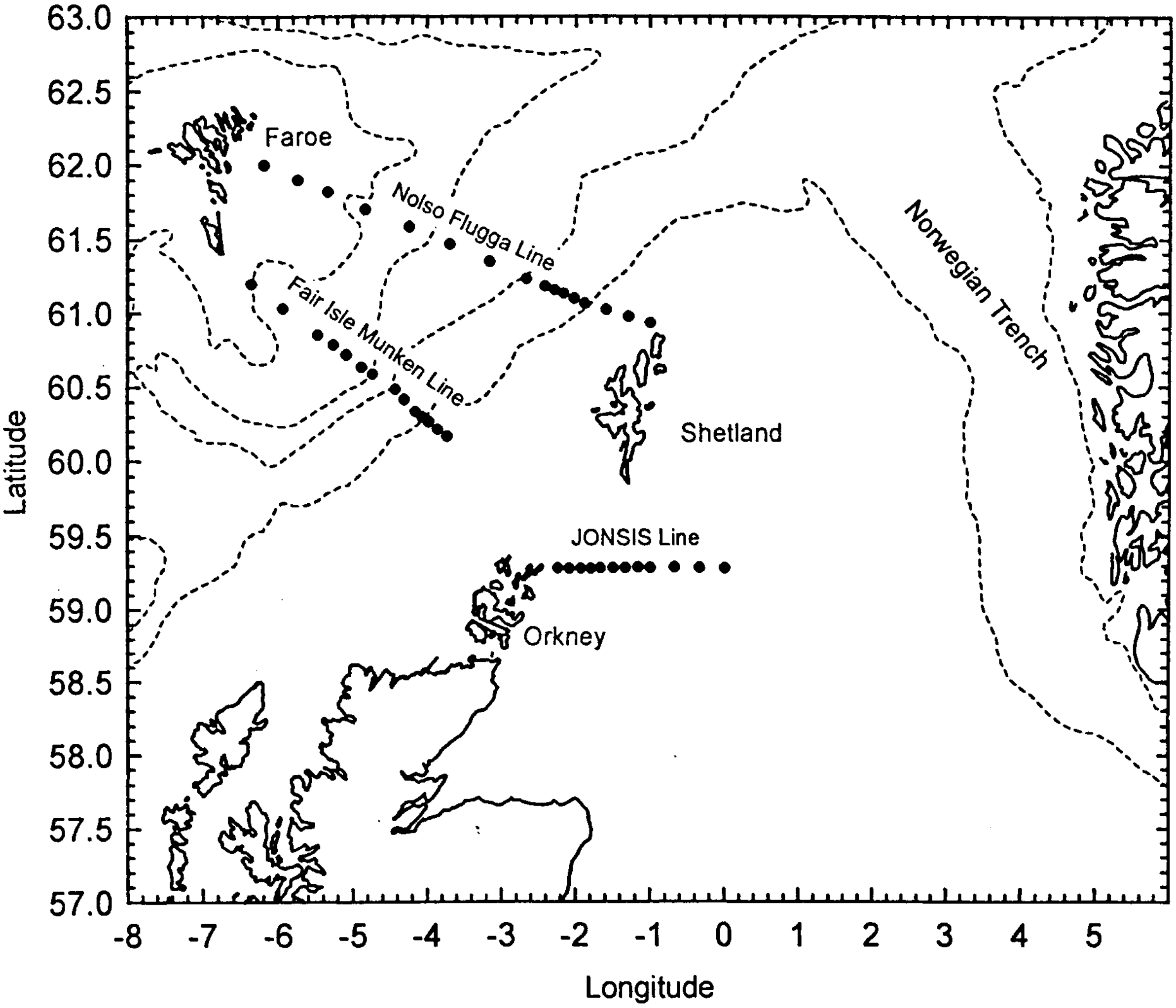

63.0
62.5
62.0
61.5
61.0
60.5
60.0
59.5
59.0
58.5
58.0
57.5
57.0
Latitude
-8
-7
-6
-5
-4
-3
-2
-1
0
1
2
3
4
5
Longitude
Faroe
Nolso Flugga Line
Fair Isle Munken Line
Norwegian Trench
Shetland
JONSIS Line
Orkney

Figure 1

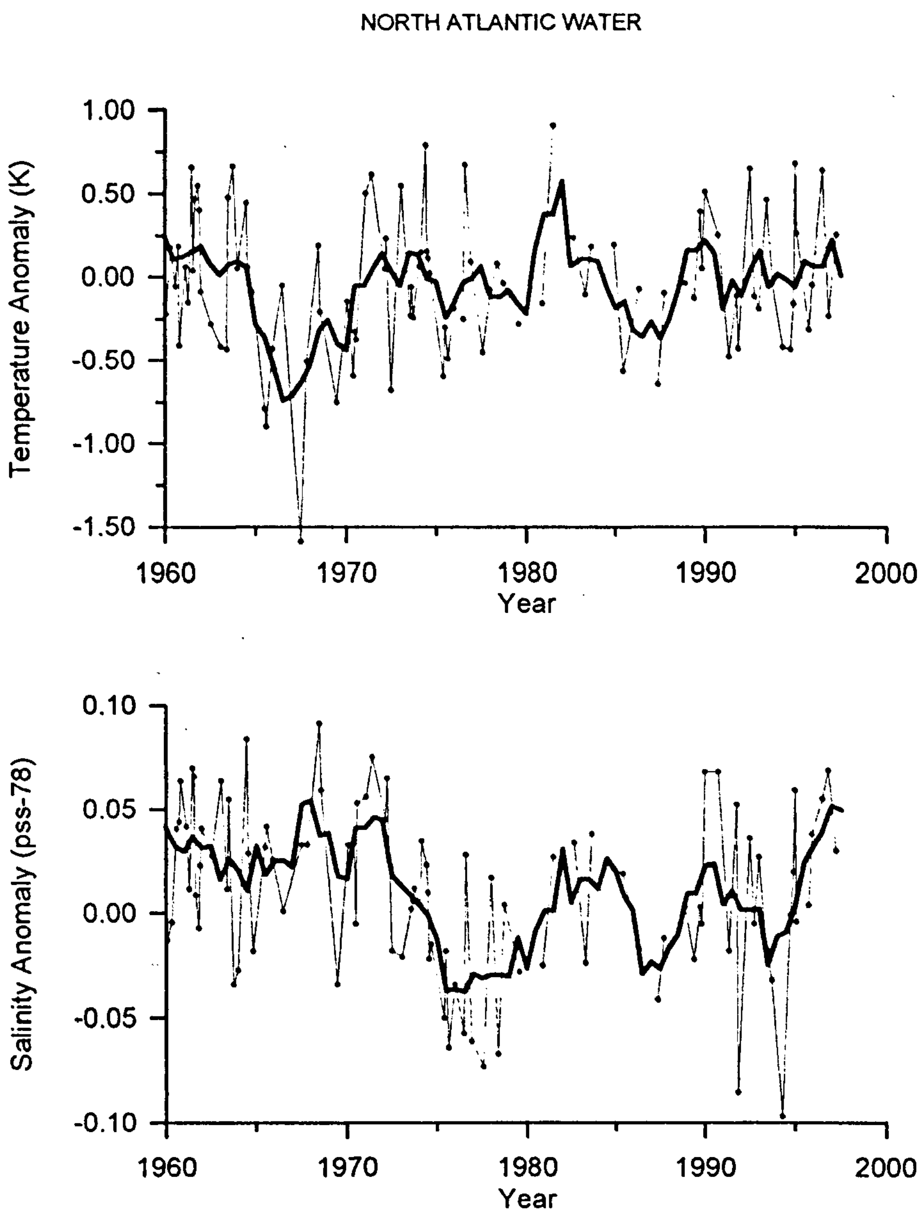
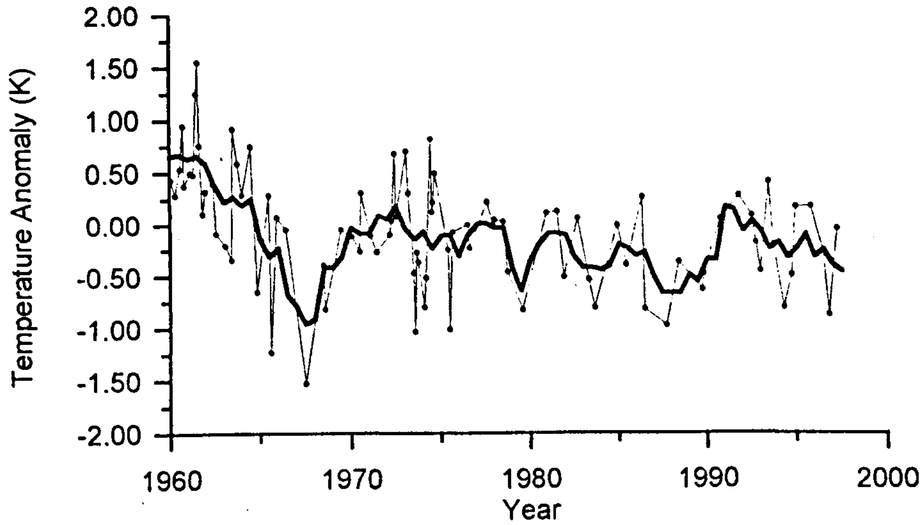

NORTH ATLANTIC WATER
Temperature Anomaly (K)
1.00
0.50
0.00
-0.50
-1.00
-1.50
1960
1970
1980
1990
2000
Year
Salinity Anomaly (pss-78)
0.10
0.05
0.00
-0.05
-0.10
1960
1970
1980
1990
2000
Year

Figure 2

MODIFIED NORTH ATLANTIC WATER



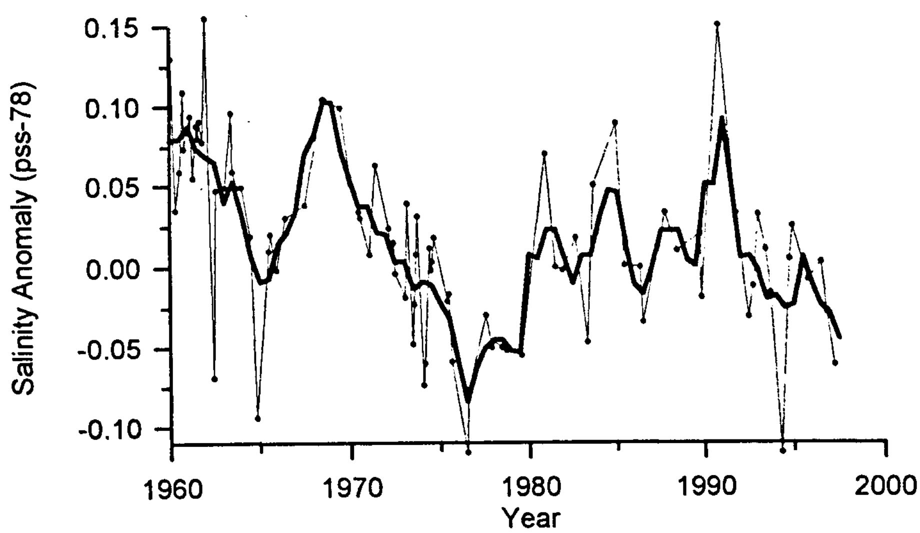




Figure 3

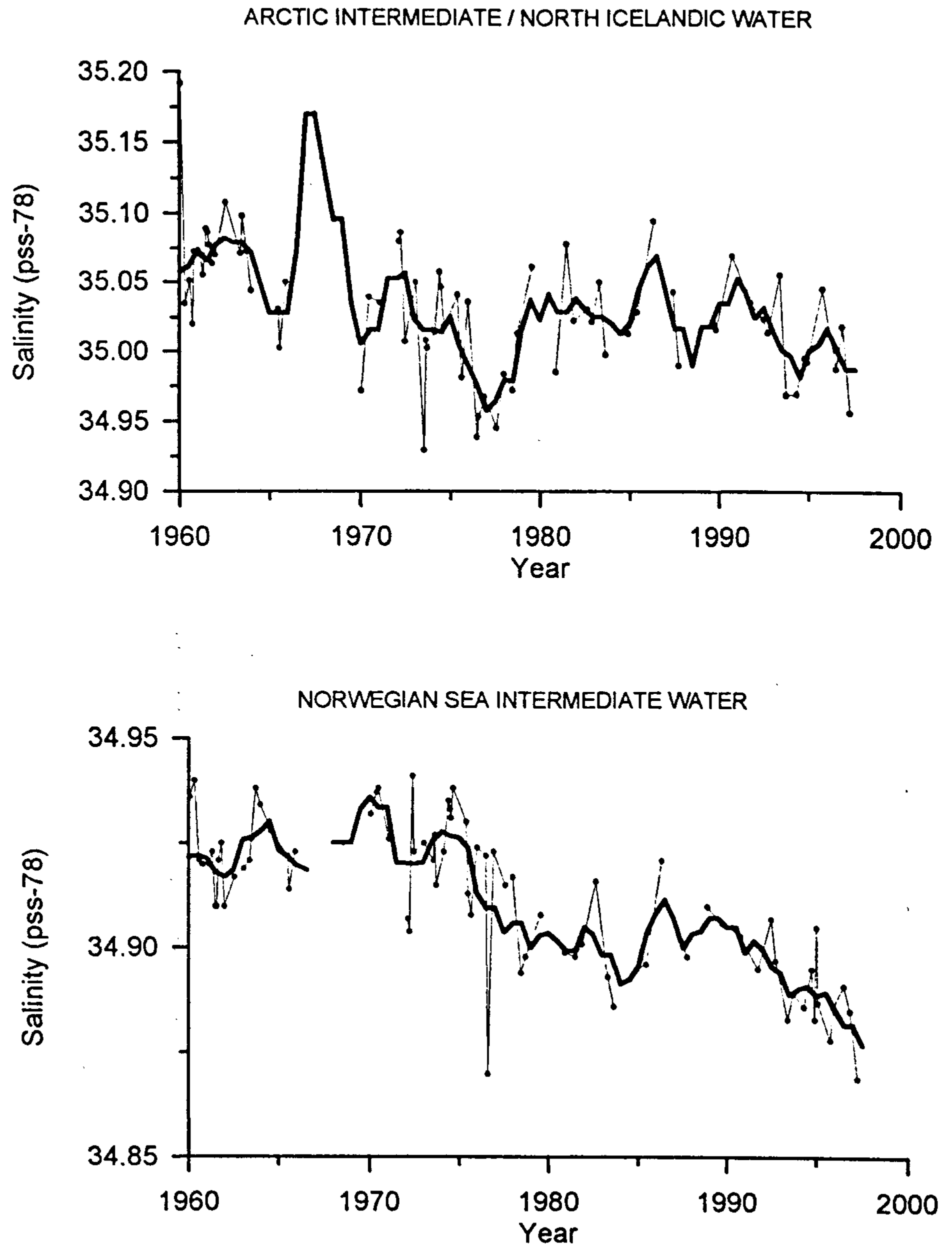

ARCTIC INTERMEDIATE / NORTH ICELANDIC WATER
35.20
35.15
35.10
35.05
35.00
34.95
34.90
Salinity (pss-78)
1960
1970
1980
1990
2000
Year
NORWEGIAN SEA INTERMEDIATE WATER
34.95
34.90
34.85
Salinity (pss-78)
1960
1970
1980
1990
2000
Year

