Hydrography Committee **ICES CM 1998/C:8**

REPORT OF THE

WORKING GROUP ON OCEANIC HYDROGRAPHY

Santander, Spain
April 27 – 29, 1998

International Council for the Exploration of the Sea

Conseil International pour l'Exploration de la Mer

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Report on the meeting of The ICES Working Group on Oceanic Hydrography
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1. Opening

The Director, Dr. Orestes Cendrero, of the Instituto Español de Oceanografía de Santander, welcomed the Oceanic Hydrography WG to Santander and to the Institute. Information on the local arrangements was provided and a tentative schedule was established. The agenda for the meeting (Annex A, which also presents the Terms of Reference) was discussed and modified to include additional presentations that are of interest to the WG. It was noted that a few of the members who regularly attend the WG meeting, were unable to do so this year because of other commitments (list of attendees is given in Annex B). The agenda was revised accordingly, as well as to accommodate members who had to depart prior to the completion of the meeting.

2. Review of Membership

The attendees reviewed the latest list of the WG members provided by the ICES Secretariat, and corrections and additions were made (Annex C). Bennekom reported that, Dr. R. Laane has been appointed as a Dutch member in the Oceanography Committee, succeeding Dr. Van Aken, but Dutch membership of the OHWG will remain the same. It was noted that two long-standing members, Dr. John Gould and Dr. Erik Buch had to leave the Working Group because of other commitments. The WG was informed that Dr. Sheldon Bacon from Southampton Oceanography Centre would be replacing Dr. Gould. No one has yet been nominated by Denmark to replace Dr. Buch; however, it is hoped that a nomination will be forthcoming. The WG expressed regrets for the departure of Drs. Gould and Buch and wished them well on their new endeavours.

3. Remarks from the ICES Oceanographer

Harry Dooley from the ICES Secretariat discussed the activities undertaken by the ICES Oceanographic Data Centre in 1997 (Annex D). It is worth noting that the Data Centre has been able to add over 50000 profiles to the archive in 1997, and several other submissions are currently being processed. However, there is still a concern that, though the submissions continue to flow to the ICES Data Centre, there are still many data sets not submitted to any of the national or international data centres.

ICES Data Centre continues to provide the data management services to programs such as MAST, ESOP, VEINS, and others. A special archive of MAST ROSCOPS continues to be maintained, and is listed on the ICES web site. All the OMEX profile and surface data sets have been merged into the ICES data bank. This task has served as a test for expanding the ICES format to encompass any number of data types, and also to assess how ROSCOP may be adapted to reflect the expansion in parameters. The nucleus of both of these developments has been the BODC/JGOFS data dictionary.

The number of requests for data, submitted annually to the Data Centre is quite significant, and is increasing resulting from the Web presence. ICES web page now provides guidance on how to submit requests to the Data Centre.

The WG members expressed their concern on the imbalance between the increasing workload of the ICES Data Centre and the decreasing resources, and reaffirmed the necessity of continued and sustained support by the Data Centre.

4. Update and Review Results from Standard Sections and Stations

Spain

Lavín presented results from the Spanish standard sections (Annex E). The meteorological conditions in the north of Iberian Peninsula follow a warming trend. The annual mean air temperatures also indicate decadel variability: for the 1990s, 1997 was the second warmest year after 1995. The air temperatures are strongly correlated with the NAO index.

The water temperatures and salinities exhibit strong seasonal and interannual variability. In the surface waters, the salinities reached a minimum in 1995, and increased to 35.7 in 1997, the highest value since 1992. The temperature on the other hand increased between 1992 and 1996, but decreased in 1997. At water depths of 100m, salinities in 1997 were near the high values of 1991/92. In 1995 nitrates also increased due to upwelling. In 1997 upwelling commenced earlier than normal, in April. In the deep layer (in 600 m) conditions were similar to that of 100 m.

At the standard station off Vigo salinity has increased, and temperatures are the highest since 1993. Spring temperatures (March-May) were the highest in 1997 since 1988. Salinity experienced maximum values in 1993, followed by a minimum in 1994. During 1997 salinity is again approaching those of 1993.

Norway

Blindheim presented results from Norwegian standard sections and stations (Annex F). Sections in the Norwegian Sea monitor the core of Atlantic water in the area. Both temperature and salinity increased from 1996 to 1997, with the largest rise in the southern Norwegian Sea, in comparison to a period of near-average temperatures and below average salinities. Recently an extensive study has taken place in the Nordic Seas using Russian, Norwegian, Scottish, Icelandic and Faroese data, as well as data from OWS 'Mike'. All time series show that, though the salinity increase after the Great salinity Anomaly can be considered to be completed by 1981, there has generally been a decrease in salinity since then. An increasing influence of the East Icelandic Current is probably the cause. Local and regional scale atmospheric pressure gradients were studied. The East / West extent of Atlantic water in the Norwegian Sea appears well correlated with the local pressure gradient and with NAO, with a possible two year lag. Strengthened south-westerly/westerly winds increase transport towards the right and onto the shelf.

Changes at intermediate depths were also discussed. Prior to the 1980's the Norwegian Sea Arctic Intermediate Water (NSAIW) was not evident as a salinity minimum, while such a minimum has been observed just above the deep water since the 1980's. This was evident in 1996. It is most likely "failed" deep water (i.e. winter convection only penetrates to intermediate depths). The thickness of the intermediate waters in the Norwegian Sea has increased.

Dickson (UK) noted that precipitation and moisture flux has increased over the Nordic Seas in the 1990's compared to the 1960's. This may also account for decreasing salinities. The 'hinge line' for such change occurs west of the UK, hence there has been a tendency to lower precipitation over Iberia.

Later in the session Blindheim went on to present results from OWS 'Mike' in the Norwegian Sea (provided by Østerhus). Freshening has been observed at all depths down to 500m. Temperature demonstrates some warming at the surface.

The warming event noted previously in the bottom water was shown. This event appears to have commenced lower in the water column (2000m) and propagated upwards. It is connected with the reversal of the supply of deep water to the Norwegian Sea Basin. It was reported that the monitoring of the input of deep water through the Jan Mayen Trench (JMT) is presently being repeated. Old Greenland Sea Water is now lying below the depth of the sill in the JMT, and hence more Eurasian Basin Water is entering the Norwegian Sea.

Loeng (Norway) presented results from Russian Kola section. Temperatures were lower in 1997 compared to the peak in the 1990's.

Denmark

Buch (Denmark) sent a substantial contribution by post presenting results from standard sections and stations west of Greenland (Annex G). The report concluded that a low salinity signal was observed in the Polar Water component off Southwest Greenland in 1996. 1996 and 1997 was also characterised by a high inflow of Atlantic water, indicated by high surface temperatures. Atmospheric conditions are very closely linked to changes in the NAO

UK

Turrell (UK) presented results from the Scottish standard sections (Annex H). Temperatures and salinities are increasing in North Atlantic Water (NAW) at the shelf edge north of the UK. Salinities are the highest since 1960, and are approaching the generally high values of the 1950s. Salinity exhibited minima in 1977, 1987 and 1994 and maxima in 1984 and 1990. This almost cyclically variability is seen in many other time series from the area and is related to the NAO. In the MNAW trends are somewhat different, with decreasing temperatures and salinities. This corresponds to trends in the Nordic Seas as noted above.

Within intermediate waters between Faroe and Shetland, conditions following the freshening event observed in the spring of 1997 are beginning to recover. The freshening in the bottom water is also continuing, and the warming seen at OWS 'Mike' at 1100 dbar is also seen in the Faroe Shetland Channel in 1992. Since then temperature have been stable.

In the North Sea the warming seen in the NAW at the shelf edge is also seen in the mixed oceanic inflow, as is the increase in salinity, and similar trends are seen in the Cooled Atlantic Water (CAW) in the centre of the North Sea basin.

Turrell went on to report on progress from the Southampton Oceanography Centre (SOC) with re-occupying the Dave Ellett standard section (Rockall Trough). The section has been extended to Iceland, and hence now covers major inflows to the Nordic Seas. The section was surveyed in October 1996, September 1997 and May 1998. Time series of salinity were presented for Eastern North Atlantic Water (ENAW), Labrador Sea Water (LSW) and bottom waters. In the discussion that followed, the continuation of this line was very much welcomed by the group. The low salinity pulse in LSW was discussed.

Iceland

Malmberg (Iceland) presented results from Icelandic waters (Annex I). 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. In 1997 the conditions improved further in the warm water from the south, the salinities rising to the same level as decades before (> 35.20). Despite this a low saline surface layer was observed in North Icelandic waters in spring 1997 as in 1996, and in the East-Icelandic Current salinities too were relatively low (< 34.7). Furthermore, nutrient content, primary production and zooplankton concentrations were in spring as expected dependent on each other, but on different stages in the different areas. From a biological point of view the overall conditions were in general favourable. The Atlanto-Scandinavian herring was observed at the eastern and southern boundaries of the cold East Icelandic Current, even farther westwards than in previous years. Noteworthy was in this case a strong warming up in the surface layer of the East Icelandic Current in late summer 1997. At last it should be noted that in winter 1997-1998 hydrographic conditions in Icelandic waters revealed a strong input of relatively high saline water (> 35.20) of the Irminger Current and relatively high salinities (> 34.7) in the East Icelandic Current as well a northerly location of the cold water (< 0°C).

In the discussion that followed it was noted that some of the results from the Iceland sections may be found on the EU project VEINS home page, http://www.hafro.is.sjora/reports/veinshom.htm. It was noted that if changes in the creation area of intermediate water north of Iceland occurs to a large extent, it may become less dense than the inflowing Atlantic water, which would have profound affects on convection in the Nordic seas.

Poland

Piechura presented results from Polish observations in the northern Norwegian Sea and the Barents Sea (Annex J). A major investigation at the border between these two seas has revealed that the volume transports across the 15• parallel had a minimum in 1993 and a maximum in 1997. Sections in the West Spitsbergen current showed a vertically orientated front separating offshore Atlantic water from shelf water. This front was modified near the mouth of a fjord, where it assumed a more horizontal orientation. An undulating CTD profile has revealed evidence of mixing on a fine scale. The steepness of the front may be associated with meandering in the West Spitsbergen current and bottom topography. Meincke (Germany) noted that other work was progressing in the area, co-ordinated by J Backhaus.

Germany

Meincke (Germany) presented results from the WOCE Trans-Atlantic section and described a recent climatic event in the sub-polar gyre. A large outflow of ice occurred through the Fram Strait in October 1994 / spring 1995. The flux of ice doubled during this event. When converted to a volume of freshwater, this volume was as large as the outflow of fresh water, which proceeded the Great Salinity Anomaly. Hence the signal created by the new event should be traceable. The first evidence of the propagation of the new anomaly was in the Greenland Sea, where the thickness of the low salinity layer greatly increased at some time between 1994 and 1996. East of Greenland a large amount of drift ice was observed in spring 1996.

North of Iceland the TS distribution was very different in 1995. Waters were very cold and relatively fresh, and a large area north of Iceland demonstrated a similar change. Malmberg (Iceland) explained that in that year the waters were not stratified as normal, and hence the TS curve was for Arctic water rather than polar. It therefore did not come from melting ice, but rather from the interior of the Iceland Sea gyre.

Results from the WOCE section (Cape Farewell - Reykajanes Ridge) demonstrated that areas with salinities of <34.96 were enlarged in 1994 / 1995 at depths of 1500m. The freshwater layer in the surface waters also increased in size from 1991 - 1996. A section due south of Cape Farewell in July 1997 showed a large amount of freshwater down to 300m. A station off Cape Desolation showed a decrease of salinity in both surface and intermediate (Irminger Sea Water) layers during 1996/97 and salinities are now the lowest since 1983.

Canada

Narayanan reported results from the NW Atlantic (Annex K). Air temperatures throughout the Northwest Atlantic generally cooled relative to 1996. On the coasts of Greenland, Baffin Island, and north-eastern Canada the air temperatures have been above normal for most of the year in 1997, along the southern Labrador, near normal, and further south, below normal. The North Atlantic Oscillation (NAO) index was below normal for a second consecutive year, but above that recorded in 1996. The ice formation was delayed, appeared on Labrador shelf late and left early; however, the peak ice cover area was higher than the 1996 value. The net effect was that the volume of sub-zero temperature water on the Labrador and Newfoundland Shelves was lower than normal. The water temperature was near to slightly above normal at most sites and depths off Newfoundland, whereas the salinities for most part were near normal or slightly below normal. On the deep basins of Scotian Shelf, the deep water remained warmer than normal whereas in the upper layers and over most of the deep layers of the northeaster Scotian Shelf, the conditions were below normal. These cold conditions have persisted since at least the mid-1980s although most regions show slight moderation over the past few years.

Netherlands

Bennekom made the presentation for the Netherlands. The WG was also informed that Van Aken could not make the presentation for the Netherlands this year, but he has been active on many fronts including CLIVAR. The Netherlands has been successful in instrumenting one of the ferries to Texel, with an extensive sensor system to measure temperature, salinity, suspended load, chlorophyll and currents (ADCP). The objective is to provide better data with which to validate water quality models of the Wadden Sea.

Bennekom went on to present a short report on recent observations of high salinity in the English Channel and southern Bight of the North Sea (Annex L). Values as high as 35.4 in the North Sea and 35.6 on the Celtic shelf were observed. Previous workers have also noted high salinities at times (e.g. the NSTF reports salinities of 35.7 in 1990, a Nature paper reported values of 35.47 in the northern North Sea). Bennekom will further analyse this event, and particularly focus on causes of this and previous high salinity events. Processes such as evaporation / precipitation ratios will be considered, and changes in river runoff. The ICES oceanography secretary prepared a summary T/S plot that appears to confirm the earlier high salinity event. River runoff in the southern North Sea area closely follows the NAO.

Dickson (UK) reported high salinities observed during February on the Fel. Rotterdam ferry route as well as in the Channel.

Climate setting and Discussion

During the discussion that followed it was suggested that the present anomaly is different in nature to the 1970s anomaly. In the sixties, there was a strong gyre in the Greenland Sea, but in the Iceland area (ice-years in north Iceland waters), the East Icelandic Current changed from being Arctic ($S>34.7$) to Polar ($S<34.7$) along with increased freshwater transport. During the present anomaly, when the central dome is weak, the anomaly has remained mainly within the Greenland Sea and has recirculated north of Jan Mayen and Mohn Ridges.

Dickson (UK) presented a climate context-setting section. This focused on the winter Hurrell North Atlantic Oscillation (NAO) index, which appears to be correlated with a number of the ocean climate change indicators described above. The high NAO index is associated with severe winters and vice versa. Hence the 1990's are characterised by a high NAO, while the 1960s were associated with a low index. Period when the NAO high are associated with:

1. Increased number of winter storms.
2. Storm tracks move away from the American coast and eastward towards the Iberian Peninsula, into the NE Atlantic and Nordic Seas.
3. Precipitation across the Nordic Seas increases, with a maximum increase of +15 cm per winter along the length of the Norwegian Atlantic Current (NAO). Southern Europe becomes drier.
4. The increased southerly airflow along the NAO boosts the transport and/or temperature of the warm, saline Atlantic water inflows to the Barents Sea and Arctic Ocean.
5. An increased efflux of ice from Fram Strait, thus reinforcing the freshening of Nordic Seas.
6. Deep-water formation is weak in the Greenland Sea and Sargasso sites, but is strong in the Labrador Sea.

Between winters 1994-95 and 1995-96, the NAO index swung from one of its highest to one of its lowest values of record. Dickson showed two examples of the way the Atlantic responded to this reversal in NAO: one, the difference in the mean sea-surface elevation between these two periods as estimated from the Topex-Poseidon altimetry in March-May by Dr. Jan Bock, and two, the difference in the precipitation anomaly across Europe between these years, calculated by the Global Precipitation Climatology Centre, Germany. The 1996-97 NAO, though still was low appears to be less negative compared to the previous year. The indications for 1997-98 are that it may be switching to a positive value again. The long positive phase of the NAO Index has therefore continued, with 16 of the last 19 winters exhibiting a positive index.

5. Progress in National and International Projects in North Atlantic

Hendry outlined the goals and preliminary results of a joint Canadian/US Newfoundland Basin Experiment that took place during 1993-95. The main goal of the study was to obtain direct measurements of the mass and heat transport in the North Atlantic Current as a contribution to WOCE. The study combined moored array measurements, repeated hydrography, subsurface float measurements, and altimetry. Preliminary estimates of the transport of the North Atlantic Current derived from the moored current meter array were presented.

Hendry summarised the status and future plans of three ongoing Canadian research efforts in the Labrador Sea:

1. The eighth annual occupation of WOCE Labrador Sea Section AR7W is planned for summer 1998. A tentative plan exists to continue annual occupations of this line as a contribution to CLIVAR.
2. A moored current meter measurement programme has maintained a mooring in the central Labrador Sea near the location of Ocean Weather Ship Bravo since June 1994. The mooring is equipped with temperature/salinity recorders. Measurements from 1994-95 presented to the Working Group showed the development of a convective mixed layer during March 1995. Further year-long deployments are planned through 1999-2000.
3. Recent Canadian analyses of historical and modern temperature and salinity

data in the central Labrador Sea were presented. They clearly showed the marked inter-annual variability in the Labrador Sea over the past 50 years. Labrador Sea Water was notably less saline than the historical norm during the mid-1990's, corresponding to the WOCE observational period.

Meinke reported on observations of interannual changes in temperature and salinity on WOCE hydrographic sections A1E/AR7E between Greenland and Ireland during 1991-1996. The observed thickness of the Subpolar Mode Water layer showed a striking correlation with the North Atlantic Oscillation (NAO) index, with increased layer thickness corresponding to decreases in the index. This was related to changes in the position of the Subarctic Front in response to changes in the large scale wind forcing. The 1996 NAO index was the lowest in nearly 30 years. The 1996 oceanic response was correspondingly strong. No measurements are planned on this section for 1998. A biannual hydrographic survey of the section beginning in 1999 has been proposed as a European CLIVAR contribution.

Meinke reported that Germany is beginning a 10-year research programme on Cyclones and the North Atlantic Climate System. The programme, which will include modelling, observations and analysis, is being supported by the Deutsche Forshungsgemeinschaft.

Malmberg showed surface drifter tracks in Icelandic waters from 1995 and 1996 deployments. The 1996 tracks showed much higher spatial dispersion. It was suggested that this might be further evidence of ocean current changes related to the anomalously low 1996 NAO index.

Dickson summarised recent activity in three programs involved in Northern Seas studies. The programmes are: (1) the Arctic Climate System Study (ACSYS); (2) Variability of Exchanges In the Northern Seas (VEINS); and (3) the European Sub-Polar Ocean Programme (ESOP-2), Thermohaline Circulation in the Greenland Sea.

1. Relatively warm northern waters in the 1990's associated with high NAO indices have led to a warming of the West Spitsbergen Current and a warming and shallowing of the North Atlantic layer in the Arctic Ocean. ACSYS investigators have reported that the upper layers of the Arctic Ocean were both warmer and less saline in 1997 than in previous years. The potential impacts on Arctic Ocean ice cover have global implications.
2. The Denmark Strait overflow was one VEINS focus. Moored current measurements of the Overflow since 1986 were summarised. VEINS moored measurements of the Denmark Strait Overflow in early 1997 showed a westward shift of the core of the Overflow. A warmer, fresher, and less-dense overflow core apparently shallowed by 300-500 m in depth as it moved up-slope. Results from a stream-tube model of the Overflow were presented. The model showed a shallowing of the overflow core accompanied by a horizontal displacement when the density of the overflow decreased.
3. One of the elements of ESOP-2 was a 1996 purposeful release of an inert tracer, sulphur hexafluoride (SF6), into the centre of the Greenland Sea at a depth of about 300 metres to investigate the formation and spreading of deep water. Unexpectedly high vertical diffusion rates were inferred from subsequent 1997 SF6 surveys.

Dickson pointed out that Arctic hydrographic measurements had recently been made under the SCICEX (Scientific Ice Expeditions) Programme. Since 1993, the US Navy has made a Sturgeon-class nuclear-powered attack submarine available for annual unclassified science cruises to the Arctic Ocean. These cruises have collected water samples and CTD casts from surface stations as well as collecting underway oceanographic and geophysical data across the entire deep Arctic Ocean.

Loeng reported on a 6-mooring current meter array between Bear Island and Norway (the Bear Island-Fugløya section). The first deployment took place in autumn 1997 and was recovered in March 1998. This was the start of a VEINS programme to monitor flows in and out of the Barents Sea. The net inflow to the Barents Sea through the section from the first deployment varied in time from less than zero to nearly 4 Sv. The observational programme is planned to continue into 1999. Related numerical models are under development.

Meincke described how the VEINS project is funded by the Commission of the European Union under the MAST III (Marine Sciences and Technologies) Programme. VEINS started in February 1997 and will last until July 2000. The fieldwork, modelling, and analysis are carried out by 18 institutions from nine European countries. A proposal for a follow-on VEINS-II project is in the early stages of planning. This would fall under the Fifth Framework Programme covering research efforts of the European Union for the period 1998-2002. Socio-economic research was highlighted as a core issue for the Fifth Framework Programme.

Malmberg reported that three current meter moorings were being maintained north-west of Iceland (Denmark Strait area), as well as four moorings north-east and east of Iceland in the East Icelandic Current since May/June 1997, to monitor the exchange between the North Atlantic and the Iceland Sea. The moored measurement programme began under Nordic WOCE and continues as part of the VEINS monitoring programme.

Lavin reported on an analysis of long-term variations of North Atlantic Ocean properties along 24°N (WOCE Section A5) on the basis of measurements in 1957, 1981 and 1991. Variations in heat flux and fresh water transport were discussed. Variations in oxygen and nutrient fluxes have also been investigated.

Lavin summarised the status of the CANIGO project "Canary Islands Azores Gibraltar Observations." CANIGO is part of the MAST-III Regional Seas Research. It involves partners from12 countries and 45 institutions. Its overall goal is to understand the functioning of the marine system in the Canary-Azores-Gibraltar region of the Northeast Atlantic through interdisciplinary basin-scale studies. This three-year study is scheduled to end in September 1999.

6. Shelf-edge, slope or eastern boundary currents

This agenda item was intended to facilitate a discussion on eastern boundary currents based on the findings from oceanographic programs in Spain and other ICES member countries. However, since the principal investigators from Spain and Van Aken from the Netherlands were unable to attend the meeting, Lavin presented the results of two Spanish Programs: SEFOS along the shelf edge of Bay of Biscay and a detailed study off La Coruña. The spring hydrographic conditions in the Bay of Biscay during the SEFOS project, 1994-96, shows the changes in salinity distribution with an increase in 1996 due to the presence of a strong poleward current found in November of 1995 and January-February of 1996. This current, named Christmas Current by Pingree, was also clearly noticeable in the SSTs computed from satellite images of the area as well as in the current meter measurements. Unfortunately, the observations could not be repeated in 1997 winter because of adverse weather conditions.

The second project focuses on the oceanographic conditions around the north-western corner of the Iberian Peninsula and how these are influenced by Mediterranean Intermediate water and North Atlantic Central Water of subpolar and subtropical origin. The physical oceanographic team of La Coruña has shown direct relationship between the lifting and lowering of the 35.8 isohaline and the cyclonic and anticyclonic gyres in this area.

7. The Ices role in GOOS

(Agenda 7, Assess developments in GOOS and Agenda 12, Comment on the 1997 ACME statement (Agenda item 21.3) concerning the development of GOOS initiatives in ICES)

The WG debated the options for a possible ICES role in GOOS. C. Res 1997 2:57 had established an ICES steering Group on GOOS under Dr. Roald Sætre, IMR, Bergen, and with the chair of the WGs under the Oceanography, Marine Habitat and Living Resources Committees as members. The WG was asked to comment on four alternative options:

1. that ICES attends and advises all appropriate GOOS fora but has no active role in the project,
2. that ICES supplements these advisory role by providing certain services for a regional GOOS effort, e.g. Databases, data management, quality control, and aspects of support for the Living Marine Services module,
3. that ICES takes responsibility for establishing and running a centre for operational fisheries oceanography dealing with climatic scale variability (months to years),
4. that ICES adds to option C a capacity in operational oceanography on meteorological time scales of days to months.

The WG was strongly of the opinion that the historical strengths and present capabilities of ICES lay with Option C and recommended that ICES should pursue this role in the north Atlantic in an analogous way to the PICES role in the Pacific.

The structure and science base of EUROGOOS was presented, but it was felt that the cost-recovery aspects of EUROGOOS are in conflict with the free and open access to data and information under ICES and GOOS. A wide ranging discussion subsequently began the task of defining the ICES role and the changes necessary to meet it in the key modules of Climate, Coastal Zone, Living Marine resources and health of the Ocean.

- Climate Status. The capability to define the climate status of ICES waters (the maintenance of key representative sections and stations, data cross-checking and quality control, and the interpretation of change) is a capability already well developed in Oceanography Committee and its Oceanic and Shelf seas WGs. The co-ordination and merging of national efforts into an Atlantic synthesis is an ICES role of central relevance to GOOS that would not simply or automatically emerge from national programs.
- The role of ICES as a regional data centre and the activities of ICES MDM to ensure the full, open and timely archiving/exchange of well-kept ocean data and meta-data are established elements of importance to GOOS. However, these capabilities may need to be enhanced and easier tools provided for the handling, checking and synthesis of the broader parameter-mix associated with Living Resources module.
- The Oceanography (and the previous Hydrograhy) Committee of ICES has long fixed a focus for regional studies of the impact of environmental change on the survival, growth and recruitment of fish stocks. Through the continuation of these studies, through the restructuring of ICES Committees into multi-disciplinary groups better able to pursue these studies, and by a range of external initiatives, ICES science is now fully-focussed on developing a sufficiently sound knowledge of environmental controls on fish stocks to permit their integration into the procedures of fish-stock assessment.

These remarks on the existing ICES capabilities in climatic status, data management and environmental effects, certainly justify an ICES involvement with GOOS but would continue anyway. What is needed are actions to document present measurement and co-ordination programs in the ICES area that are relevant to GOOS, and establish how existing efforts, such as the above, might be adjusted to mutual benefit.

The next step will be to establish mechanisms to ensure that projects of interest to ICES and GOOS are brought under their joint sponsorship.

The hope is that such joint sponsorship might strengthen the science and its funding-base. It might also provide funding stability for ICES ocean monitoring and the development and upgrade of instrumentation such as the CPR, Moving Vessel CTDs, and others.

8. Trans-Atlantic ADCP Survey Proposal

Rossby had informed the WG that the prospect for installing an ADCP on a Greenland freighter is good. Pending approval from Lloyds, the ADCP is planned to be installed when the vessel identified for this will be going on dry-dock in early May.

9. Assess and Evaluate Oceanographic instrumentation

A letter from Carlberg (Chairman ACME) dated 25 Feb 1998 and notes from the Marine Chemistry WG meeting 2-6 April 1998 asking the opinion of OHWG about the use of units, µmol/l or µmol/kg for oxygen and nutrients were discussed.

The group noted the advantages of units on a mass basis (µmol/kg). They do not change with pressure or temperature and correlations with data on other quantities such as carbon compounds, which are usually given in µmol/kg), are easier. Conversion of litres to kilograms needs the density of the samples, hence requires measurement of temperature and salinity at the time of analysis. As explained in the MCWG report, taking 1.025 for the density causes only small errors in open-ocean work, usually negligible for nutrients, but not entirely negligible for oxygen. The OMEX CDROM contains oxygen only in µmol/l and stores the conversion factor for computing µmol/kg.

It was noted that the real danger is not knowing what units are used. The OHWG felt that it is better to continue the normal practice and document the data appropriately, but the data centres must accept data in both units.

Some remarks were made on Quality Assurance, such as carried out in the Quasimeme project. It was noted that these projects were extremely useful in detecting irregularities caused by, for example, high blanks or impure chemicals. Repeated intercalibrations have always shown to decrease inter-laboratory differences. There is still an interest in certified and maintainable seawater samples for nutrients. The OHWG would like the MCWG to consider implementing inter-laboratory calibrations for key variables.

It was also noted that in some cases small changes are made in standard analytical procedures for unknown reasons. Since this can be detrimental to time series, these changes should be avoided.

Bennekom reported on the results and advantages of measuring oxygen equivalents of iodine in the Winkler procedure by spectrofotometry instead of by titration (Annex M).

Hendry reported on the use of CTD profilers while steaming. Accuracy was about 0.01% in salinity and, if properly attended, cable wear was not serious.

10. Consider future work programme in relation to the remit of the Oceanography Committee and the development of the ICES five-year plan. Including co-operation with other working groups

Harald Loeng introduced this topic. He had canvassed comments from the Oceanography Committee members as to the key topics the Oceanography Committee should be focusing on in the next five years. He also wanted input form each of the WGs under the Oceanography Committee. The Oceanic Hydrography WG was unanimous in their opinion that a major focus for the Oceanography Committee in the next few years should be " climate variability and its effect on the ecosystem". This topic is closest to the experience and the interest of its WG members. There was general agreement that this topic provided a wide range of inter-disciplinary links between the ICES committees and working groups, both in terms of attractive science and potential for useful application.

The WG decided to restrict its contribution to the development of a five-year plan for the Oceanography Committee to a climate-related topic and specified as follows:

Proposed topic: Ocean Climate Change
Related Activity:

- Oceanic Hydrography
- Study of Oceanographic variability
- Ocean data search and rescue
- Investigat6ion of causes of oceanographic variability and their dependence
- Study of effects of oceanographic variability's on:
  - Planktonic ecosystems
  - Commercial fish stocks (survival, growth, recruitment, etc.)
- Consideration of global change
- Modelling, synthesis and prognosis
- Preparation of quick responses-support for ocean managers.

11. Second decadel Symposium Proposal

Plans for this symposium are moving forward at an appropriate rate.

1. The National Museums of Scotland marketing assistant Mrs. Wilma Henderson confirms that the Lecture Theatre in Edinburgh has been provisionally booked from 8-10 August 2001 and the Great Hall of the Royal Scottish Museum has been booked on 9 August 2001 for the Symposium banquet. The Chief Executive CEFAS and the Director SOAFD Laboratory Aberdeen have agreed to contribute to the cost. No further action needs to be taken on this heading until nearer to the time of the meeting, apart from an annual check on the booking.

2. Steering Group. This year we are required by ICES to form and approve the Steering Committee for the Symposium. The following names for the Steering Group has been identified by the two co-convenors, Dickson (CEFAS, UK) and Meincke (IFMH, Germany), and approved by the WG. Though the roles of these members are intended to be overlapping, these named individuals will take special responsibility for encouraging good papers as indicated:

   - **Hendrik van Aken**, Netherlands (Physical oceanography, East Atlantic and European Shelf)
   - **Olafur Asthorsson**, Institute of Marine Research, Reykjavik, Iceland (Plankton, throughout the ICES area, all aspects)

- **Alicia Lavin**, Instituto Español de Oceanografía de Santander, Spain (Physical Oceanography, South-eastern area (plus associated biological input)
- **Pentti Malkki**, Institute of Marine Research, Helsinki, Finland (Baltic Marine Science in all its aspects)
- **Manfred Stein**, Hamburg, Germany (Physical Oceanography of West Greenland and NW Atlantic plus will act as an interface with NAFO whose interest and co-sponsorship are warmly welcomed)
- **Bill Turrell**, SOAFD, Marine Laboratory, Aberdeen (Will chair an editorial group of consisting of himself, Ken Drinkwater, Canada, and a biologist, to be selected. This group will be responsible for editing the Volume of Conference proceedings)
- **Cisco Werner**, UNC, Chapel Hill, North Carolina (Cod and climate, fisheries and environmental change including Georges Bank physical oceanography)
- **Co-convenors**. Conference arrangements, climate and deep sea phys. oceanog of Arctic/Subarctic seas

3. Special Lecture. Additionally, there will be a Special Lecture on the Climatic Context of the 1990s with special reference to Global Change by an international authority on the subject. Dr Phil Jones of the Climate Research Unit, UEA, Norwich, has been approached and has accepted.

4. Honorees. As with the previous symposium in Mariehamn, the intention will be to honour five ICES members who have contributed to the maintenance and interpretation of time series over recent years and who will by then be retired or on the point of retirement. The names of these individuals will be forwarded to ICES at a later date.

5. Procedure. The SSG intends to conduct its business via the annual meetings of the ICES WGOH and by correspondence in the interim. The Co-convenors and the SSG members will also initiate the local arrangements for the symposium.

The WG decided that it would be beneficial to have NAFO as a cosponsor of this symposium. Both ICES and NAFO conduct annual reviews of oceanographic conditions in the north Atlantic and relate them to climate variability. Both groups address the longer time scale variability not only to understand and predict these but also to assess the impact on fisheries. Consequently, co-sponsorship by NAFO will enhance the participation in the symposium and the quality of the papers. The Convenors are requested to convey to the ICES General Secretary the WG's request to invite NAFO to be a co-sponsor of the Decadal Symposium scheduled in 2001 in Edinburgh, Scotland.

12. Analyse the conclusions of the WKPDOC and make proposals on future work on the topic

The report of the ICES/GLOBEC workshop on the Prediction and decadel-scale Ocean Climate fluctuations (WKPDOC) of the north Atlantic was not available for the OHWG for review. The Chairman of the Oceanography Committee received a preliminary draft of the report prior to the meeting; however, this version did not have the section on recommendations. The OH WG urges the Chairman of the WKPDOC to complete the report as soon as possible.

13. Any Other Business

AMAP: Loeng introduced the letter from Lars-Otto Reiersen, Executive Secretary of Arctic Monitoring and Assessment Programme (AMAP), to ICES, requesting ICES participation and co-operation in the planning and implementation of its activities for the period 1998-2003, as was done, quite successfully, during the first phase of AMAP. In particular, AMAP would like some of the ICES working groups and programmes, such as WGOH, WGCCC and GLOBEC, could be involved in the AMAP work during the second phase.

The WG members viewed the request as quite reasonable and natural. The members noted that it is within the mandate of the WGOH to provide support scientifically and in data management to collaborative programmes in marine sciences in areas of interest to ICES member countries. Consequently, the WG will be very pleased to participate in AMAP. It was pointed out that the mechanism for such collaboration is already in place through the participation of Loeng, the Chairman of the ICES Oceanography Committee, in AMAP.

Report: In 1997, an overview of the state-of-the-ocean was prepared and presented at the ICES Annual Science Congress (ASC). The format and content of the overview for the 1998 ASC was discussed. As in 1997, Turrell accepted the responsibility to prepare this overview in collaboration with Narayanan and Lavin.

The members discussed the usefulness of producing a "FACT SHEET", a four page summary of the state-of-the ocean for general use. Many of the member countries are producing such publications for their regions in support of fisheries research and management. However, until now there is no synthesis is available on a regular basis. The members felt that ICES OHWH should take the lead on producing a north Atlantic FACT SHEET. Turrell with the assistance of Narayanan, Lavin and Dickson will produce a draft for discussion, and revise it to produce a first issue. Norway agreed to print the sheet. The FACT SHEET will be distributed to ICES committee members, as well as to other organisations such as GOOS, CLIVAR and NAFO.

Theme Sessions: The members were concerned about the lack of opportunity for oceanographers to present scientific papers at ICES ASC. Under the present system, a paper is accepted for presentation when it is on one of the theme session topics. For young scientists who may not have achieved the networking necessary for participation in international programs such as GLOBEC for example, lack of opportunity for presenting his/her paper, may become an impediment for getting involved in ICES. The WG strongly recommends that a few general sessions are included in the ASC to attract increased participation of the scientists.

The WG recommends two theme session, one for 1999 and the other for 2000. The WG feels that a theme session on "Global Change Aspects" is timely and necessary and recommends that this session be organised in 1999. Dr. Ross. Hendry, Bedford Institute of Oceanography, Canada and Dr. Steingrimur Jonsson, Marine Research Institute, Revjevik and University Akureyri, Iceland, has agreed to be the coconvenors of this session.

How the environmental changes that have been documented in the recent years are affecting the food web is a topic of interest to ICES. Since this topic is also of interest to the WG on Zooplankton Ecology, which has been scheduled to meet in Santander from April 6-8, the Chairman of WHZE, Roger Harris was informed of the idea and requested to nominate a possible co-convenor for the session. The WGZE supports the theme session and has nominated Dr. Peter Wiebe from Woods Hole as a co-convenor. The WG recommends a theme session on " Environmental Effects on Plankton Communities" be held in 2000, with Ken Drinkwater from Canada and Peter Wiebe as co-convenors.