Figure 4

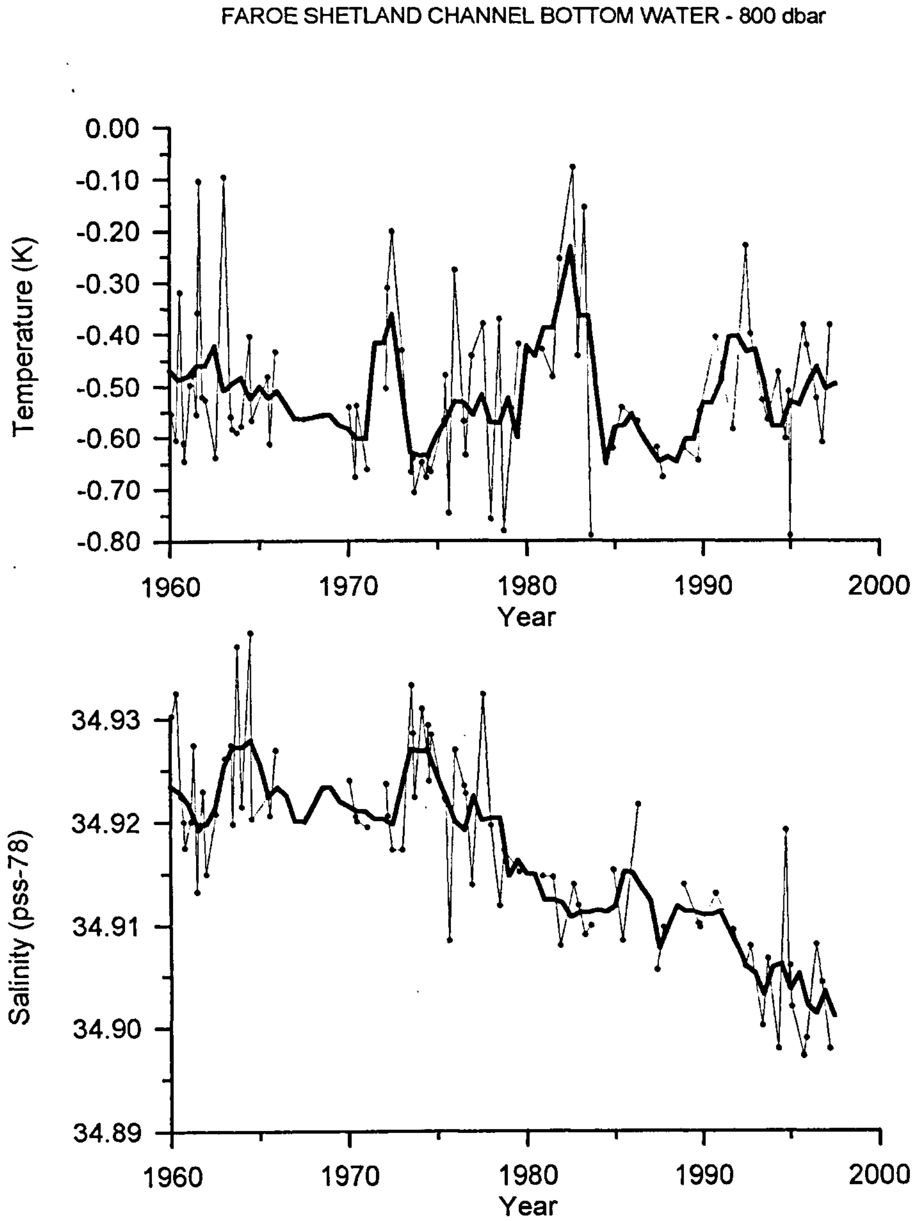
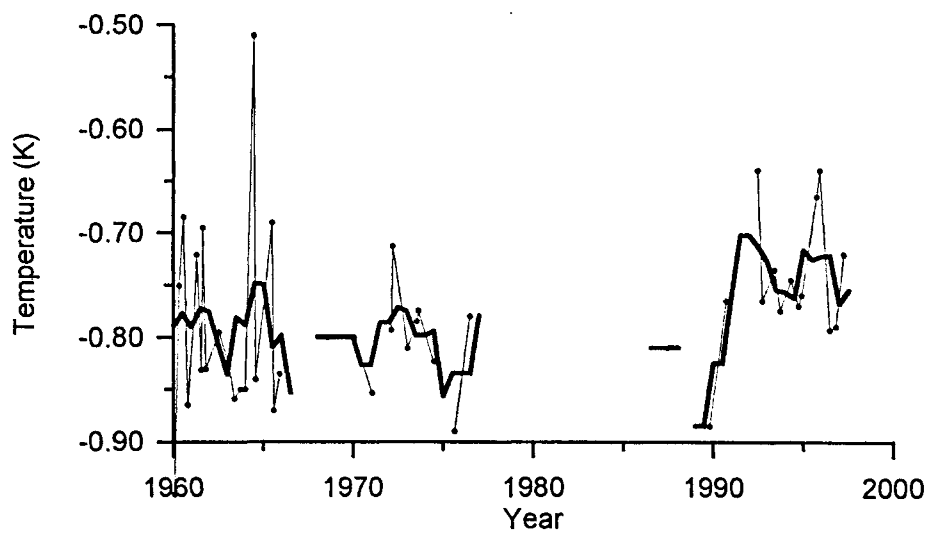

FAROE SHETLAND CHANNEL BOTTOM WATER - 800 dbar
Temperature (K)
0.00
-0.10
-0.20
-0.30
-0.40
-0.50
-0.60
-0.70
-0.80
1960
1970
1980
1990
2000
Year
Salinity (pss-78)
34.93
34.92
34.91
34.90
34.89
1960
1970
1980
1990
2000
Year

Figure 5

FAROE SHETLAND CHANNEL BOTTOM WATER - 1100 dbar



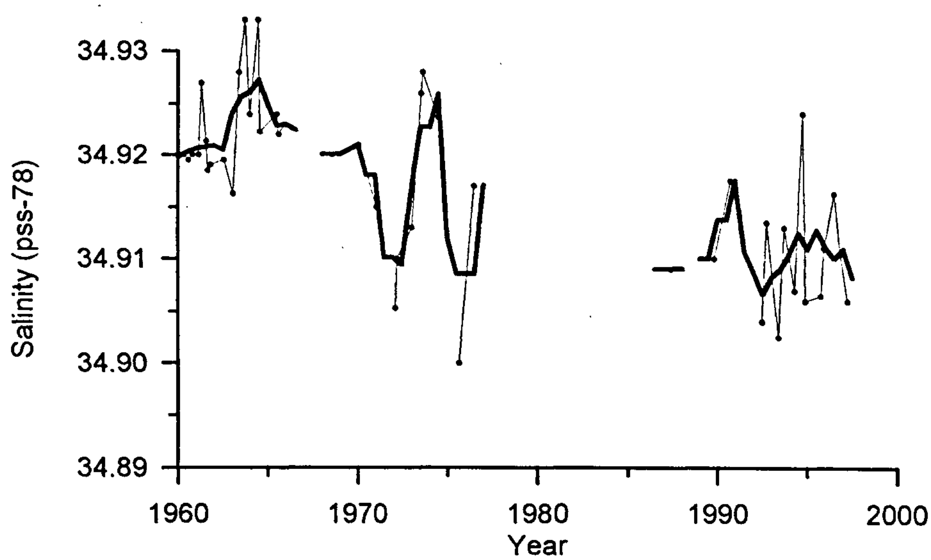




Figure 6

FAIR ISLE CURRENT WATER

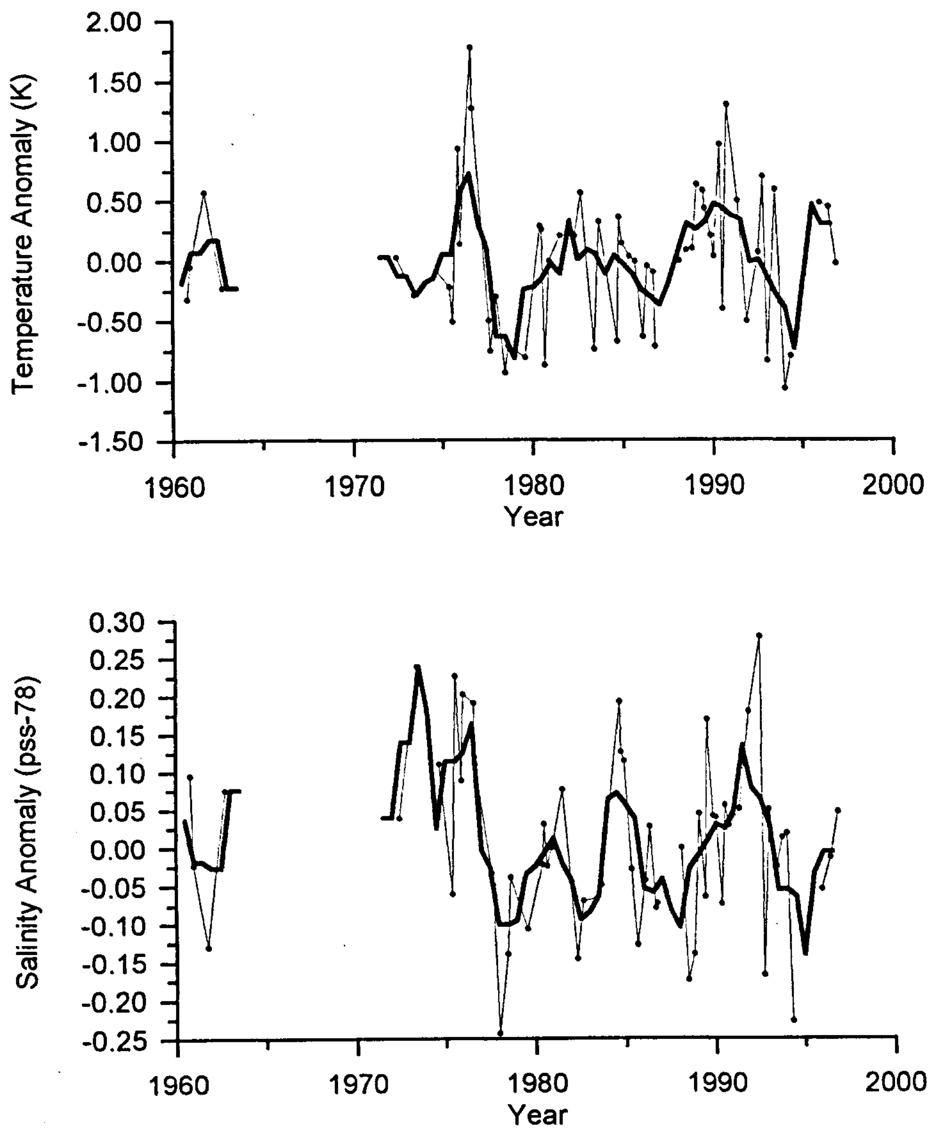



Figure 7

COOLED ATLANTIC WATER

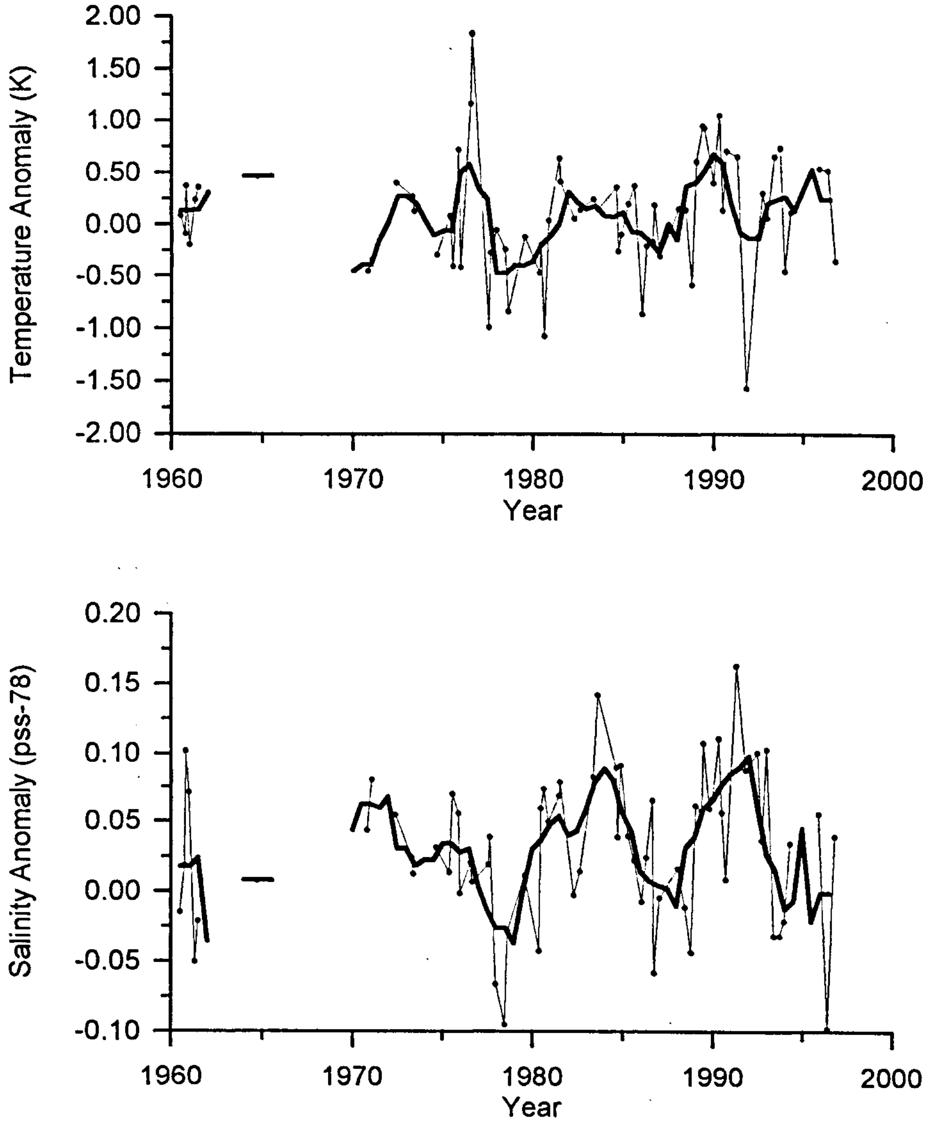
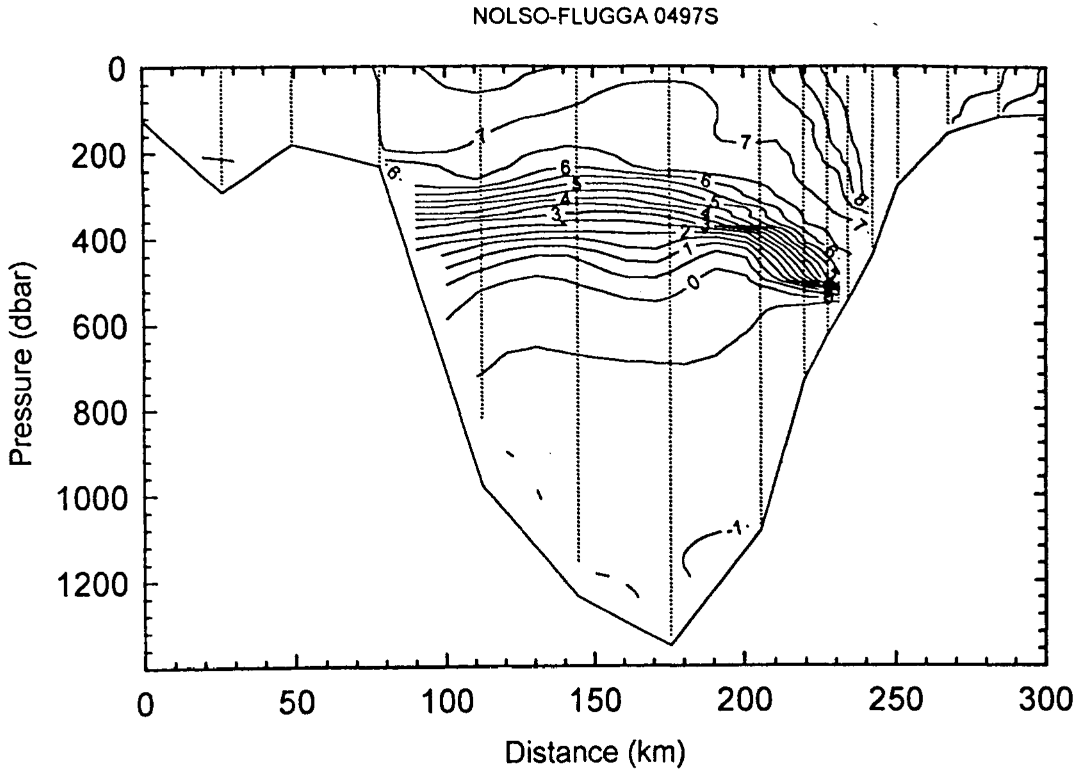



Figure 8


NOLSO-FLUGGA 0497S
Pressure (dbar)
Distance (km)

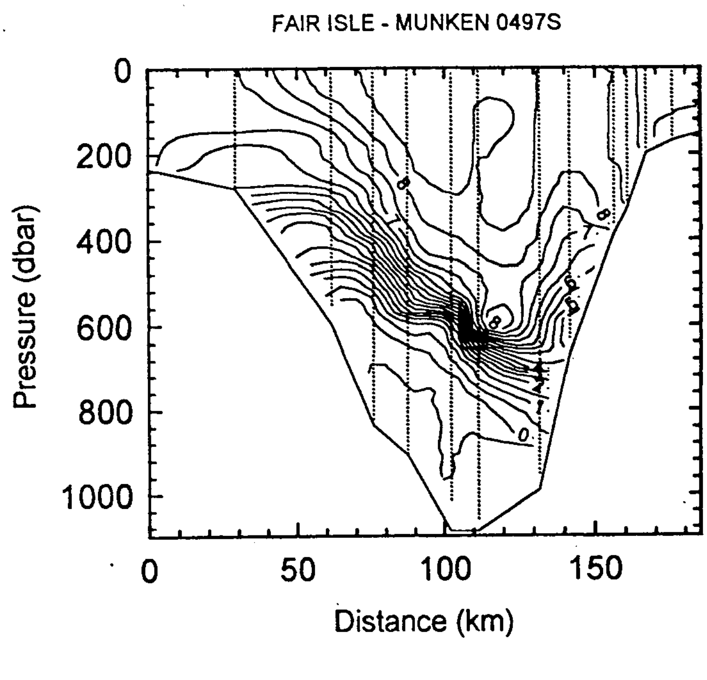

FAIR ISLE - MUNKEN 0497S
Pressure (dbar)
Distance (km)