14. Date and Place of Next Meeting

F. M. Troyanovsky, Director of PINRO, Knipovich Polar Institute of Marine Fisheries and Oceanography in Murmansk, Russia, has invited the WG to hold its 1999 meeting at PINRO in conjunction with the centennial anniversary of Russian oceanographic observations at the "Kola Meridian" section in the southern Barents Sea. PINRO will be celebrating the centennial anniversary with a special one-day symposium with presentations on the Barents Sea Climate and its effects on fisheries, the significance of the Kola Meridian section and other standard sections in the investigations of water mass and circulation, and on the history of this section. The WG members were unanimous in their acceptance of the invitation, and are looking forward to participating in the centennial symposium. The Oceanic Hydrography WG proposes to meet from 13 to 15 of April 1999, following the symposium on April 12th.

15. Recommendations

A. The WG recommends the following theme sessions for the Annual Science Conference:
   1. Global Change Aspects in 1999, with Dr. Ross. Hendry, Bedford Institute of Oceanography, Canada and Dr. Steingrimur Jonsson, Marine Research Institute, Revjevik and University Akureyri, Iceland, as co-convenors.
   2. Environmental Effects on Plankton Communities, in 2000, with Ken Drinkwater Bedford Institute of Oceanography, Canada and Peter Wiebe, Woods Hole Oceanographic Institute, as co-convenors.

B. The Working Group on Oceanic Hydrography (Chairman S. Narayanan) will meet at PINRO, Knipovich Polar Institute of Marine Fisheries and Oceanography in Murmansk, Russia, from 13-15 April 1999 to:

1. update and review results from Standard Sections and Stations;
2. consider the format and content of the Fact Sheet and annual climate summaries, and compile relevant information for 1998;
3. review progress in national and international projects in north Atlantic such as WOCE, VEINS, CLIVAR/ACSYS, TASC, ESOP2, Trans-Atlantic Section of Currents, and others;
4. review recent research on shelf-edge, slope and eastern boundary currents;
5. review the progress in the installation of vessel-mounted ADCP surveys on ships-of-opportunity;
6. review present status of the operational use of new oceanographic equipment;
7. review progress in the planning of the Second decadel Symposium (C.Res.1997/2.2)
8. appraise the current and future role of the ICES Oceanographic Data Centre;
9. assess developments in GOOS of relevance to ICES in the wake of the GOOS Agreements meeting, taking into account the work of the Steering Group on GOOS;
10. consider possible future directions for Oceanography Committee and the Annual Science Conference with specific regard to the part physical oceanography must play in ICES

Justifications

A. Theme Sessions

Theme Session 1, Global Change aspects. There is a renewed focus on Climate change research in ICES member countries, as a consequence of the recent collapse of many fisheries in the north Atlantic, and the concurrent occurrence of the unusual environmental conditions of the 90s. Even though the recorded data on the environment extends back only for a century or so, there are numerous proxy data, such as from the ice cores for example, may be used in climate studies. Before launching into the next phase of climate change monitoring, prediction and adaptation, it is almost essential to, once again take stock on what we know, what we need to know and what focus should be there in future. This session will provide an opportunity for scientists with expertise in a number of disciplines, conducting research on climate variability from interannual to paleo time scales, to communicate their knowledge and discuss the climate science.

Theme Session 2, Environmental Effects on Plankton communities. Considerable research is being conducted in ICES member countries, on the interannual and longer-time scale variability in plankton species. Many of these indicate significant climatic influences on these species. This theme session will provide a forum to review and synthesise these findings. This is particularly important in view of the planned effort under the different modules of GOOS.

B. Agenda for 1999

1. 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, and a 1998 Fact Sheet on the climate.
2. WG recognises the need for disseminating climate information in a timely and appropriate manner. The first issue of the climate review was prepared in 1997. The next issue of the climate review, and a Fact Sheet (a short summary for wider distribution) was produced in 1998. During this agenda item, the WG will review how well these items were received by the ICES community and discuss changes in its format and content. The WG report contains considerable information on the state-of-the-environment in the north Atlantic, but these are on a country by country basis. A synthesis will be more useful for the general public. Two types of synthesis will be appropriate: one, as a quick reference with a pointer to more information (a FACT SHEET), and two, a comprehensive synthesis. This agenda item will allow the WG members to prepare these two documents during the meeting, thus avoiding delays in the dissemination of the information.
3. This agenda item will provide an opportunity for the WG to be informed of programs in the ICES area. Since many planned and funded activities are now being co-ordinated via funded proposals, such information is necessary to take advantage of national and international funds and to establish collaborations among members.
4. Considerable activity is taking place in Spain, Holland and other countries, with respect to shelf-edge, slope and eastern boundary currents. This agenda item is in aid of a focused discussion on these currents.
5. 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.
6. 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.
7. This item is to review the progress on the second decadel symposium planning.
8. ICES data centre plays a very important role in ICES. As the funds decrease and the number of large international programs increase, the data centre activities need to be strengthened and realigned to meet the changes. The WG will discuss their expectations from the data centre

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

10. This agenda is to discuss the decisions of the ICES as to the direction of the Oceanography Committee and the role of its WG. Theme sessions provide an opportunity to collectively address a topic that is of importance to ICES. This agenda item will provide an opportunity to discus the high priority oceanographic issues that need to be addressed.

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

Agenda

1. Opening
   Review of Membership
2. Remarks from the ICES Oceanographic Secretary
3. Update and review results from Standard Sections and Stations
4. Review progress in national and international projects in north Atlantic WOCE, VEINS, CLIVAR/ACSYS, GLOBEC , OMEX, ESOP2, Trans-Atlantic ADCP sections, CANIGO, and others
5. Shelf-edge, slope or Eastern boundary currents
6. Assess developments in GOOS
7. Review the progress of ships-of-opportunity vessel-mounted ADCP surveys
8. Assess and evaluate oceanographic instrumentation
9. Review plans for the ICES Second Decadal Symposium
10. Analyse the conclusions of the WKPDOC and make proposals on future work on this topic
11. Comment on the 1997 ACME statement (Agenda item 21.3) concerning the development of GOOS initiatives in ICES
12. Consider future work program in relation to the remit of the Oceanography Committee and the development of the ICES five-year Plan. Including co-operation with other working groups.
13. Other business

Terms of Reference

1. Update and review results from Standard Sections and Stations
2. Review progress in national and international projects in north Atlantic WOCE, VEINS, CLIVAR/ACSYS, GLOBEC , OMEX, ESOP2, Trans-Atlantic ADCP sections, CANIGO, and others
3. Assess developments in GOOS
4. Review the progress of ships-of-opportunity vessel-mounted ADCP surveys
5. Assess and evaluate oceanographic instrumentation
6. Review plans for the ICES Second Decadal Symposium
7. Analyse the conclusions of the WKPDOC and make proposals on future work on this topic
8. Consider future work programme in relation to the remit of the Oceanography Committee and the development of the ICES five-year Plan. Including co-operation with other working groups.
9. Comment on the 1997 ACME statement (Agenda item 21.3) concerning the development of GOOS initiatives in ICES

Justifications

1. 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.
2. 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 co-ordinated via funded proposals, such information is necessary to take advantage of national and international funds and to establish collaborations among members.
3. 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.
4. 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.
5. 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.
6. This item is to review the progress on the second decadal symposium planning.
7. The WG is asked to consider the reasons for the degree of success of this workshop on decadal ocean climate variability and make proposals on future work on this topic

Annex B: List of Participants

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A. J. van Bennekom	Netherlands
R. R. Dickson	UK
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R. Hendry	Canada
A. Lavin	Spain
H. Loeng	Norway
S. Narayanan	Canada
S. A. Malmberg	Iceland
J. Meincke	Germany
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Annex D: ICES Oceanographic Data Centre

A Progress report

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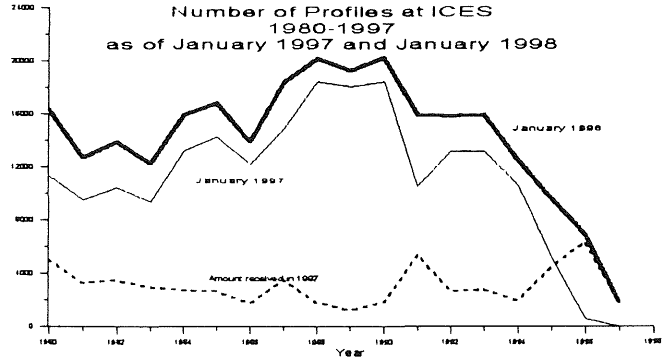
1) During 1997 55,055 profiles were added to the database for the years subsequent to 1980. The distribution on the number of profiles by year is in given below. For the first time we have more than 20,000 profiles in any one-year (i.e. in 1988 and 1990).



2) A number of submissions have been received in the past few weeks, notably from Finland and France, and these have yet to be processed. Concern persists around the very low submissions from a number of countries, especially with regard to UK (NERC), Germany, Ireland, Spain, Portugal, and Norway (for nutrients). One country has requested the withdrawal of all of its data for the period 1989-1991 because of suspected quality problems.

3) A special archive of MAST roscops continues to be maintained, and listed on a special MAST part of ICES web site. In spite of the compulsory requirement to provide roscops for MAST projects, it is still incomplete.

4) Activities in connection with the MAST Projects ESOP and VEINS are well underway, with some difficulties.

5) All the OMEX profile and surface data sets have been merged into the ICES databank. This task has served as a test for expanding the ICES format to encompass any number of data types, and also to see how Roscop may be adapted to reflect the expansion in parameters. The nucleus of both of these developments has been the BODC/JGOFS data dictionary.

6) Software systems have continued to be developed to facilitate the data management activities. No proprietary software is in use apart from producing final graphical products. The software is both windows-based (data management), and Unix-based (for the preparation of gridded products which now represents more that 50% of the requests received).

7) ICES web page now provides guidance on how to submit requests to the data centre - there has been a rather large increase in requests resulting from the Web presence. The contents of the page are:

8) Data may be requested from ICES Oceanographic Data Centre with the following information:

- Time Period
- Latitude/Longitude limits
- Parameters

- Standard parameters are Temperature, Salinity, Oxygen, Phosphate, Total Phosphorus, Silicate, Nitrate, Nitrite, Ammonium, Total Nitrogen, Hydrogen Sulphide, pH, Alkalinity and Chlorophyll 'a'.

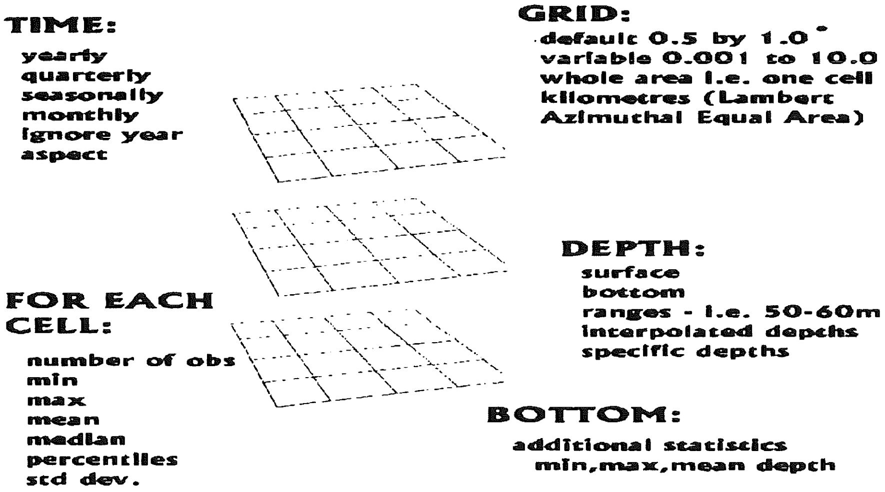
•Observation depths (e.g. surface/bottom/profile/high res. CTD)

•Any processing? Here include the need for gridded products (specify grid interval and depth interval. We would be happy to discuss with you the production of any products that may meet your needs.

•What price? Charges normally not exceeding 400 US$ per requested item can be made if the request is to be used for commercial purposes or is in support of work being undertaken as part of a funded contract. •Data are normally made available from our ftp server, compressed using pkzip (DOS). The format can be either ICES oceanographic format, or converted to a simple comma-separated value table format (via ICES-CSV.EXE). Please specify.

PLEASE NOTE:
For all data collected within the last 10 years we have to refer to the data originator for permission to pass these data on. In these circumstances you should supply us with a brief description of your use of the data. This permission is not necessary if your needs are for gridded data or other products.

The production of gridded products in particular has become very popular, the following illustrating the sort of capability we currently have



9) The number of requests for data is quite significant and is continuing to increase.

Annex E: Spanish Sections

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The Standard Sections sampled by the Instituto Español de Oceanografia are given in Figure 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 follow a warming tendency. In annual mean air temperature (according to the Spanish Instituto Nacional de Meteorología) 1995 was one of the warmer year of the period 1961-1997, mean temperature fell by 0.9° C. in 1996 and recover by 0.8°C in 1997. Anomalies of annual mean temperature relative to the 1961-1990 mean (Figure 2) show that the temperatures were higher than normal in1997, except for July. Furthermore, 1997 was the second warmest year (after 1995) in the 90s. Air temperatures were normal or above during the winter and autumn. The net effect was that the annual temperature anomaly was positive reversing the reduction that occurred in 1996.

Air temperature pattern has some similarity to the NAO but correlation is low (Figure 3). It is to be noted that when the NAO index is high there is a northward displacement of the intensified Westerlies (Alheit and Hagen, 1997), Northern European weather is mild, but the Iberian Peninsula is blocked from the Westerlies and a strong high pressure cell is located in the western part. Seasonal correlation may be higher than the annual mean as has been shown in the Moroccan precipitation (Lamb et al., 1997)

Contours of temperature, salinity and nitrates at stations 2, 4 and 6 for the period (November 1991- December 1997) for the Santander Section are presented in Figures 4, 5 and 6. 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 pycnocline is broken, in summer in the upper layers, due to advection of warm surface water, and in spring, due to river outflow. On nitrate distributions, high values appear in the mixed period and, due to upwelling events, in the stratified part of the year (Lavín et al, 1998).

In figures 7a and 7b, we present monthly values of seawater temperature at 10 m depth and salinity at 50 m depth. The increasing trend in temperature from 1991 to 1995 in summer and winter temperatures stopped in 1996 and maxim and minima values have been maintained since then. Salinity values follow a decreasing trend from 1991 to around 1995, but reversed since then. 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.

To detect changes in that data and to extract the general trend in the series, we remove the seasonal cycle using moving averages. A 12-month running mean at 10m depth is presented in figure 8. Average temperatures begin to increase in late 1993 until middle 1995, remained around 16.1°C until the beginning of 1996 when a notable cooling happened until the middle of this year. Temperatures were around 15.4°C during 1996 and began to increase again in spring 1997. These changes in temperature in the upper layers (10 m) are related to the anomaly in air temperatures. Consistent warm tendency occurs when the increase in air temperature from the previous year is large, as during 1994 and 1997 when these increases are 0.7 and 0.8°C. Small increases, as during 1993 or 1995 (0.1 or 0.2°C), produce very little warming. A notable reduction of air temperature, as during 1996 of 0.9°C produced similar reduction in seawater temperature at 10m depth.

Temperature and salinity distributions at station 3 in front of Ría de Vigo from 94 to 97 are shown in Figure 9. This period marks an important change in seawater temperature all over the water column. The 13°C isotherm is located around 40 m depth during 1994 and 1995, in the following years only appears occasionally, playing the same roll that 12°C water had played in previous years, near the bottom or at surface in winter. Signal of the poleward current (higher temperature and salinity) clearly appears at the end of 1994 and 1995, but not clearly noticeable in 1996, and a strong warming appears in autumn 1997 (17°C water reach 60 m depth), but the signal in salinity is not detected. Maybe it is due to the fact that there was no sampling in December.

Salinity has an increasing trend as was in Santander. Since autumn 95 most of the water column has salinity higher than 35.75. In January 96 salinity reached 36.00, this could be the signal of the poleward current that in the mouth of the Ría appear below the runoff water. The mean value of temperature from 5m to the bottom in the spawning time (March – May) gives an increasing trend in temperature from 1995 and also the mean salinity values from 10m to the bottom since the decrease that occurred in 1994 (figure 10). Both parameters continued to increase during 1997.

As summary, 1997 marks the return of the warming trend, mainly in the last part of the year in Santander, but in Vigo this increase occurred the previous year. Salinity also has an increasing trend in the upper waters of the North and North Western of the Iberian Peninsula.

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Lavín A., L. Valdés, J. Gil and M. Moral 1998 Seasonal and interannual variability in properties of surface water off Santander (Bay of Biscay) (1991-1995) Oceanologica Octa (in press)

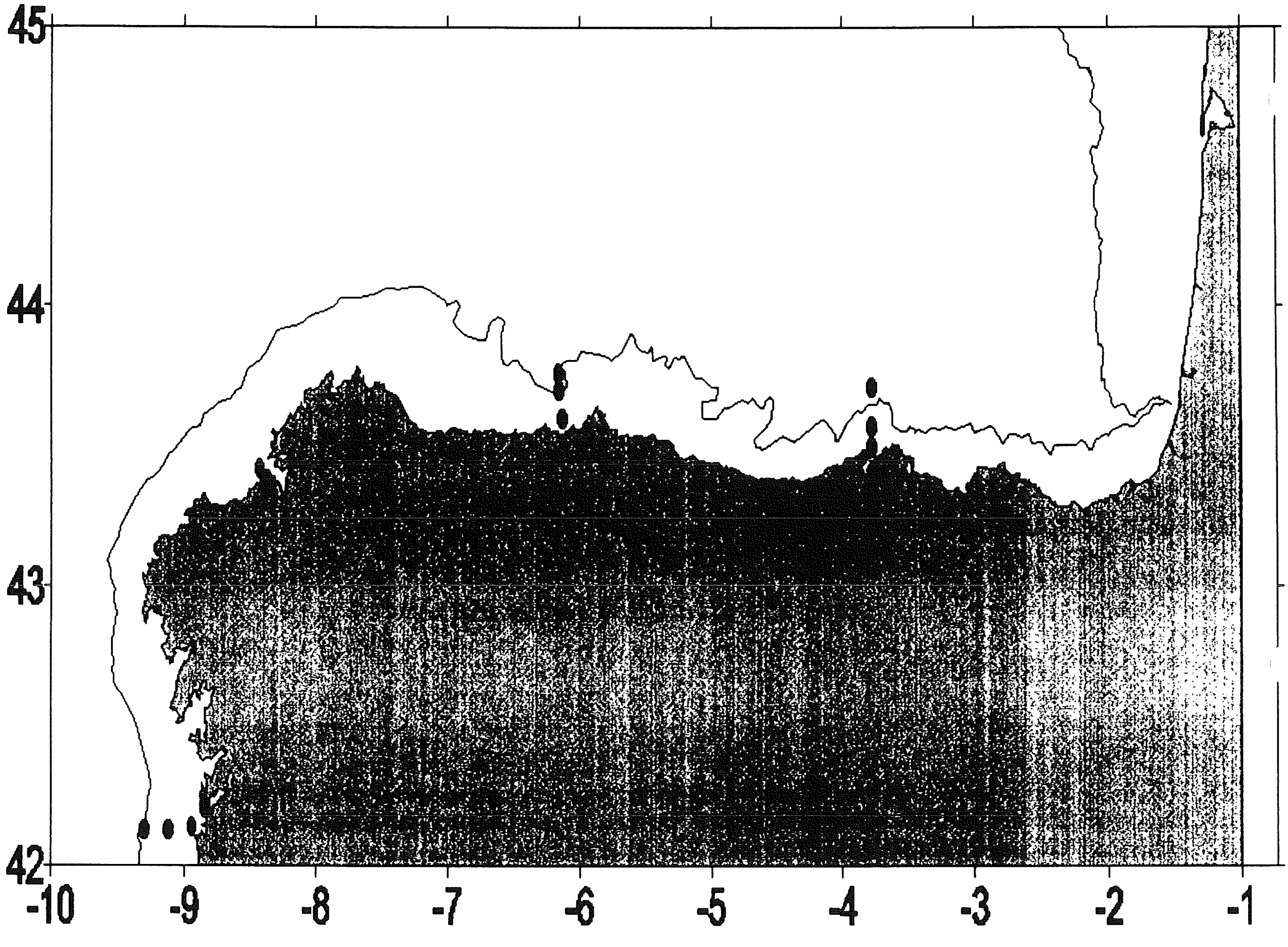


Fig. 1 Location of the Sections

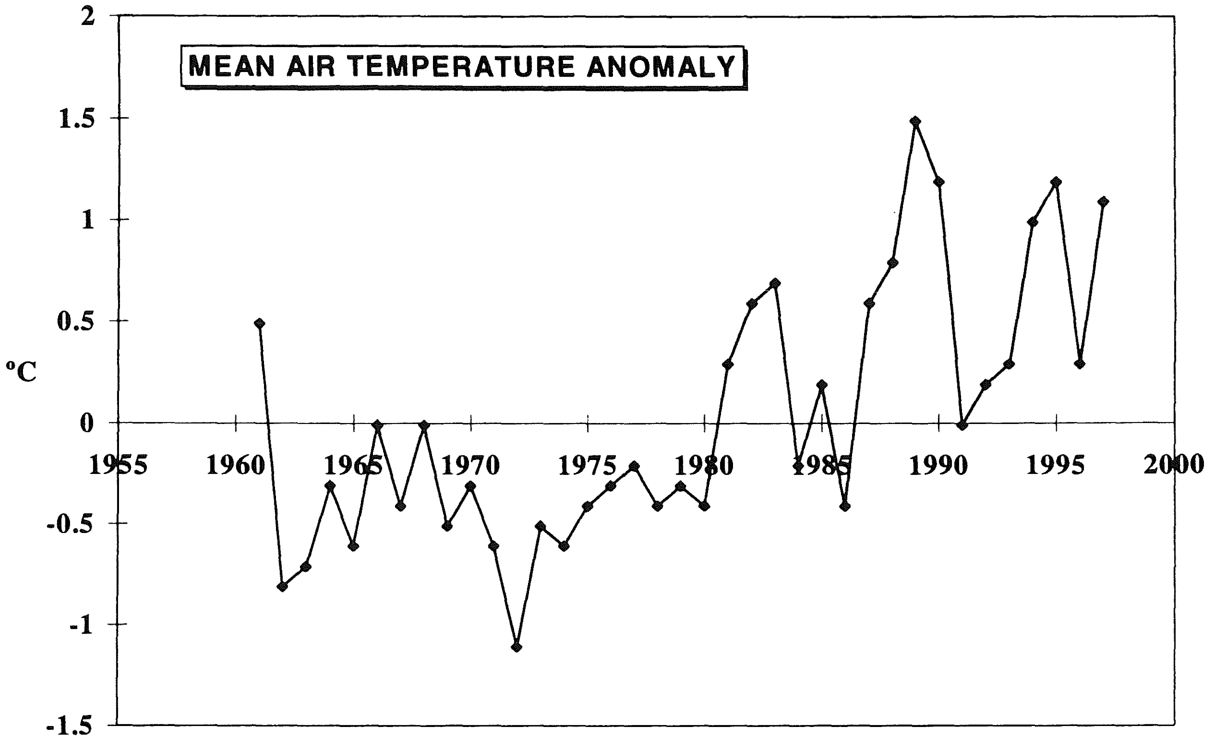


Fig. 2 Anomalies in annual mean temperature relative to the 1961-1990 mean. Centro Meteorológico de Cantabria y Asturias. Instituto Nacional de Meteorología

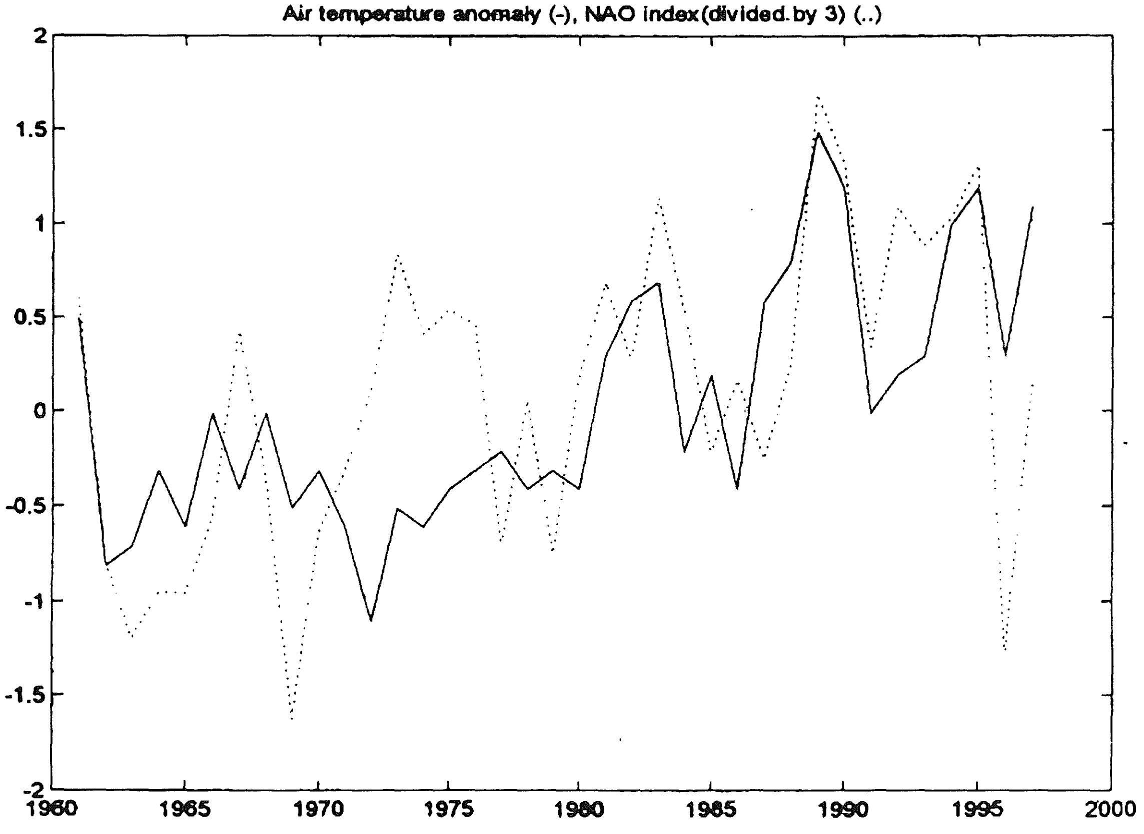


Fig. 3 Anomalies of air temperature and NAO index from 1961 to 1997

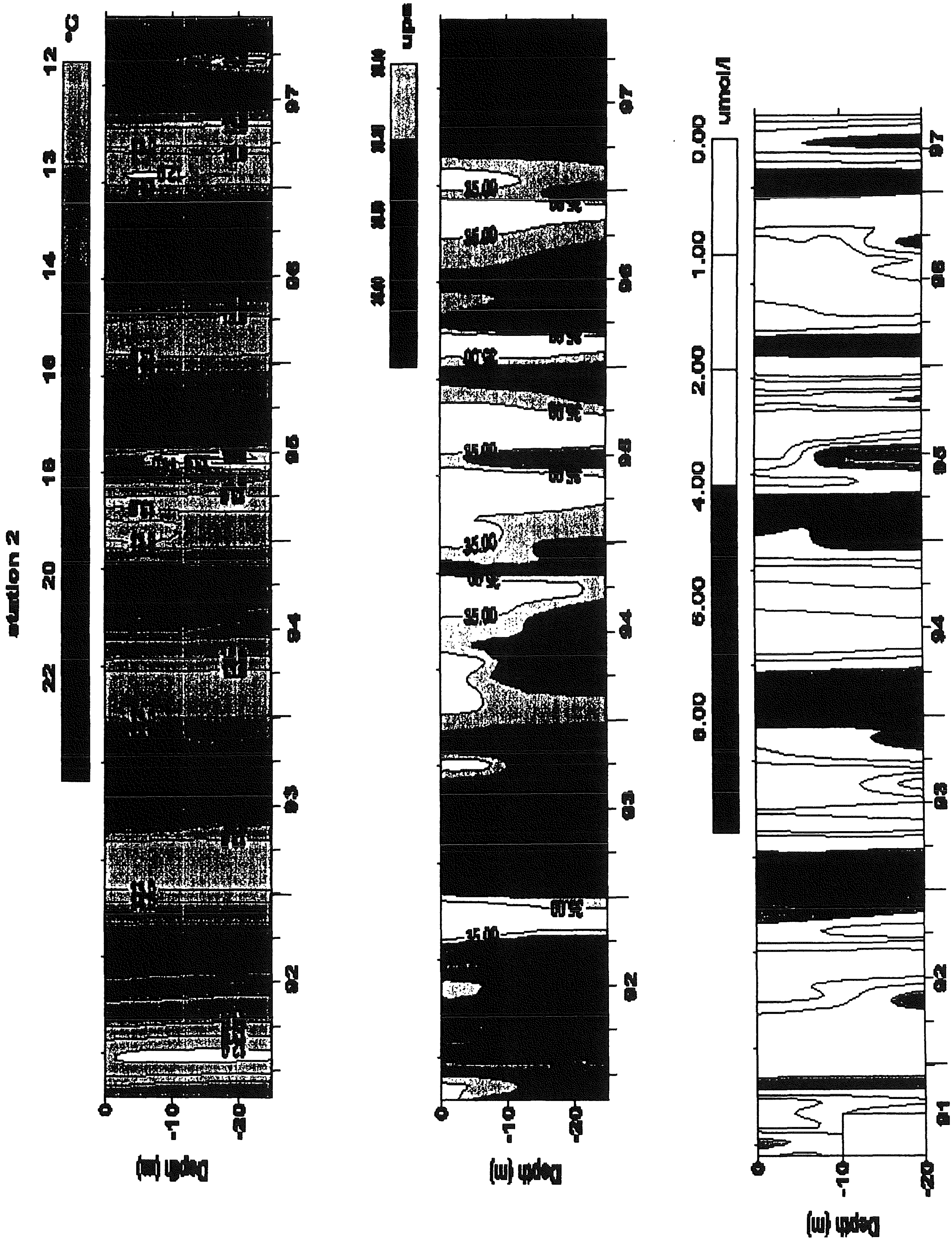


Fig. 4 Distribution of temperature, salinity and nitrates at station 2 (Santander Section)

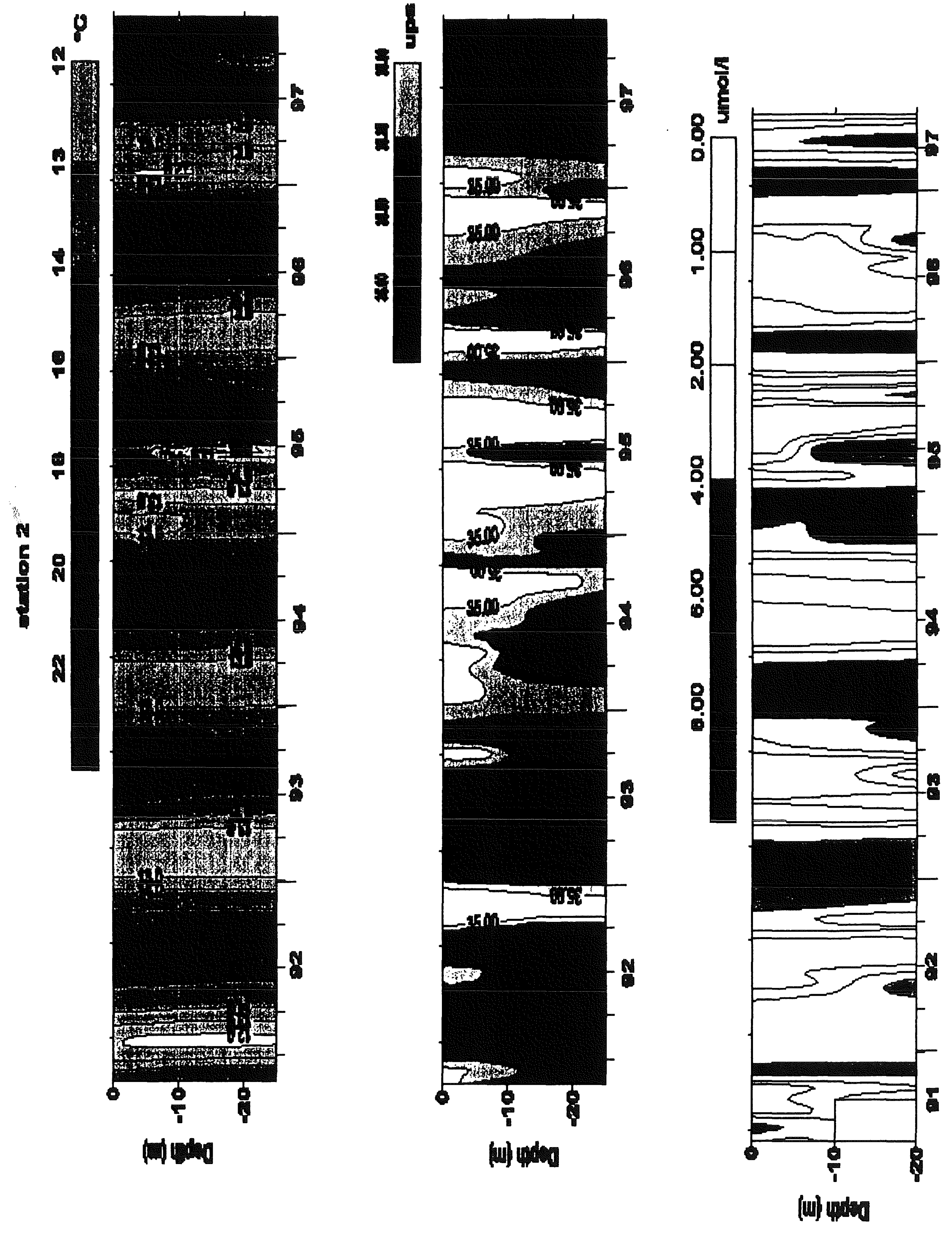


Fig. 5 Distribution of temperature, salinity and nitrates at station 4 (Santander Section).