Figure 9

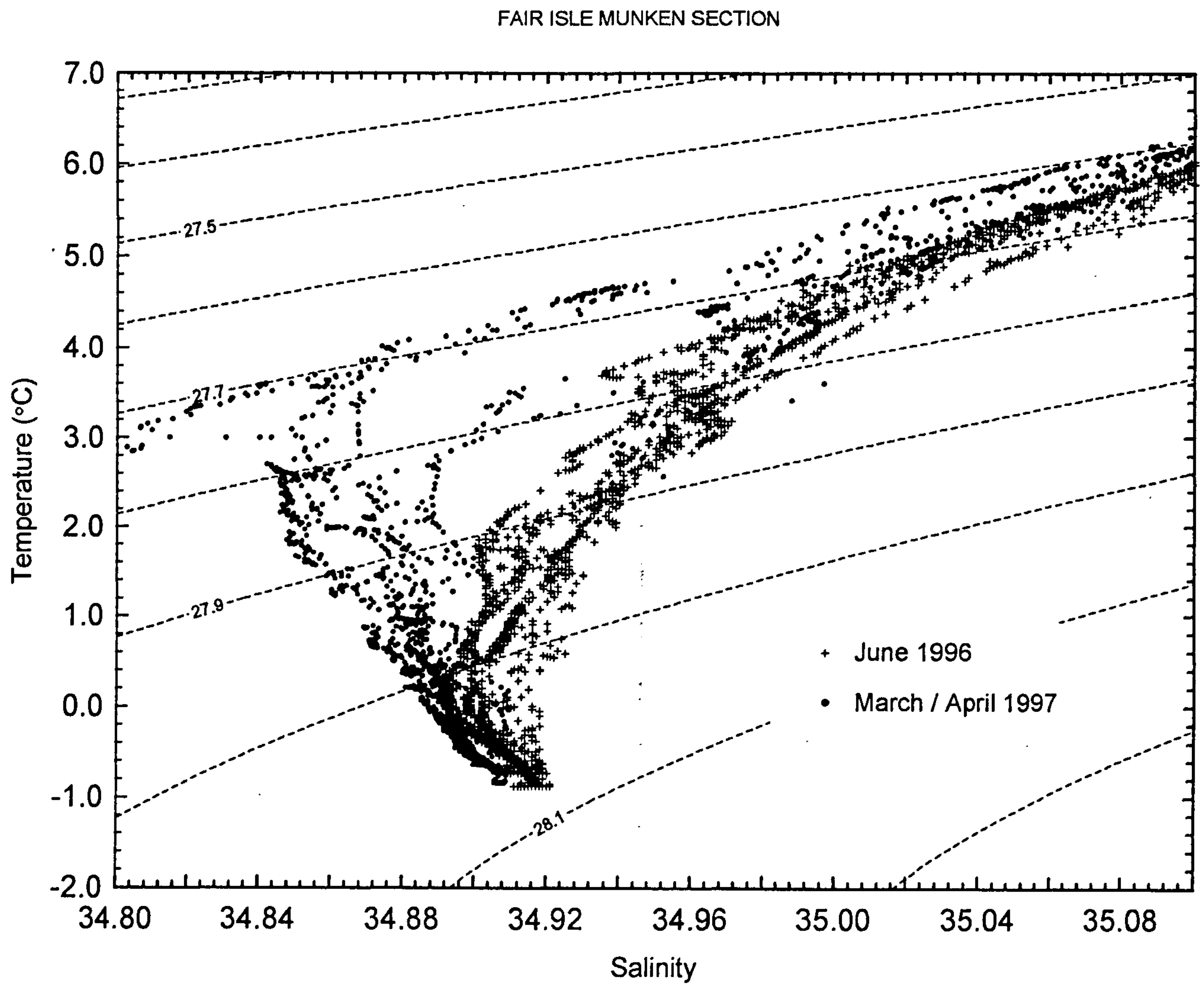

FAIR ISLE MUNKEN SECTION
Temperature (°C)
Salinity
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
34.80
34.84
34.88
34.92
34.96
35.00
35.04
35.08
27.5
27.7
27.9
28.1
+ June 1996
• March / April 1997

Figure 10

# Annex J: Norwegian Sections

**Johan Blindheim, Institute of Marine Research**
**P.O.Box 1870, Nordnes**
**5024 Bergen, Norway**

The location of Norwegian standard sections are indicated in Fig. 1. The intention with this set of sections is to monitor the flow of warm water from the North Atlantic, into the Nordic Seas. An important reason for this monitoring is the rather considerable effect of inter-annual temperature fluctuations on the state and development of the commercially important fish populations in the area

The transport of Atlantic water enters the Nordic Seas Mainly through the Faroe-Shetland channel and to a considerable extent, also in the current branch which passes north of the Faroes. Important branches divert from the main current along the continental shelf break, into the important fishing areas in the North Sea and the Barents Sea. The standard sections are repeated to monitor fluctuations in this system.

### The Barents Sea

The Barents Sea is a shelf sea covering an area of approximately 1.4 x $10^6$ $km^2$ where the mean depth is about 230 m. The bottom topography strongly influences distribution and movements of the water masses. Around the Central Bank, in about the middle of the area, the inflow of Atlantic water, the North Cape Current, splits into a main southern branch and a northern one which is somewhat smaller. The Barents Sea is characterised by considerable inter-annual fluctuations in water mass properties, particularly in heat content and consequently, ice coverage. These fluctuations are monitored in three sections which are repeated regularly; the Fugløy-Bjørnøy Section, between 19°E and 20°E from the Norwegian coast to Bear Island, the Vardø-N Section, along 31°13'E, and the Sem Islands-N Section along 37°20'E. Time series of temperature and salinitiy, averaged between 50 and 200 m depth across the main Atlantic inflow in these sections are shown in Fig. 2

In general, the temperature in the Barents Sea has been above the long term mean during the period 1989-1995, with warmest conditions in 1991-1992. During 1996 the temperatures have decreased and are now below the long term mean. This decrease was larger in the two eastern sections than in the western part of the Barents Sea. Also in salinity there has been a similar decrease, falling from a maximum in 1991-1992 to present values below the long term mean.

Figure 3 shows the distribution of temperature at 100m depth in 1992, which was a relatively warm year, and in 1996 which was considerably colder. As seen in the figure, the temperature decrease was particularly large in the frontal zone in the central Barents Sea.

During the winter 1995-1996 the ice coverage was relatively large, with the ice border lying between 74°N and 75°N during the winter. During summer the whole Barents Sea was ice free. The ice index given in Fig. 4 which is based on the ice coverage for the whole year, indicates slightly more ice than average.

## The Norwegian Sea

Figure 5 shows the fluctuations in temperature and salinity in the sections Svinøy-NW, Gimsøy-NW and Sørkapp-W (West Spitsbergen) which are situated in the southern, central and northern Norwegian Sea, respectively (Fig. 1). As in the Barents Sea, the entries also in this figure are mean values of temperature and salinity, averaged between 50 and 200 m across the core of the Atlantic inflow off the shelf break. They are based on measurements taken in the period late July - early September.

In the Svinøy-NW Section there was an increase in temperature and salinity from 1994 to 1995 so that the summer situation in 1995 was very close to the average for the period since 1978. The salinity was close to the long term average also in the two sections further north while the temperatures in 1995 were above the mean, with increasing anomalies toward north. From 1995 to 1996 all three sections showed decrease in both temperature and salinity.

The figure shows that some of the variations appears clearly in all three sections, as for example the period with high values in both temperature and salinity around 1990. This period showed, however, also local differences. Hence, in the northern Norwegian Sea this warm period had a longer duration and larger temperature anomalies than further south. The large temperature decrease from 1995 to 1996 in the Sørkapp-W Section shows that this period with locally high temperatures now is broken.

All three sections in the Norwegian Sea also show a general decreasing salinity trend over most of the observational period. In the Svinøy-NW Section a similar decrease is clear also in temperature. This is a feature which is observed also in longer time series in the Norwegian Sea and in the Faroe-Shetland area since about 1960, affecting the upper part of the water column, into the upper layers of the deep water.

## The North Sea and Skagerrak

The North Sea is mainly a shallow shelf sea where about 2/3 of the area is shallower than 100 m. Greater depths occur in the Norwegian Trench where the depths exceed 700 m in Skagerrak. Most of the water masses in the North Sea flow in from the North Atlantic while some is runoff from land. The vertical mixing during the winter reaches the bottom in the shallow areas with small temperature differences between surface and bottom as consequence. The summer warming results in a well developed thermocline at depths varying between 20 and 50 m.

The circulation in the North Sea is largely cyclonic, and almost all of the water passes through Skagerrak before it leaves the area in the Norwegian Coastal current. Inter-annual fluctuations around this mean situation influences the whole ecosystem in the North Sea. The most important forcing mechanisms for such climatic variability are fluctuations in inflow of Atlantic water, wind conditions, heat exchange with the atmosphere and fresh water discharge from land.

The winter 1995/96 was relatively cold and dry over Europe. As a result, particularly the southern North Sea was up to 3°C colder than normal during the winter. This remained as cold bottom water during the following summer, with bottom temperatures about 1,5°C below the long term mean.

Figure 6. shows time series of temperature and salinity in the north western North Sea (Position A) and over the western slope in the Norwegian Trench (Position B), both located on a section from Utsira toward west along 59°17'N (Fig. 1). The measurements at A are taken to represent the "winter water" in the western branch of the Atlantic inflow. The observations in Fig. 6 B show the conditions in the core of the Atlantic inflow from the Norwegian Sea which follow the western slope of the Norwegian Trench. The figure show that the temperature is in general 1°-2°C lower on the North Sea plateau than in the inflow in the Norwegian Trench. After a warm period on the plateau around 1990, there has been a cooling and freshening trend since 1993. This is somewhat in contrast to Fig. 6B where the two last years have been relatively warm.

Figure 7 shows series of temperature, salinity and oxygen content at 600 m depth in the Skagerrak Deep. The time series show that deep water renewal occurred in 1991 after a long period without deep water exchange. At the end of this period the oxygen concentration in the deep water was at the lowest since the observations were initiated. This period with stagnant and warm water lasted until 1994 when colder water with higher oxygen content sank into the basin from the North Sea plateau. Further supply of new bottom water during the winter of 1996 brought the temperature further down.

## Coastal Water

At 8 fixed stations along the cost, temperature and salinity are observed at standard depths 2-4 times monthly. Fig. 8 shows the temperature and salinity trends at the fixed station "Skrova" for the period 1936 - 1996, averaged over the first quarter, Jan. - Mar., at 10 m depth and over the third quarter at 150 m depth. While the observations in the surface layer are rather vulnerable to local effects, the observations at 150 m are more reflecting the oceanic conditions and the variations in the Norwegian Atlantic Current. The high temperatures and salinities of the very warm period around 1990 reached a maximum in 1991, but the following cooling and freshening culminated in 1994. The seasonal trend at the same depths is also shown in the figure.

Figure 9 shows similar graphs for the fixed station at "Utsira". Averages for the first quarter at 10m depth and for the third quarter at 150m depth. Also at this station the observations at 150m depth reflects the conditions in the Norwegian Atlantic Current, but here in the flow which diverts into the North Sea. The warm period around 1990 is indicated also in this time series.

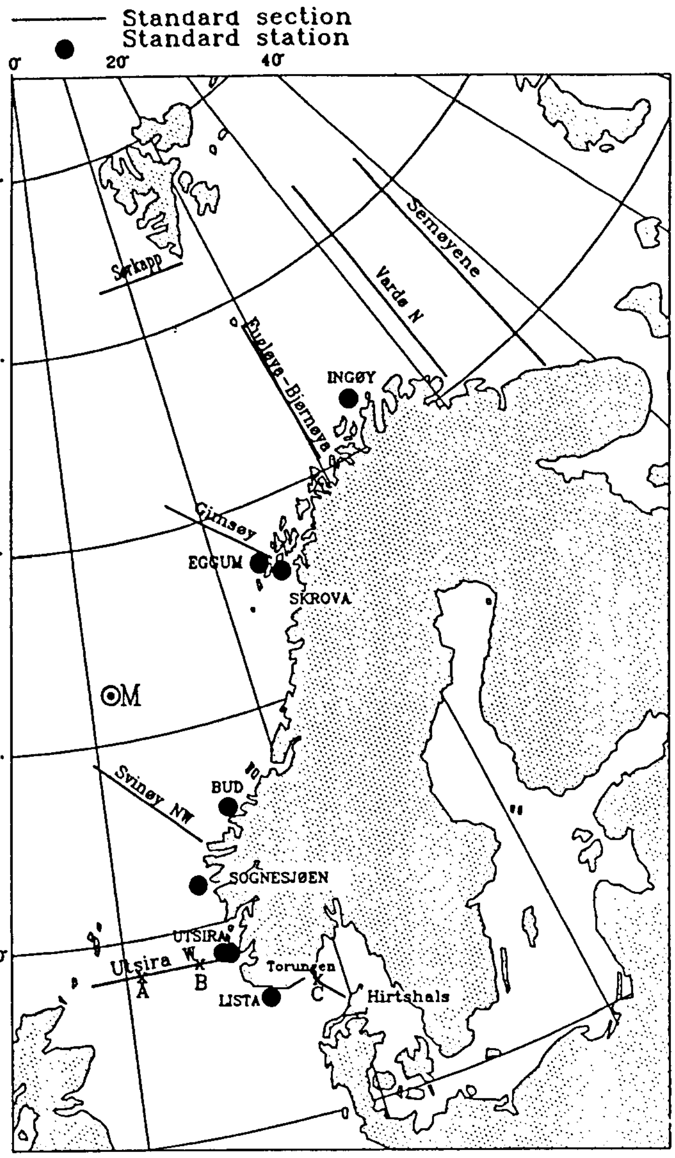
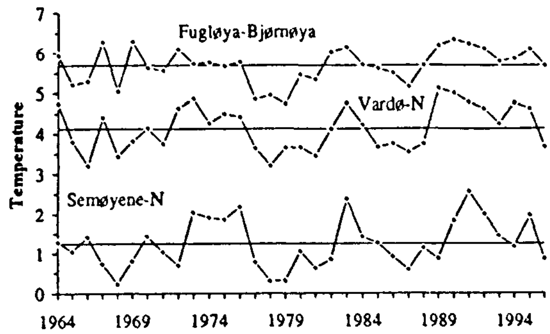



Fig. 1. Hydrographic standard sections and fixed oceanographic stations



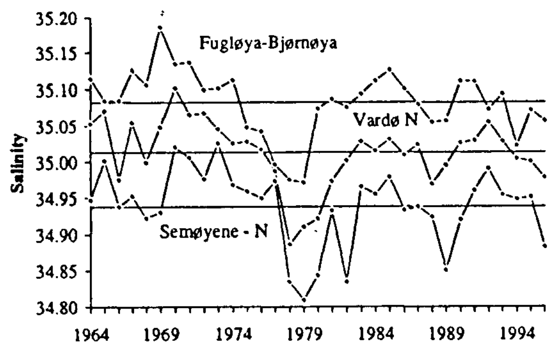




Fig. 2. Mean temperature and salinity between 50 and 200 m depth in the sections Fugløya-Brørnøya, Vardø - N and Sem Islands - N. Observations from August/September, 1964 - 1996.

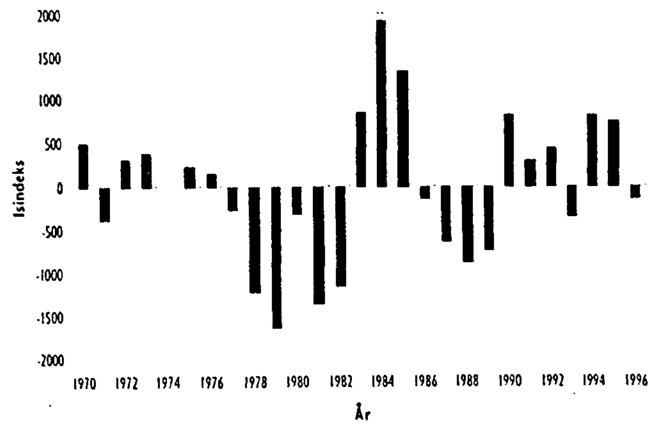



Fig. 3. Ice index for the period 1970 - 1995. Positive indices represent less ice than average.