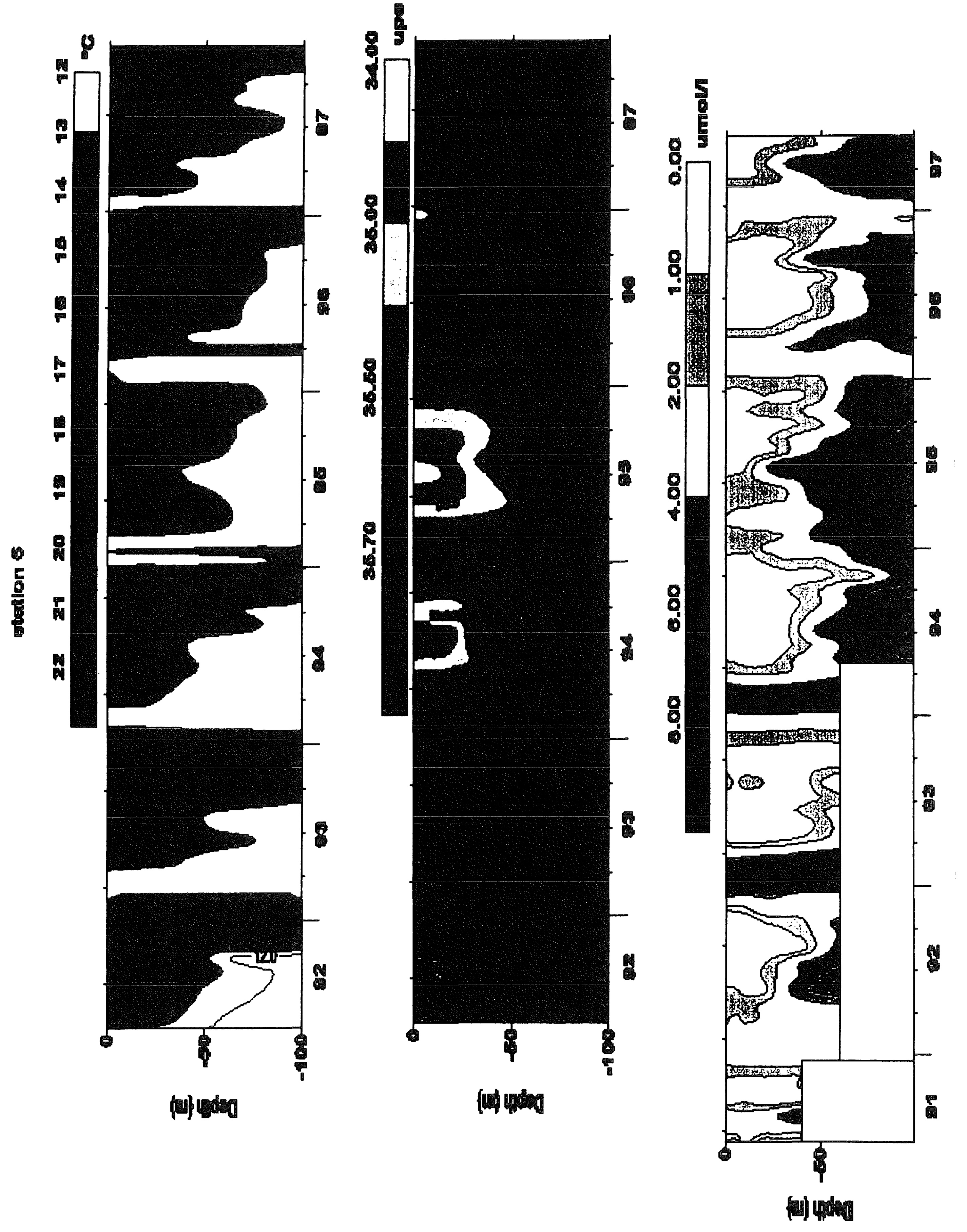
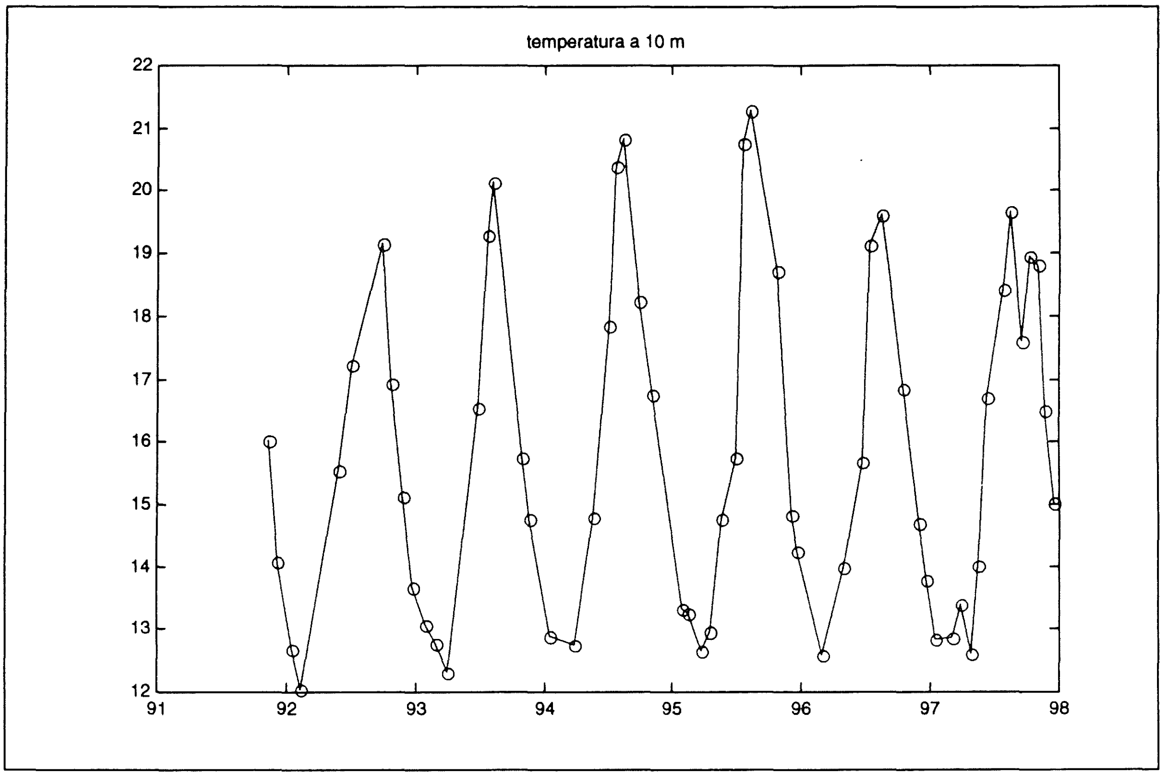


Fig. 6 Distribution of temperature, salinity and nitrates at station 6 (Santander Section)



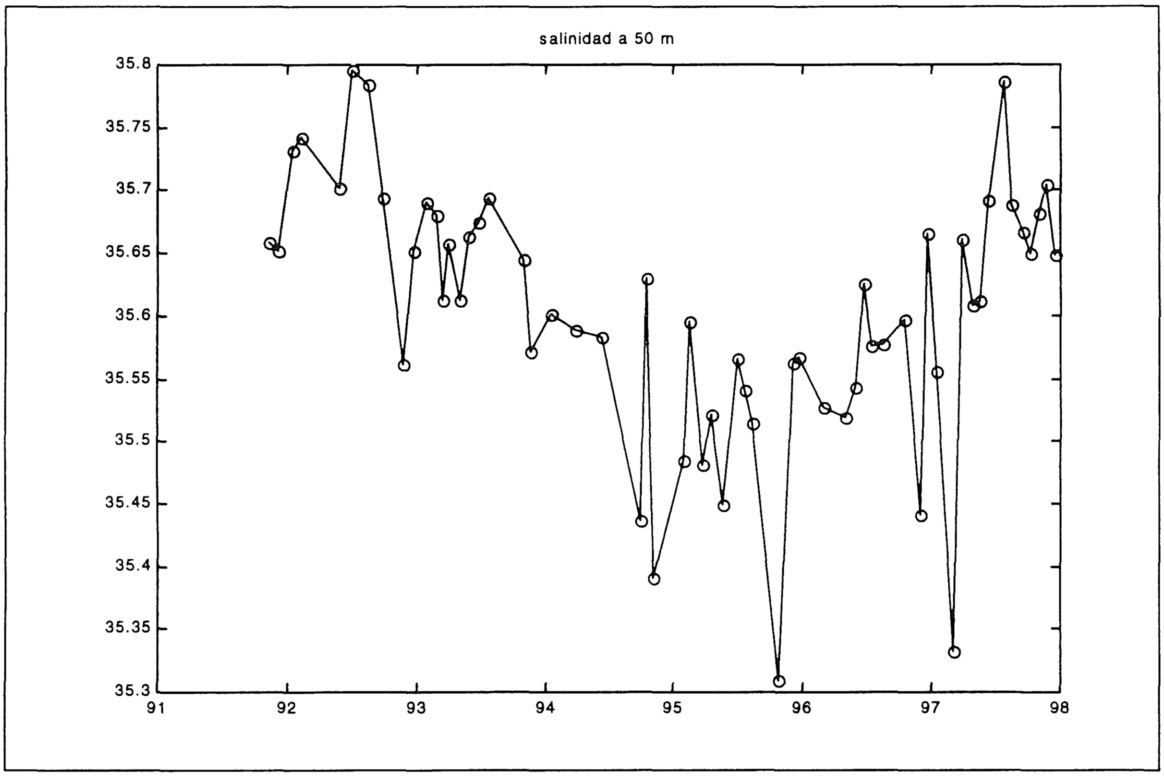
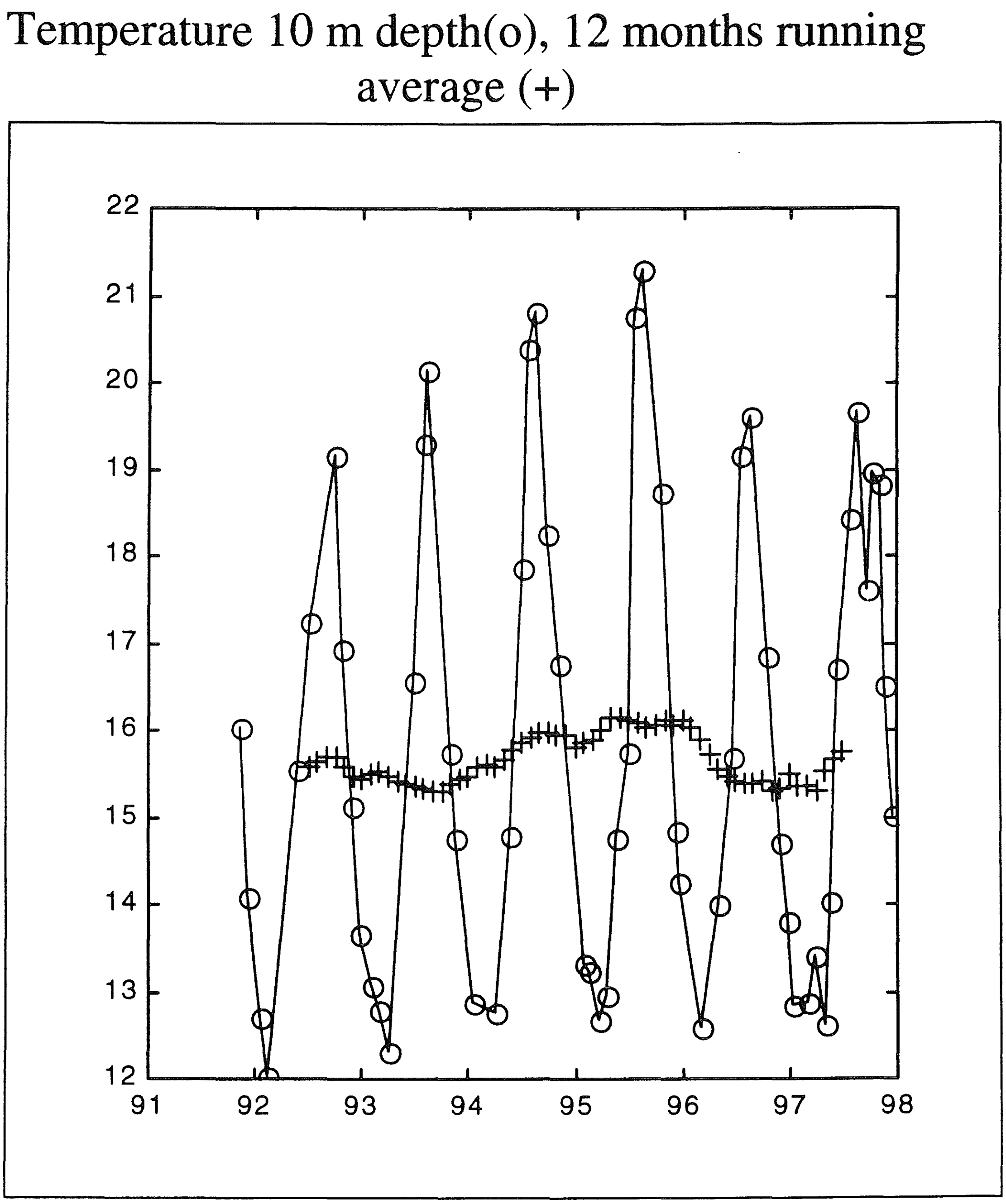
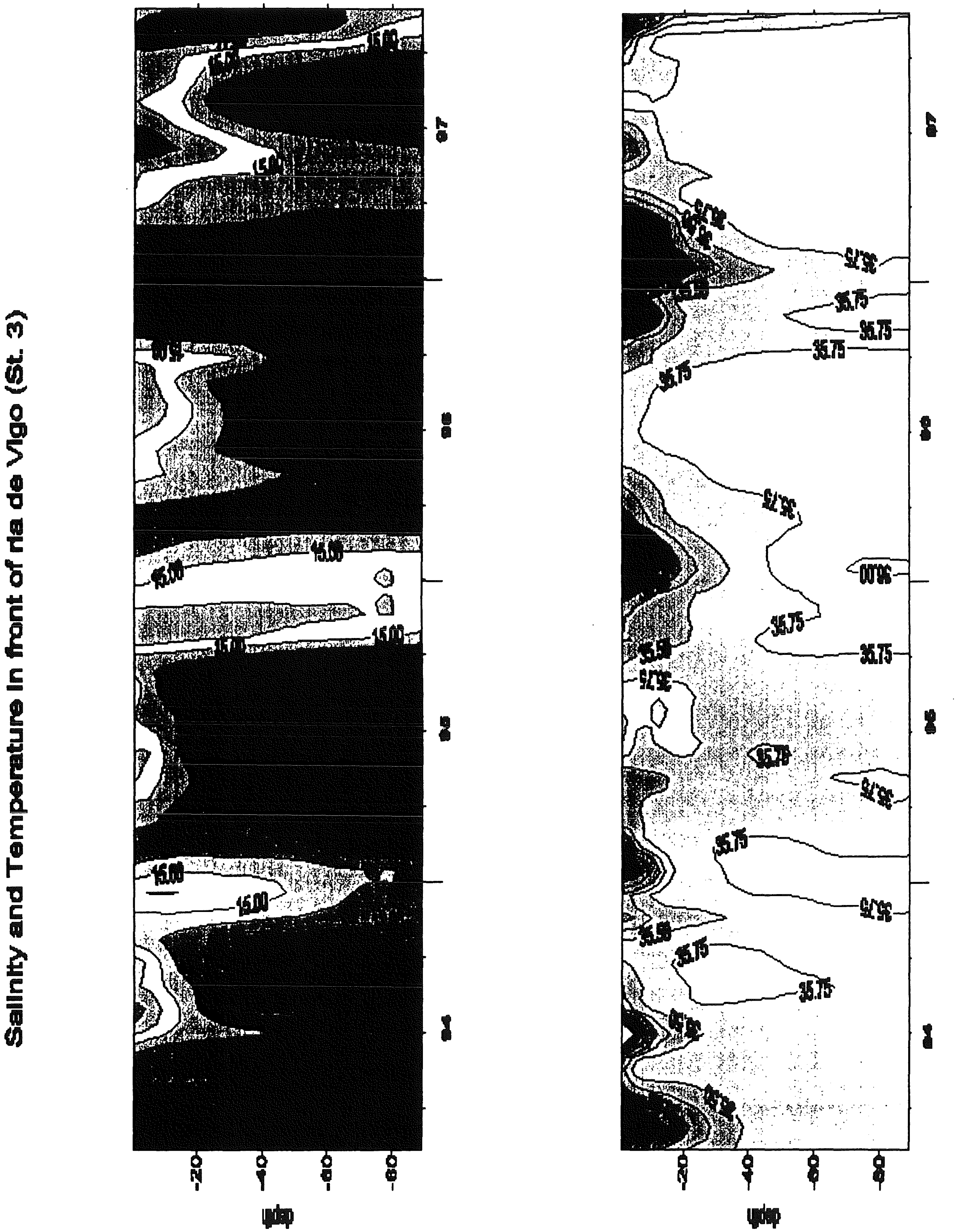


Fig. 7 **A: Temperature at 10 m depth at station 4**
B: Salinity at 50 m depth at station 4
(Santander Section)



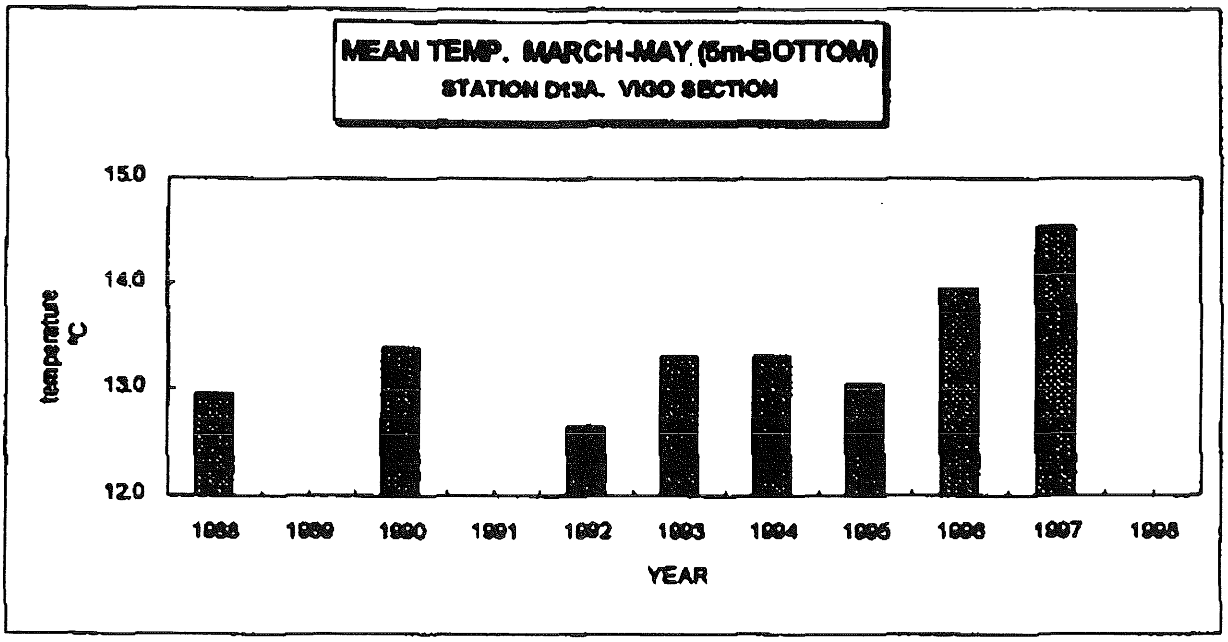
Temperature 10 m depth(o), 12 months running average (+)

Fig. 8 Temperature at 10 m depth at station 4 and 12 months running mean (+) (Santander Section)



Salinity and Temperature in front of ria de Vigo (St. 3)

Fig. 9 Distribution of Temperature and Salinity at station 3 (Vigo Section)



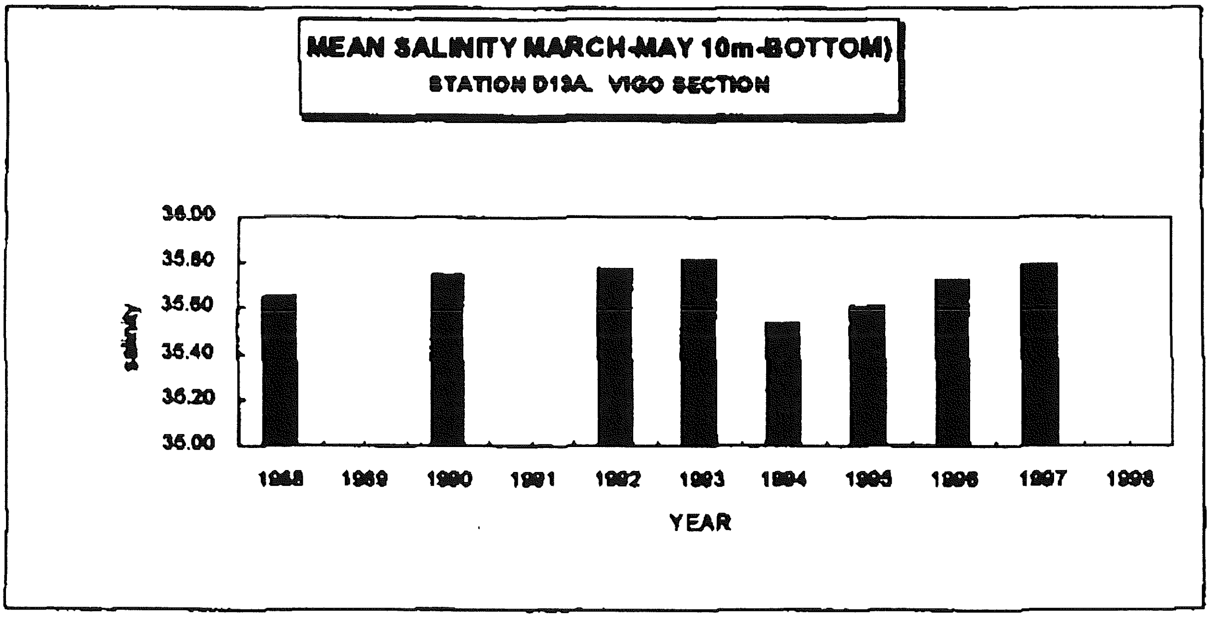


Fig 10 Distribution of mean temperature (5m to the bottom) and mean salinity (from 10m to the bottom) at station 3 (Vigo Section) from 1988 to 1997

Annex F: Norwegian Sections

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Norwegian Sea

The time series in Fig. 1 are from sections across the Atlantic inflow in the southern, central and northern part of the Nordic Seas, observed in July/August. The graphs indicate properties in the main core of Atlantic water just off the shelf break, presented as mean values for the core water, averaged vertically between 50 and 200 m depth and horizontally across the core. In general, both temperature and salinity increased from 1996 to 1997 with the largest rise in the southern Norwegian Sea. As demonstrated in the Svinøy - NW section (Fig. 1), the temperature increase which amounted to 1.07°C, resulted in the highest temperature for the whole period since 1978. This interrupted a period since 1991 with temperatures close to the average and salinities mainly below average. Also in the central Norwegian Sea (Fig. 1 - Gimsøy - NW) the increase was considerable with a temperature rise from the lowest of the observational period in 1996 to well above the overall mean. The salinity was close to average after a moderate increase since 1996. Near Spitsbergen (Fig. 1 - South Cape section) the properties changed little since 1996, remaining near the overall mean in both temperature and salinity.

While the salinity increase after the Great Salinity Anomaly can be considered to be completed by 1981, there has generally been a decrease in salinity since then. This amounted to 0.09 PSU in the Svinøy section and to 0.03 and 0.06 in the two other sections, northward. The reason for smaller salinity decrease in the central Norwegian sea than further south and further north, seems to be less influence of Arctic water ultimately coming from the upper layers of the East Greenland Current, principally via the East Icelandic and Jan Mayen currents.

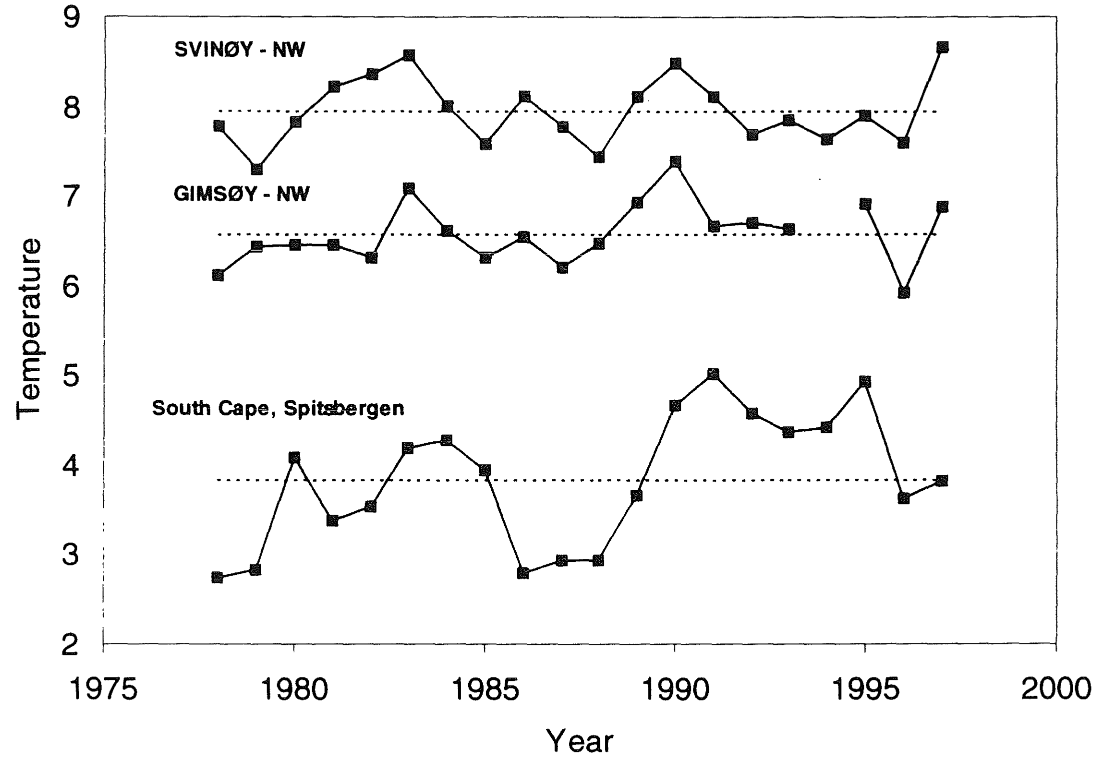
The Gimsøy and South Cape sections show a warming since 1978. The reason for this is probably reduced regional cooling, partly due to mild winters and partly due to increasing stability in the water column as a result of the warming and freshening. Note also that the warming in the Svinøy section is less than the warming in the inflowing water over the Scottish slope in the Faroe-Shetland Channel, probably as a result of the influence from the East Icelandic Current

Barents Sea

The Barents Sea is a shelf area, receiving an inflow of Atlantic water from the west and demonstrating considerable inter-annual fluctuations in water mass properties, particularly in heat content and consequently ice coverage. Controlled by the bottom topography the inflow bifurcates, with the main branch flowing eastward in the southern Barents Sea. Time series of temperature and salinity, averaged between 50 and 200 m depth across the main branch in three standard sections are shown in Fig. 2.

Temperatures in the Barents Sea were generally above the long-term mean during the period 1989-1995, with the warmest conditions in 1991-1992. During 1996 and 1997 temperatures in the western Barents Sea (Fig. 2 - Fugløya - Bjørnøya section) decreased to a value slightly below the long term mean while in the central area there was an increase in 1997 compared with 1996, bringing the temperature to about the long term mean (Fig. 2 - Vardø - N section). In the eastern Sem islands - N section no observations were obtained during 1997. The salinity fluctuations were parallel to the temperature variation, bringing the salinity close to the long-term mean in the Vardø - N section and somewhat below in the western Barents Sea. The decrease in temperature has coincided with increasing ice cover during the two last winters.

Also in the Barents Sea the long-term trend is characterised by a warming and freshening. The salinity shows the same general decrease in all the three sections, amounting to about 0.04 PSU during the period 1964-1997. The warming trend is, however strongest in the east, increasing from about 0.3°C in the western Barents Sea to about 0.5°C in the Sem islands - N section. This shows that the warming is due to reduced winter cooling while the salinity decrease derives from the reduced salinity in the Norwegian Atlantic Current.



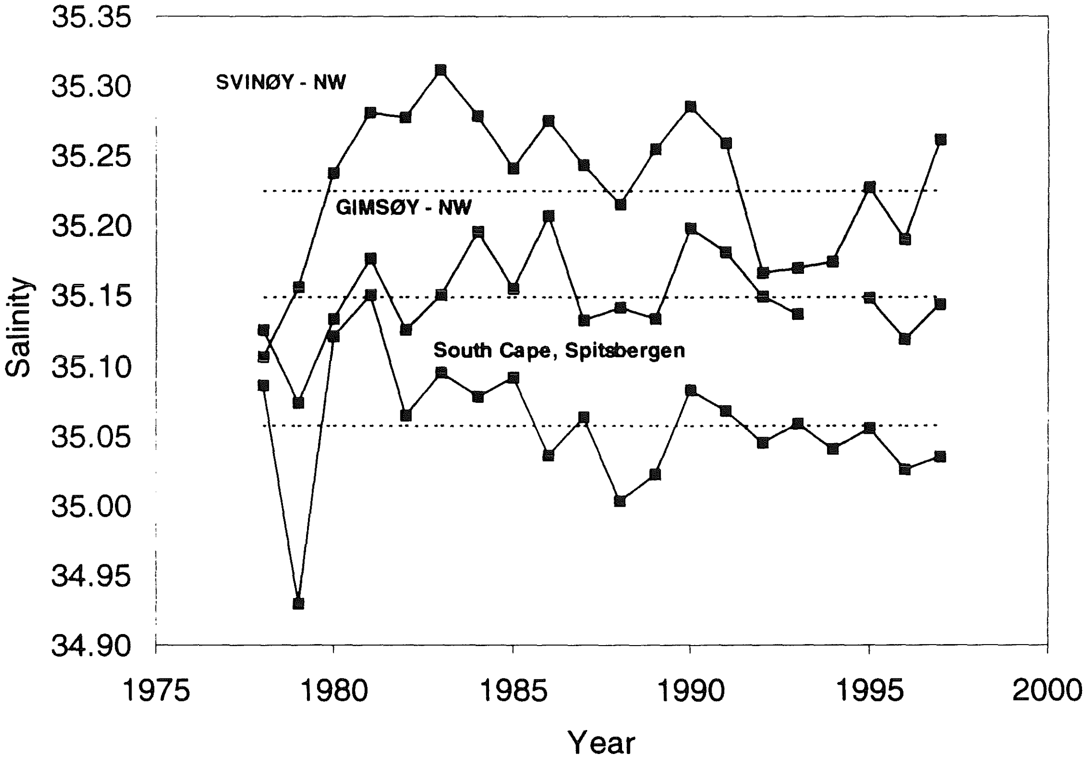
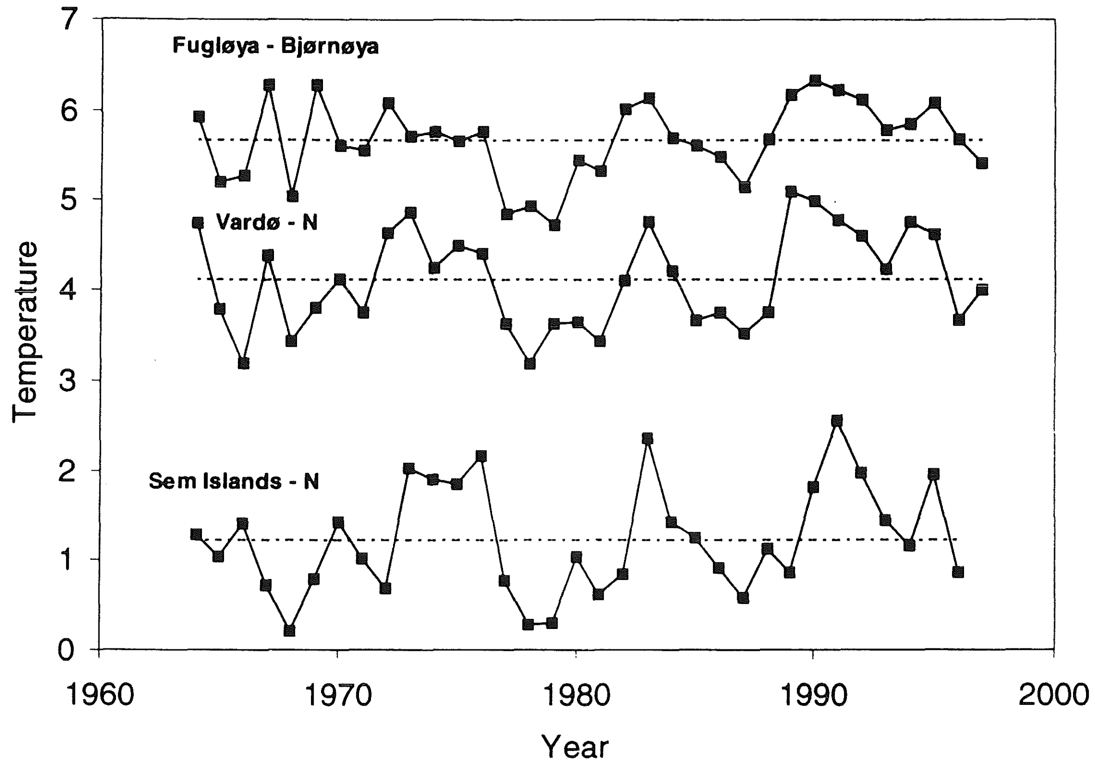


Fig. 1 Temperature and salinity observed in July/August in the core of the Atlantic water in the Norwegian Sea; Southern Norwegian sea - Svinøy-NW, central Norwegian Sea - Gimsøy-NW and northern Norwegian Sea - Sørkapp-W. Values have been averaged between 50 and 200 m depth.



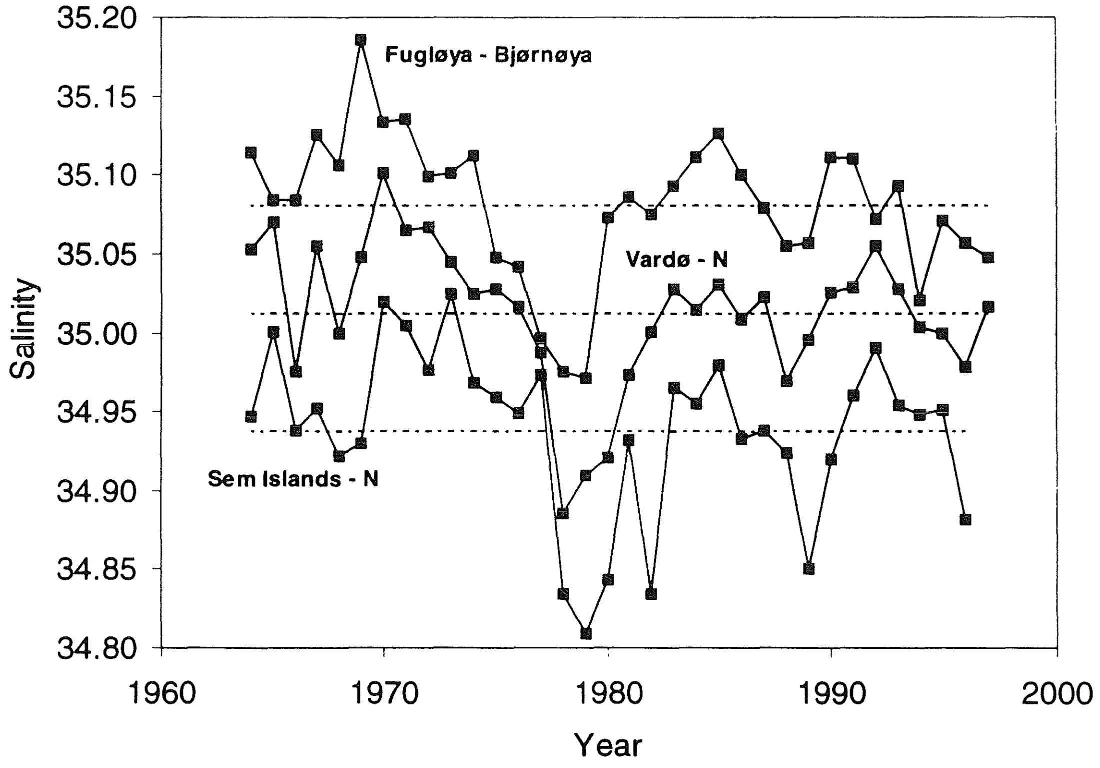


Fig. 2 **Mean temperature and salinity between 50 and 200 m depth in the Barents Sea, at the Fugløy-Bjørnøy Section (between 19°E, near Bear Island, and 20°E on the Norwegian Coast), Vardø-N (along 31° 13'E) and the Sem Islands-N Section (along 37° 20'E). Observations are from August/September 1964-1996**

Annex G: Oceanographic Conditions in West Greenland Waters

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The Greenland Fisheries Research Institute has since its foundation in 1947 has been occupying NAFO sections in Subarea 1 at least once a year and especially the Fylla Bank section several times per year. The observations from these sections, though intermittent especially during the early years, except from Fylla Bank which was more readily accessible because of its proximity to Nuuk, where the research ships of the Greenland Fisheries Research Institute is stationed, are used to examine the oceanographic conditions in west Greenland waters.

Surface conditions

One of the important oceanographic time series from West Greenland is the Mid-June mean temperature on top of Fylla Bank (Fylla Bank st.2, 0 - 40 m), which the Greenland Fisheries Research Institute maintains due to its importance to the cod stock assessment (Fig. 1).

The temperature may vary quite drastically from one year to the next, often more than by 1°C, reflecting the variability of both the atmospheric influence and the inflow of Polar Water. In addition, these temperatures reflect the large-scale climatic variability,
revealing some very distinct climatic events:

- The 1950 - 1968 period generally showed high temperatures around 2°C.
- Around 1970 a cold period - the coldest - was experienced. The cold climate of this period was due to an anomalous high inflow of Polar Water, (Buch, 1990) which was closely linked to the "Great Salinity Anomaly", Dickson et al. (1988).
- The early 1980's and early 1990's two extremely cold periods were observed reflecting the cold atmospheric conditions in the Davis Strait area.
- A remarkably low temperature was observed in 1997 although the atmospheric conditions were quite warm, which could indicate a high inflow of Polar Water.

The "Great Salinity Anomaly" around 1970 is clearly reflected in this data set, while the climatic anomalies in the early 1980's and 1990's are not reflected in any significant way in the surface salinities at Fylla Bank. This may be because the 80s and 90s cold periods were due to atmospheric cooling.

Relatively low salinity's were observed in 1996 and 1997 indicating that the inflow of Polar Water have been above normal in these years. This could be a sign of a new "Salinity Anomaly" although not yet of the same dimension as the one experienced around 1970. Analysis of data from the other West Greenland sections show extremely low salinity values at the sections north of Fylla Bank (station 2 on the Lille Hellefiske Bank - and Holsteinsborg sections) in 1996, comparable to the low values observed in the late 1960's. At the southernmost sections - Cape Farewell to Frederikshaab – where the time series are short, but judged from the observations made in June-July since 1992 abnormally low salinities were observed only at the Cape Farewell section in 1996.

It may therefore be concluded that in 1996 a "low salinity signal" was observed in the Polar Water component off Southwest Greenland at most sections.

1996 and 1997 was additionally characterised by a high inflow of Atlantic Water (Irminger- as well as Sub-Atlantic Water) in the southern part of Southwest Greenland physically evidenced by surface temperatures well above 6°C, in 1996 even above 7°C, at the outermost stations at the Cape Farewell Section.

Further offshore - just west of the fishing banks there exists relatively long time series of July temperatures and salinities from the following sections and stations:

- Fylla Bank st.4, start 1952
- Lille Hellefiske Bank st.5, start 1970
- Holsteinsborg st.5, start 1970

The mean temperatures and salinities of the upper 50 meters from the three stations are shown in Fig. 2. The time series reveal that

- The overall tendency in the interannual variability at the three stations are comparable although individual years may show large differences in temperature and salinity as well as opposite signs in the development from the preceding year.
- Generally the highest temperatures and salinities are observed at the Lille Hellefiske Bank, while the lowest salinities most often are observed at Fylla Bank. This is due to the fact that the Fylla Bank area is influenced by Polar Water and the Holsteinsborg station at this time of the year often is influenced by melting west ice and possibly also by cold, relatively fresh water of Polar origin flowing southward on the Canadian side of the Davis Strait; but none of these reach the Lille Hellefiske Bank area.
- The three cold periods mentioned above is also reflected in these time series. Opposite to the conditions at Fylla Bank St.2 a significant decrease in salinity was observed at all three stations during the 1982 - 1984 period, especially in 1982 which properly was caused by a high inflow of polar ice to the Southwest Greenland area in 1982 combined with the heavy formation of ice in the Davis Strait during the extremely cold winters in 1983 and 1984.
- Relatively warm and saline conditions were experienced in 1979-80.
- Some years extremely cold and low saline conditions were observed at the Holsteinsborg station, which is due to the presence of ice at the time of observation.

Deeper layers

The variability in the deeper layers are illustrated by the July time series of temperature and salinity from the same three stations just west of the fishing banks that were used above. In Figs.3, 4 and 5, the mean values of temperature and salinity are given for the depth layers, 50 – 150 m, 150 - 400 m and 400 - 600 m in the water column. This layering has been chosen for the following reasons:

- The 50 - 150 m layer is mainly influenced by Polar Water
- The 150 - 400 m layer is the transition zone between Polar Water and water of Atlantic Origin
- The 400 - 600 m layer is occupied by Atlantic water masses.
- It is the 400 - 600 m layer is occupied by Atlantic water masses.

It is seen from the three figures that there is great interannual variability at all depth levels, although the amplitude of the fluctuations naturally decreases with depth. This is a clear indication of the fact that the Southwest Greenland waters are influenced by the dynamics of several currents having their origin in different parts of the North Atlantic. The variability of the oceanographic conditions in the Southwest Greenland area therefore reflects the individual strengths of the various currents the particular year but also the climatic signal that the currents carry with them from their respective area of origin.

In the 50 - 150 m Layer the temperature fluctuations in general follows the same pattern as was observed in the surface layer. The cold periods are clearly seen also in this layer, because vertical convection caused by the extreme atmospheric cooling during wintertime creates cold conditions in this layer and superimposed on this is the inflow of cold Polar Water. The fluctuations in the salinity signal have, as expected, decreased compared to the surface layer. In 1982 the salinity was extremely low at the Fylla Bank station, actually it was even lower than during the period with the Great Salinity Anomaly" around 1970. This is a clear sign of a great inflow of Polar Water and as mentioned above 1982 was a year with a great inflow of Polar Ice to the Southwest Greenland area, which is a clear sign of a high transport rate in the Fast Greenland Current. In 1997 both the Fylla Bank and the Lille Hellefiske station showed relatively low salinity's as well as relatively low temperatures which could be a sign of a new salinity anomaly as discussed earlier in relation with surface conditions, although the negative trend in 1997 is less compared to those around 1970 or 1982.

In the 150 - 400 m layer the temperature fluctuations still are sizeable. The cold periods still can be recognised but it is evident that other signals play a dominant role in this layer, which of' course was to be expected in a layer forming the transition between two different current regimes. The warm conditions as experienced in the late 1970's and late 1980's therefore reflect a dominance of water of Atlantic origin i.e. Sub-Atlantic Water.

The salinity is generally highest at the Lille Hellefiske Bank, which may be due to the fact that at this depth interval the Fylla Bank and the Holsteinsborg stations are more influenced by Polar Water than the Lille Hellefiske Station. Extremely low salinity values were observed at the Fylla Bank station around 1970 and in 1982, 1984, 1990 and 1997, which can be interpreted as a sign of Polar Water dominance and confirms the trends observed in the shallower layer except for the 1984 situation. The low saline conditions at Fylla Bank in 1984 was discussed was discussed by Buch. 1990, who argued that vertical convection during the previous extremely cold winter had caused huge amounts of low saline surface water to sink to great depth off Southwest Greenland preventing inflow of Sub-Atlantic Water at normal rates.

The 400 - 600 m layer is characterised temperatures around 4°C and salinities around 34.8. Salinities higher than 34.8, and especially values close to 34.9, indicate high inflow rates of lrminger Water. The salinities at the Holsteinsborg station at this depth interval is generally lower than on the other stations, because the Atlantic components, especially the Irminger component, do not in full strength reach as far north as the Holsteinsborg area. The most extreme event was observed in 1984 at Fylla Bank and in the temperature signal also at Lille Hellefiske Bank. The explanation to these low temperature and salinity- conditions is believed to be the same as given above for the similar observations in the 150-400 m layer.

The observations from the summer cruises at the southernmost sections in recent years have not been incorporated into the time series discussed above because the series still are too short. However, it can briefly be mentioned that 1996 and 1997 were characterised by a higher than normal inflow of Irminger Water. Both years a tongue of high saline water ($S > 34.95$) was reaching as far north as to an area between the Frederikshaab and the Fylla Bank sections, and in 1997 water with salinity's above 35 was observed at the Cape Farewell section.

Summary

There are some indications, but not a totally clear picture, of great amounts of Polar Water entering the area in 1996 and 1997 i.e. a new "Salinity Anomaly". The negative anomaly in temperature and salinity can be traced at most of the relevant sections, but the signal is, however, not as strong as the one observed during passage of the well known "Great Salinity Anomaly" around 1970. 1996 and 1997 have additionally been characterised by a higher than normal inflow of Irminger Water to the southernmost part of the Southwest Greenland area.

The great variability in the oceanographic conditions off Southwest Greenland do have a strong impact on the living conditions on a number of fish stocks living close to the limit of existence in this area. The cold conditions experienced in this area during the recent two to three decades have caused a dramatic change in the ecological balance. Cod was found in great quantities from the 1920's up until 1970, since then only in small amount and in recent years, after the latest cold period, cod is almost absent along the West Greenland fishing banks. To Greenland, being almost totally economically dependent on fishery, the disappearance of the most important fish stock is a disaster.

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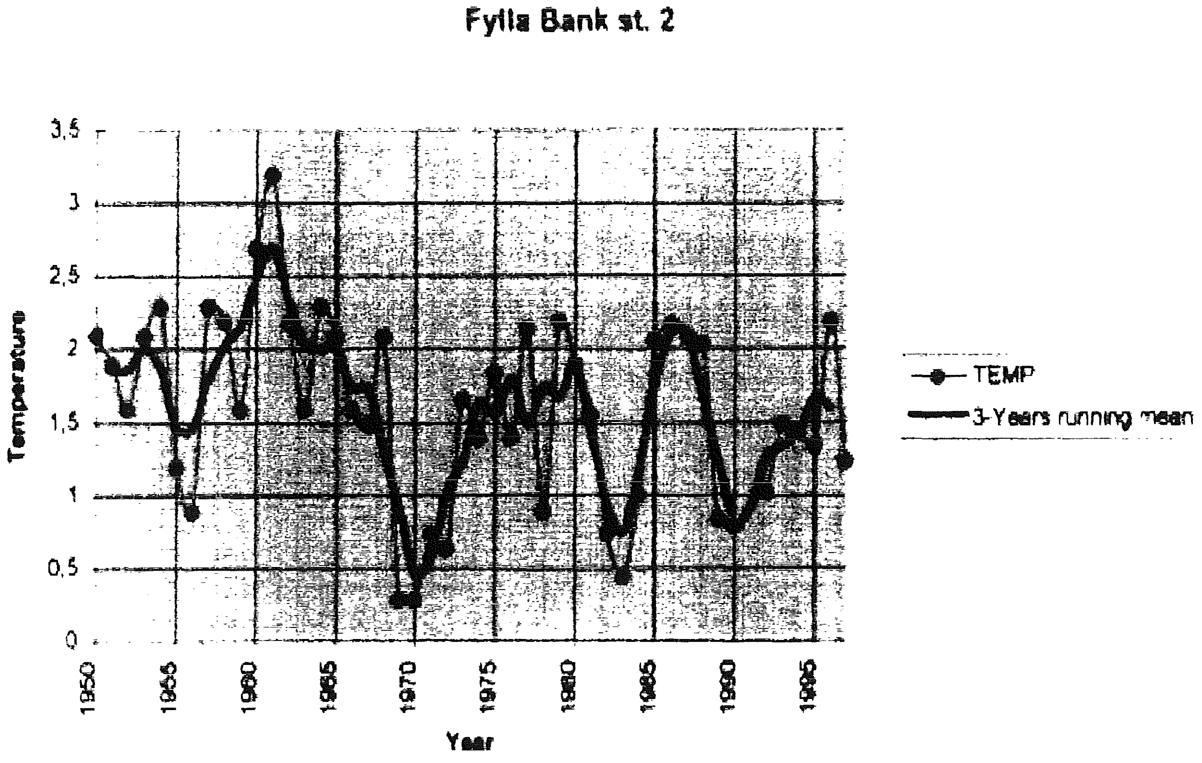


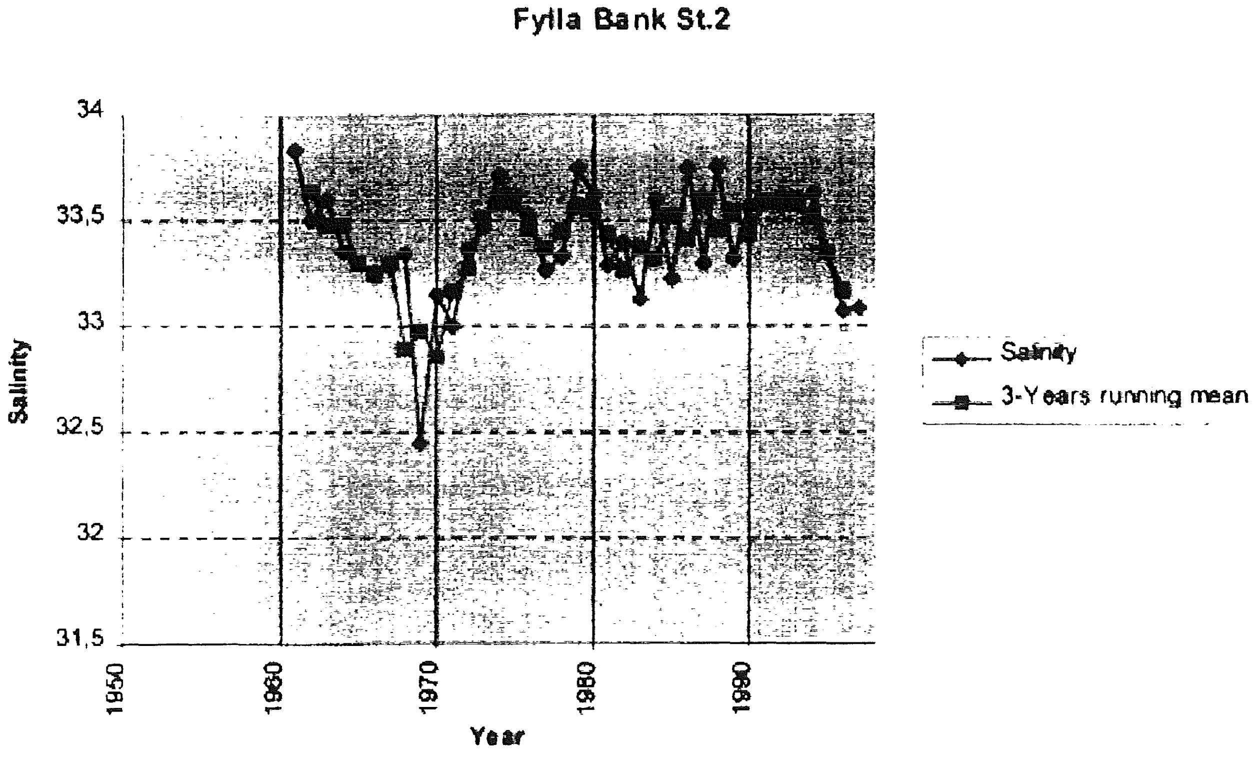


Fig. 1 Depth averaged (0 – 40 m) July temperatures and salinities from Fylla Bank St. 2

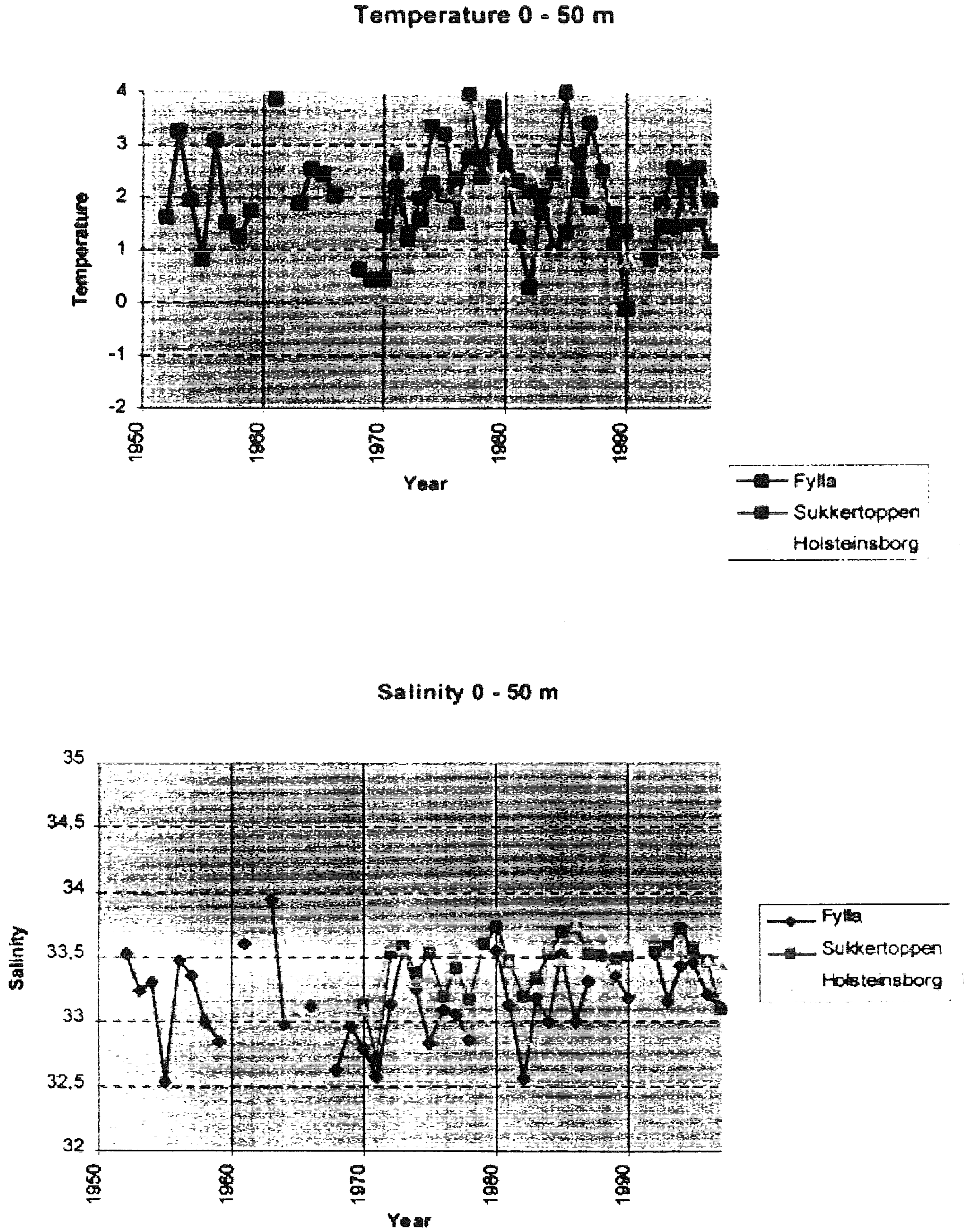
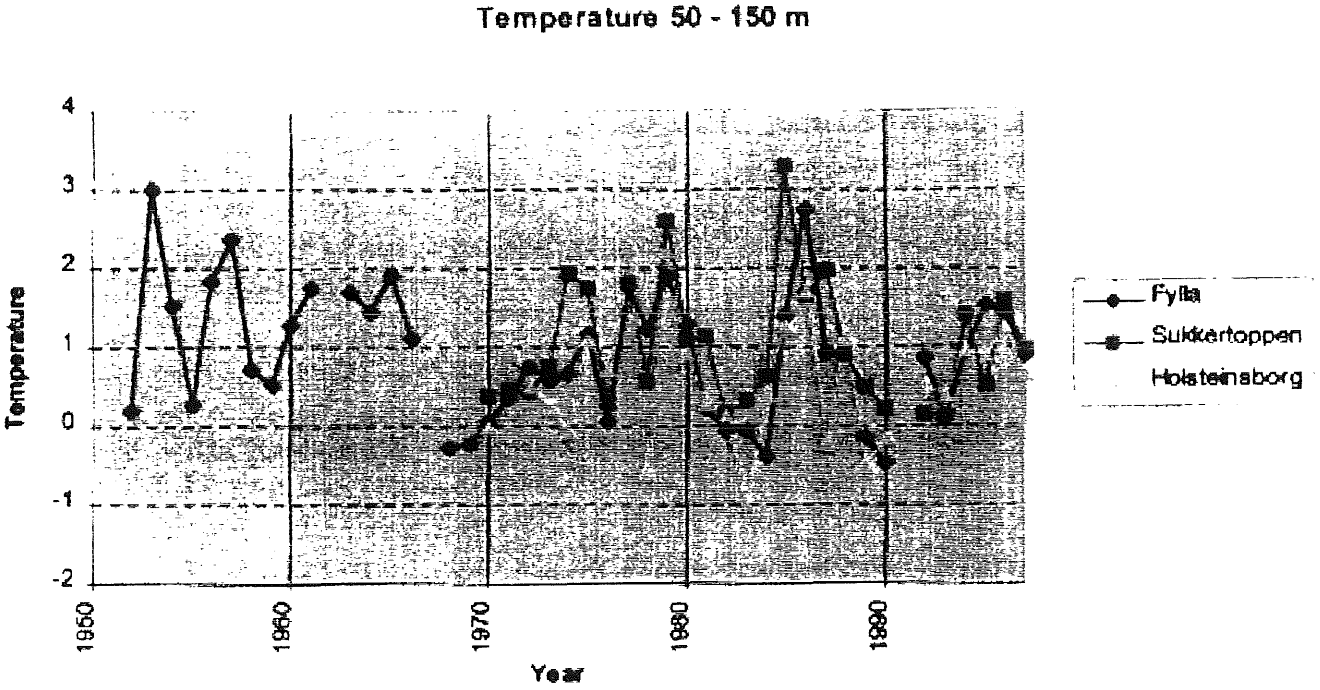


Fig. 2 Depth averaged July temperature and salinity from Fylla St. 4, Lille Hellefiske St. 5, Holsteinsborg St. 5



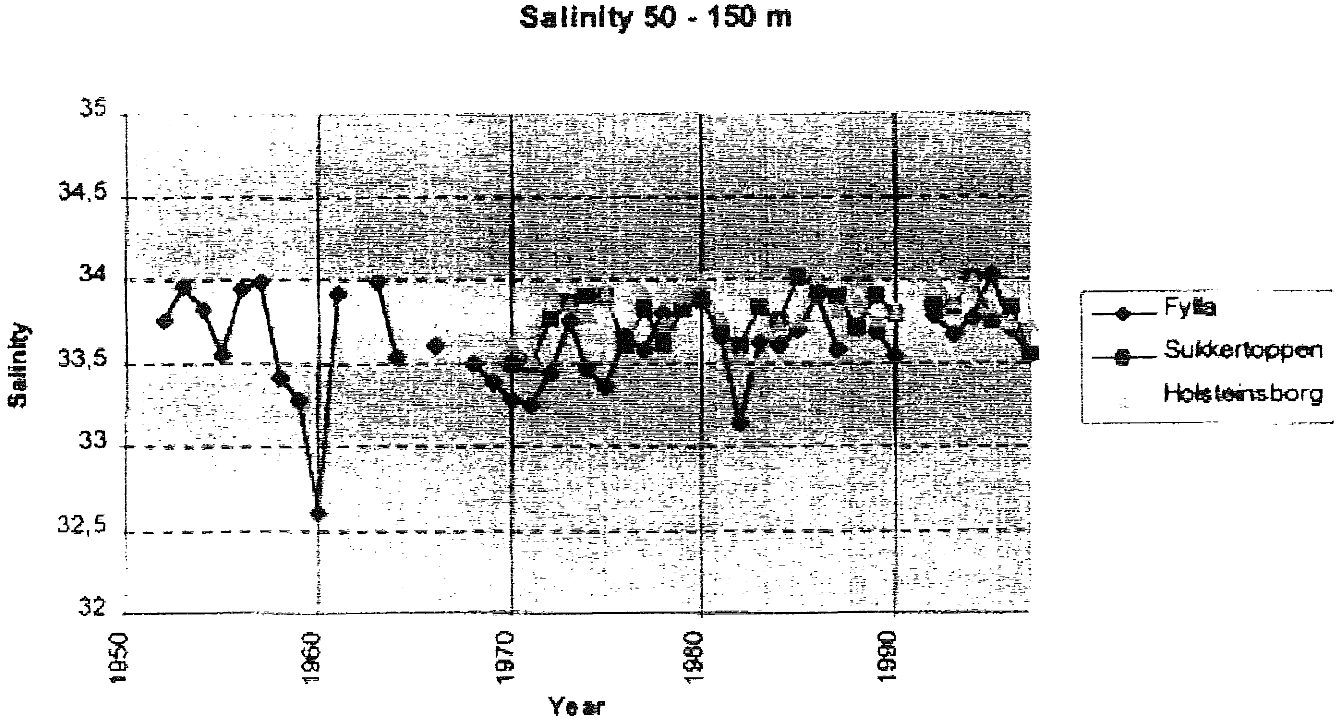
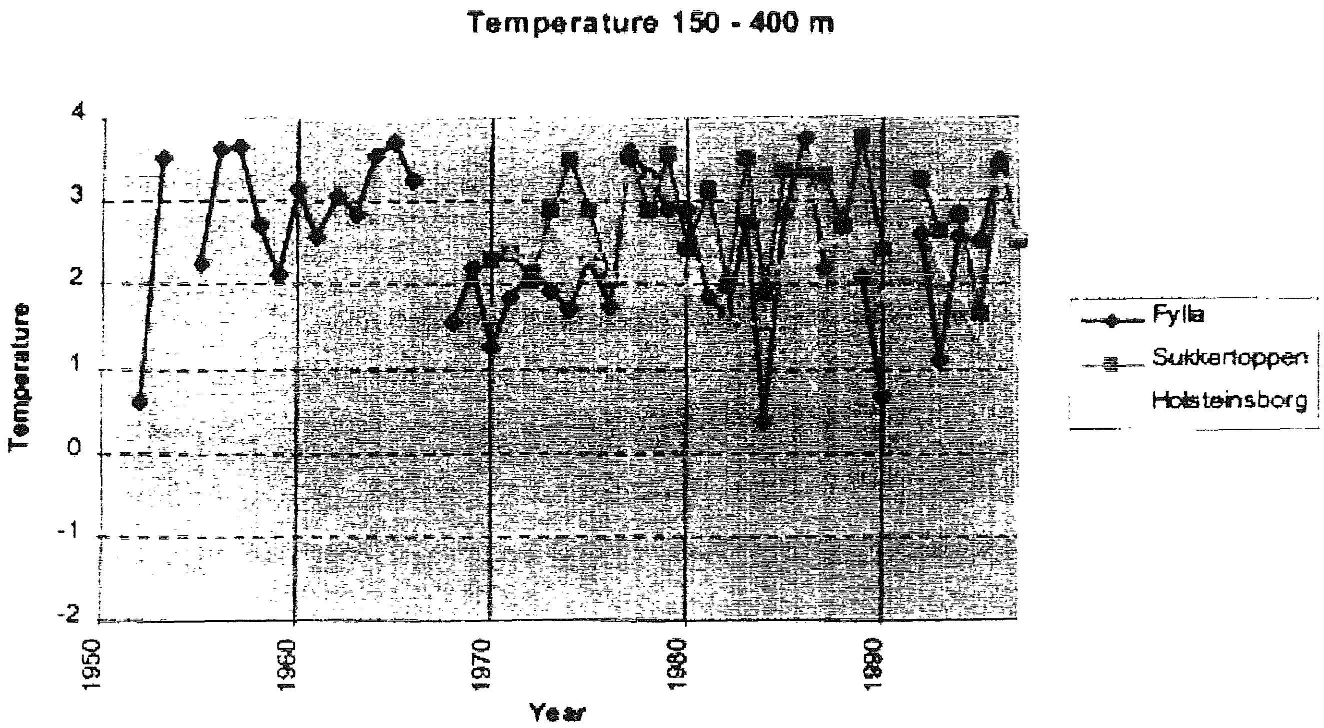


Fig. 3 Depth averaged July temperature and salinity from Fylla St. 4, Lille Hellefiske St. 5, Holsteinsborg St. 5



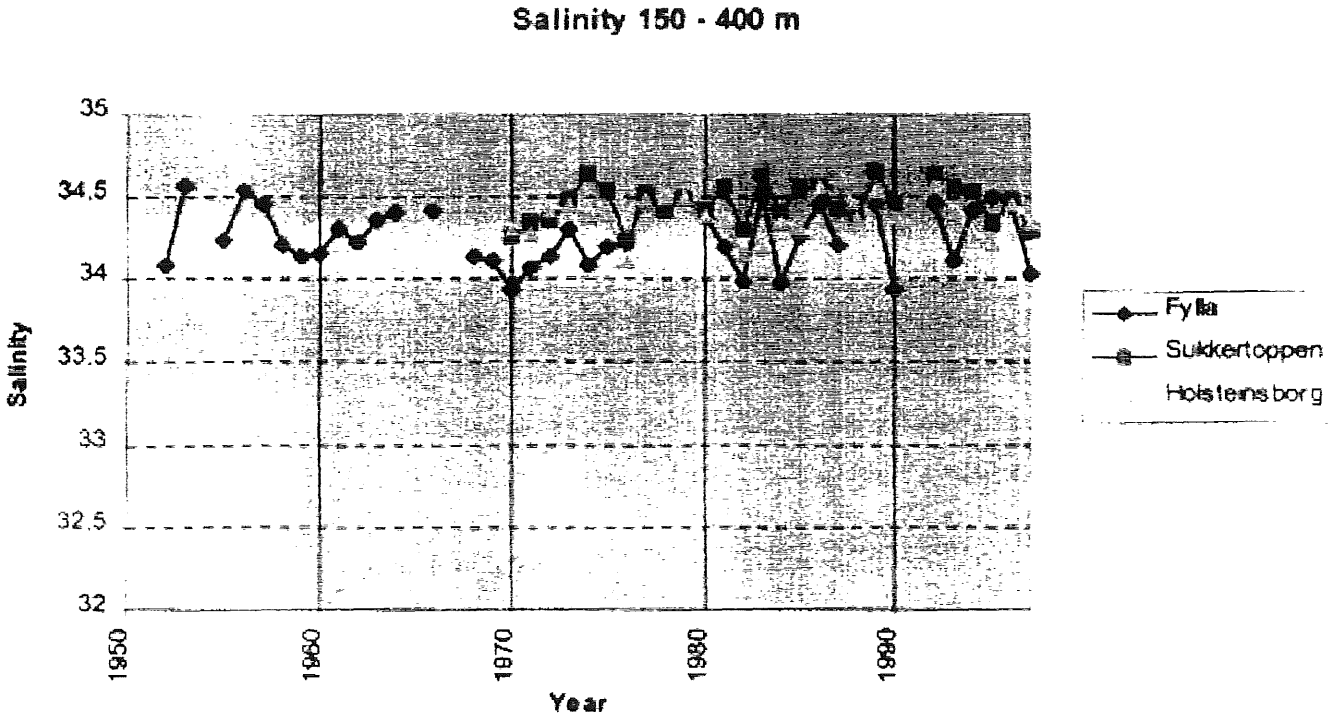


Fig. 4 Depth averaged July temperature and salinity from Fylla St. 4, Lille Hellefiske St. 5, Holsteinsborg St. 5.

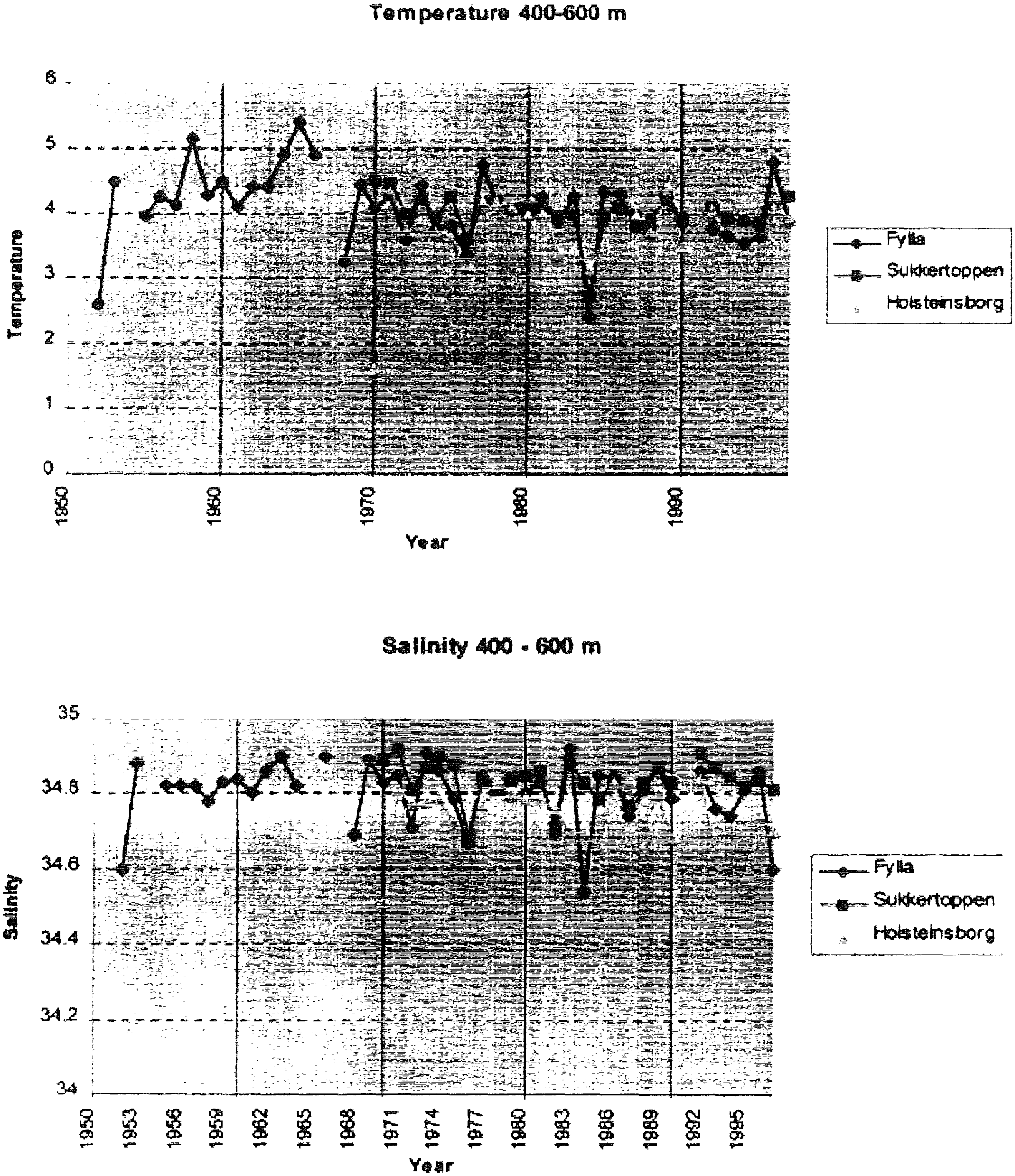


Fig. 5 Depth averaged July temperature and salinity from Fylla St. 4, Lille Hellefiske St. 5, Holsteinsborg St. 5.

Annex H: Results From the Scottish Standard Sections

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Introduction

The two standard Faroe-Shetland Channel sections (Nolso (Faroe) -Flugga (Scotland) and Fair Isle (Scotland) - Munken (Faroe)) have been occupied by the Marine Laboratory Aberdeen on two occasions since April 1997; October 1997 and March 1998. In addition the North Sea JONSIS section was also occupied during these surveys (Figure 1), and during a survey in May 1997.

The results presented here are based on the definitions of time series presented in the Scottish submission to the OHWG 1997 report. These definitions are not ideal, and are being further developed. However they may be used to give an indication of ocean climate change in the areas monitored by Scottish standard sections until April 1998.

Summary of Results

SurfaceWaters

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

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

Modified North Atlantic Water (MNAW), at the Faroese shelf edge, has demonstrated quite different trends to those of NAW (Figure 3). There has been a general cooling of MNAW since 1960 at a rate of O(0.3°C/decade). The rapid warming observed in the NAW since 1987 is certainly not observed in the MNAW, and hence the temperature difference across the channel is increasing.

The salinity of MNAW has also behaved differently from that of NAW. Although the min-max-min-max-min cycle of 1977-1984-1987-1990-1994 is evident in MNAW salinities, it is less pronounced. More prominent is a continued freshening since 1991, which is part of a general freshening since 1960 at a rate of O(0.02/decade). Salinities are approaching those values observed during the GSA period, and are the second lowest this century (Figure 3b).

Intermediate Waters

Trends in temperature cannot be determined in intermediate waters using the present definitions, but salinity continues to decrease (Figure 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) still demonstrates the salinity decline at a rate of O(0.01/decade). The warming observed at 1100 dbar, which commenced in 1990, had disappeared by 1992, after which temperatures have been fairly constant (Figure 5 and 6).