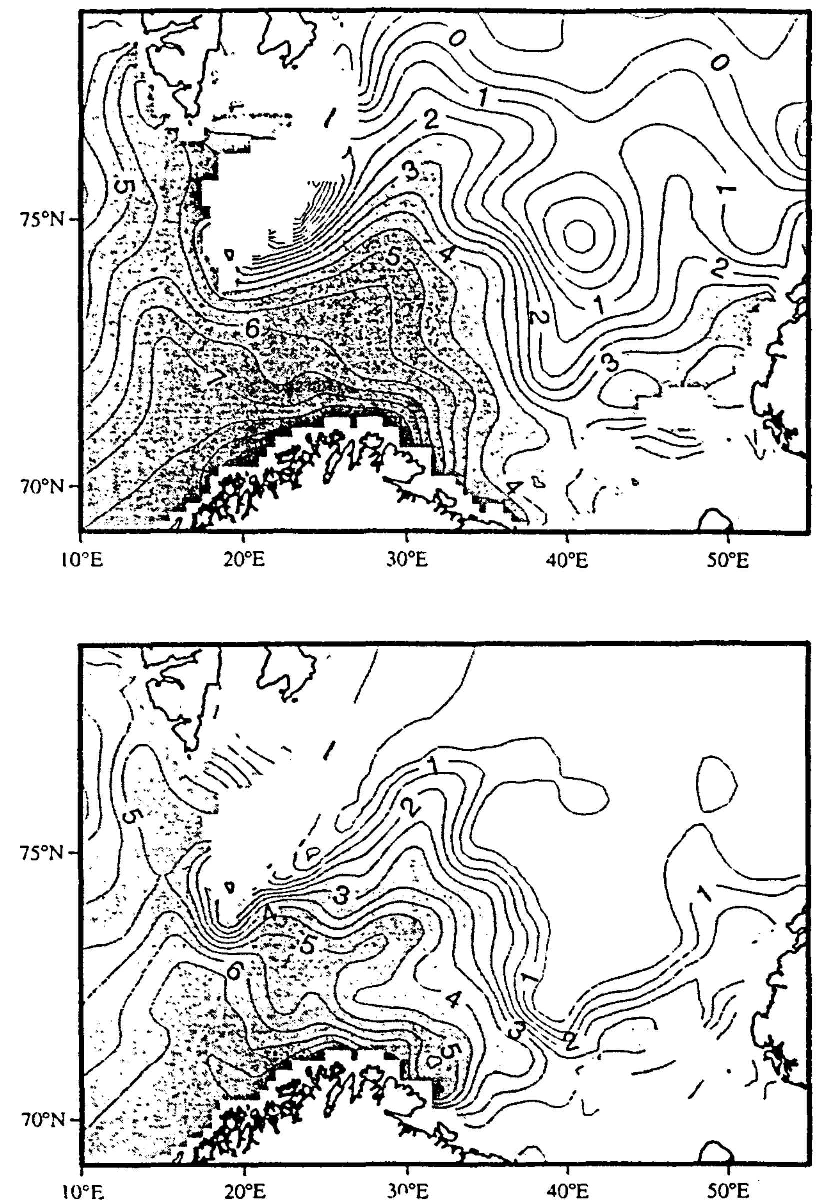



Fig. 4. Distribution of temperature at 100 m depth in the Barents Sea during August-September in 1992 (upper panel) and 1996 (lower panel)

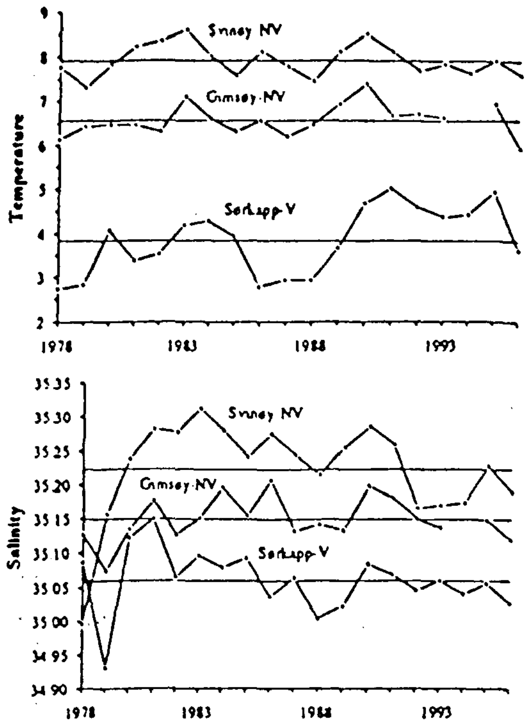



Fig. 5. Temperature and salinity, observed in July/August, in the core of the Atlantic water in the sections Svinøy-NW, Gimsøy-NW and Sørkapp-W. Averaged between 50 and 200 m depth.

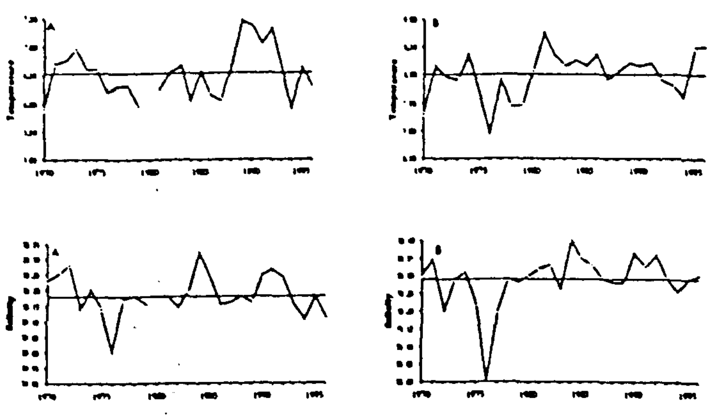



Fig 6. Temperature and salinity near the bottom in the north western North Sea (A) and in the core of the Atlantic water (B) over the western slope of the Norwegian Trench during the summers of 1970-1996. Locations of A and B in Fig 1.

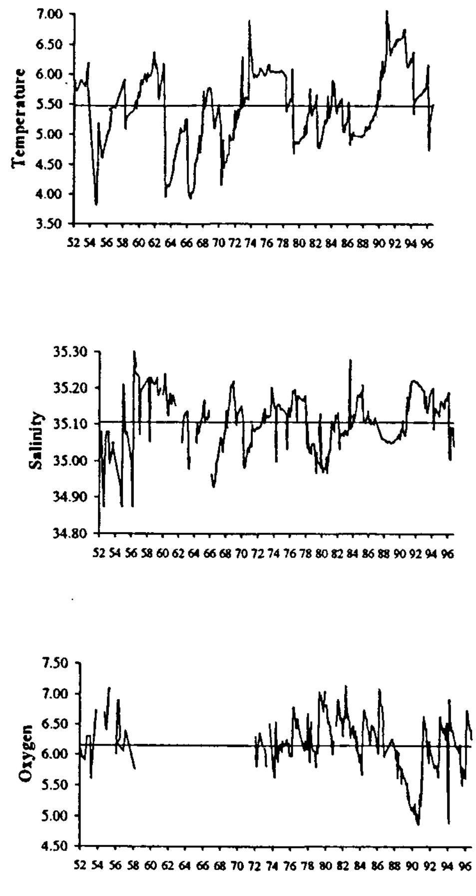



Fig. 7. Variations in temperature, salinity and dissolved oxygen in the bottom water at 600 m depth in Skagerrak, 1952 - 1996. Position indicated by C in Fig. 1.

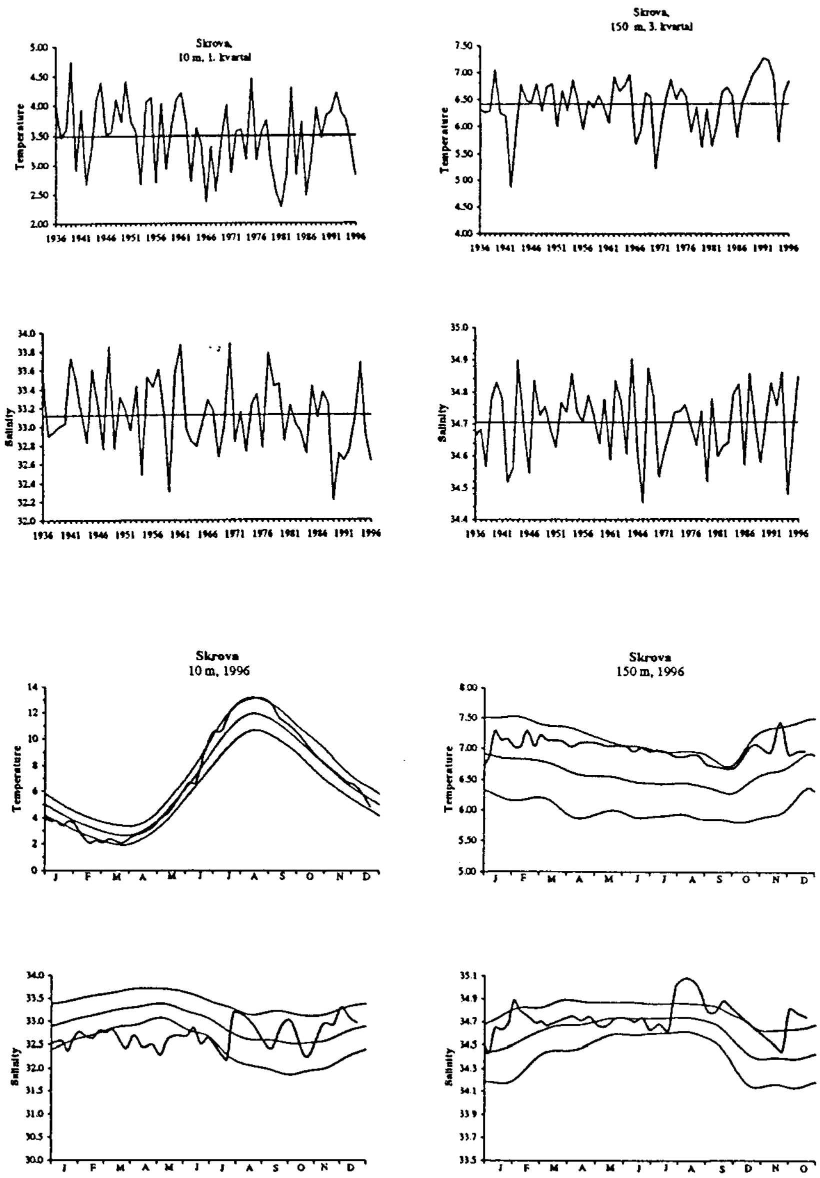



Fig 8. (Uppe panel) Time series of temperature and salinity for the period 1936 - 1996 at the fixed station "Skrova". The figure shows plots of means for the first quarter (Jan.-Mar.) at 10 m depth and of means for the third quarter at 150 m depth.
(Lower pannel) Seasonal trends of temperature and salinity at 10 m and 150 m depth at "Skrova". Seasonal mean values with standard deviation are also shown.

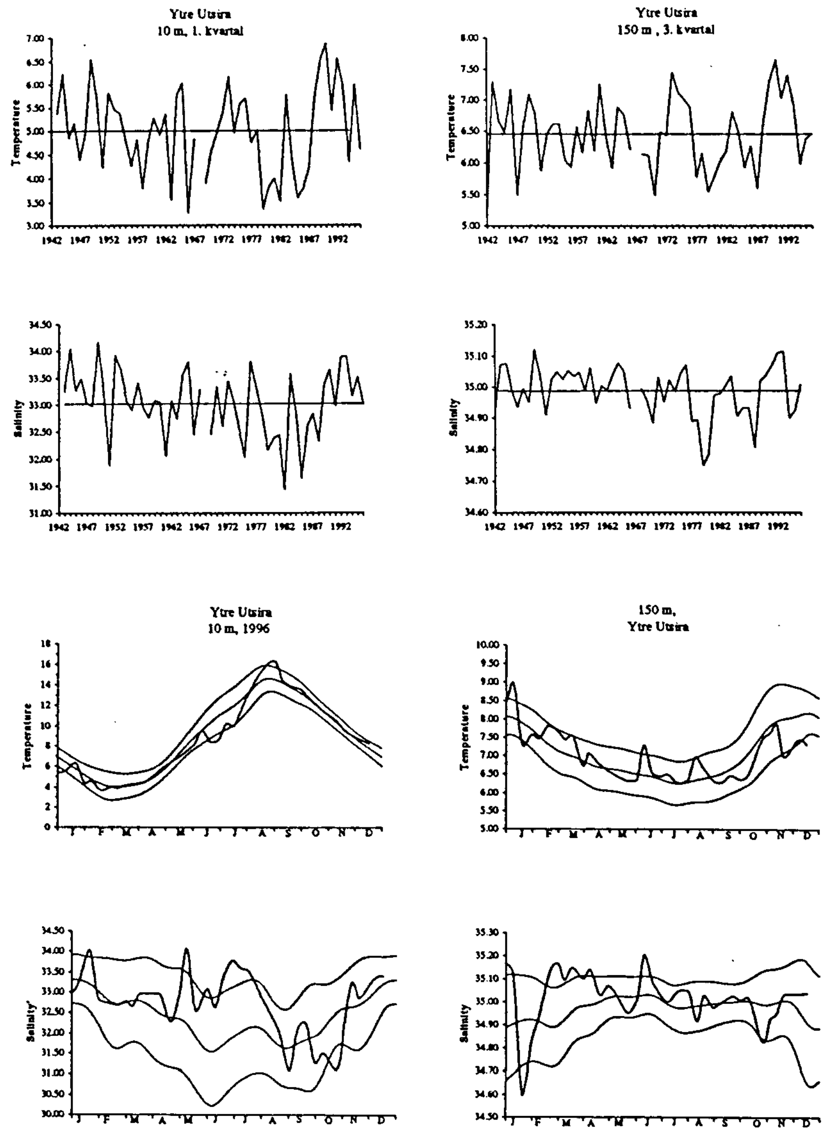



Fig 9. (Upper panel) Time series of temperature and salinity for the period 1942 - 1996 at the fixed station "Utsira". The figure shows plots of means for the first quarter (Jan.-Mar.) at 10 m depth and of means for the third quarter at 150 m depth.
(Lower pannel) Seasonal trends of temperature and salinity at 10 m and 150 m depth at "Skrova". Seasonal mean values with standard deviation are also shown.

# Annex K: Results from Spanish Sections

**Alicia Lavín and J.M. Cabanas, Instituto Español de Oceanografía**
**Laboratorio de Santander**
**Apdo 240, 39080 Santander, Spain**

The Standard Sections sampled by the Instituto Español de Oceanografia are given in Fig. 1. In Bay of Biscay and Atlantic waters there are 4 sections, 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), which are sampled monthly.

The meteorological conditions in the North of the Iberian Peninsula have become mild after a warm period. In annual mean air temperature (according to the Spanish Instituto Nacional de Meteorologia) 1995 was one of the warmest year of the period 1961-1996, and in 1996 mean temperature fell by 0.9°C. Anomalies in annual mean temperature relative to 1961-90 mean, are shown in Fig. 2 for the period 1961-1996. The anomaly temperature patterns of the Centro Meteorologico de Santander consistently follow those of the NAO Index.

Contours of temperature and salinity at stations 2, 4 and 6 for the period (November 1991-December 1996) for the Santander Section are presented in Figs 3, 4 and 5. The seasonal cycle in temperature is clearly marked, mainly over the central part of the shelf (st 4) and shelf-break (st 6) in the upper layers and throughout the water column at the inner station (st 2) due to mixing. Stratification develops between April-May and October-November, and during the remaining period the water column is mixed over the shelf and shelf-break. Salinity contours show high salinity at the beginning of winter, due to the poleward current, and sporadically in spring-summer due to seasonal upwelling events. Low salinity appears in autumn, when the seasonal picnocline is broken, in summer in the upper layers, due to advection of warm surface water, and in spring, due to river overflow.

Nitrate distributions at stations 2, 4, and 6 are presented in Fig. 6. High values appear in the mixed period and, due to upwelling events, in the stratified part of the year.

Increasing trends in temperature and decreases in salinity detected from 1991 to 1995 have stopped (Figs 7a and b). This change in temperature trend in the upper waters (10m) is related to a decrease in air temperatures. The decreasing trend in salinity occurred in the relaxed part of the high salinity anomaly that moved around the North Atlantic at the end of the 80's, and arrived in the Bay of Biscay during 1991-1992, and continued until 1994-1995 before changing.

Temperature, salinity and nitrate distribution at stations 14b, 13a and 11a in the Vigo section are shown in Figs 8, 9, 10, 11 from inside the ria de Vigo to outside. Poleward current salinity increase is clearly detected in autumn 95 and winter 96.

To study distribution of properties along the shelf from the western part of the Iberian Peninsula to the Northern part, we have computed the correlation between salinity conditions in La Coruña and Santander, in the former case at any station on the shelf at 72m depth, and in the latter, at 100m depth. Monthly data were fitted by cubic splines to fortnightly data to compare the two series. Salinity at 70m depth is significantly correlated with time between La Coruña and Santander, with a maximum correlation of 0.63 for a lag of 2 months (Fig. 12). In the opposite direction correlation is lower and diminishes with time. We think this correlation and lag provide indications on the direction and mean speed of the shelf-edge current from the western part of the Iberian Peninsula to the northern part.

These results are coherent with a year of current measurements sampled at 75m depth over the shelf-break in Asturias (43.5° N, 6°W). In the stratified period, when a picnocline develops and winds are mainly easterly, current direction changes frequently from eastward to westward and speed is quite low, but in autumn and winter, when water is homogeneous, the direction is predominantly eastward and monthly mean velocities are around 20 cm/s. This is the sign of the poleward current. These current measurements correspond to the Feb 95-Feb 96 period, and in winter 96 an important flow of the poleward current is marked by the high salinity and temperature in the sections detected throughout the area, but with greater intensity in Vigo.