North Sea

In the North Sea the salinity variability in the past has been well correlated with that of NAW, with a possible 1 year lag. Certainly the min-max-min-max-min cycle since 1977 is very evident, in both salinity and temperature. It is now clear that the salinity of mixed oceanic water flowing into the North Sea within the Fair Isle Current (Fair Isle Current Water - FICW) is still tracking that of NAW, with a 1 year lag, and is now showing the salinity rise seen in NAW since 1994 (Figure 7). The cool period previously noted in the mid 1990s was terminated by the onset of a rapid warming since 1994, and like NAW, temperatures in the FICW are now the highest since 1960.

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

Update on Changes at Intermediate Depths in Faroe Shetland Channel

Figure 11 shows the θS diagrams for the last four surveys along the Fair Isle Munken line. The dramatic change, which occurred in March 1997, can now be put into some context. The θS curve for October 1996 may be seen as somewhat typical of the present decade, with an inflection at approximately 3°C indicating the presence of the influence of AI/NIW and a salinity minimum at approximately 0°C indicating NSAIW. In March 1997 the freshening at intermediate depths resulted in the AI/NIW being fresher than the NSAIW, although this water mass was still evident as a slight inflection in the curve at 0°C. In October 1997 the θS curve was recovering to a more 'normal' appearance, although the AI/NIW was still marked by a salinity minimum. However, the θS characteristic had again changed. Although now NSAIW may once again be a salinity minimum, the curve for March 1998 is not yet 'typical', and there may be four distinct water types at intermediate depths below 4 °C.

	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
May 97	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Oct 97	-0.17	0.073	-0.94	-0.011	n/a	n/a	n/a	n/a
Mar 98	1.61	0.072	0.18	-0.037	n/a	n/a	n/a	n/a

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).

	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
Oct 97	2.27	34.866	2.31	34.869	-0.27	34.885	-0.30	34.891
Mar 98	1.64	34.887	2.33	34.896	-0.25	34.887	0.21	34.884

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.

	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
Oct 97	-0.60	34.901	-0.75	34.907	-0.70	34.907
Mar 98	-0.51	34.899	-0.74	34.907	-0.71	34.907

Table 3. Characteristic θ and S at three pressure levels during 1995 - 1997. Values have been obtained using the automated methods described above.

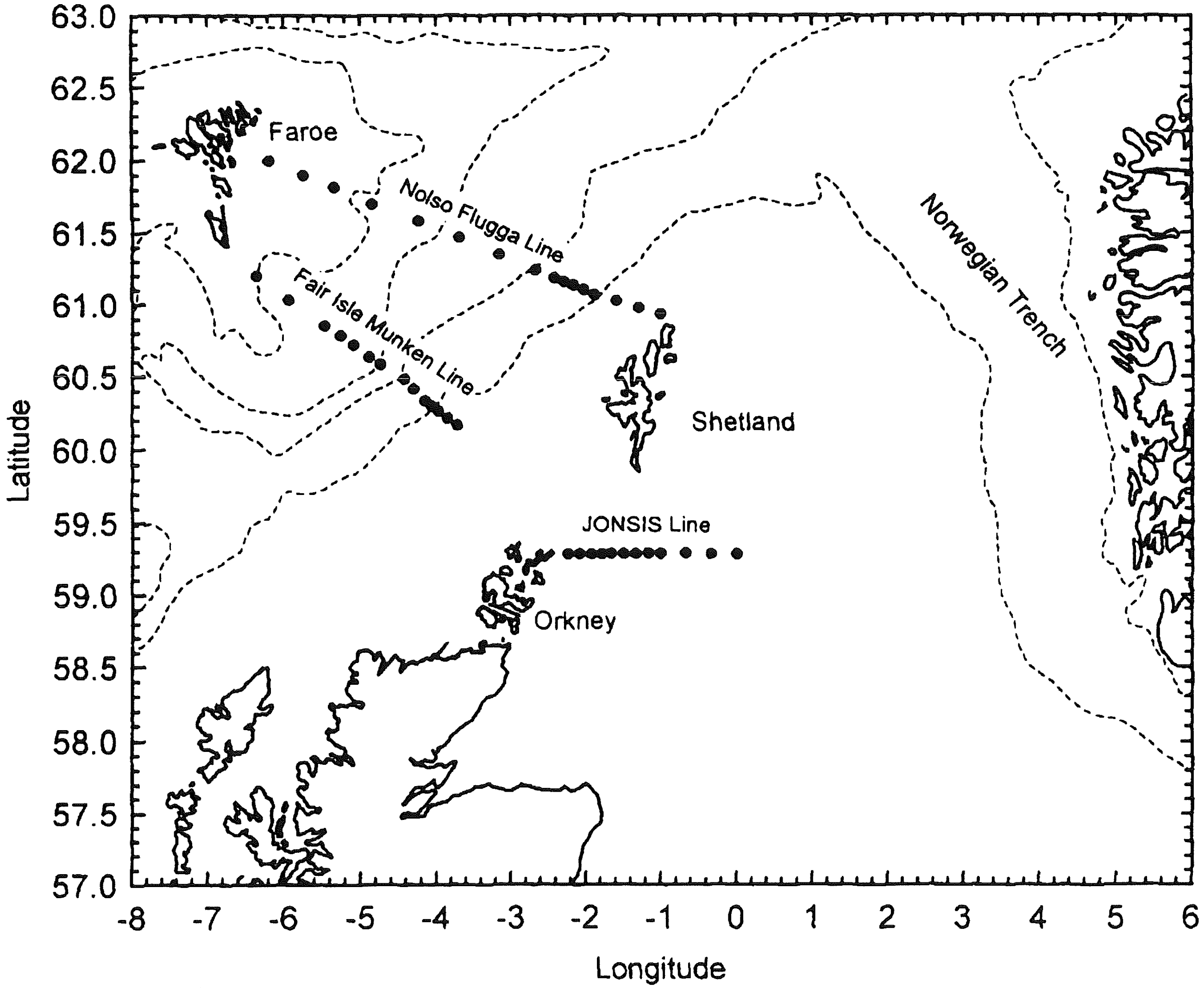


Figure 1

Figure 2

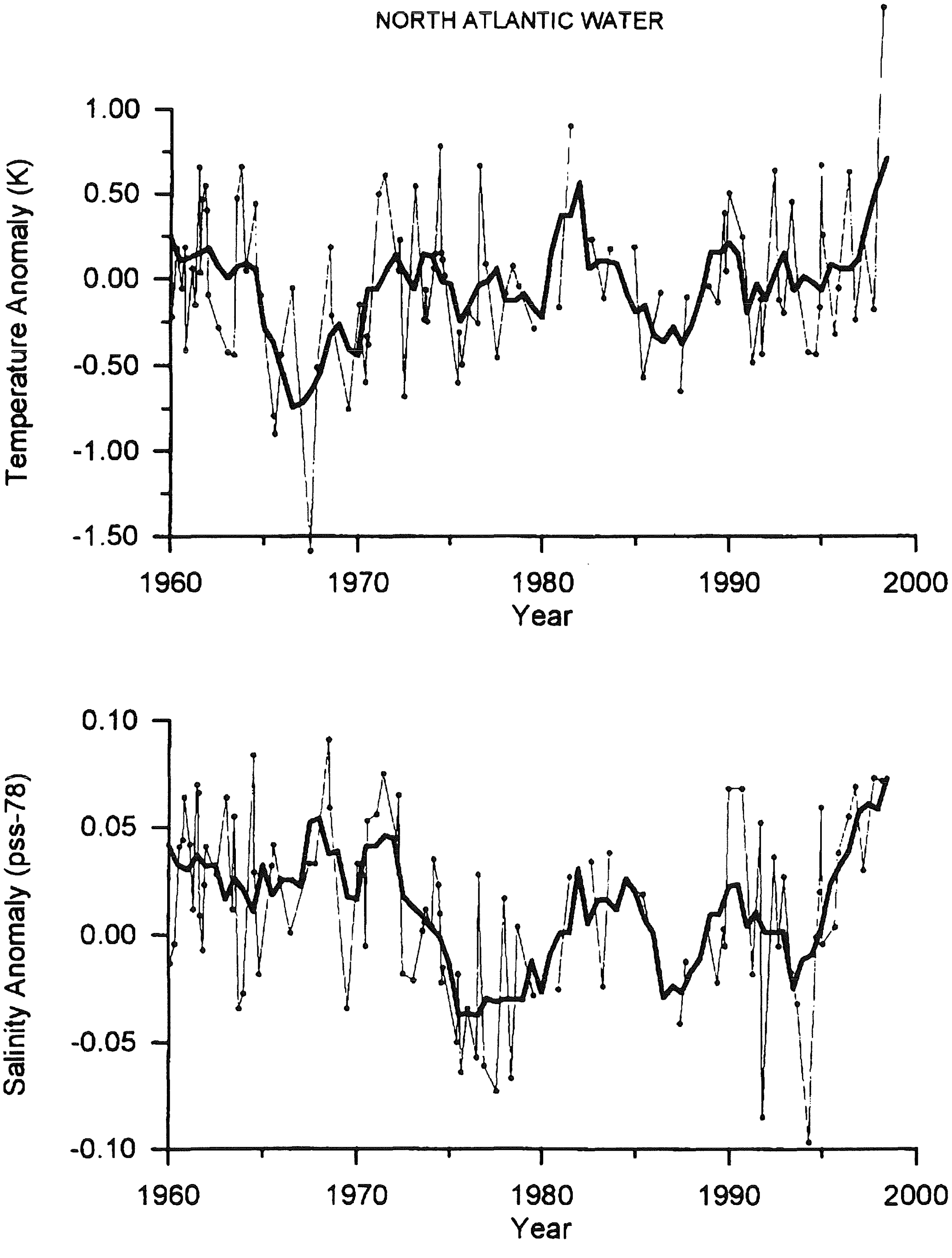

NORTH ATLANTIC WATER
Temperature Anomaly (K)
1.00
0.50
0.00
-0.50
-1.00
-1.50
1960
1970
1980
1990
2000
Year
Salinity Anomaly (pss-78)
0.10
0.05
0.00
-0.05
-0.10
1960
1970
1980
1990
2000
Year

Figure 2b

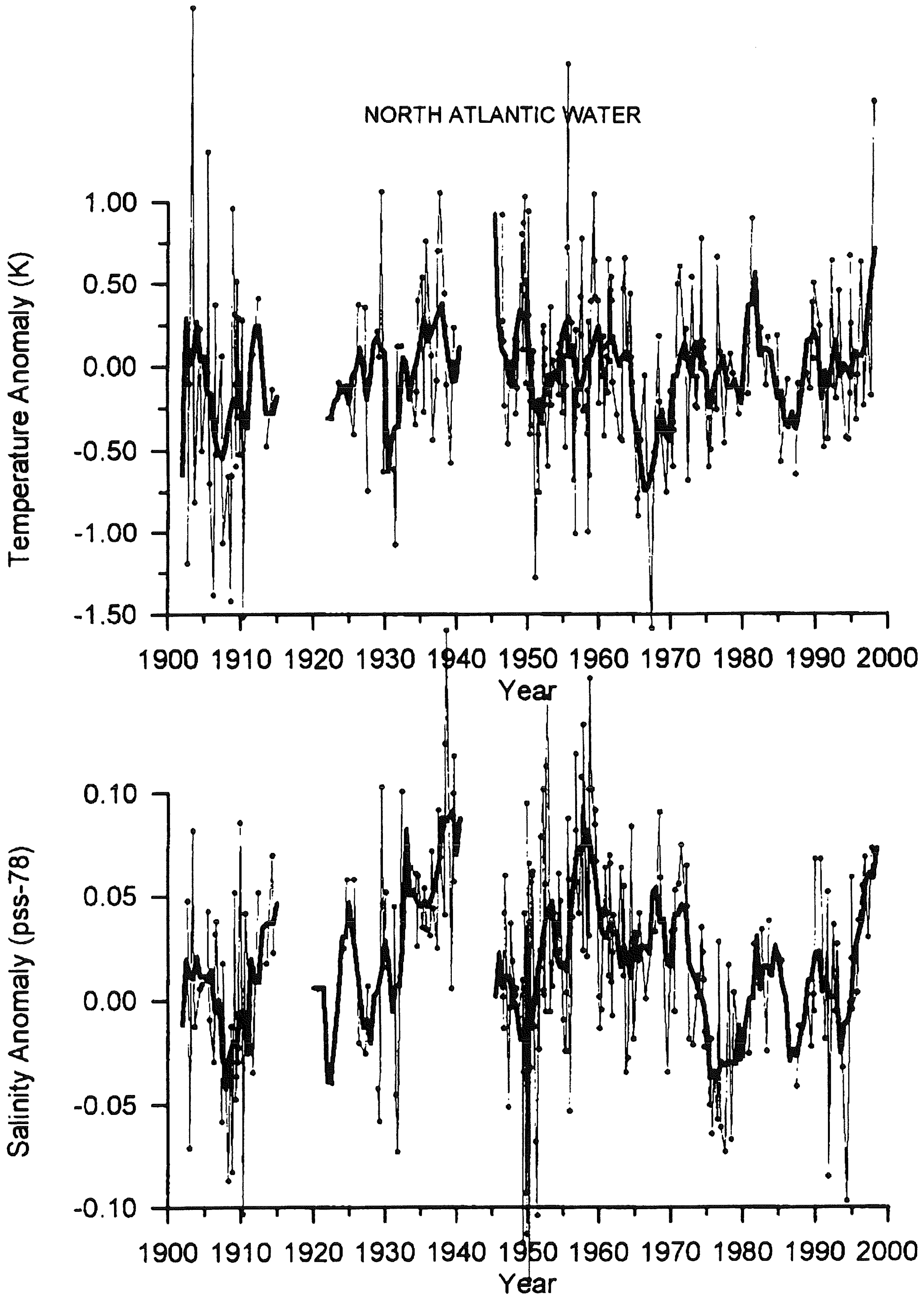

NORTH ATLANTIC WATER
Temperature Anomaly (K)
1.00
0.50
0.00
-0.50
-1.00
-1.50
1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000
Year
Salinity Anomaly (pss-78)
0.10
0.05
0.00
-0.05
-0.10
1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000
Year

Figure 3

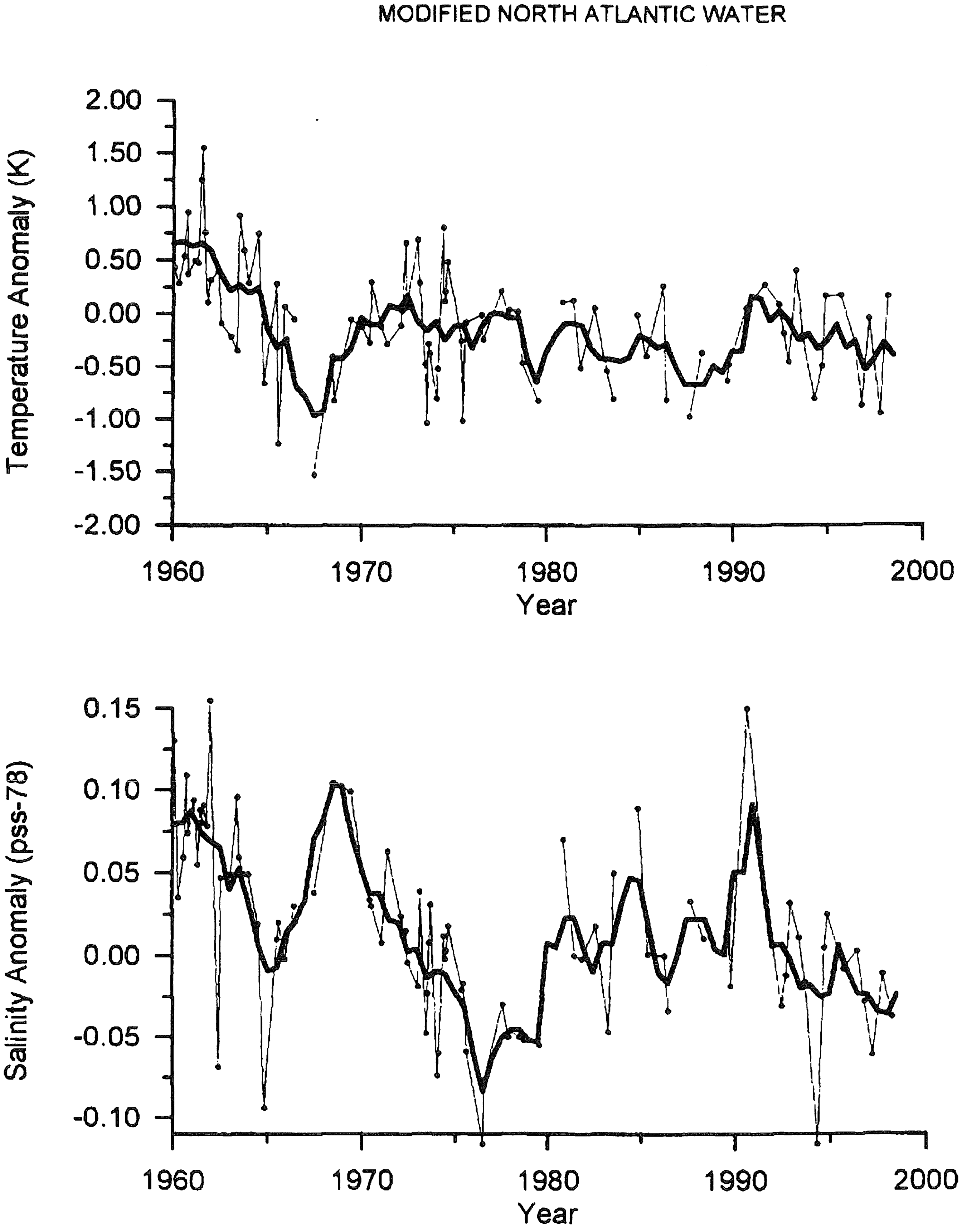

MODIFIED NORTH ATLANTIC WATER
Temperature Anomaly (K)
2.00
1.50
1.00
0.50
0.00
-0.50
-1.00
-1.50
-2.00
1960
1970
1980
1990
2000
Year
Salinity Anomaly (pss-78)
0.15
0.10
0.05
0.00
-0.05
-0.10
1960
1970
1980
1990
2000
Year

Figure 3b

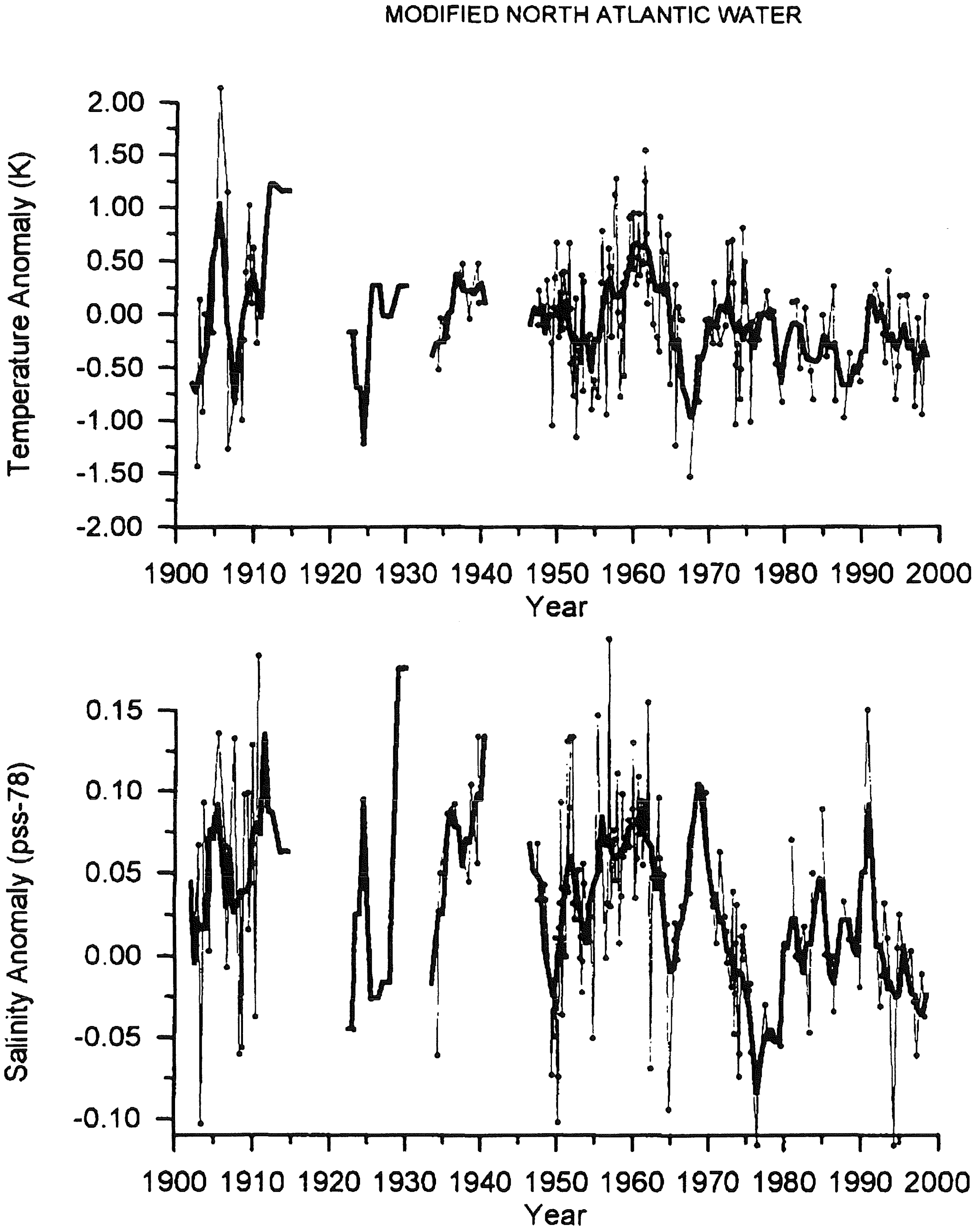
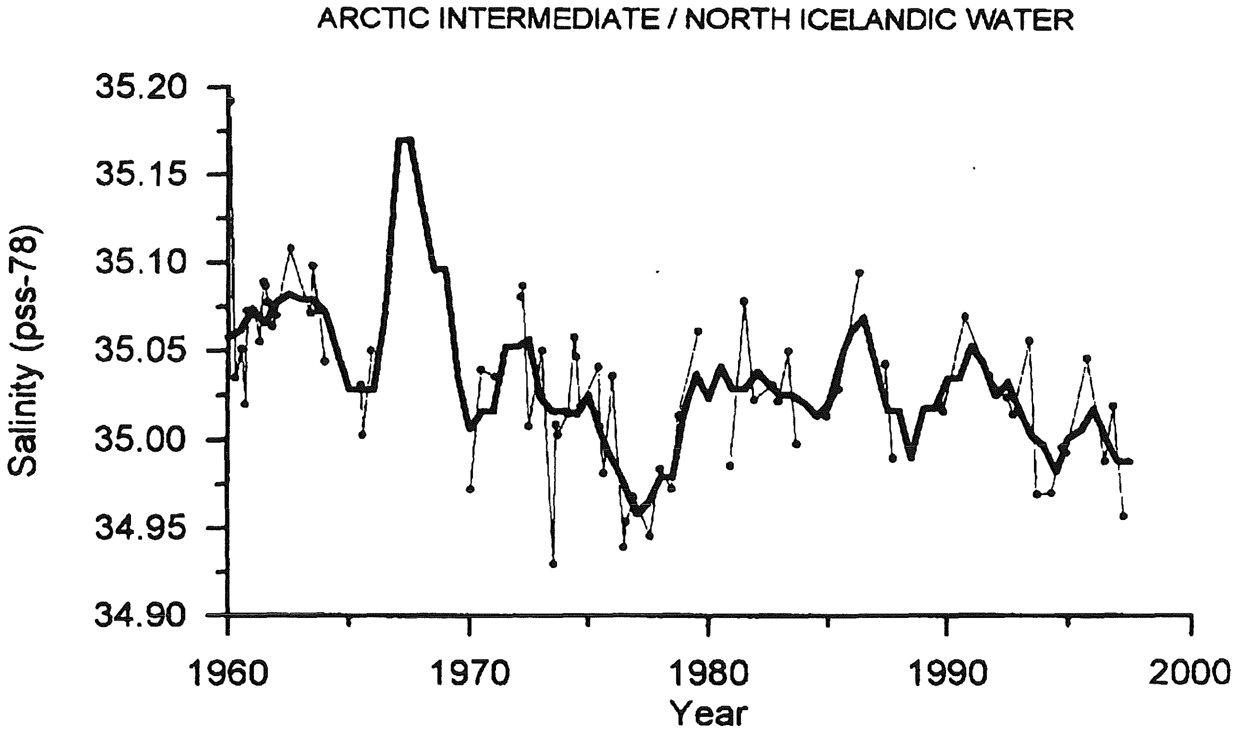

MODIFIED NORTH ATLANTIC WATER
Temperature Anomaly (K)
2.00
1.50
1.00
0.50
0.00
-0.50
-1.00
-1.50
-2.00
1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000
Year
Salinity Anomaly (pss-78)
0.15
0.10
0.05
0.00
-0.05
-0.10
1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000
Year

Figure 4


ARCTIC INTERMEDIATE / NORTH ICELANDIC WATER

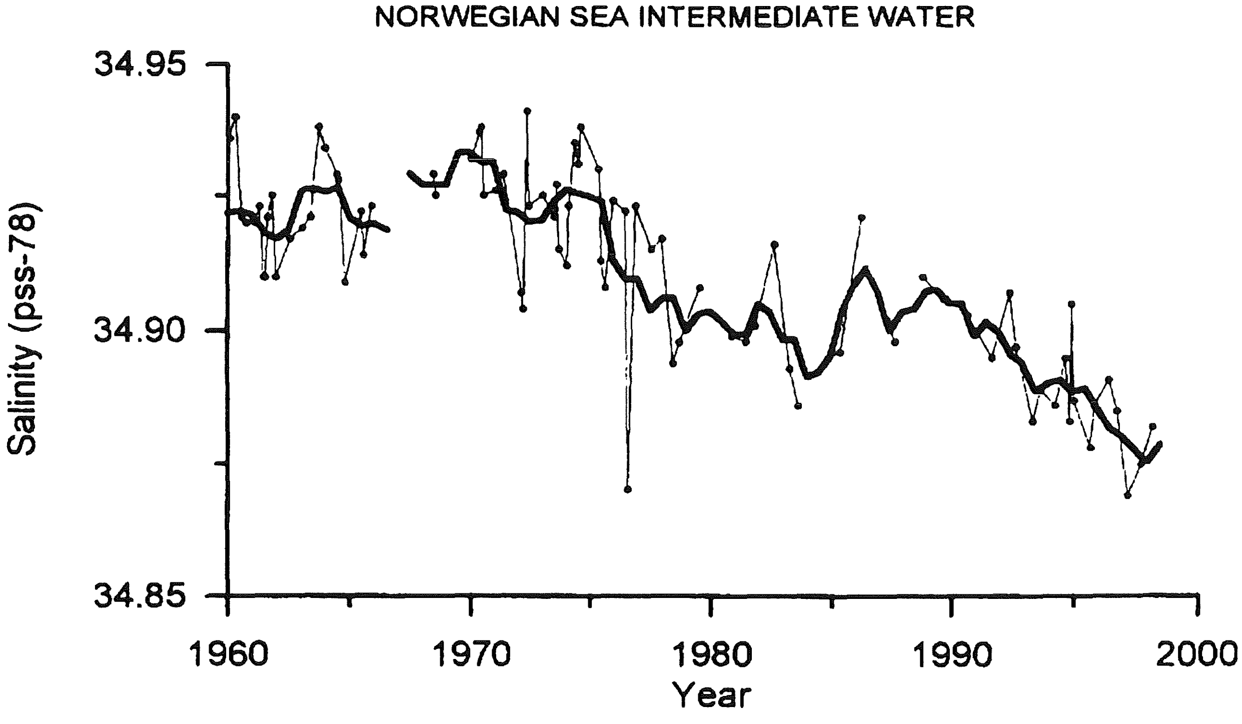
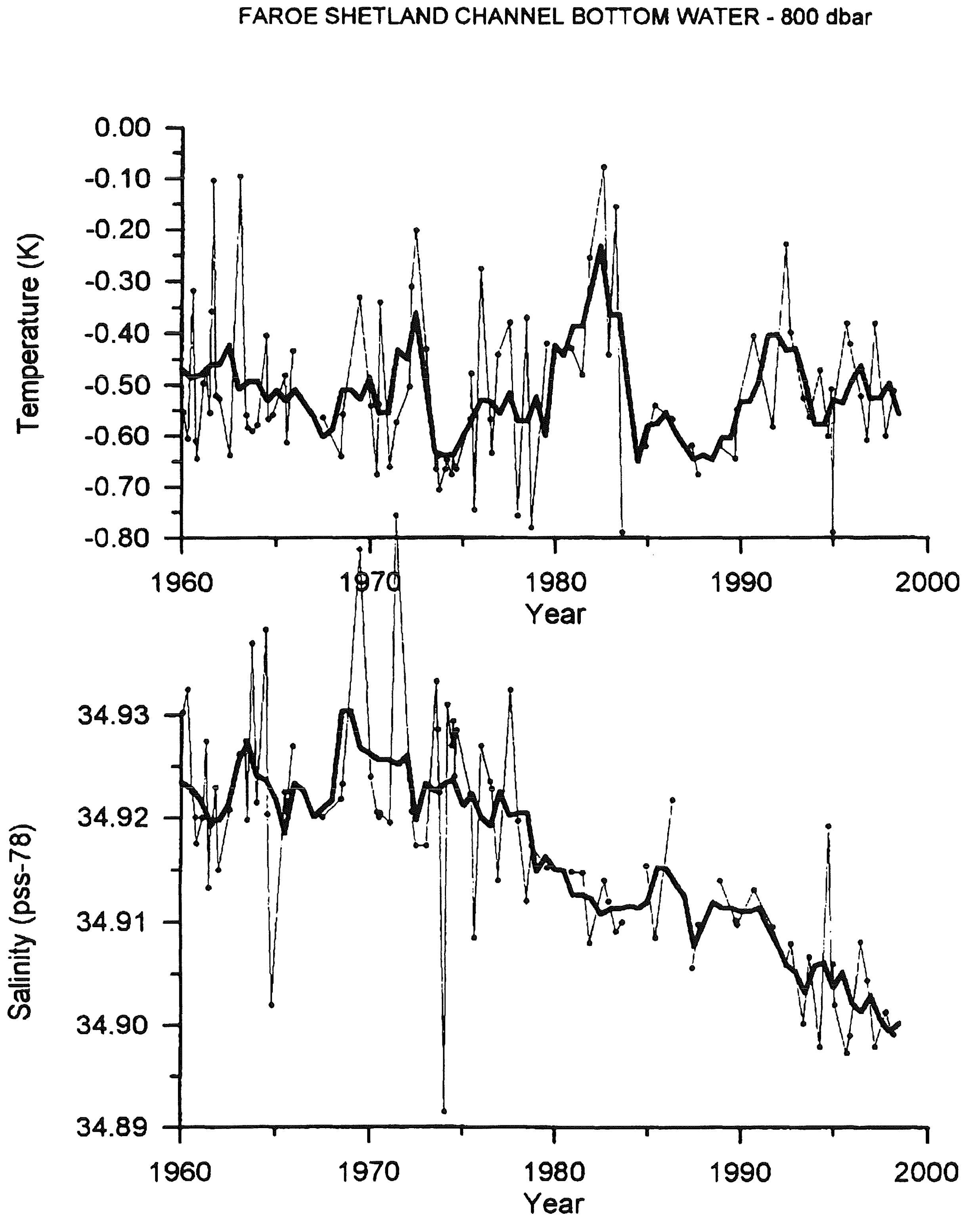

NORWEGIAN SEA INTERMEDIATE WATER

Figure 5



FAROE SHETLAND CHANNEL BOTTOM WATER - 800 dbar

Figure 6

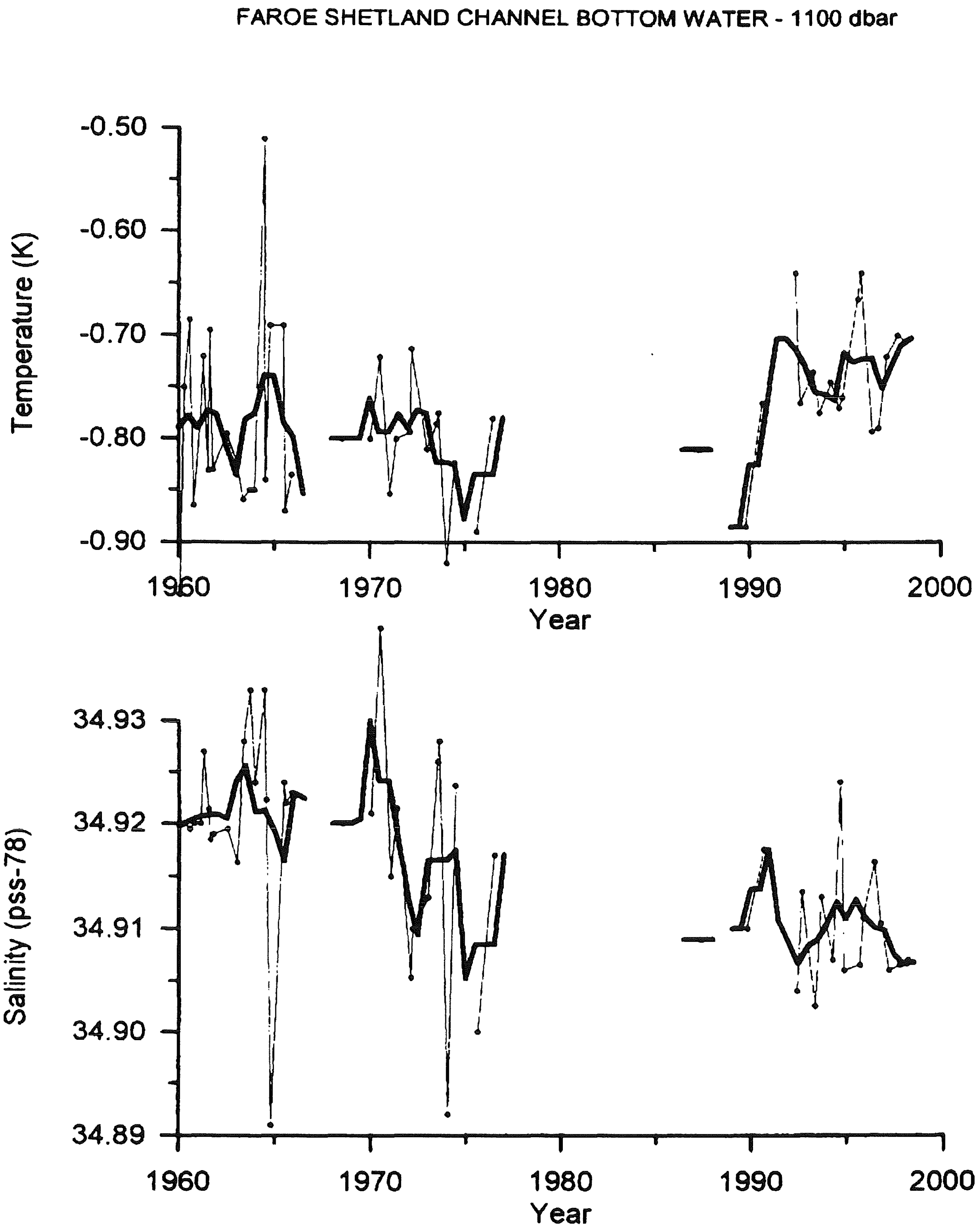
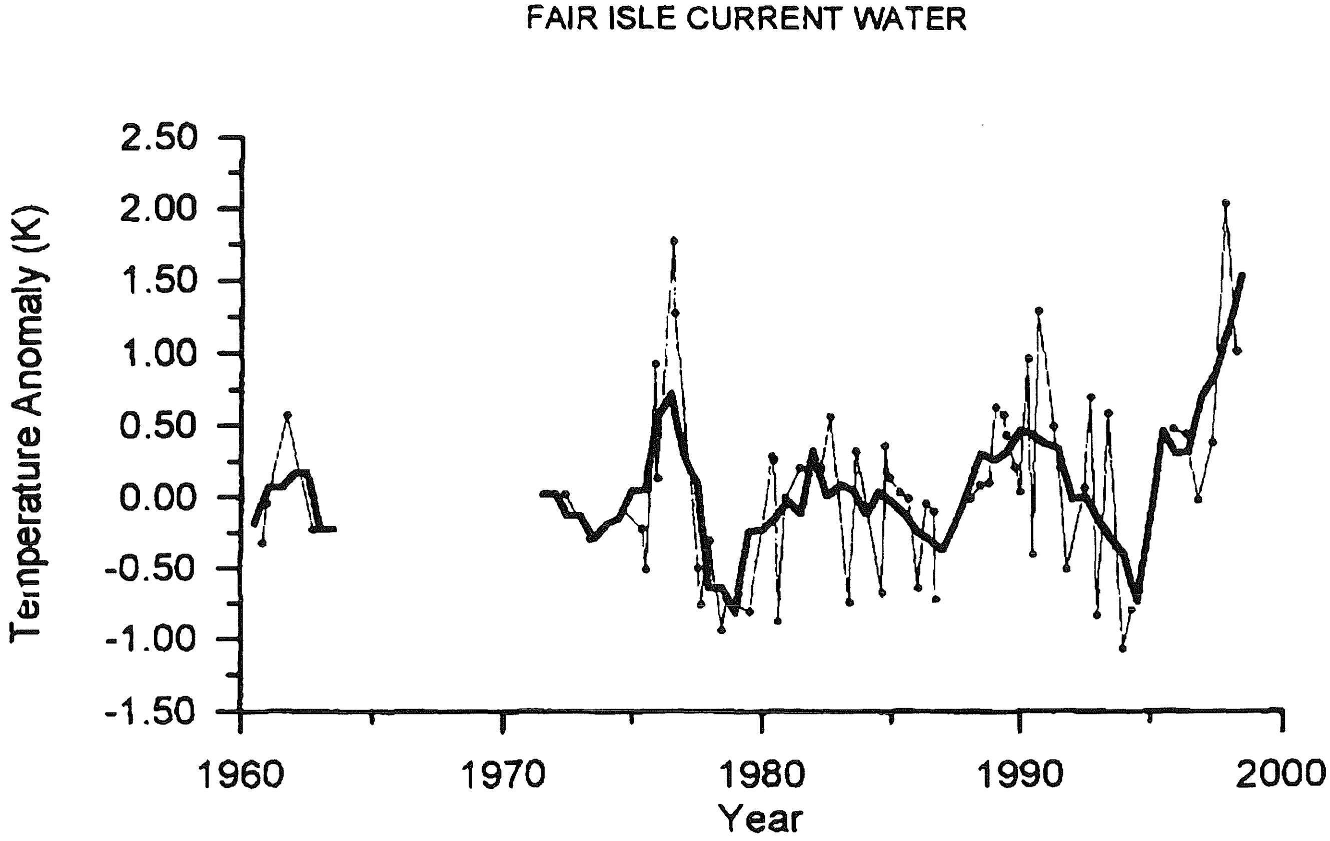
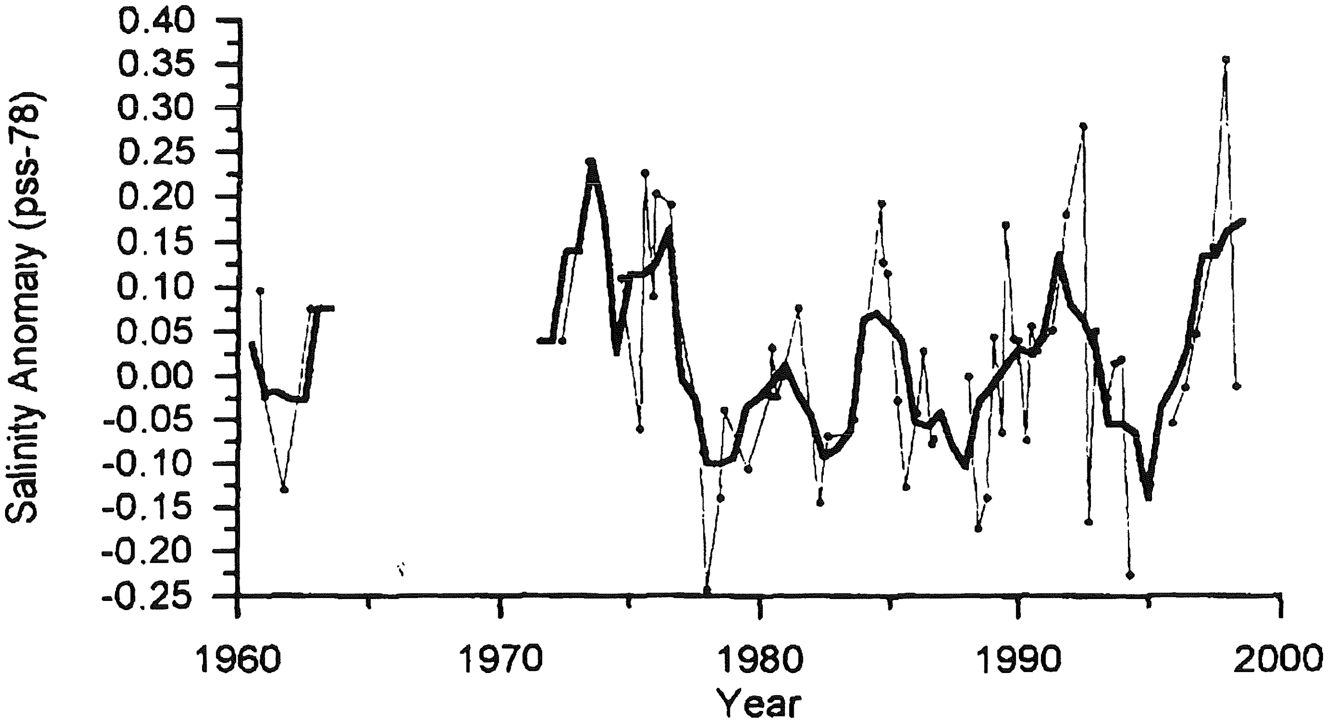

FAROE SHETLAND CHANNEL BOTTOM WATER - 1100 dbar
Temperature (K)
-0.50
-0.60
-0.70
-0.80
-0.90
1960
1970
1980
1990
2000
Year
Salinity (pss-78)
34.93
34.92
34.91
34.90
34.89
1960
1970
1980
1990
2000
Year

Figure 7



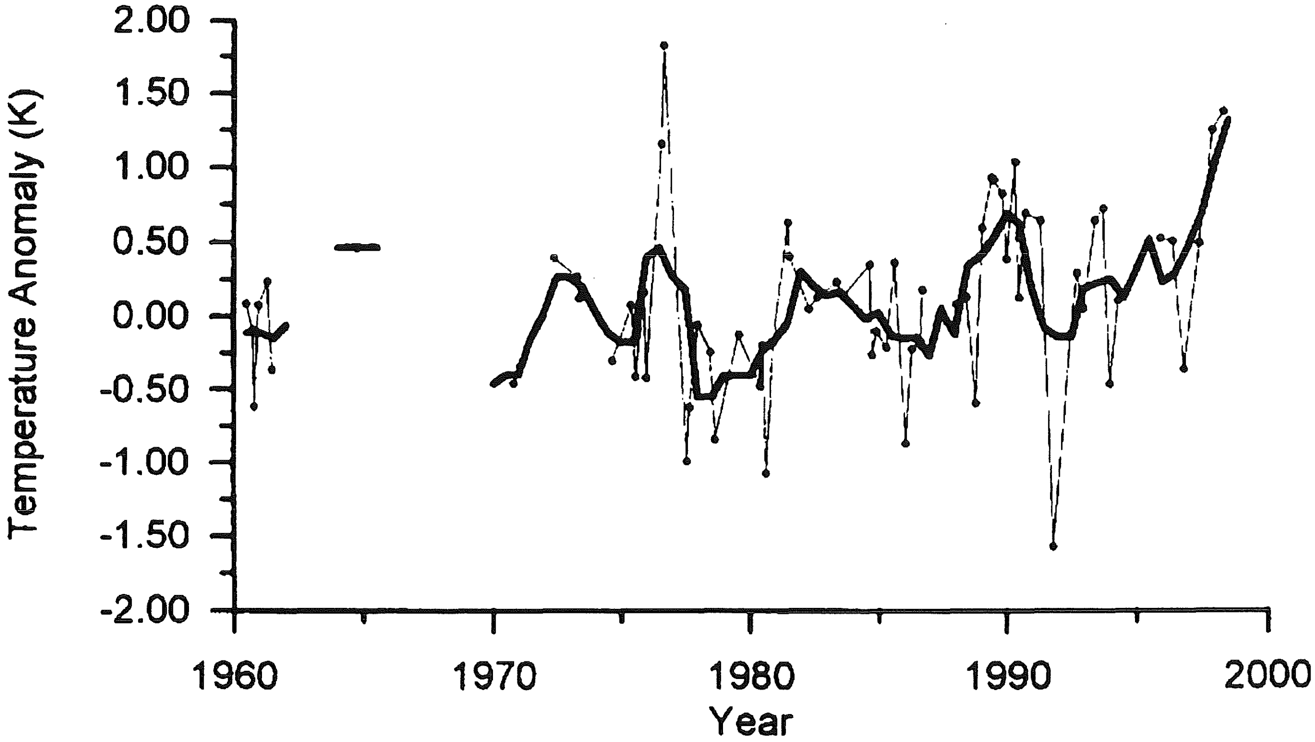
FAIR ISLE CURRENT WATER
Temperature Anomaly (K)
2.50
2.00
1.50
1.00
0.50
0.00
-0.50
-1.00
-1.50
1960
1970
1980
1990
2000
Year



Salinity Anomaly (pss-78)
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
-0.10
-0.15
-0.20
-0.25
1960
1970
1980
1990
2000
Year

Figure 8

COOLED ATLANTIC WATER



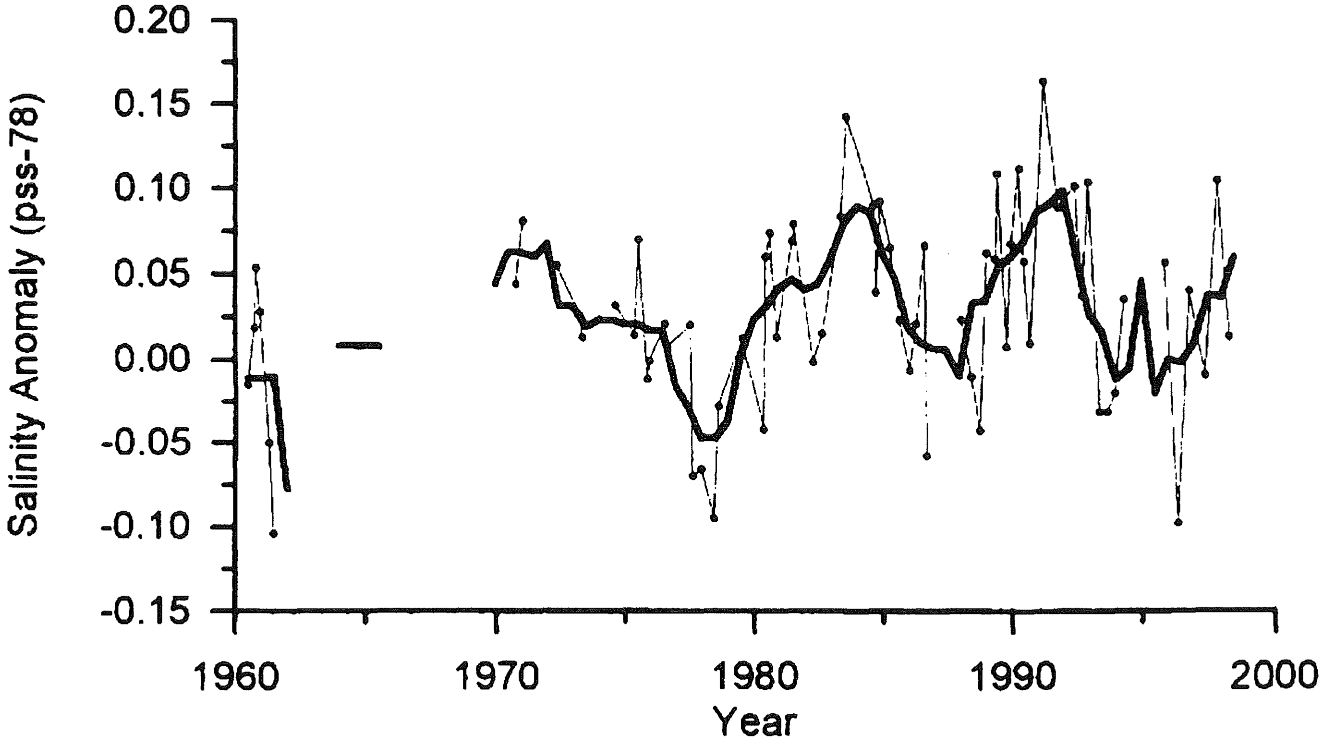
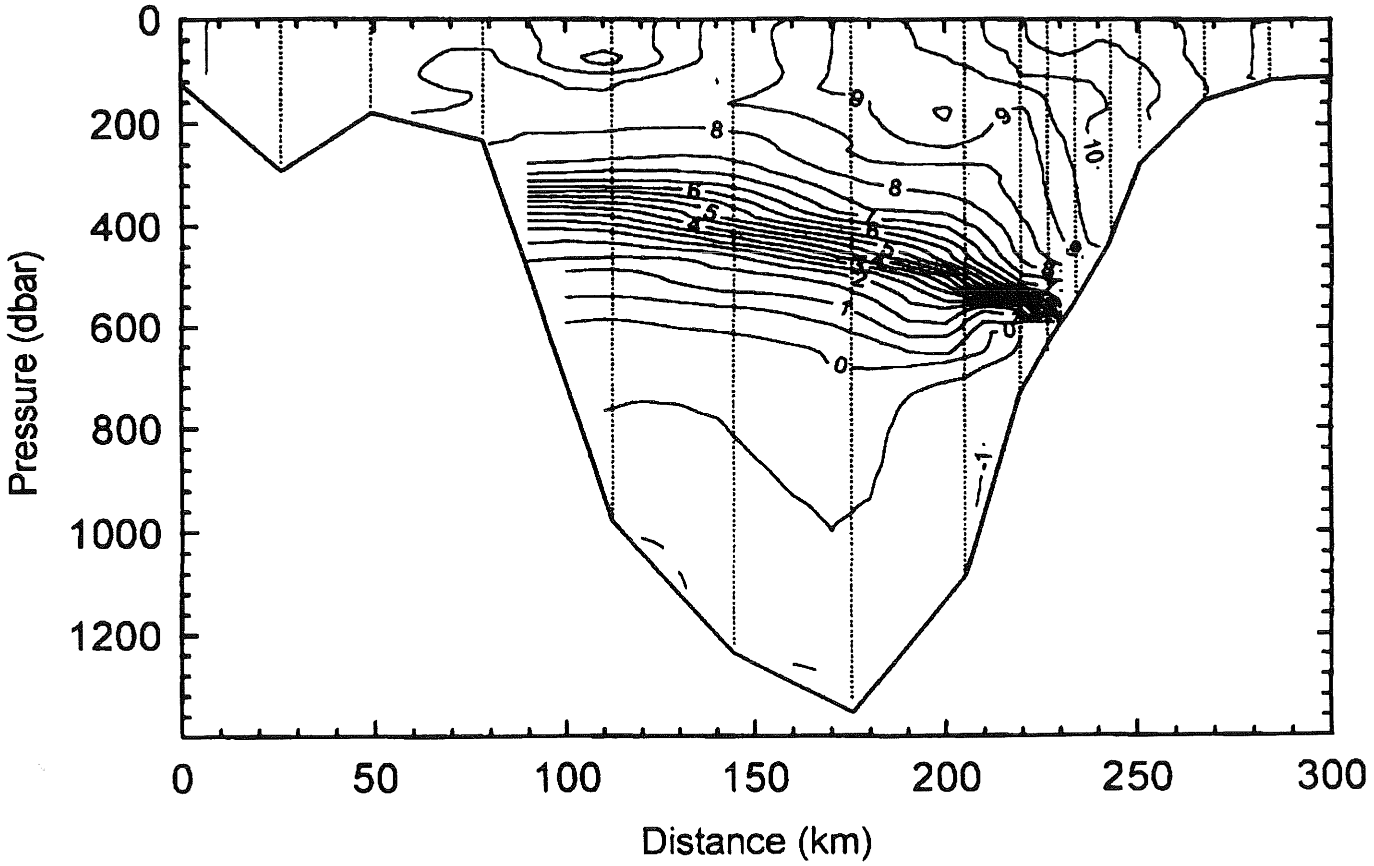


Figure 9

NOLSO-FLUGGA 1397S



FAIR ISLE - MUNKEN 1397S

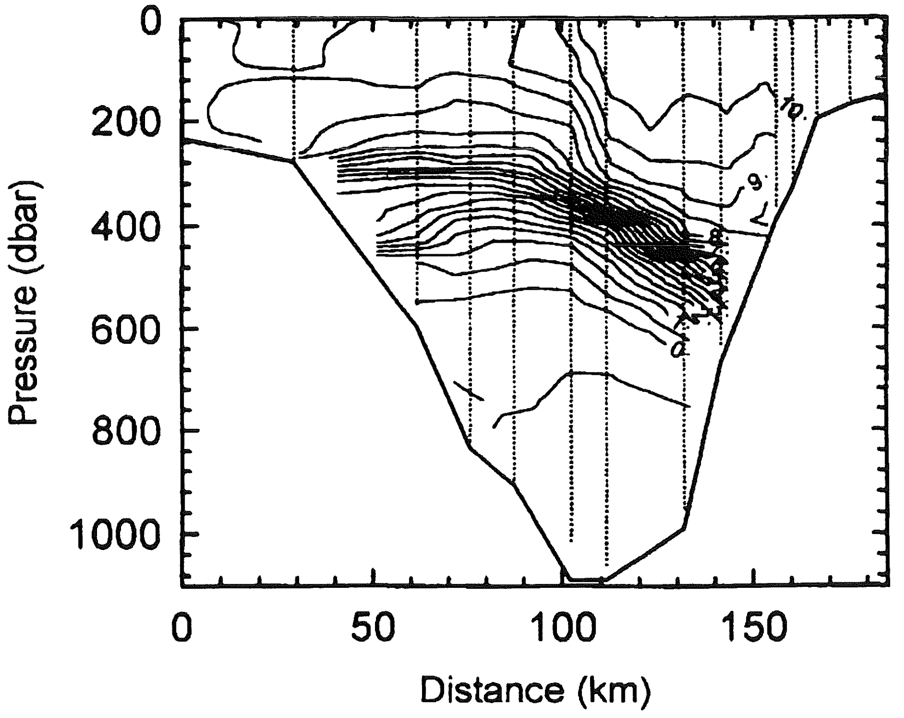
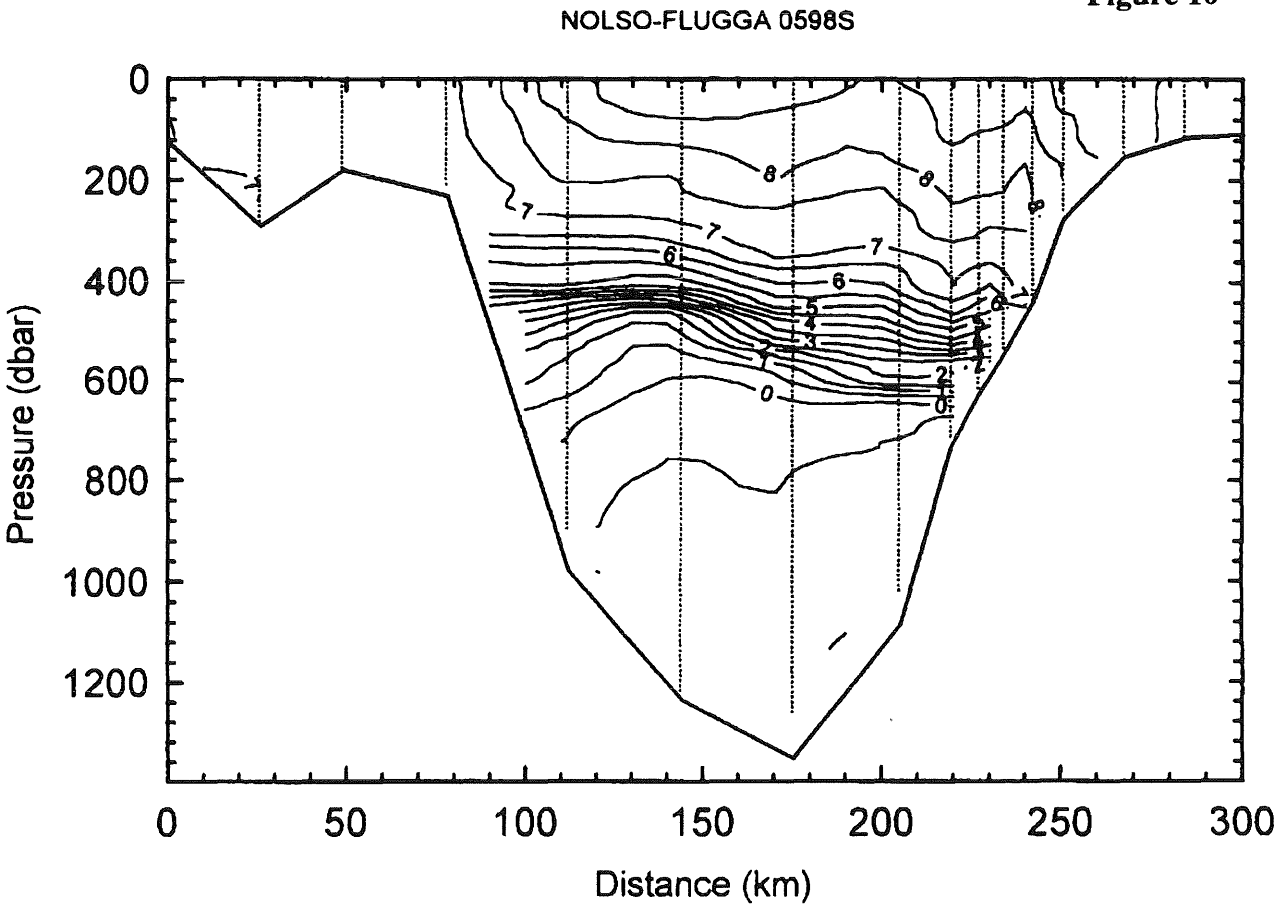


Figure 10


NOLSO-FLUGGA 0598S
Pressure (dbar)
0
200
400
600
800
1000
1200
Distance (km)
0
50
100
150
200
250
300
8
7
6
5
4
3
2
1
0

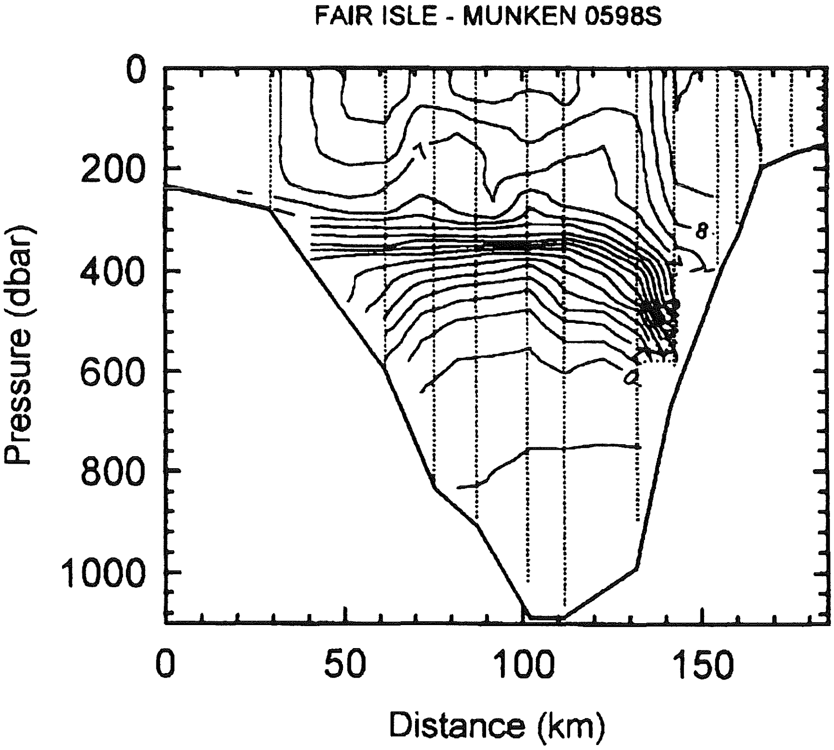
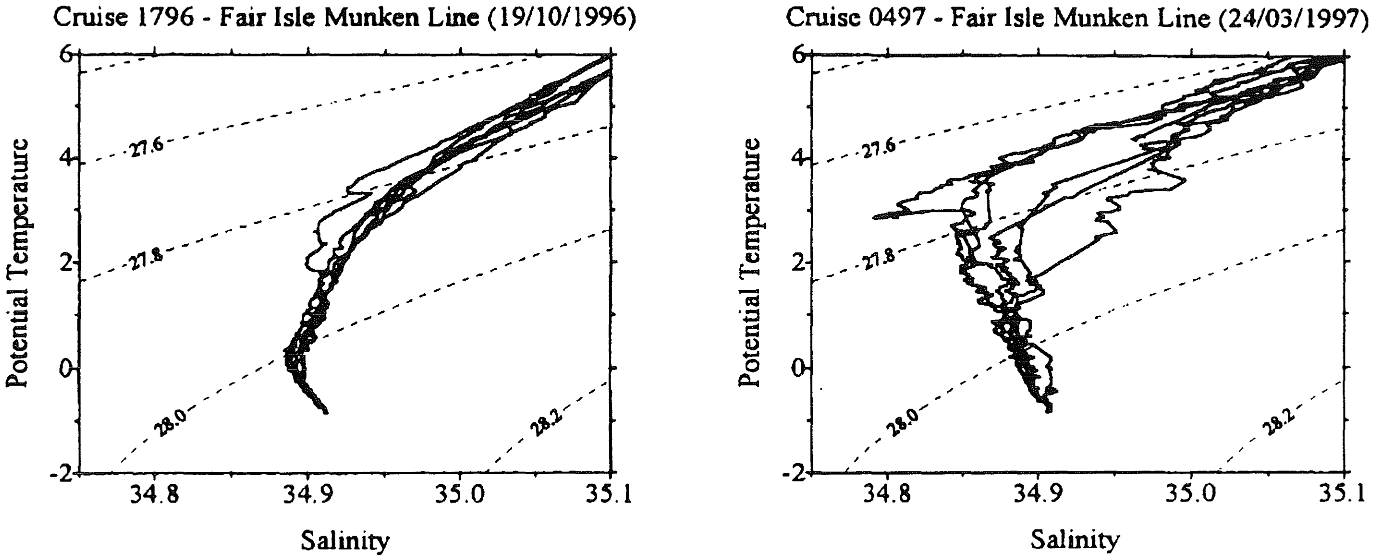
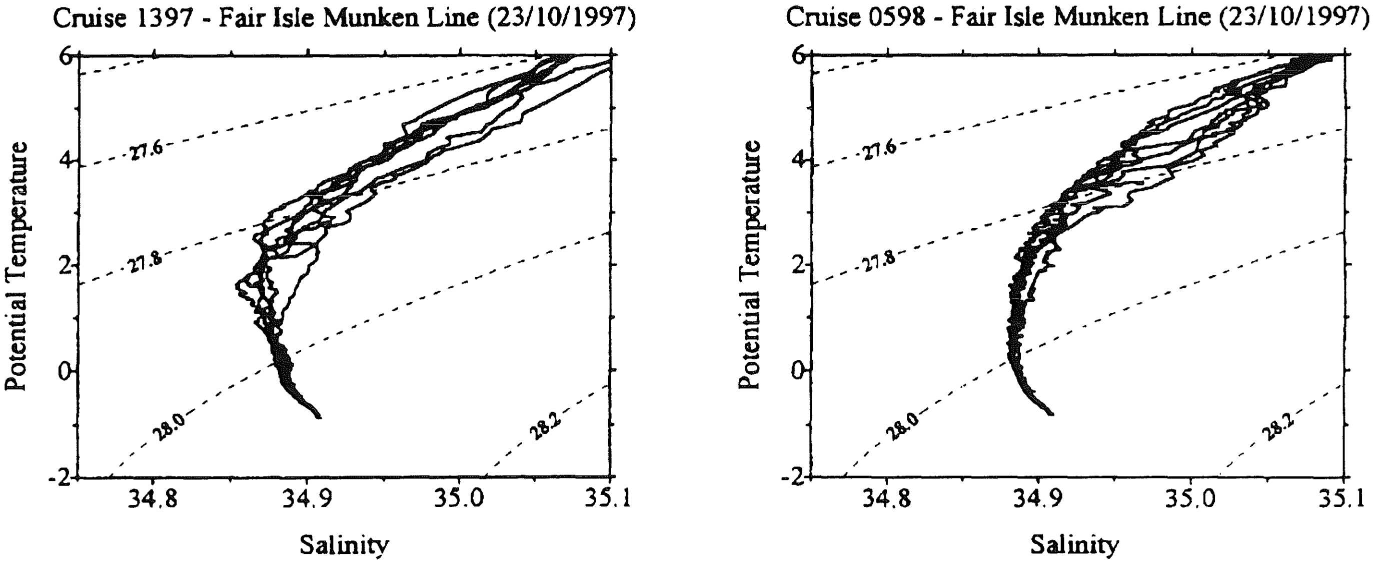

FAIR ISLE - MUNKEN 0598S
Pressure (dbar)
0
200
400
600
800
1000
Distance (km)
0
50
100
150
7
8
0

Figure 11



Cruise 1796 - Fair Isle Munken Line (19/10/1996)

Cruise 0497 - Fair Isle Munken Line (24/03/1997)



Cruise 1397 - Fair Isle Munken Line (23/10/1997)

Cruise 0598 - Fair Isle Munken Line (23/10/1997)

Annex I: Results From Icelandic Waters

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Introduction

Iceland is situated at the meeting place or fronts of warm and cold ocean currents (Fig. 1.) which meet at this point because of the geographical position and the submarine ridges (Greenland-Scotland Ridge) which form a natural barrier against the main ocean currents around the country. To the south is the warm Irminger Current, which is a branch of the North Atlantic Current (6 to 8°C), and to the north are the cold East-Greenland and East Icelandic Currents (-1 to 2°C). There are also deep and bottom currents in the sea around Iceland, principally the overflow of deep cold water from the Nordic Seas and the Arctic Ocean south over the submarine ridges into the North Atlantic. The different hydrographic conditions in Icelandic waters are also reflected in the atmospheric or climatic conditions in and over the country and the surroundings seas, mainly through the Iceland Low and Greenland High. These conditions in sea and air have their impact on biological conditions, expressed through the food chain in the waters including recruitment and catches of commercial fish stocks.

Hydrographic Conditions

a) North Icelandic Waters 1924-1996

A selected hydrographic station in North Icelandic waters (S-3, Figs 2, 3) has been used to characterise 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 characterised by Polar influence, 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 unfavourable and of neither Atlantic nor Polar character, but with a relatively homogenous water of an Arctic character ($T \sim 0°C$ to 3°C; $S \sim 34.8$ to 34.9).

Thus annual hydrographic variations in North Icelandic waters depend on variations of the inflow of warm Atlantic water from the south and west (Irminger Current) as well as on variations of the cold currents from the north (East-Greenland and East Icelandic Currents). The East-Icelandic Current can be of an arctic respectively polar character depending on salinity in the upper layers (> 34.7 respectively < 34.7). During polar conditions the low salinity prevents overturning by cooling or advection, thus favouring drift-ice conditions as well as ice-formation in North Icelandic waters. The close connection between the marine and atmospheric conditions in Iceland is revealed (Fig. 2) in the annual mean temperature in Reykjavik (southern Iceland) and Akureyri (northern Iceland). The hydrographic conditions north of Iceland reflect again the large-scale features in the atmosphere (Iceland Low, Greenland High) and furthermore the North Atlantic Oscillation in general.

A continuous temperature recording in the sea at the island of Grímsey in North Icelandic waters during the years 1987-1997 (Fig. 4) reveals low winter/spring temperatures in 1988 and 1995 and relatively high temperatures in 1987, 1991-1994 and 1996-1997 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 Iceland waters

In the warm waters south of Iceland periods of relatively high (> 35.15) and low (< 35.15) salinities occur (Fig. 3). Noteworthy were the low salinities observed in the mid-70s (Great Salinity Anomaly) and again at least in 1988 and 1992-1996 rising to 35.20 in 1997. Along with low salinities in the area low temperatures are also generally observed. Noteworthy is that in 1996-1997 the salinities in the East Icelandic Current were on the contrary relatively low (< 34.7) and the extension of the "cold tongue" north-east of Iceland was quite pronounced in 1995 and 1997, but less so in 1996.

Concluding remarks on conditions in 1997

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. In 1997 the conditions improved further in the warm water from the south, the salinities rising to the same level as decades before (> 35.20). Despite this a low saline surface layer was observed in North Icelandic waters in spring 1997 as in 1996 (Figs. 2, 3) and in the East-Icelandic Current salinities too were relatively low (< 34.7; Fig. 3). Furthermore, nutrient content, primary production and zooplankton concentrations were in spring as expected dependent on each other, but on different stages in the different areas. From a biological point of view the overall conditions were in general favourable. The Atlanto-Scandian herring was observed at the eastern and southern boundaries of the cold East Icelandic Current, even farther westwards than in previous years. Noteworthy was in this case a strong warming up in the surface layer of the East Icelandic Current in late summer 1997. At last it should be noted that in winter 1997-1998 hydrographic conditions in Icelandic waters revealed a strong impute of relatively high saline water (> 35.20) of the Irminger Current and relatively high salinities (> 34.7) in the East Icelandic Current as well a northerly location of the cold water (< 0°C).