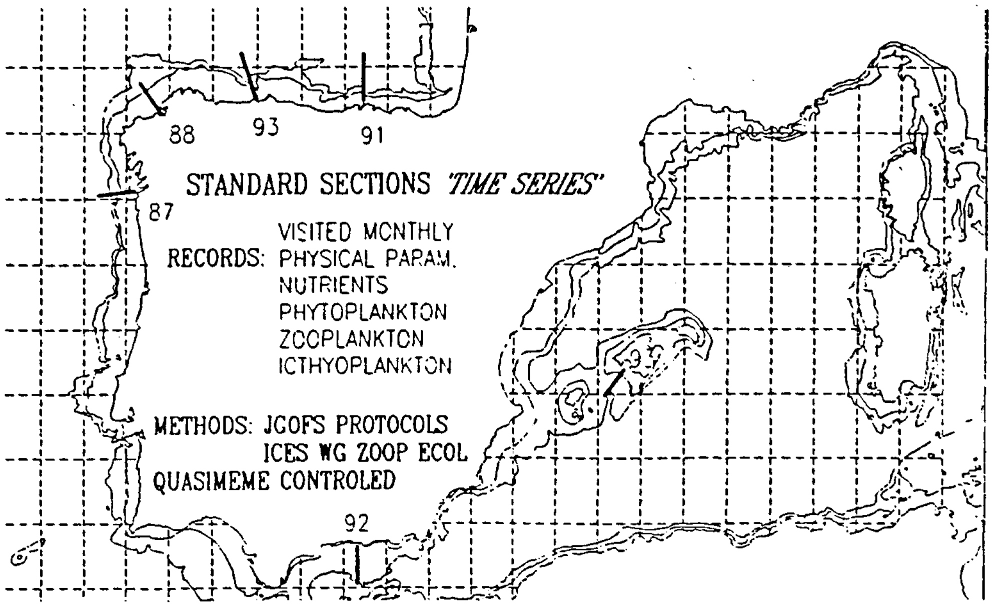



Figure 1. Location of the Sections

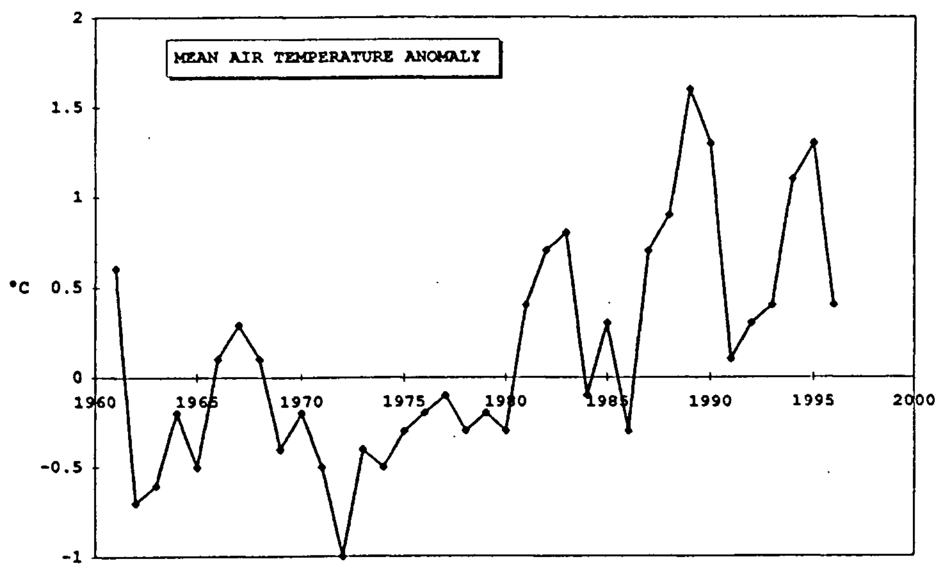



Figure 2. Anomalies in annual mean temperature relative to the 1961-1990 mean. Centro Meteorológico de Santander. Instituto Nacional de Meteorología.

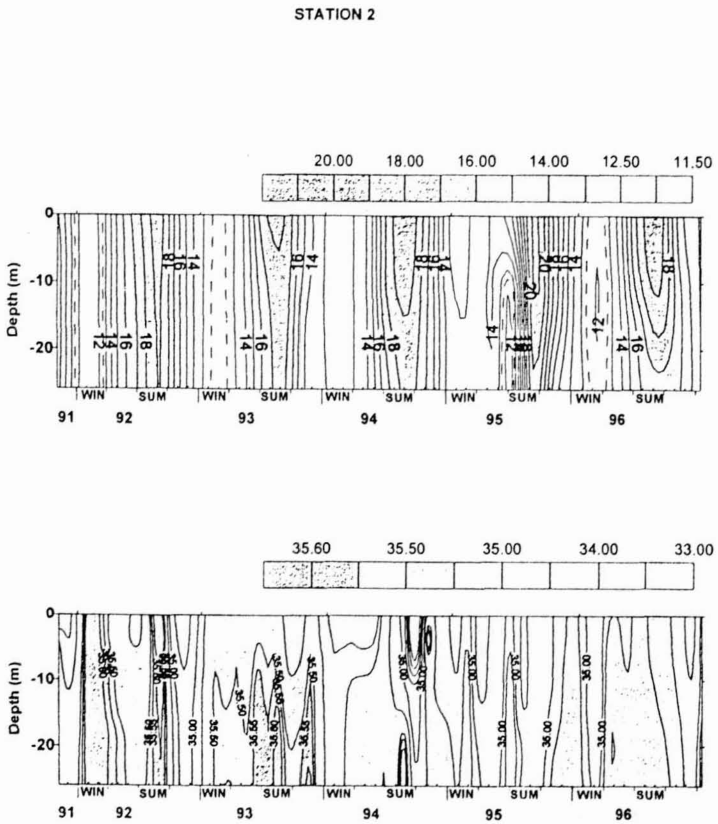



Figure 3. Distribution of Temperature and Salinity at station 2 (Santander Section).

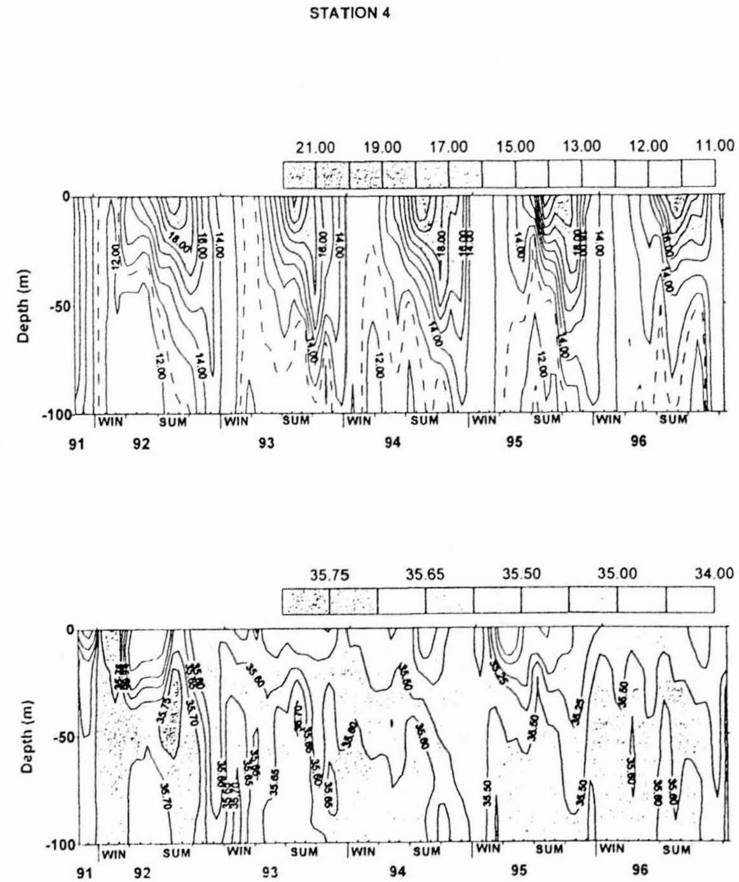



Figure 4. Distribution of Temperature and Salinity at station 4

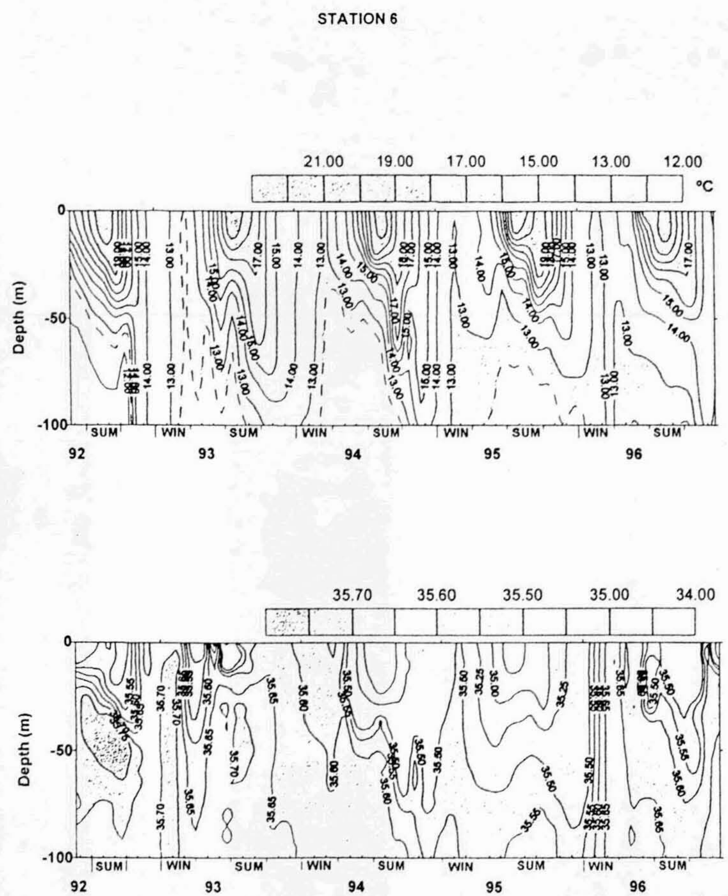



Figure 5. Distribution of Temperature and Salinity at station 6 (Santander Section).

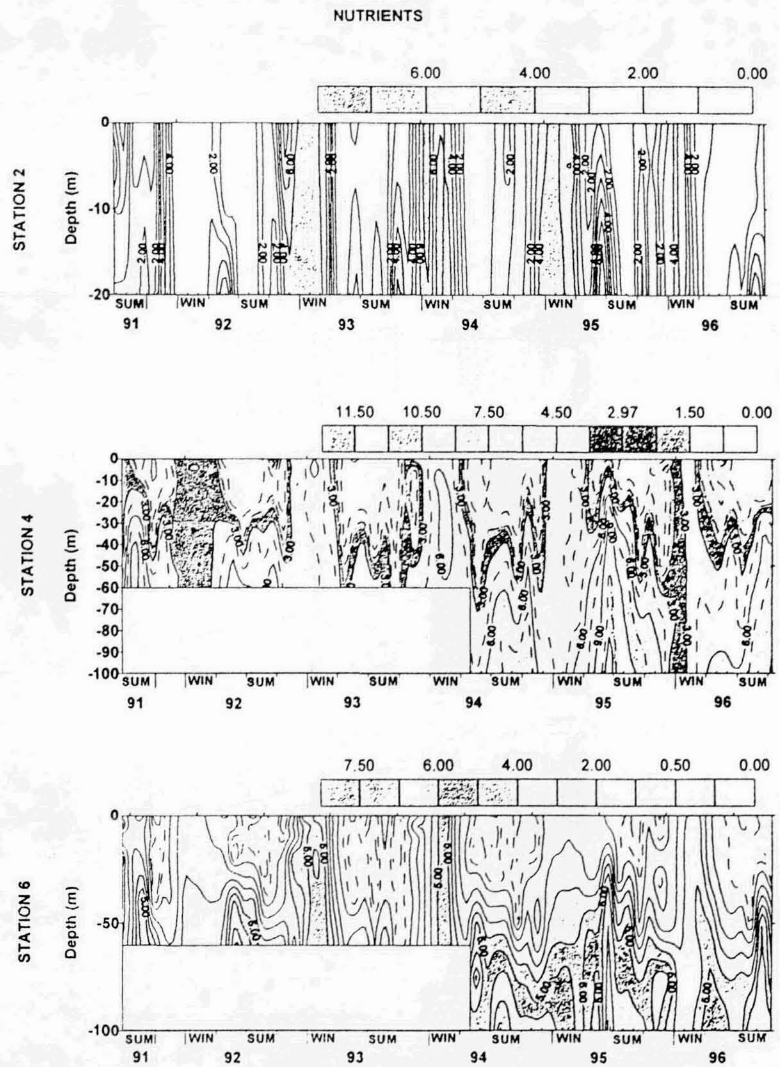
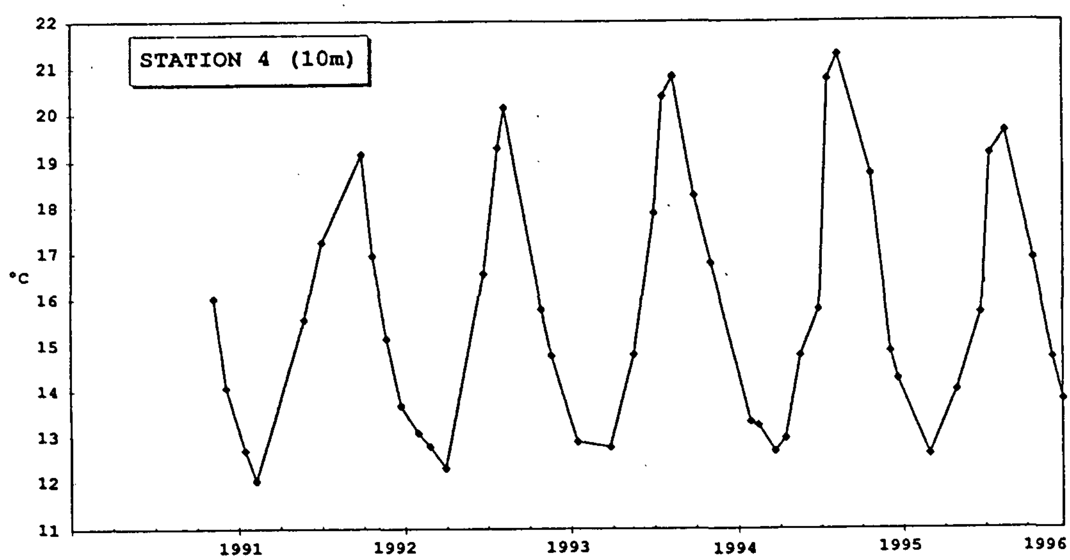



Figure 6: Nitrate distributions at stations 2, 4 and 6 (Santander Section).

A




B

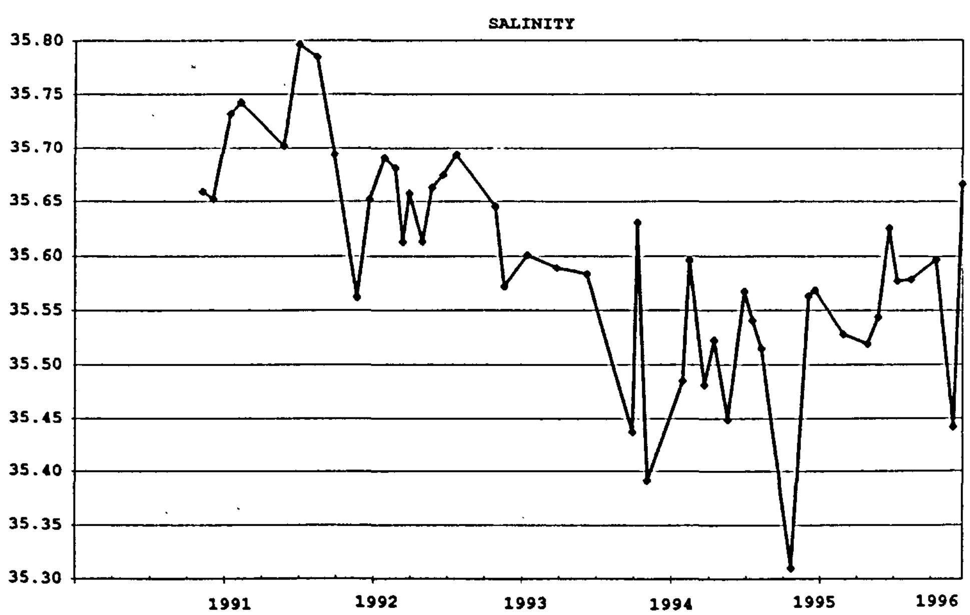



Figure 7. A: Temperature at 10 m depth at station 4. B: Salinity at 50 m depth at station 4 (Santander Section)

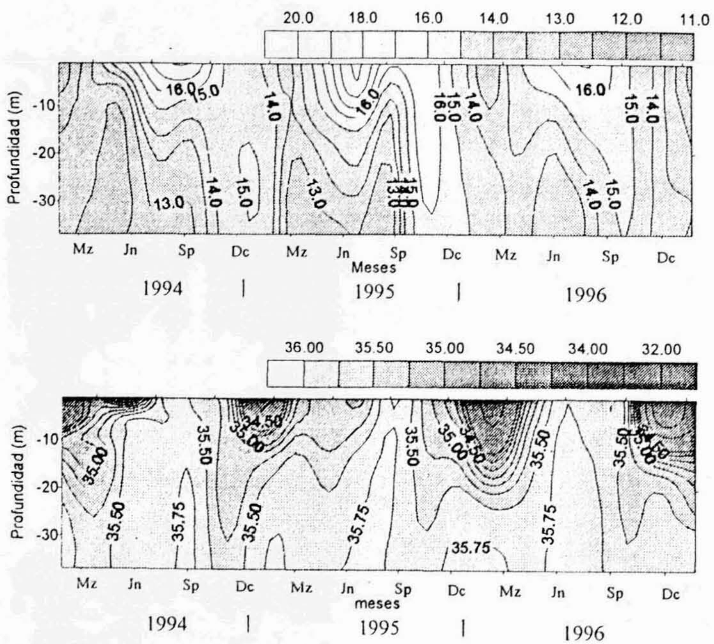



Figure 8. Distribution of Temperature and Salinity at station 14b (Vigo Section).