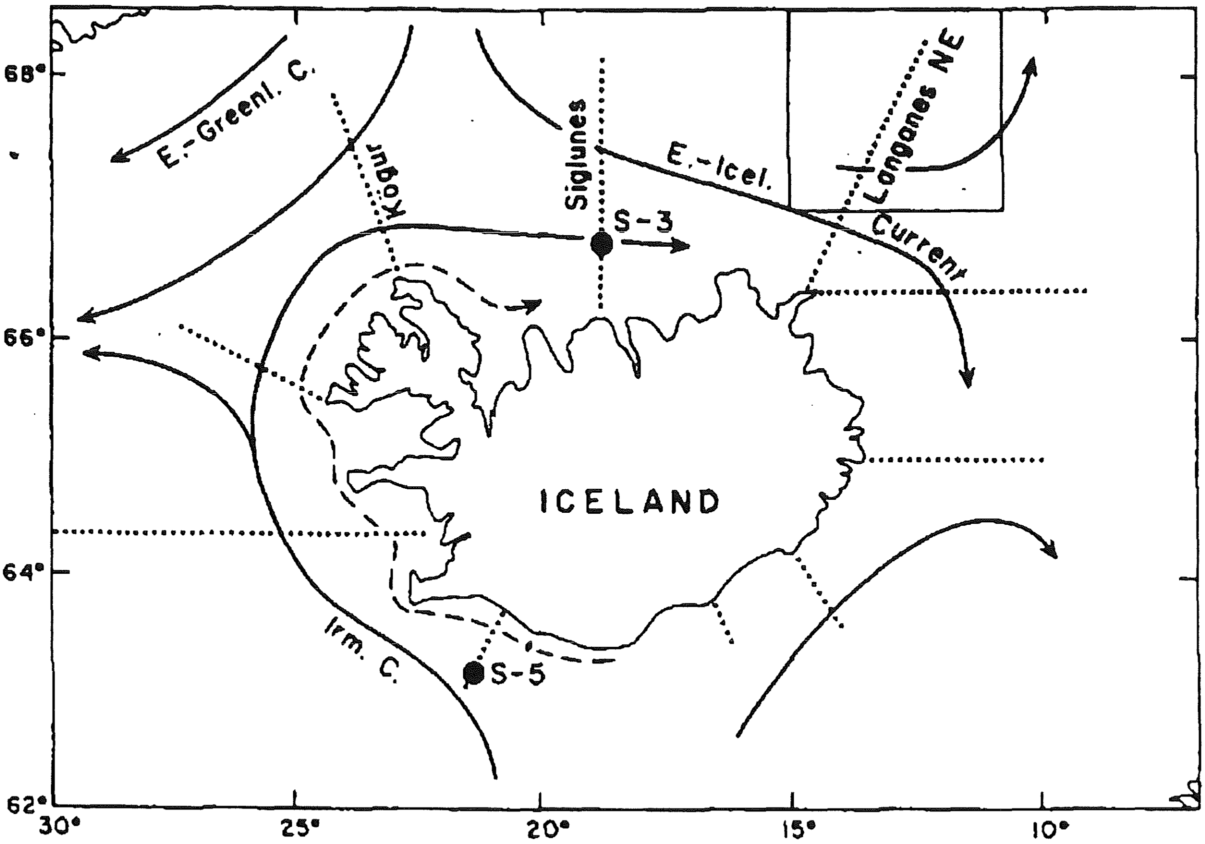

Fig. 1 Main currents and location of standard hydro-biological sections in Icelandic waters. Selected areas and stations dealt with in the report are indicated

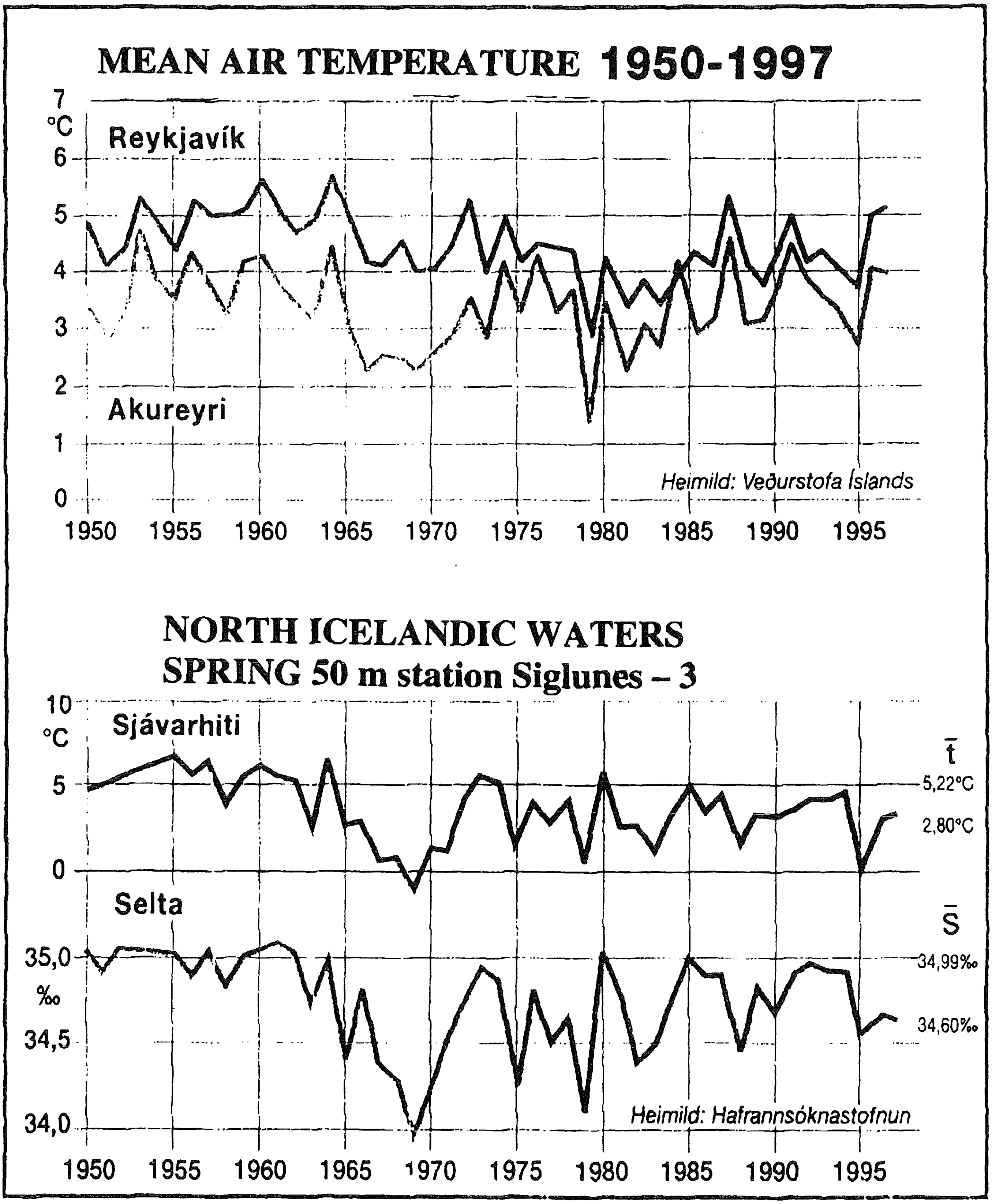

Fig. 2 a) Mean annual air temperature in Reykjavik and Akureyri 1950-1997.
b) Temperature and Salinity at 50 m depth at a hydrographic station in North Icelandic waters (S-3, see Fig. 1) in May/June 1950-1997.

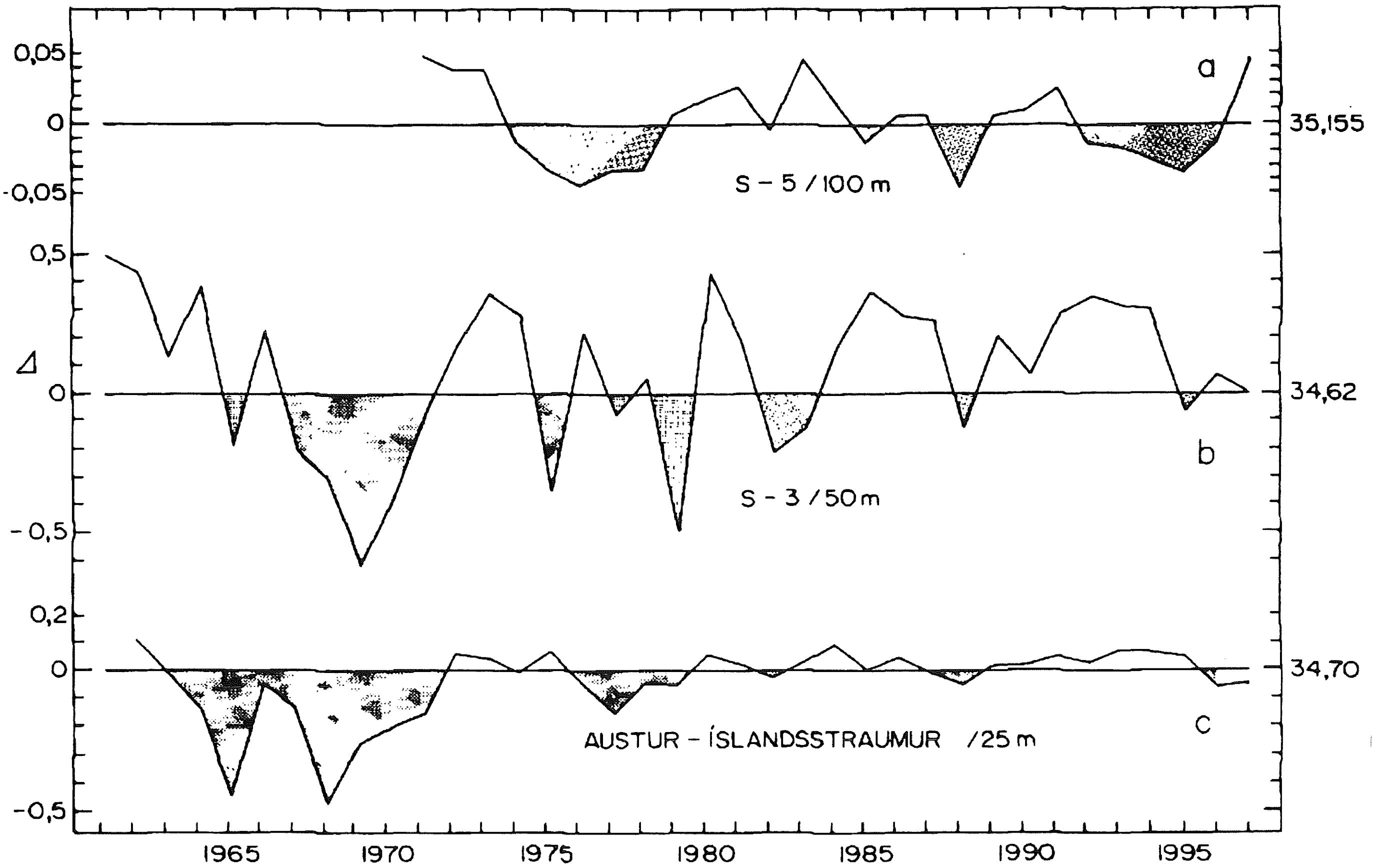

Fig. 3. Salinity deviations in spring at

a) 100 m depth in the Irminger Current south of Iceland (S-5; 1971-1997);
b) 50 m depth in North Icelandic waters (S-3; 1961-1997);
c) 25 m depth in the East Icelandic Current (1962-1997).
(for location see Fig. 1)

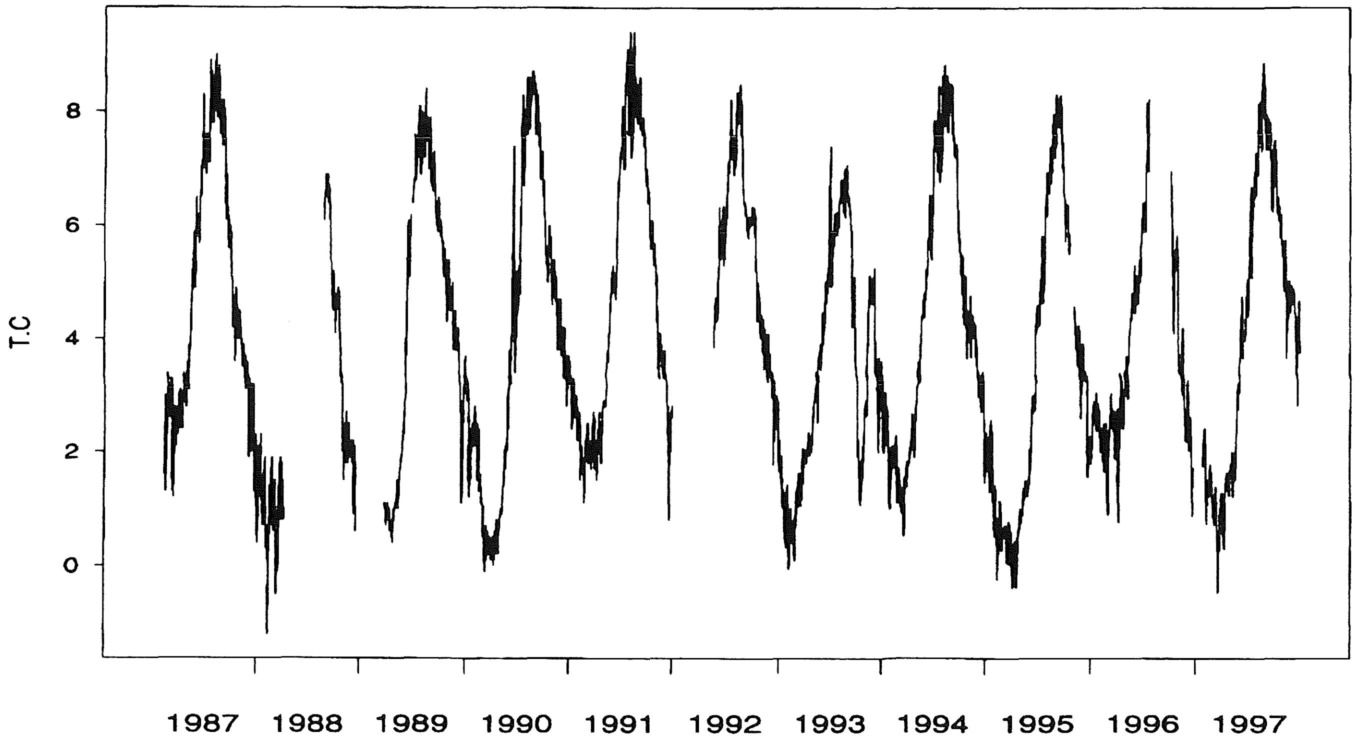

Fig 4 Annual and seasonal variation in the sea-surface temperature at Grímsey. North Iceland in 1987 – 1997.

Annex J: Some Results of the Polish Research in Norwegian, Greenland and Barents Seas in 1997

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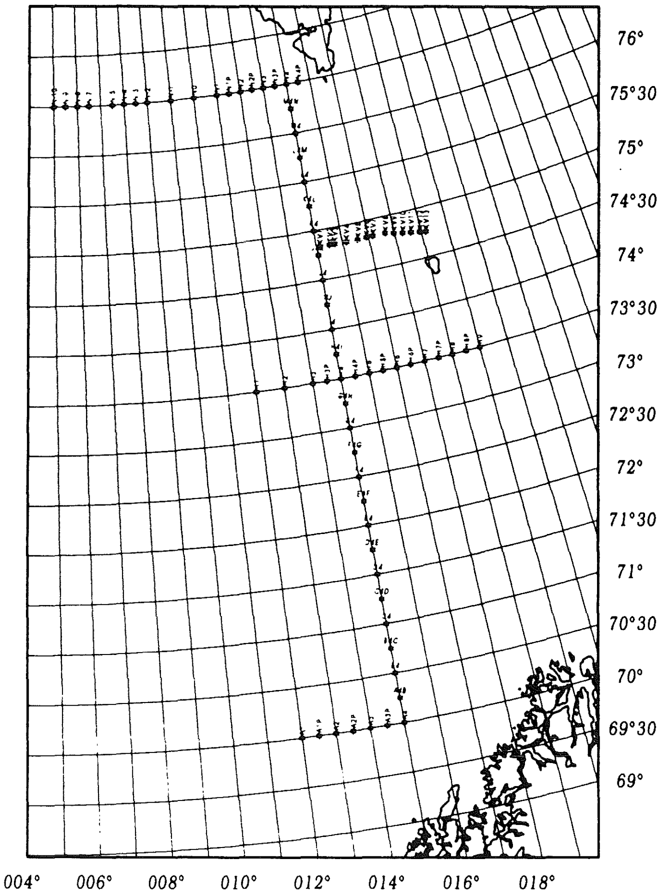
In 1997 Institute of Oceanology PAS in Sopot has continued research in region at the border of the Norwegian, Greenland and the Barents Seas (15°E transect) and started more intensive research of the West Spitsbergen Current (fig.1). A little lower salinity in the thinner layer of Atlantic water was observed during 1997 summer (fig.2) than in previous years. On the other hand the water transport across 15°E meridian was higher then that of one year earlier (fig.3). Much denser coverage of the West Spitsbergen Current (WSC) region with the CTD stations reveals same details of structure of this current. Its main stream follows the Svalbard's continental slope (fig.4 and 5). Second, more westerly-located branch is much weaker. In the northern most location ≈ 79°N this branch is visibly turning to the west. Due to bottom topography and interaction with the shelf waters eastern boundary of the WSC in some locations where flat shelf turns to sharp slope is vertically oriented and forms distinct front, (fig.5), while opposite the fjord mouth and with complicated bottom topography of the shelf the front with the shelf waters is more horizontal and less distinguished (fig.6).

Confluention Zone



West Spitsbergen Current

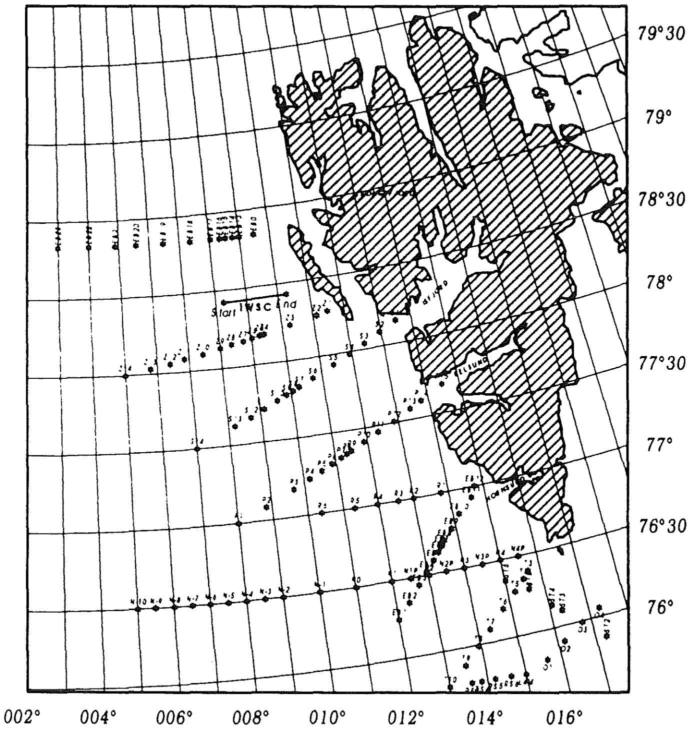


Fig. 1

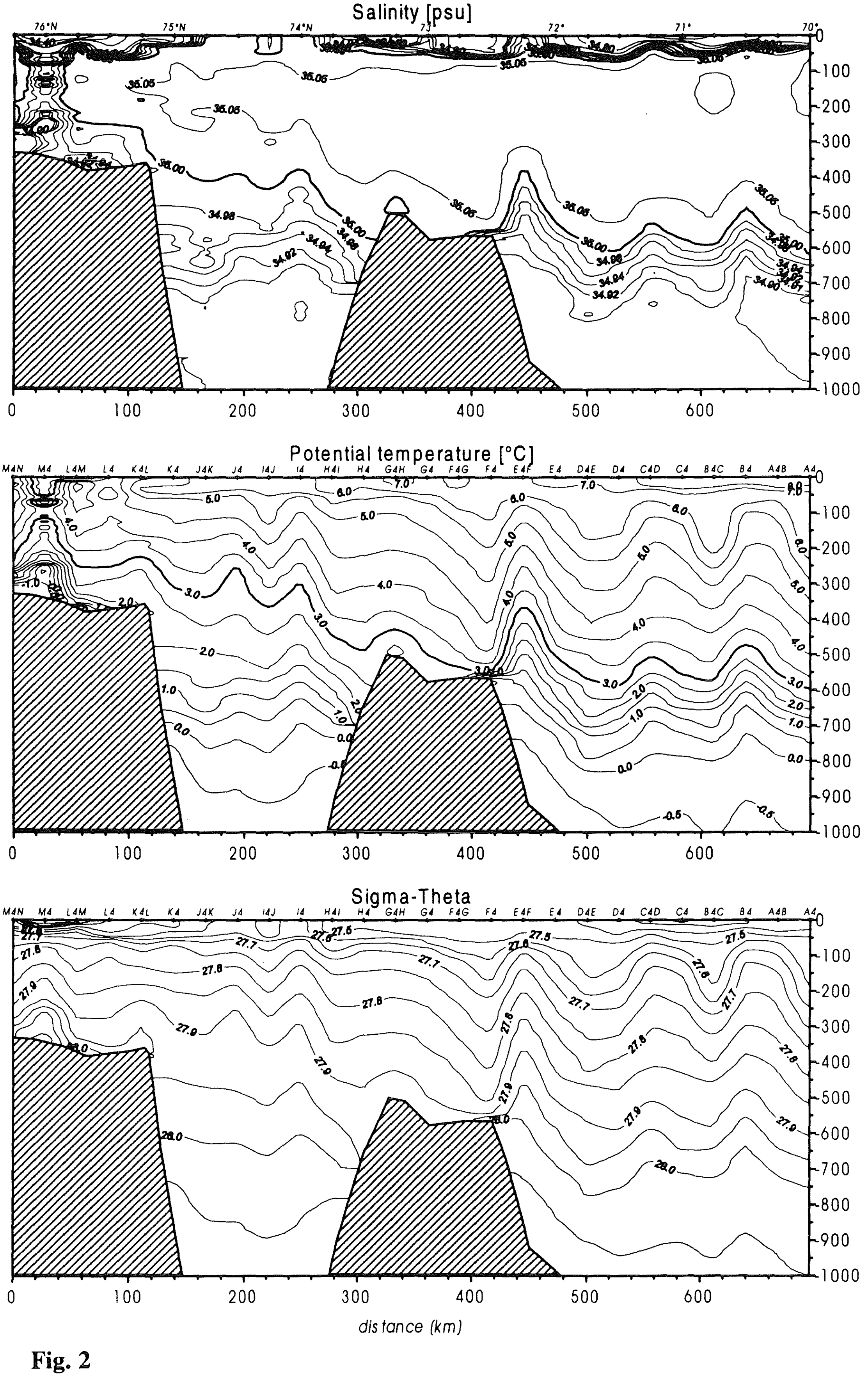

Salinity [psu]
76°N
75°N
74°N
73°
72°
71°
70°
34.40
34.90
35.05
35.06
35.00
34.98
34.94
34.92
34.96
34.90
Potential temperature [°C]
M4N
M4
L4M
L4
K4L
K4
J4K
J4
I4J
I4
H4I
H4
G4H
G4
F4G
F4
E4F
E4
D4E
D4
C4D
C4
B4C
B4
A4B
A4
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
-0.5
-1.0
Sigma-Theta
27.5
27.6
27.7
27.8
27.9
28.0
depth (m)
0
100
200
300
400
500
600
700
800
900
1000
distance (km)
0
100
200
300
400
500
600

Fig. 2

	015°E			*017°E*		
Year	Total Volume Trans. [Sv]	Vol + Transport [Sv]	Vol - Transport [Sv]	Total Volume Trans. [Sv]	Vol + Transport [Sv]	Vol - Transport [Sv]
1988	2.56	4.58	2.02	1.92	2.22	0.30
1989	4.51	11.79	7.28	3.25	3.58	0.33
1990						
1991	1.40	8.61	7.21			
1992	0.11	7.72	7.61			
1993	-0.47	3.07	3.54	0.51	1.69	1.18
1994	2.63	5.67	3.04	3.04	3.13	0.09
1995	2.96	11.54	8.58			
1996	2.08	9.94	7.86			
1997	4.44	11.02	6.58			
Mean	2.25	8.22	5.97	2.18	2.65	0.47

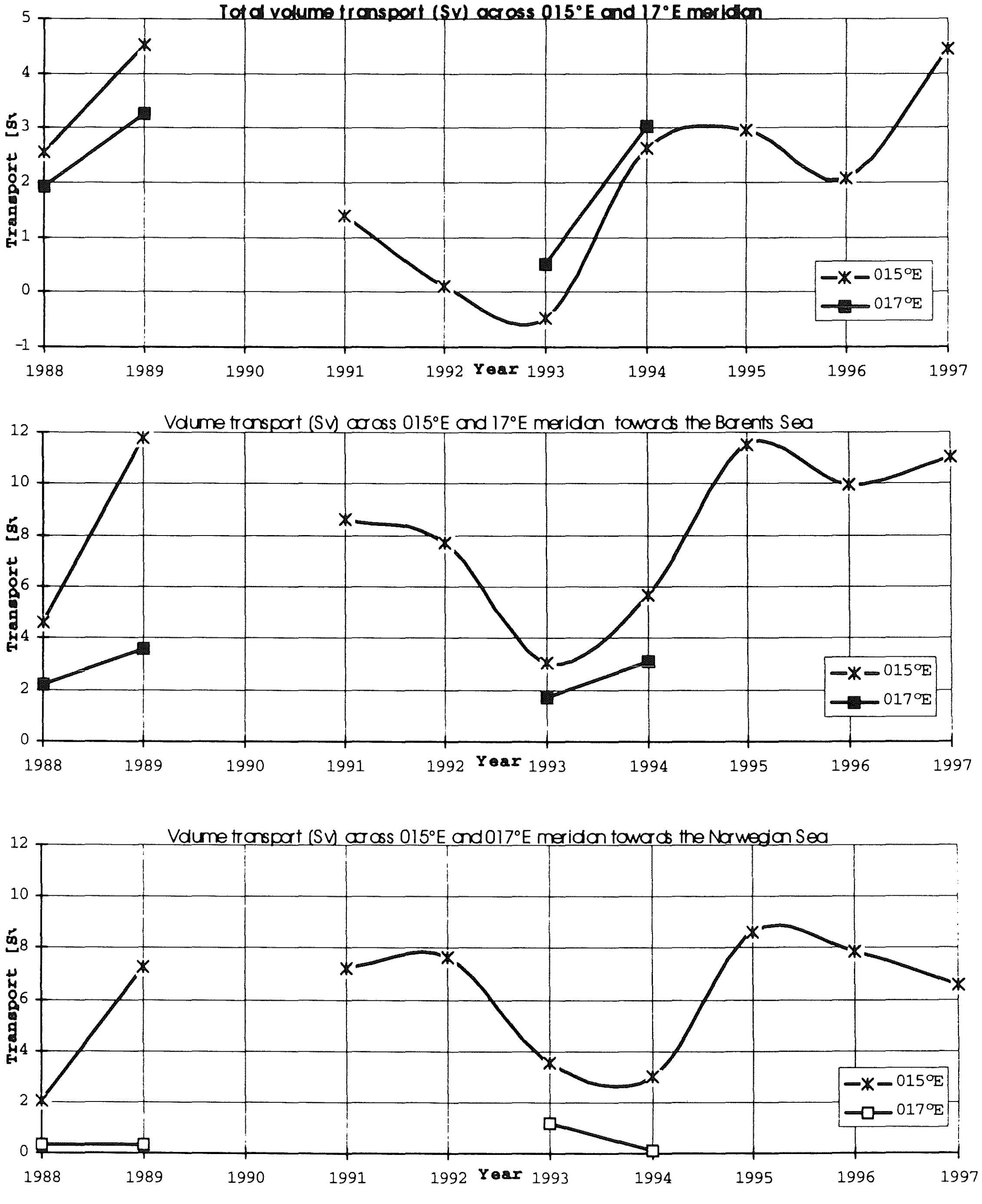


Fig. 3 Volume Transport [Sv] across 015°E and 017°E meridians.

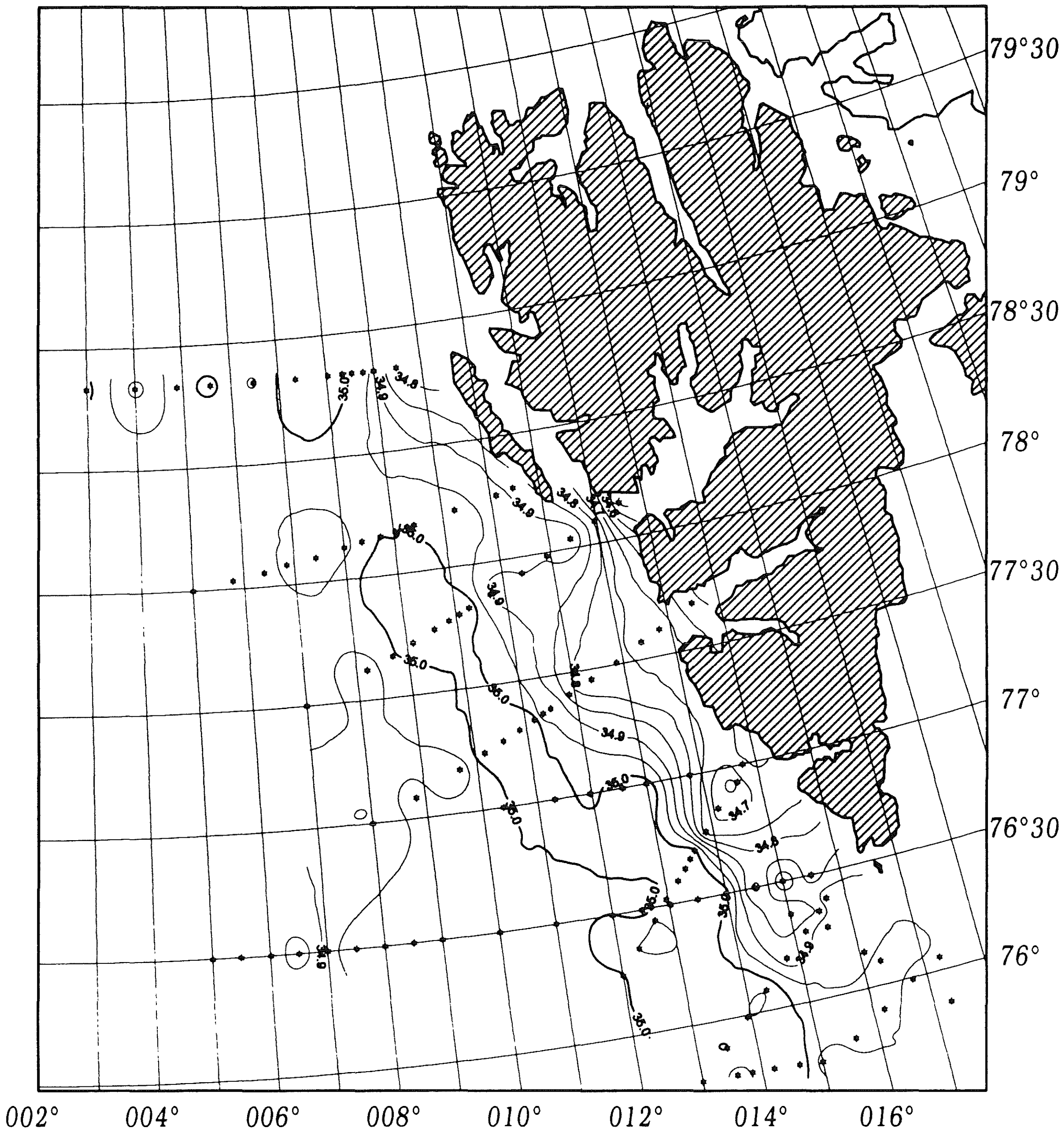

79°30
79°
78°30
78°
77°30
77°
76°30
76°
002°
004°
006°
008°
010°
012°
014°
016°
35.0
34.9
34.8
34.7

Fig 4

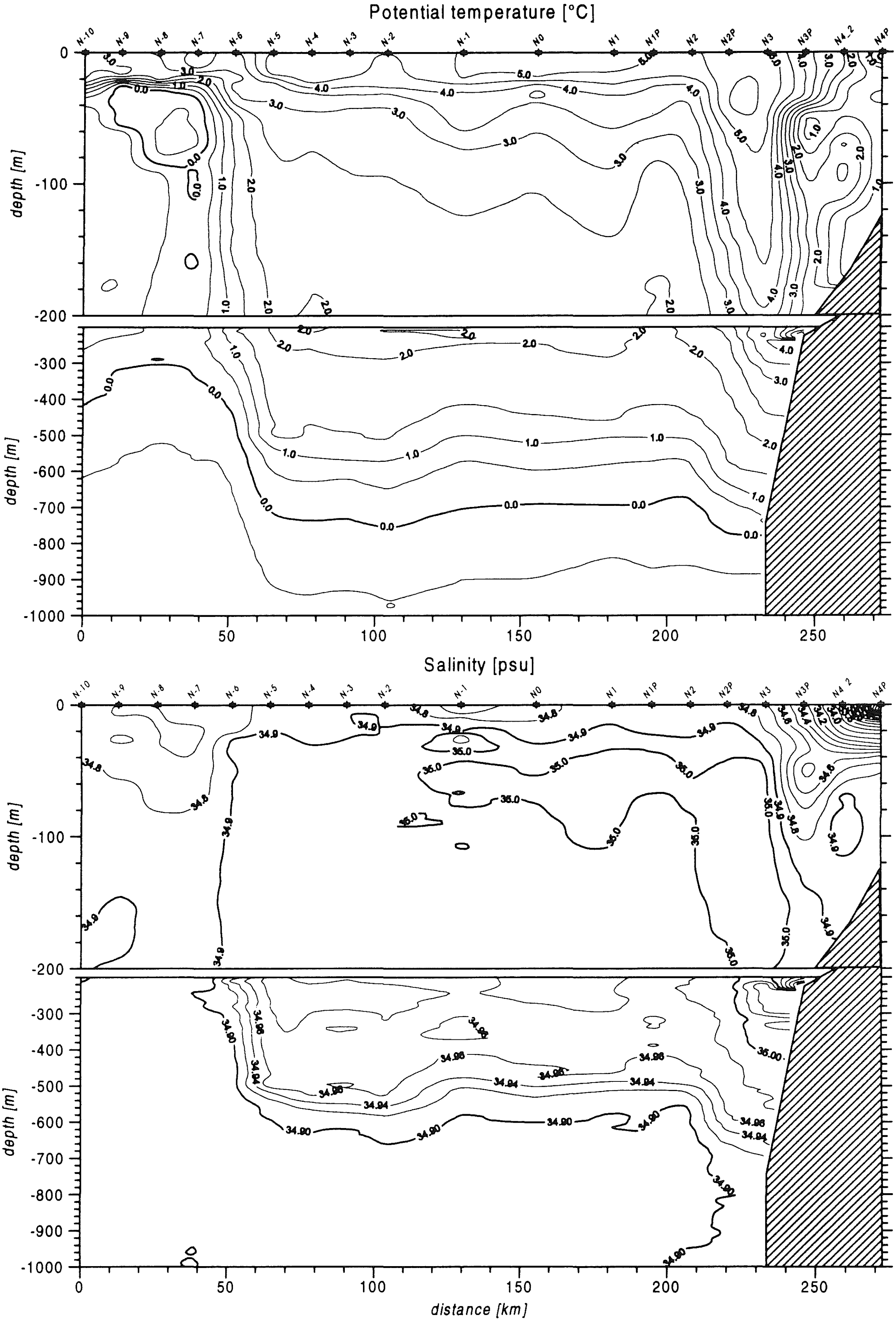
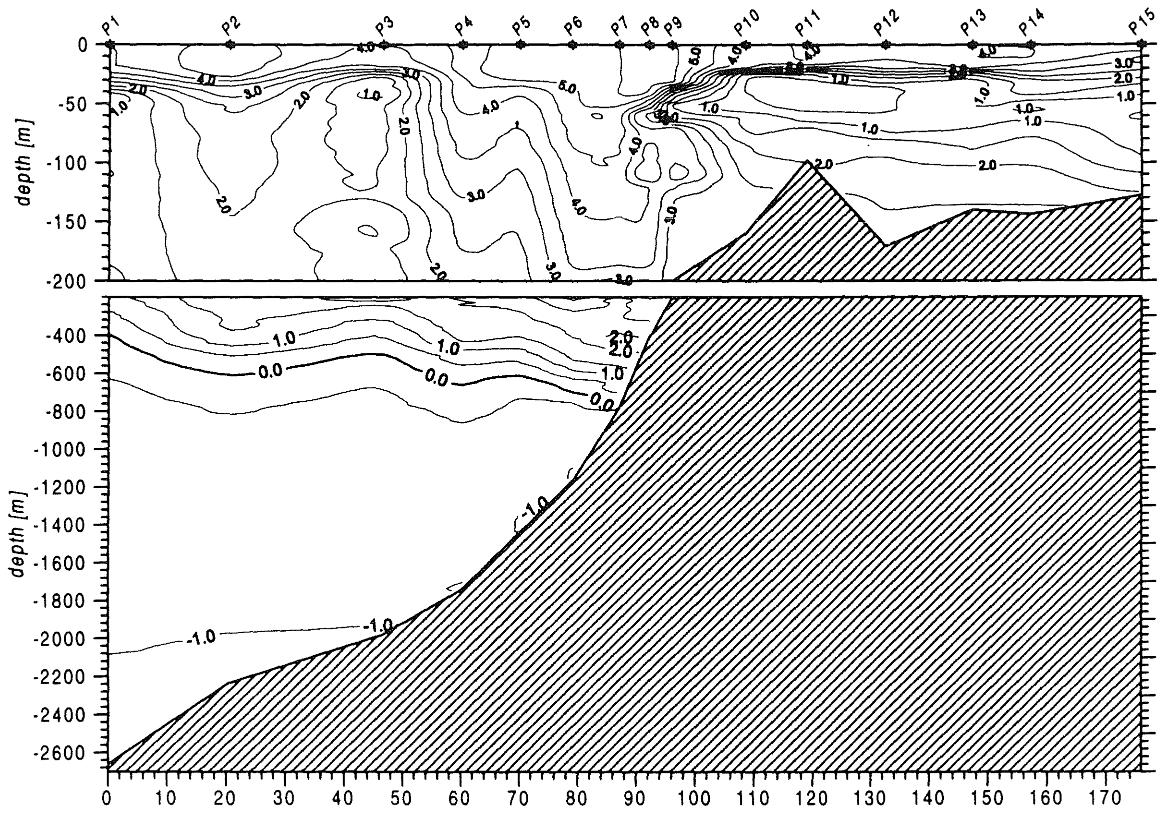
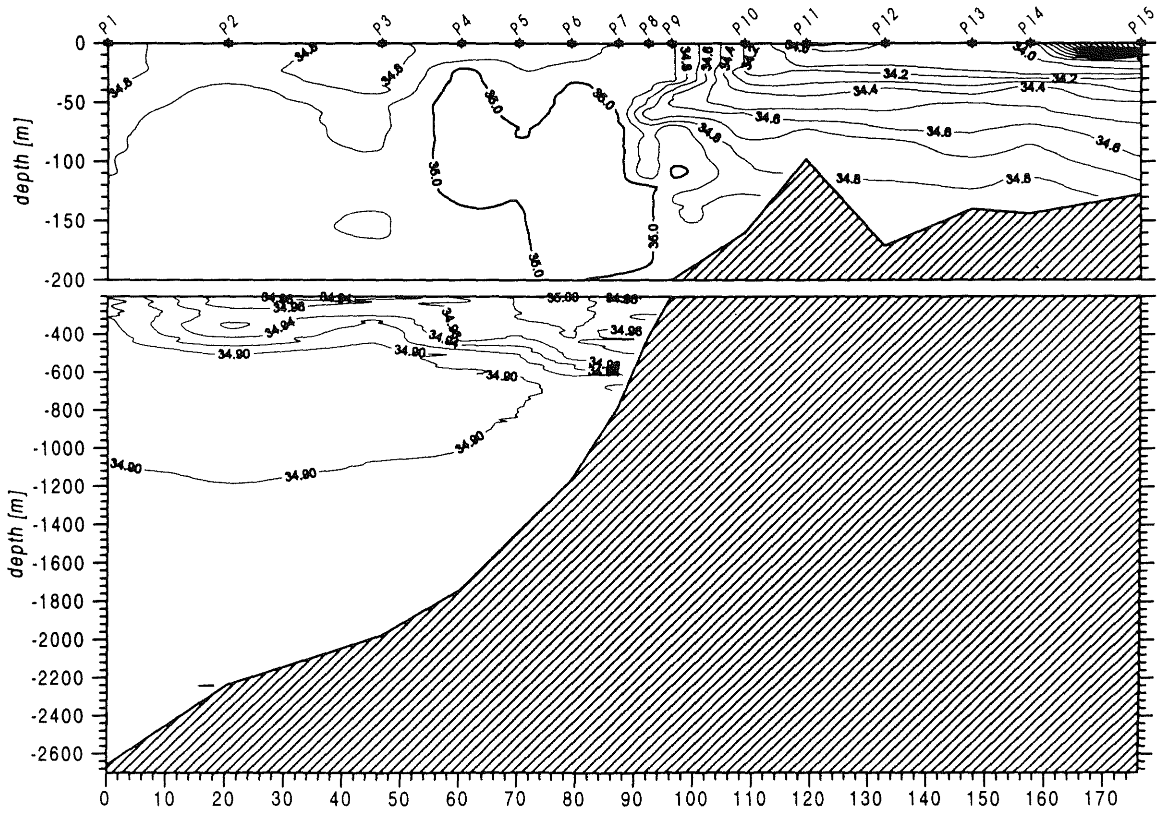

Potential temperature [°C]
N-10
N-9
N-8
N-7
N-6
N-5
N-4
N-3
N-2
N-1
N0
N1
N1P
N2
N2P
N3
N3P
N4.2
N4P
depth [m]
0
-100
-200
-300
-400
-500
-600
-700
-800
-900
-1000
0
50
100
150
200
250
0.0
1.0
2.0
3.0
4.0
5.0
6.0
Salinity [psu]
34.8
34.9
35.0
34.90
34.94
34.96
35.00
34.6
34.4
34.2
34.0
distance [km]

Fig. 5



Potential temperature [°C]



Salinity [psu]

upper part of fig. - intervals between isolines 0.1 psu
lower part of fig. - intervals between isolines 0.02 psu

Fig. 6

Annex K: Northwest Atlantic Sections

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Introduction

In the following, the meteorological and oceanographic conditions that prevailed in 1997 off the Canadian east coast have been described. The data presented here were collected by a number of researchers in Canada and Europe and compiled into time series for the standard sections and stations (Fig. 1). Colbourne in Newfoundland, and Drinkwater, Petrie, Prinsenberg and Peterson at Bedford Institute of Oceanography provided the time series and diagrams for this presentation.