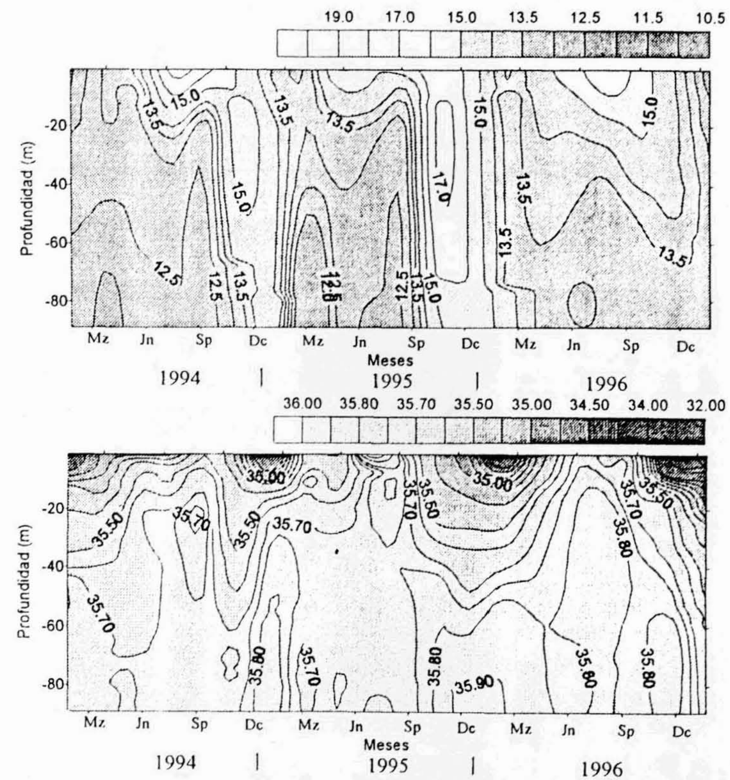



Figure 9. Distribution of Temperature and Salinity at station 13a (Vigo Section).

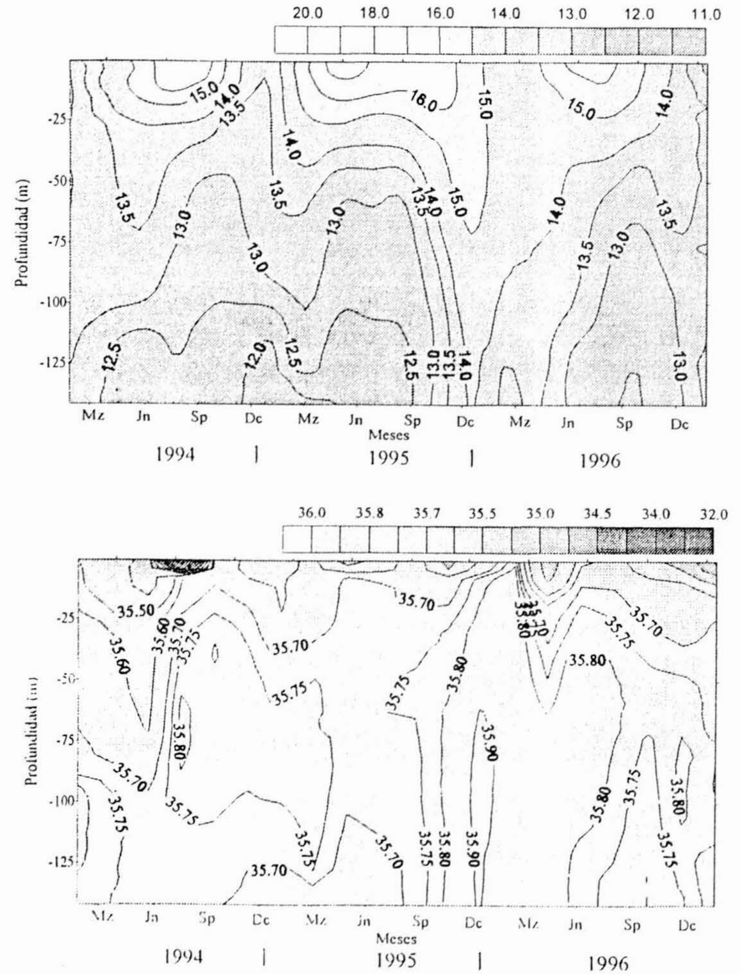



Figure 10. Distribution of Temperature and Salinity at station 11a (Vigo Section).

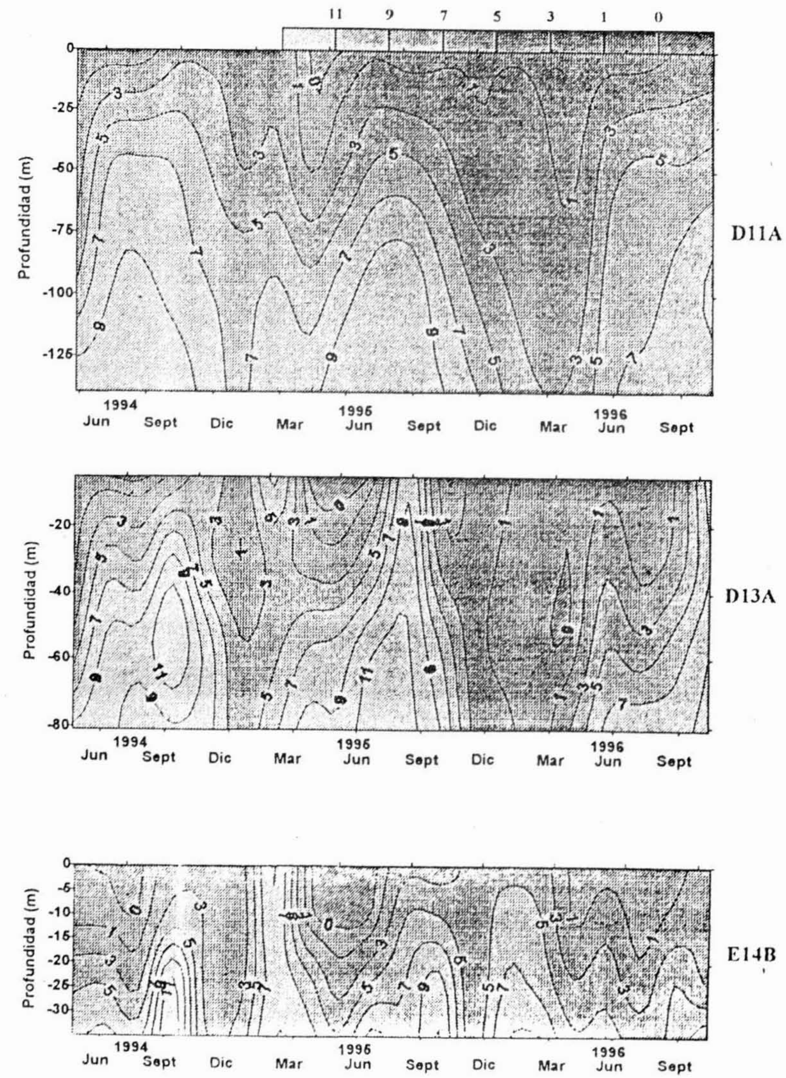



Figure 11. Nitrate distributions at stations 14b, 13a and 11a. (Vigo Section)

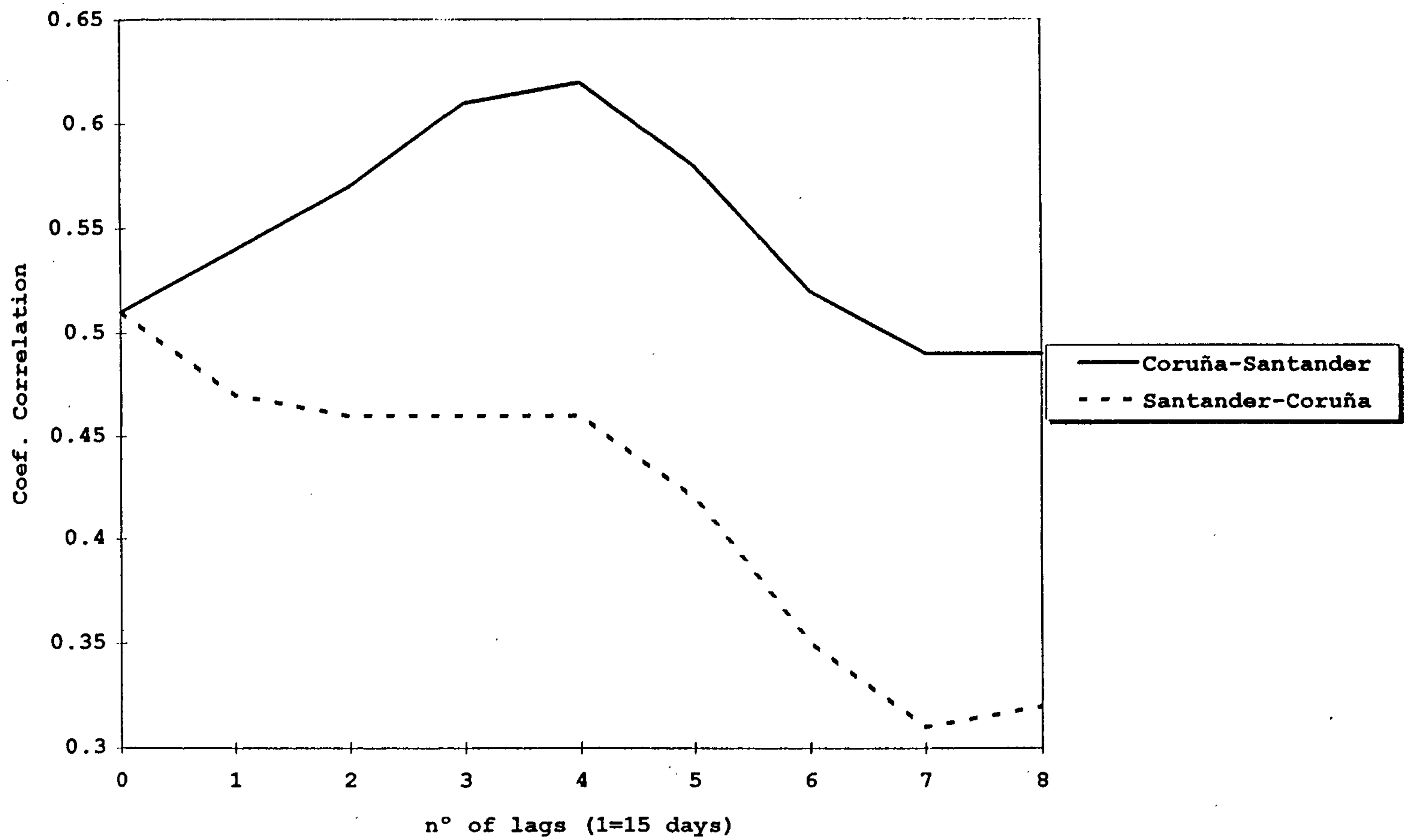



Figure 12. Correlation between salinity conditions at 70 m depth in La Coruña and Santander.

# Annex L: Results from Barents Sea

**J. Piechura, Polish Academy of Sciences**
**Institute of Oceanography, P.O. Box 6**
**Düsternbrooker, ul. Powstancow, Warszawy 55**
**81-712 Sopot, Poland**

## Inflow of the Barents Sea Waters

Every summer since 1987 (except 1990) the Institute of Oceanology has conducted oceanographic research in the area between Norway and Spitsbergen from the board of R.V. "Oceania". 1987 salinity data were found too high and were rejected.

Quite substantial, interannual variations of physical properties and transport were observed. We would like to call more attention to variability of the Barents Sea Water flow into the Greenland Sea, especially in the Sorkapp region. Most probably this is the Barents Polar Water (BPW). In the most cases the BPW transported with the Sorkapp Current which is mainly the surface current penetrates into the layer 200-400m just above the bottom of the small plateau to the south of the South Cape (Figs1, 2, 3). Temperature and salinity of these waters fluctuated from below minus 1°C and 34.86 psu (summer 1995) to nearly 3.5°C and 35.00 psu (summer 1991). High temperature and salinity were recorded also in the summers of 1994 and 1996 and low TS in 1992. Data also show different stages of penetration and different volume of cold, less saline waters from the Barents Sea. In 1989 and 1995 the large volume of "new" BPW is seen while 1991 and 1994 they were well mixed with Atlantic water and only traces can be seen in temperature distribution mainly. In 1992 only small amount of BPW was recorded.

Different type of water flows into the Greenland Sea in the bottom layer of Storfjord and Storfjordrenna (Fig. 4).

There are two large bodies of very dense winter waters on the transect along the axis of the Storfjordrenna. One of them – is located in the north-eastern part of the Storfjdrenna between stations 06 and 09. Its temperature is as low as -2°C, the salinity is close to 35 spu and the density over 28.16. The other body is located at the opposite end of the transect, i.e. between stations L4 and O2; the temperature in its core is –1.8°C and the density is 28.12 – 28.14. Salinity rises to nearly 35 psu but only in a very thin bottom layer. The salinity increase in the western part of the lens is more probably due to the Atlantic waters located in the intermediate layer to the west. Intrusions of low salinity water are observed in the upper part of these cold water lenses: <34.84 psu in western and <34.76 psu in eastern.

Density distribution suggests eddy – type circulation which cause redistribution of dense waters and complicates picture.

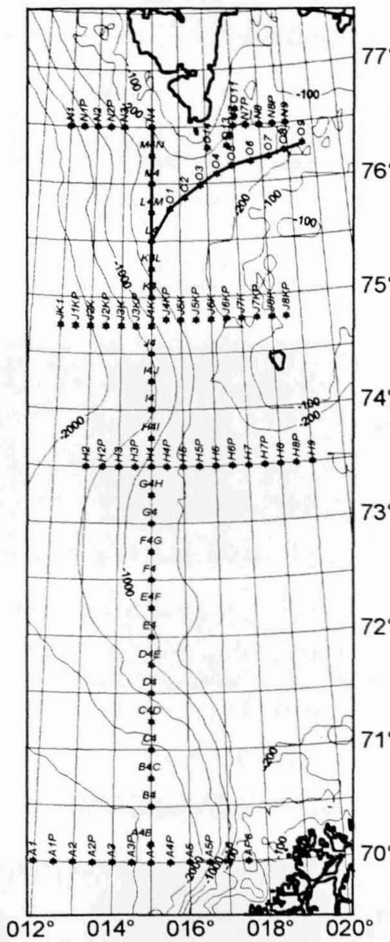



Fig.1 Area of investigations in Norwegian - Barents Seas Confluence Zone. Transect "O" and northern part of Transect "15" - bold lines.

*Fig.2 Potential temperature [°C] and salinity [psu] distributions at the northern part of transect 15°E.*

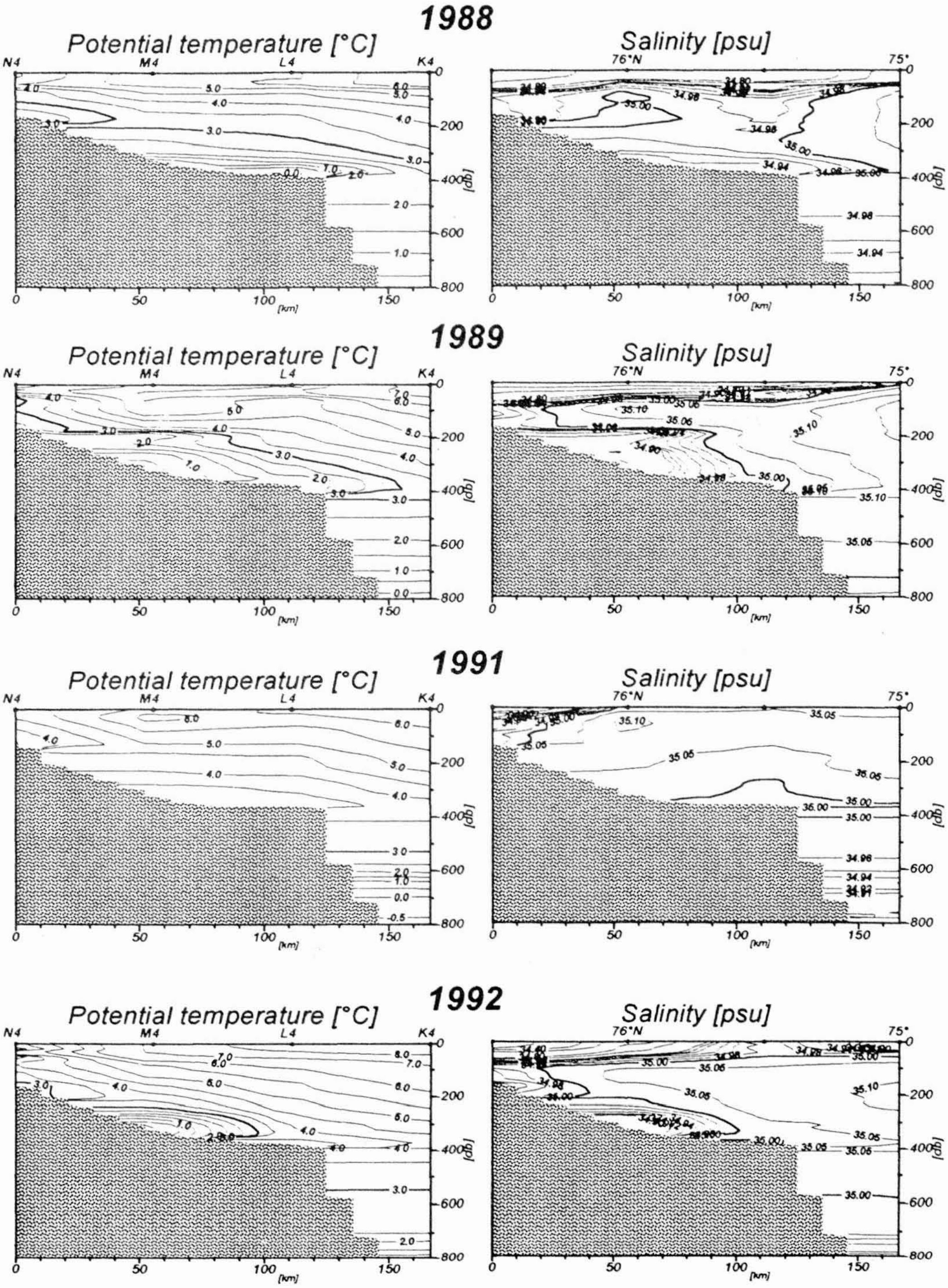


Fig. 2 cont'd *Potential temperature [°C] and salinity [psu] distributions at the northern part of transect 15°E.*

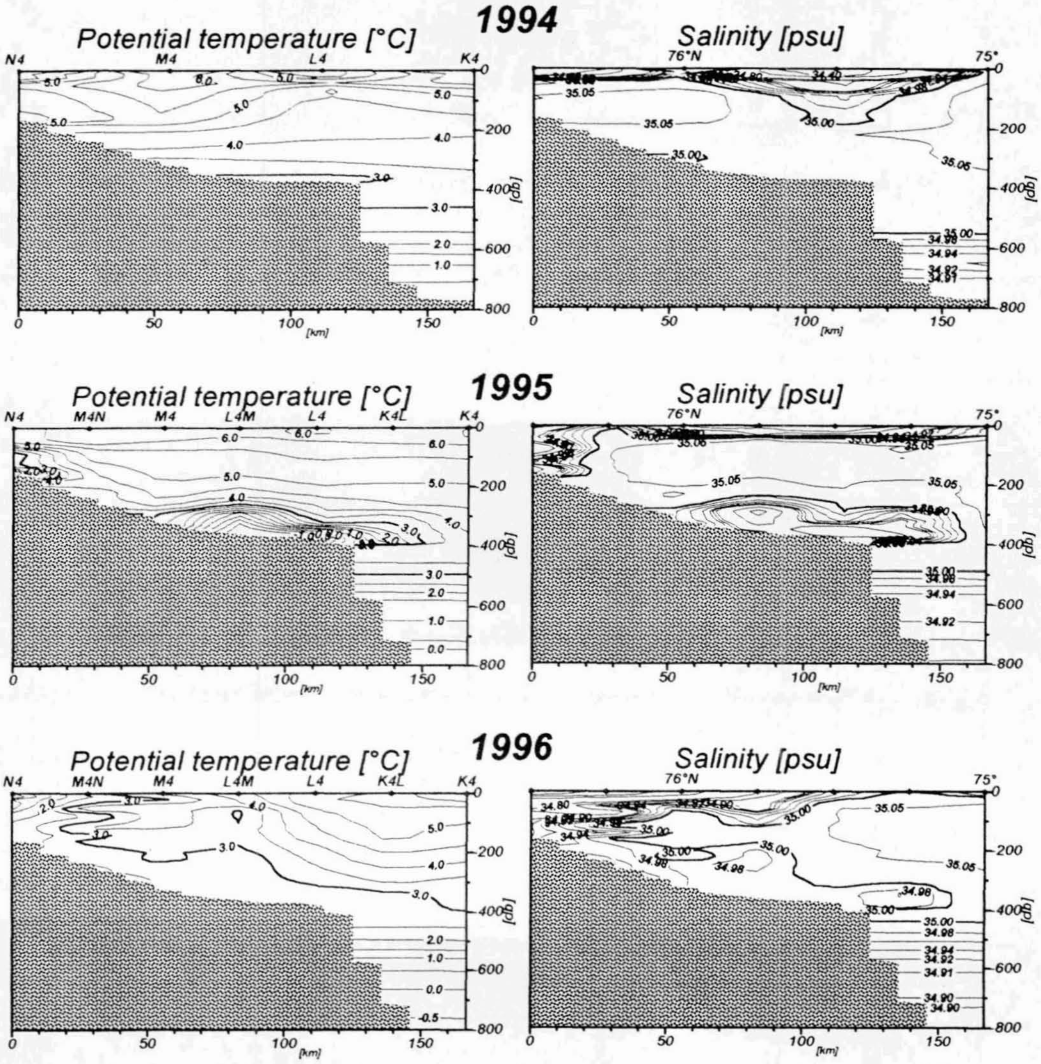
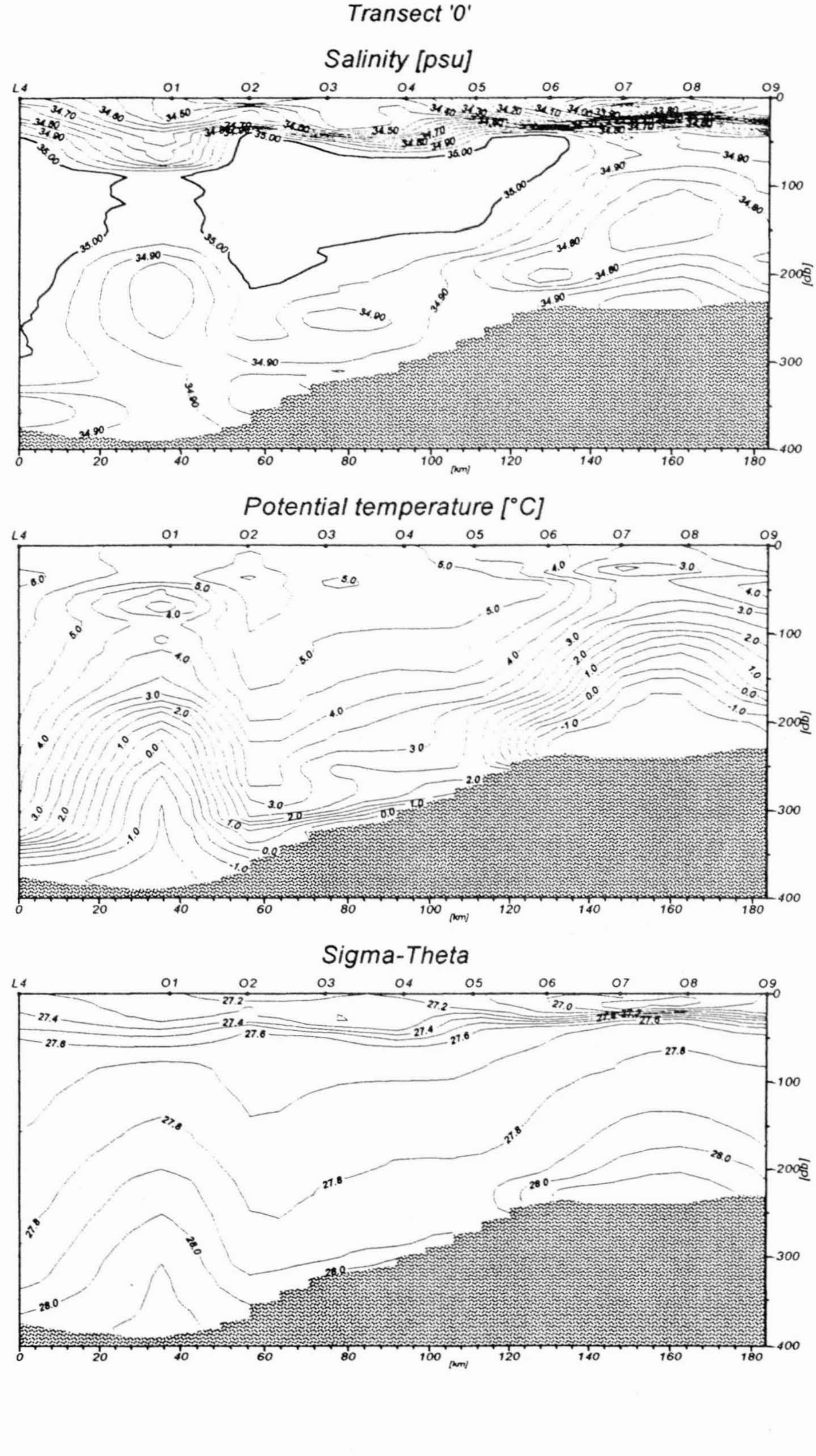


Fig. 3 AREX'95 Confluence Zone



# Annex M: Report on WOCE Section A1E

**Jens Meincke, Institut für Meereskunde der Universität Hamburg**
**Troplowitzstras, se 7, 22529, Hamburg, Germany**

The ongoing work on the WOCE-section A1E (Fig. 1) is reported here. This section has been repeated 5 times since 1991 with approximately 65 CTD-Stations between Kap Farvel and Porcupine Bank (SW-Ireland). The most prominent change has been observed with the eastward spreading of Labrador Sea Water. By means of Fig. 2 it is demonstrated, that the LSW formed during 1988/98 convection event has reached the European continental slope in 1995, i.e. 3 times faster than expected from earlier published work. The present analysis focusses on the changes of Atlantic waters and the overflows. The section will be continued, however at a reduced repetition rate after 1997.

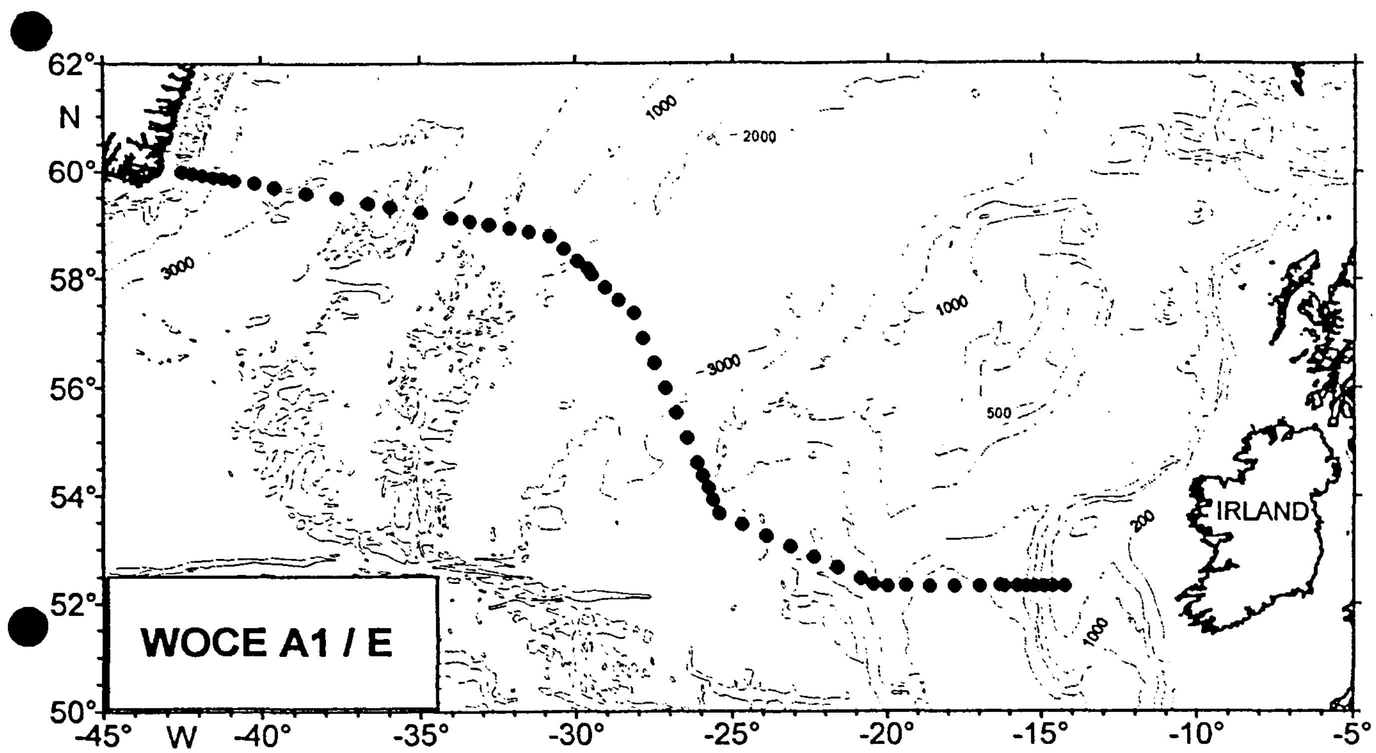



Figure 1

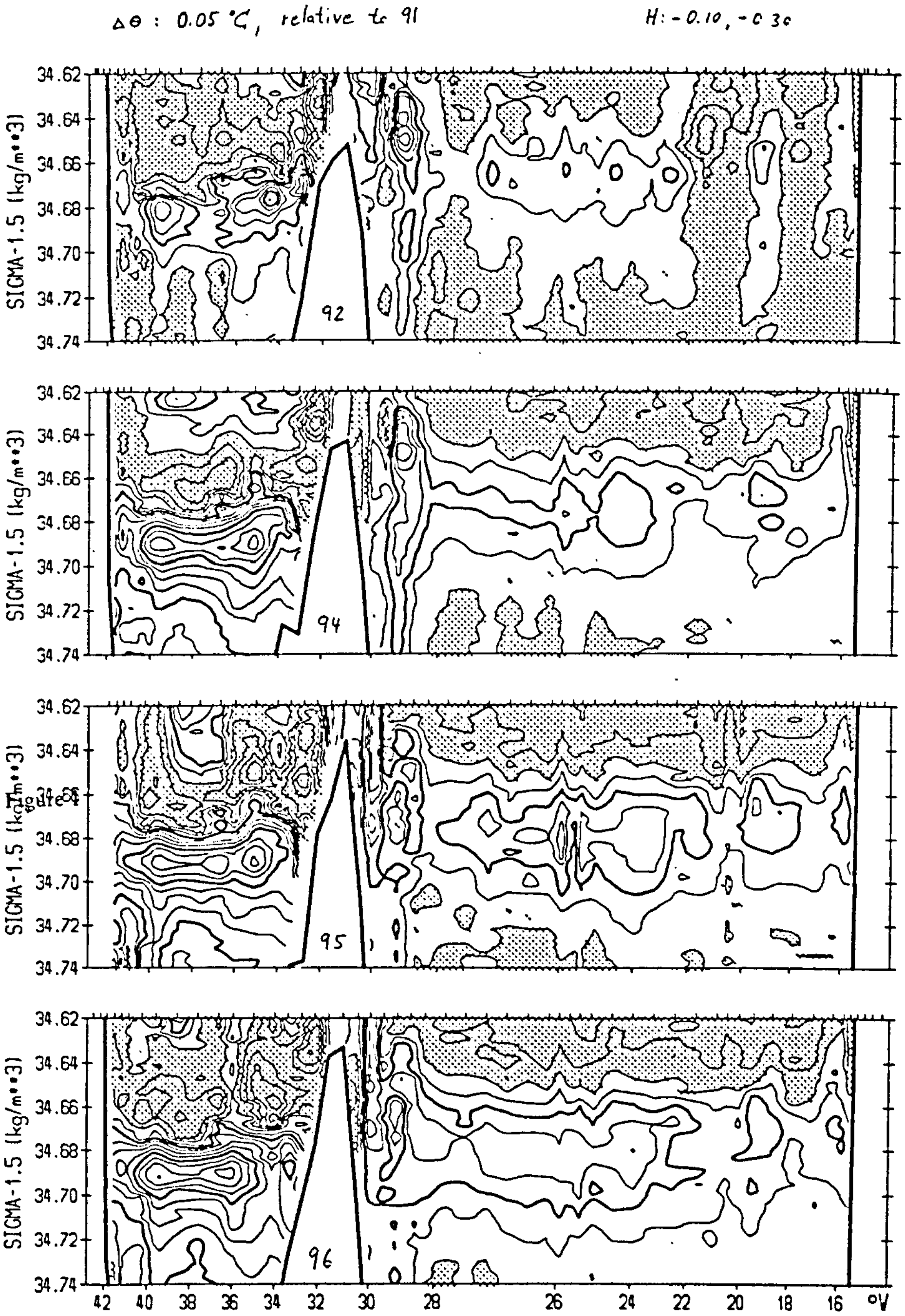



Fig. 2 a) Difference of Potential Temperatures against Sigma 1.5 along the WOCE A1E -Sections in 1992, 1994, 1995 and 1996 against 1991. Hatched: Warmer against 1991

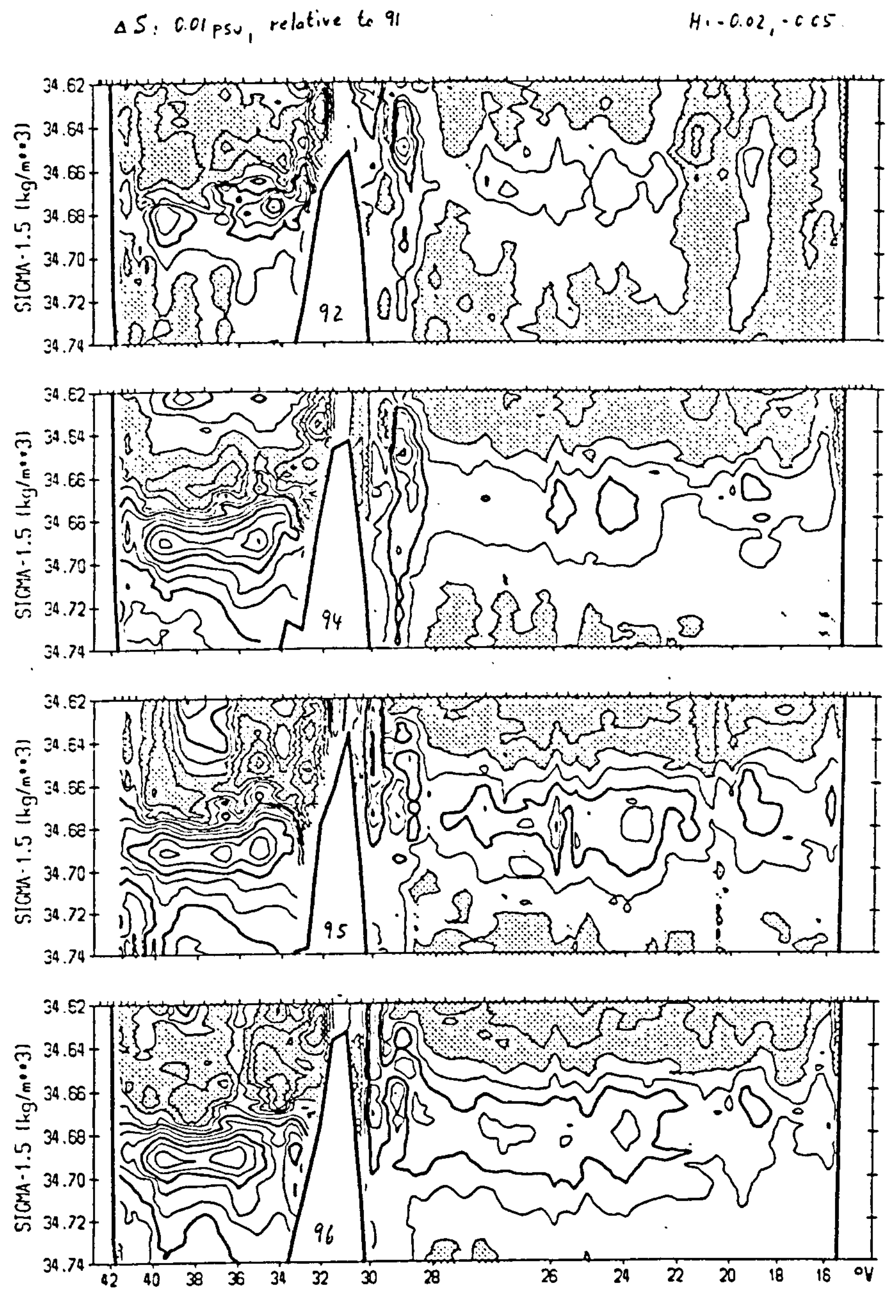



Fig 2 b) As in a), but for Salinity. Hatched: saltier against 1991. The density range covers the Labrador Sea Water (LSW). Agenda item 6: Progress in national and international projects

# Annex N: Further Changes in Norwegian Sea Deep Water

**Mr. A.J. van Bennekom**
**Netherlands Institute for Sea Research**
**P.O. Box 59, 1790 AB Den Burg, Texel**
**The Netherlands**

Presented at the 1997 OHWG meeting as a follow-up to the 1996 OHWG discussion

Table 1 shows that applying the corrections to the salinity of Standard Sea Water batches (Mantyla JPO 17:547, 1987 and DSR 41: 1387, 1994) improves the consistency of the salinity time series in adiabatic NSDW. It strengthens the conclusion of Svein Osterhus (OHWG 1996 meeting) that during the last 15 years the salinity of adiabatic NSDW did certainly not increase. The decrease of 0.001 PSU is not significant in view of measurement accuracy.

Salinities of NSDW before 1981 were higher than at present. It is difficult to find pertinent statistics in literature; 34.92 is often given for deep water from the Norwegian Sea, based on "Arnauer Hansen" cruises in 1935 and 1936, tabulated by Mosby.

Preliminary data from a 1996 Johan Hjort cruise (Francisco Rey) show that the changes in NSDW properties further proceeded slightly since 1994: Decrease in potential temperature and thickness of the adiabatic layer and increase in silicic acid concentration.

The scenario for the changes in NSDW and GSDW seems to be: Nearly total overturn of GSDW was last found in 1971 and since than the depth of overturn in the Greenland Sea progressively decreased. Behaviour of NSDW is lagging behind. Production of new GSDW enhances the flow of bottom water through the Norwegian Sea, detectable from the disappearance of gradients in silicic acid concentration in bottom waters. Throughflow of NSDW gradually diminished until about 1990, when it virtually stopped. Stagnancy of NSDW is shown by a re-appearance of a near-bottom $H_4SiO_4$ gradient (Fig. 1).

Silicic acid measured on board by F. Rey and measured 14 days later at NIOZ (van Bennekom and Bakker) in samples filtered on board and sent by post, were the same (average difference 0.002 μM for 23 samples).

Table 1. **Properties of Adiabatic Norwegian Sea Deep Water (> 2500 m depth), around 65 N; 5 W (SW Norwegian Sea)**

Compilation by A.J. van Bennekom from data reports.
Salinity corrected for SSW batches (Mantyla, JPO. 17: 547, 1987 & DSR 41: 1387, 1994)

| | Sal. | Corrected | $\Theta$ | Ox, µmol/kg | Si, µmol/kg |
|---|---|---|---|---|---|
| Armauer Hansen [1]<br>1935, 4 Stt. | 34.92<br>±0.005 | | -1.14<br>± 0.006 | 302 ±2 [2] | |
| 1972 Geosecs [3]<br>St 19 | 34.912 | **34.912**<br>±0.002 ? | -1.043 | 302 | 14.1 |
| 1981,TTO/NAS<br>St 143 | 34.907 | **34.910**<br>(34.910 - 34.911) | -1.052 | 305 | 13.1 |
| 82-001, Hudson<br>St 116 | 34.909[3] | **34.910[3]**<br>(34.910 - 34.911) | -1.055 | 297-8 | 13.0 |
| !982, Meteor [4]<br>St 284 | 34.909 | ? | -1.048 | 299 [2,4] | 13.05 |
| 1987, Tydeman<br>St 3 | 34.910 | **34.910**<br>(P103 [5]; -0.0002/3) | -1.052 | 300.2 | 12.7 |
| 1994, Pelagia<br>St 4 | 34.909[5] | **34.909[5]**<br>(34.909 -34.910)<br>(P119 [5]) | -1.033 | 300.9 | 13.0 |
| 1996, Johan Hjort<br>St 1266 | 34.909 to<br>34.910 | | -1.028 to<br>-1.032 | | 13.14<br>± 0.02 |

**(Preliminary data; Pers. Comm. Francisco Rey, IMR, Bergen, Norway)**

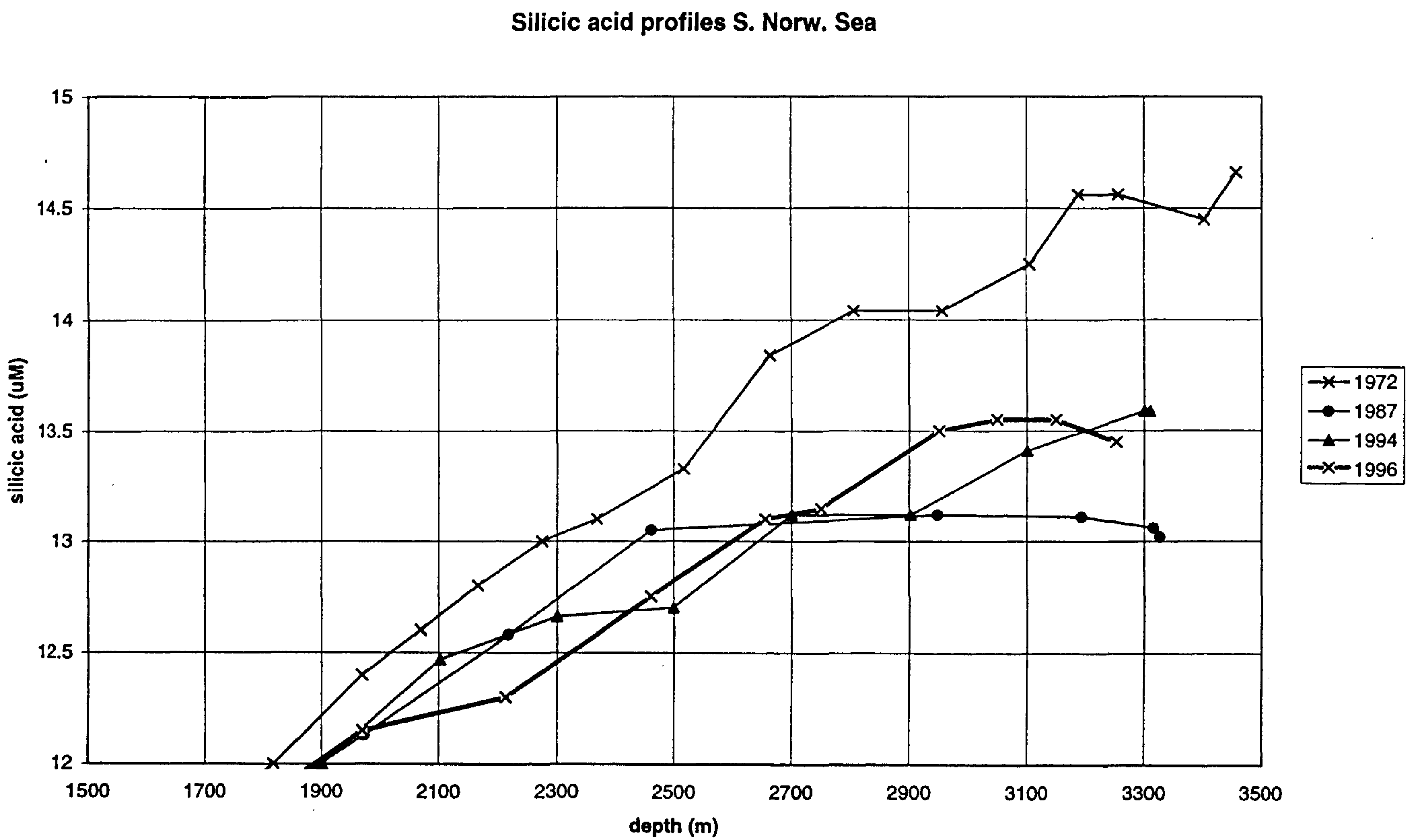
[1] Håkon Mosby (1966) Oceanographical Tables, Armauer Hansen in the Norwegian Sea, 1935, Geophysical Institute Bergen University, Norway, 118 pp.

[2] From ml/L with the conversion factor 44.66, and ρ 1.026 at pickling temperature.

[3] A. Bainbridge (1981) Geosecs Atlantic Expedition, vol 1, Hydrographic Data, IDOE-NSF, Washington, 121 pp. Salinity slightly less accurate than others, pers. comm. A. Mantyla

[4] G.A. Becker (ed.)(1986) Data Report FS "METEOR" Reise nr 61, 150 pp. Not the same position; about 200 km east of the other stations. St 285 more north (central Norwegian Basin) gives S = 34.914 at the same $\Theta$ , Ox = 298 and Si = 13.15.

5) Batch of Standard Sea Water used for salinity calibration; correction not known for P119, probably very small


Silicic acid profiles S. Norw. Sea
silicic acid (uM)
15
14.5
14
13.5
13
12.5
12
1500
1700
1900
2100
2300
2500
2700
2900
3100
3300
3500
depth (m)
1972
1987
1994
1996

# Annex O: An Overview of VEINS

**Jens Meincke, Institut für Meereskunde der Universität Hamburg**
**Troplowitzstras, se 7, 22529, Hamburg, Germany**

The scope and the aims of the EU-MAST III Project VEINS (Variability of Exchanges in the Northern Seas) is presented here.

The overall objective of the project is to measure and model the variability of fluxes between the Arctic Ocean and the Atlantic Ocean with a view on implementing a longer term system of critical measurements needed to understand the high-latitude oceans steering role in decadal climate variability.

Exchanges between the North Atlantic and the Arctic Ocean result in the most dramatic water mass conversions in the World Ocean: Warm and saline Atlantic waters flowing through the Nordic Seas into the Arctic Ocean are separated by cooling and freezing into shallow fresh waters (and ice) and saline deep waters. The outflow from the Northern Seas to the south provides the initial driving of the global thermohaline circulation cell, the one to the north is of major impact to the large scale circulation of the Arctic Ocean. Measuring these fluxes is a major requirement to quantify the turnover-rates within the large circulation cells of the Arctic and the Atlantic Oceans and a basic condition to understand the role of these ocean areas in climate variability on interannual to decadal scales.

For this purpose a consortium of 18 institutions with long standing experience in high latitude observations and modelling with obtain 3 year synoptic time series of water and property transports in the key passages from the Arctic Ocean through the Nordic Seas into the Atlantic Ocean. These measurements will provide integral information on the water mass formation processes in the Northern Seas and on the forces driving the circulation between the different basins. This makes them especially suitable for the validation of large scale circulation models.

Its results will be used to develop an efficient observational design to measure time series resolving up to decadal time scales, which are considered to be the most crucial measurements for advancing our predictive capabilities for shorter term climate changes.

Figure 1 shows the areas, which VEINS will cover.

The Working Group notes the importance of the VEINS Project for the general aims of ICES-activities in the Northern Seas. It is evident, that this study of a predictive capability for longer term physical changes in Atlantic Water inflow and deep water outflow is of direct relevance to estimates of productivity-changes for the most prominent fishing grounds in the Northern North Atlantic. It is therefor recommended, to closely monitor the progress of VEINS by holding a theme-session on VEINS-results, preferably during the 1999 Statutory Meeting.

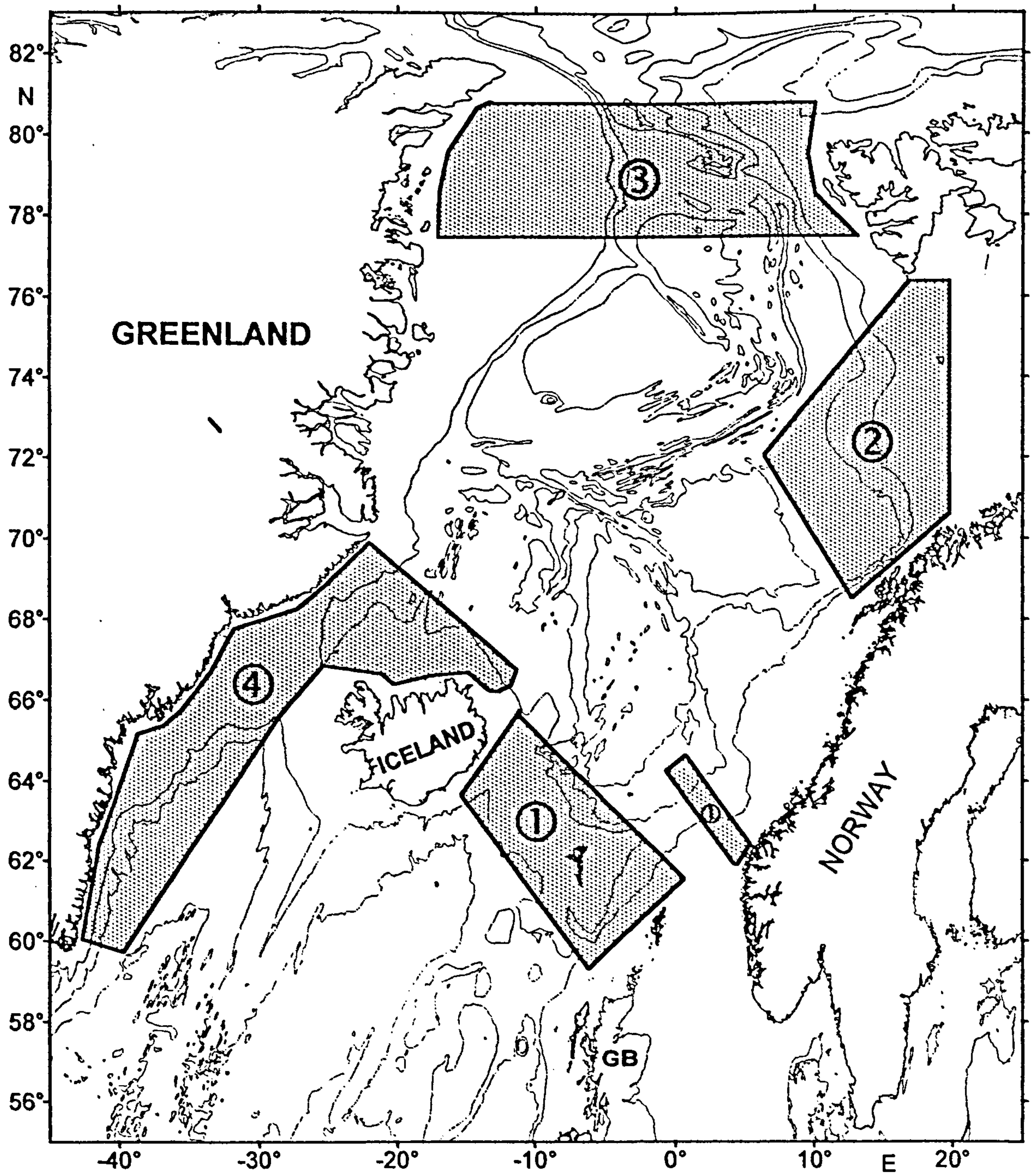



Figure 1. Areas which VEINS will cover