Meteorological conditions

Air temperatures are monitored at Godthaab in Greenland, Iqaluit on Baffin Island, Cartwright on the Labrador Coast, St. John's in Newfoundland, and Sable Island on the Scotian Shelf. The data for these sites were obtained from: the Canadian Climate Summaries published by the Environment Canada (Canadian sites), and from the NOAA publication *Monthly Climatic Data for the World* (other sites). The monthly air temperature anomalies at these sites relative to their 1961-90 mean (Fig. 2) indicate warmer-than-normal conditions in January at all sites, continuation of the1996 conditions. However, the anomalies reversed to very cold conditions in February at all northern sites, and remained below normal until April, although the magnitude of the strengths of the negative anomalies decreased. From April onwards, at most northern sites the conditions remained warmer-than-normal with some minor reversals, whereas at St. John's and Sable, the conditions were predominantly colder-than-normal. The net effect was that the annual temperature anomalies at Godthaab and Iqaluit were above normal, at Cartwright, near-normal, and at the southern sites, they were below-normal (Fig. 3). At all sites, the annual anomalies show a decline from the local maxima established in 1996.

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 north-west winds, warm air temperatures, and limited ice cover. The annual NAO index anomaly (Fig. 4) for 1997 was still negative, however was above that observed in 1996. The two consecutive years of negative NAO index contrast the trend of very high positive anomalies of previous years.

The above normal air temperatures during the late fall of 1996 until January of 1997 had the effect of slowing the ice formation and a delay of approximately 2 weeks in the arrival along the southern Labrador coast. However, the below-normal temperatures for the rest of the winter brought the ice cover to near median values by February, and to values between median and maximum by April. Off Newfoundland, the pack ice was more offshore during the early part of the winter due to strong north-westerly winds, but was pushed against the coast in the spring. The ice retreat more or less followed the median pattern. Consequently, the 1997 peak ice extent south of 55°N on the Labrador Shelf was larger compared to 1996 (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. Recognising the usefulness of this index in monitoring the climate variability, the Department of Fisheries and Oceans occupies a series of cross-shelf transects in the July/August period of every year. The resulting temperature transects are used to derive the CIL areas and the anomalies relative to their 61-90 means (Fig. 6). The anomalies from the Seal Island and Bonavista continued to be negative in 1997 and lower than the 1996 values, indicating the prevalence of the warmer-than-normal conditions on the Labrador and Newfoundland shelves. Across Grand Bank however, the CIL area was approximately 20% above normal compared to slightly below normal values in 1996. Overall, the amount of subzero water on the Canadian continental shelf was below normal, 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 Newfoundland Shelf (Bonavista), the upper layers up to approximately 20 m depth, were slightly colder than normal, and saltier, whereas the intermediate and bottom layers were warmer than normal. The salinities over most of the shelf, except near the coast, were generally above-normal. The conditions were similar along the other two Sections.

Data from the fixed stations off the Canadian East Coast confirm the continuation of the warming trend in the north-west Atlantic. At station 27 located off St. John's, Newfoundland (Fig 10), the upper layer was warmer than normal during the winter months, below normal throughout the spring and summer, whereas the conditions below were near normal throughout the year. The salinities were generally near to slightly below normal, in contrast to the fresher-than-normal conditions that prevailed during the previous years. The low pass filtered time series of temperatures and salinities at standard depths (Fig. 11) indicate that, in 1997, overall near-normal conditions prevailed at all depths, compared to warmer and fresher than normal conditions in 1996. The heat and salt contents in the water column as estimated by the vertically averaged temperatures (0-176 M) and salinities (0-50 M) at Station 27 show conditions representative of near-normal temperatures and slightly fresher than normal salinities (Fig. 12).

The deep-water temperatures on the Scotian Shelf have also been found to have significant coherence at low frequencies horizontally from Laurentian Channel to mid-Atlantic Bight. Episodic intrusions of the warm slope water have been hypothesised 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 6 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 just above normal, representing a slight increase relative to 1996, and salinities mostly below normal, but higher than 1996 values. (Fig. 14).

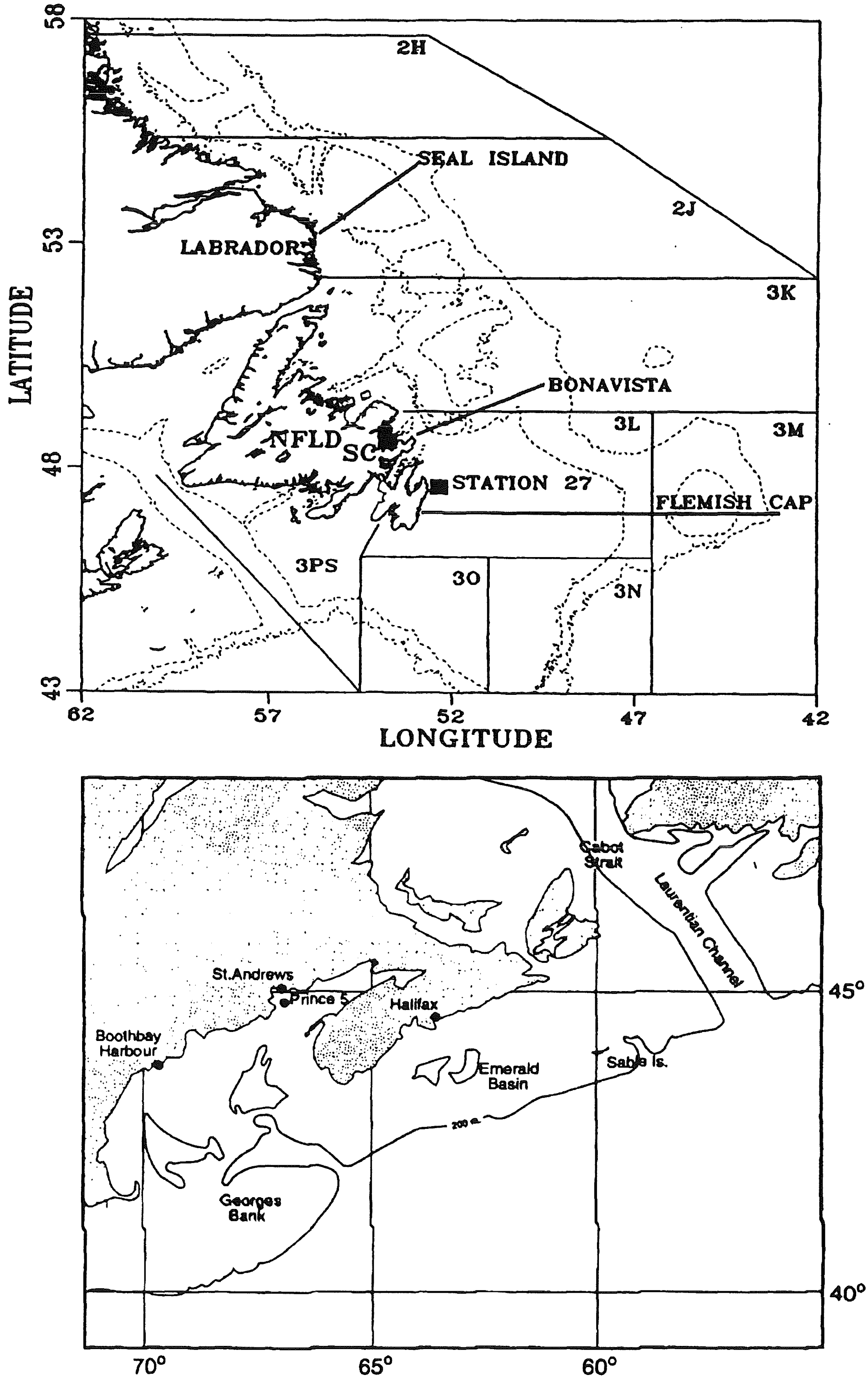
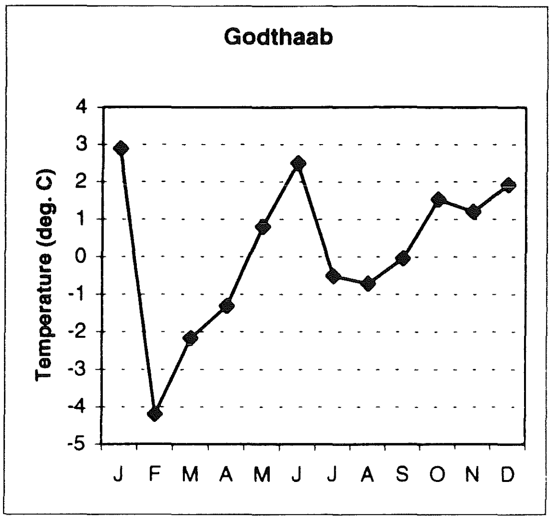
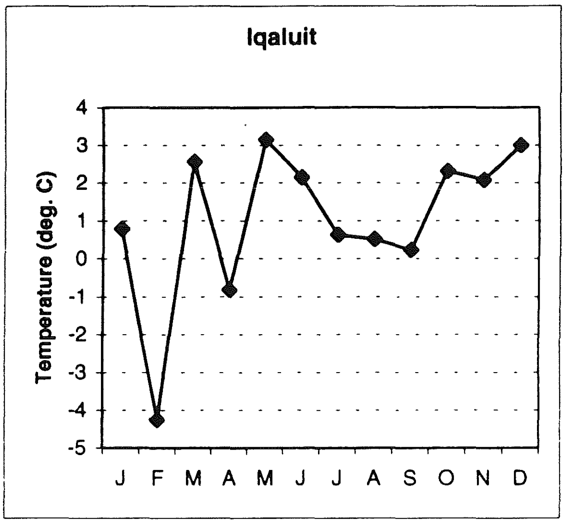
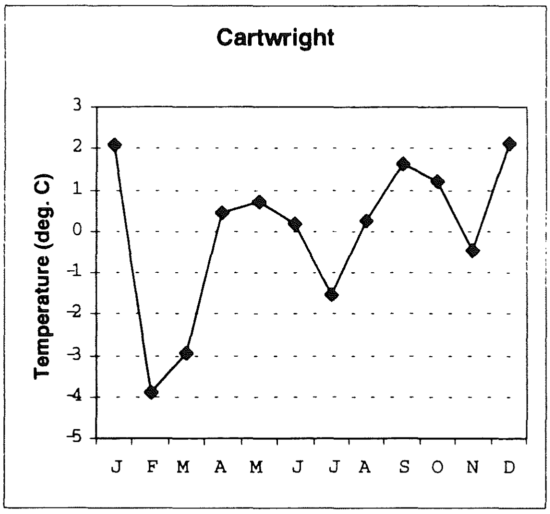
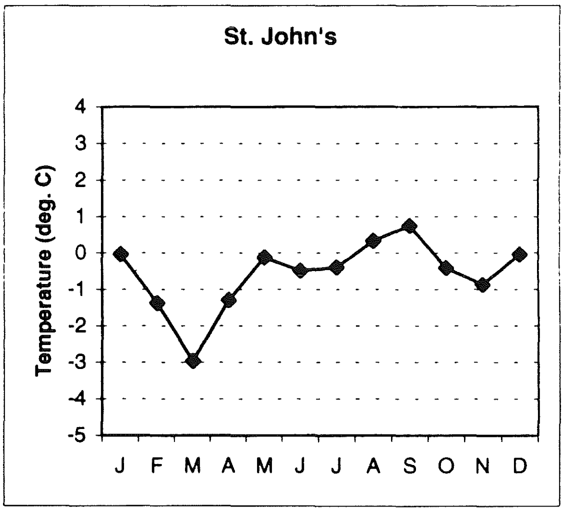


Fig. 1 Standard Stations and Sections – East Coast of Canada









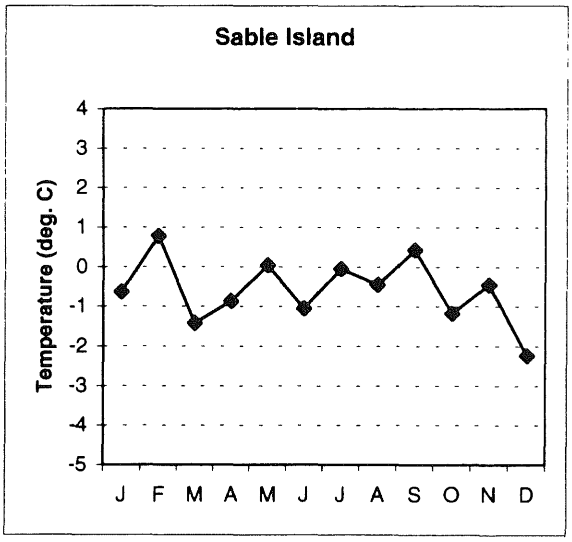


Fig. 2 Monthly air Temperature anomalies relative to 1961-1990 means: 1997

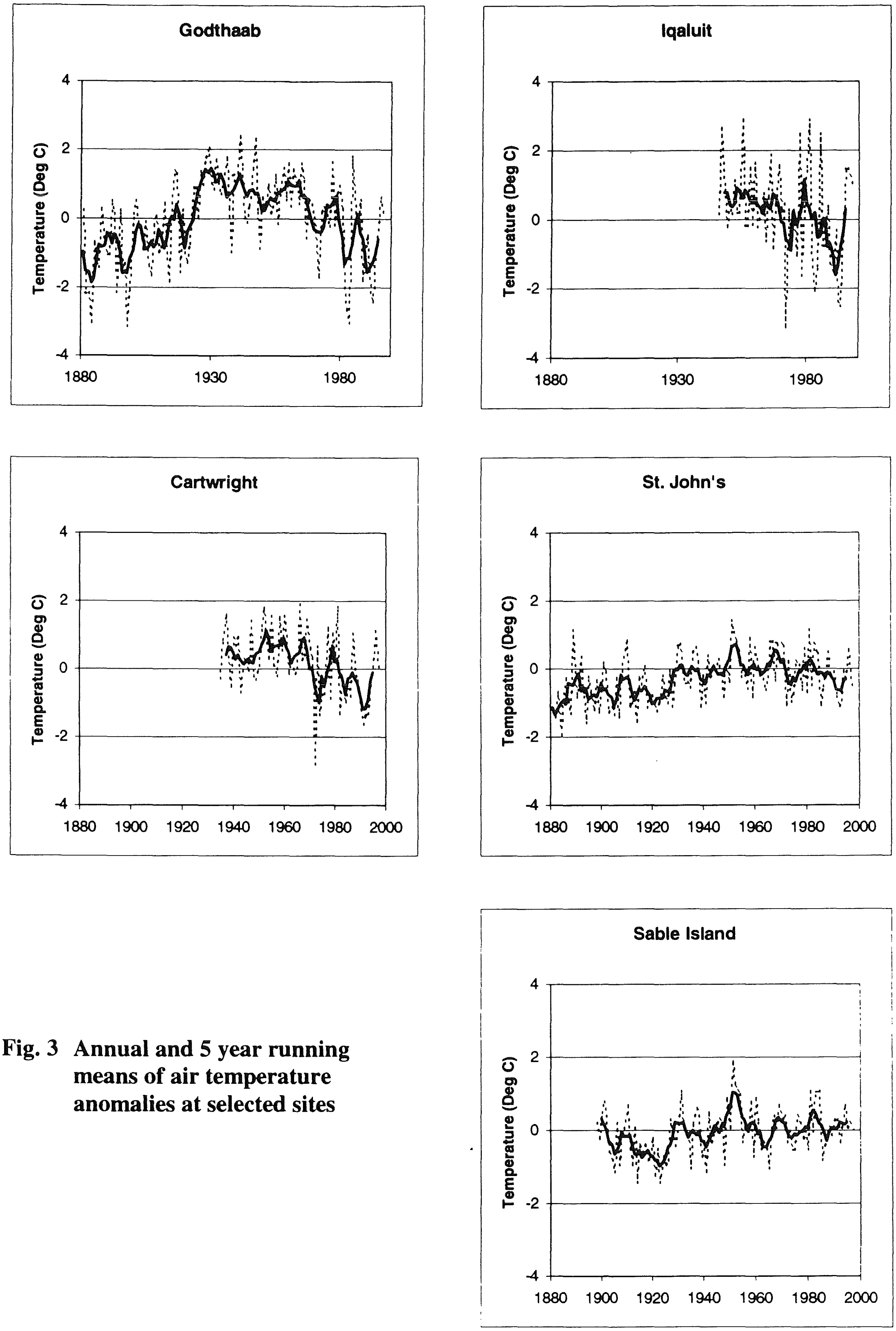
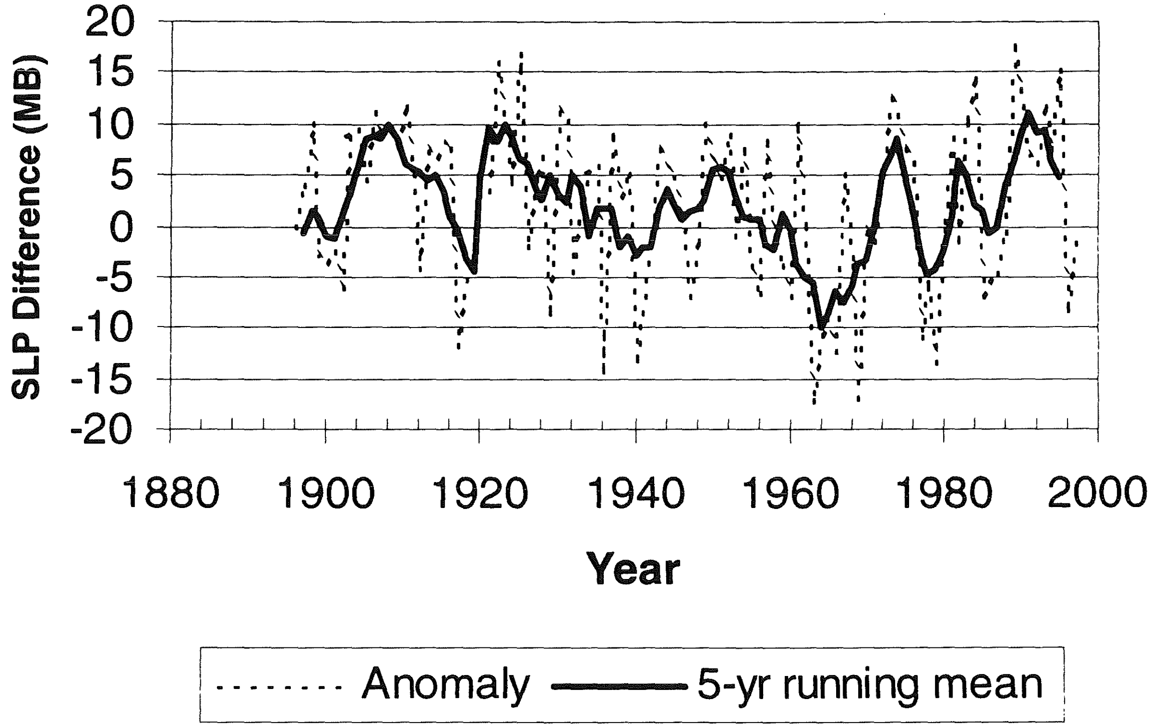


Fig. 3 Annual and 5 year running means of air temperature anomalies at selected sites

Fig. 4 NAO Index Anomalies



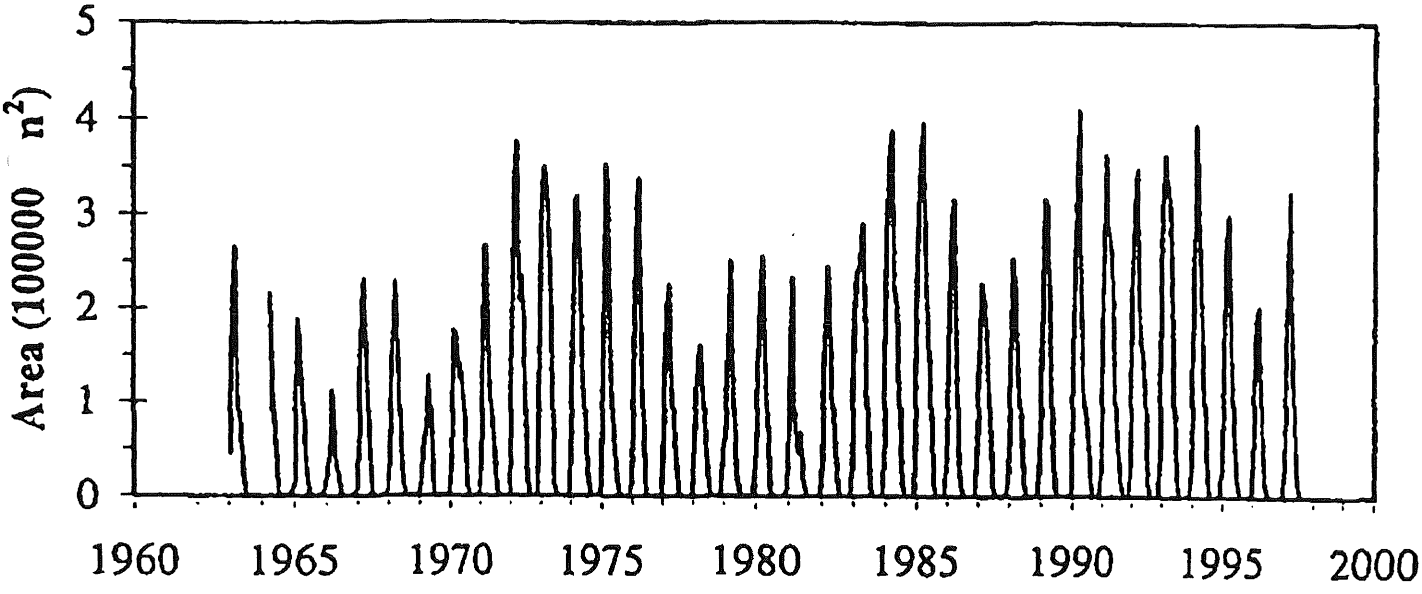
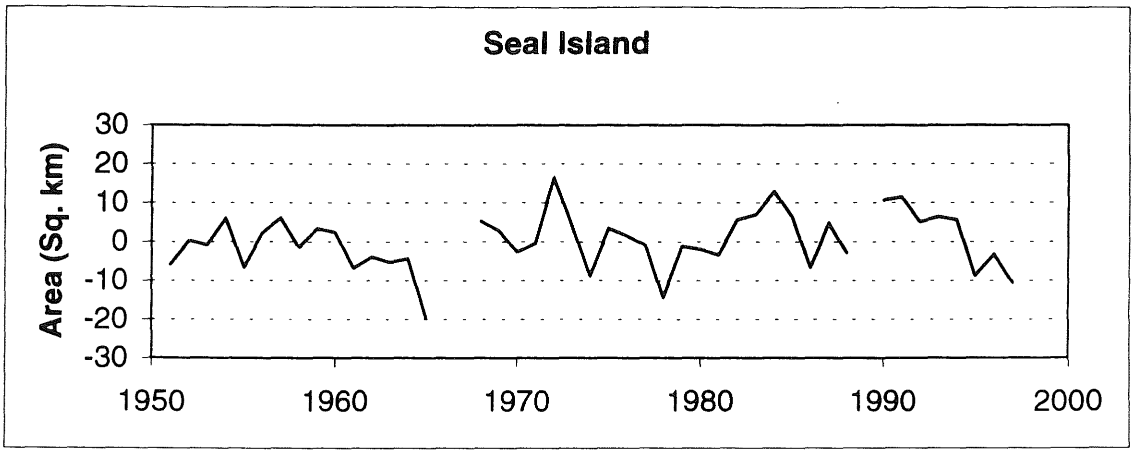
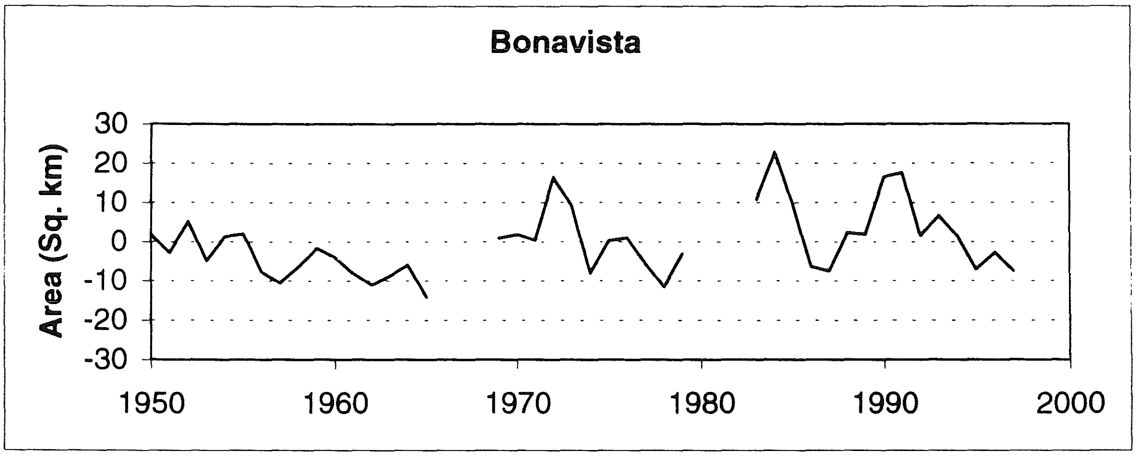


Fig. 5 Monthly mean ice area of Newfoundland and Labrador between 45°N and 55°N





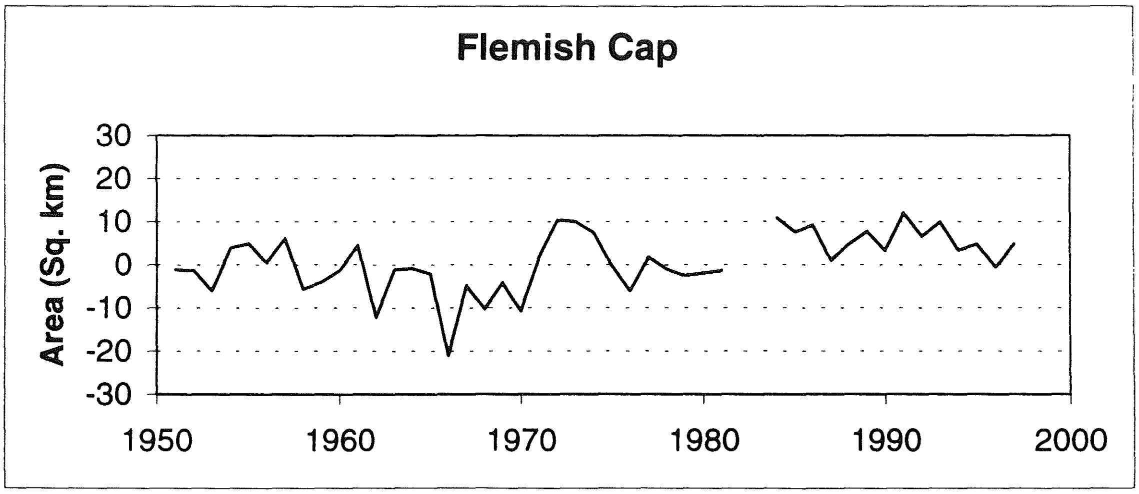


Fig 6 CIL Area anomalies relative to 61-90 average

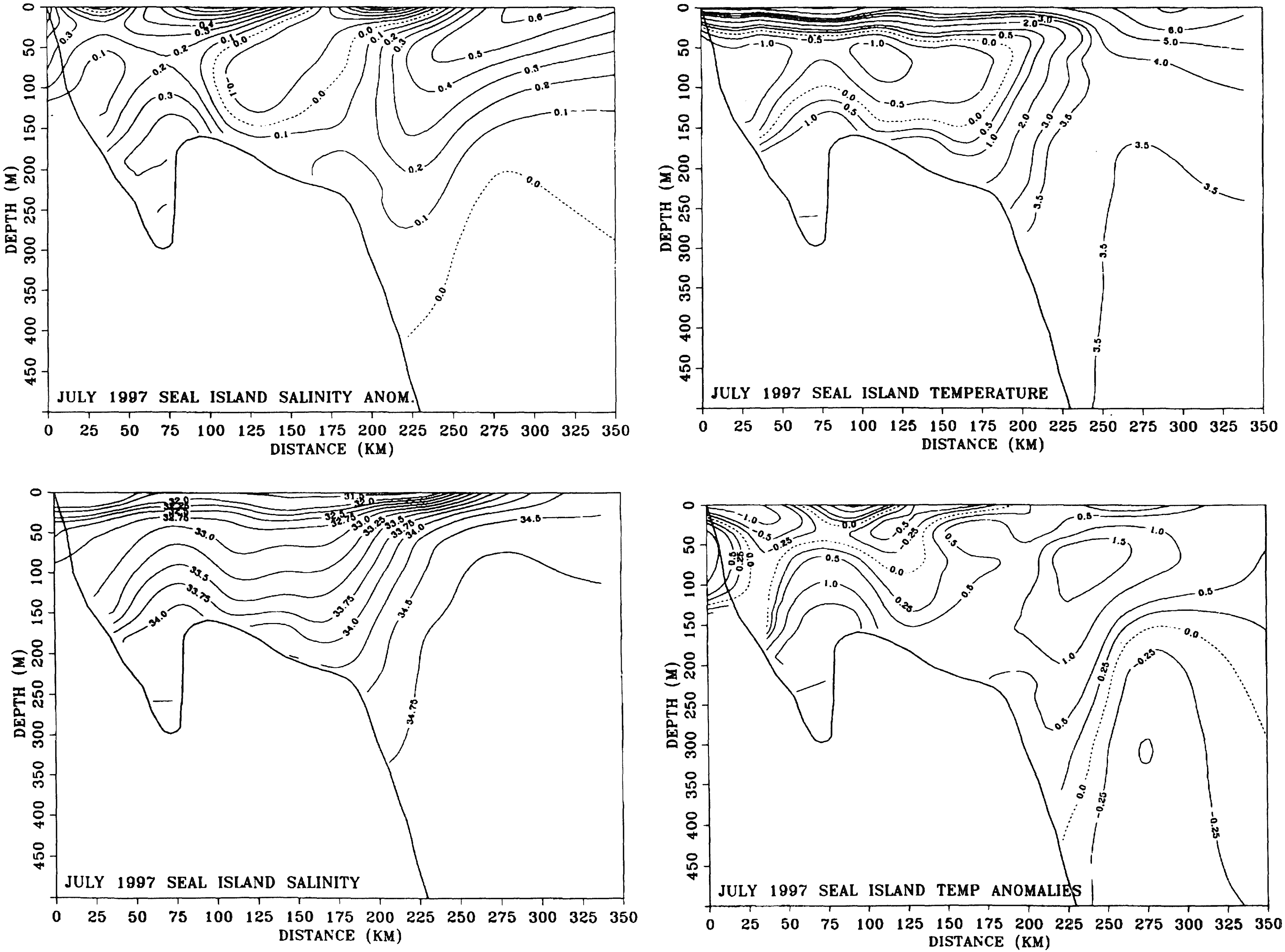


Fig. 7 Temperature and salinity transects – Seal Island

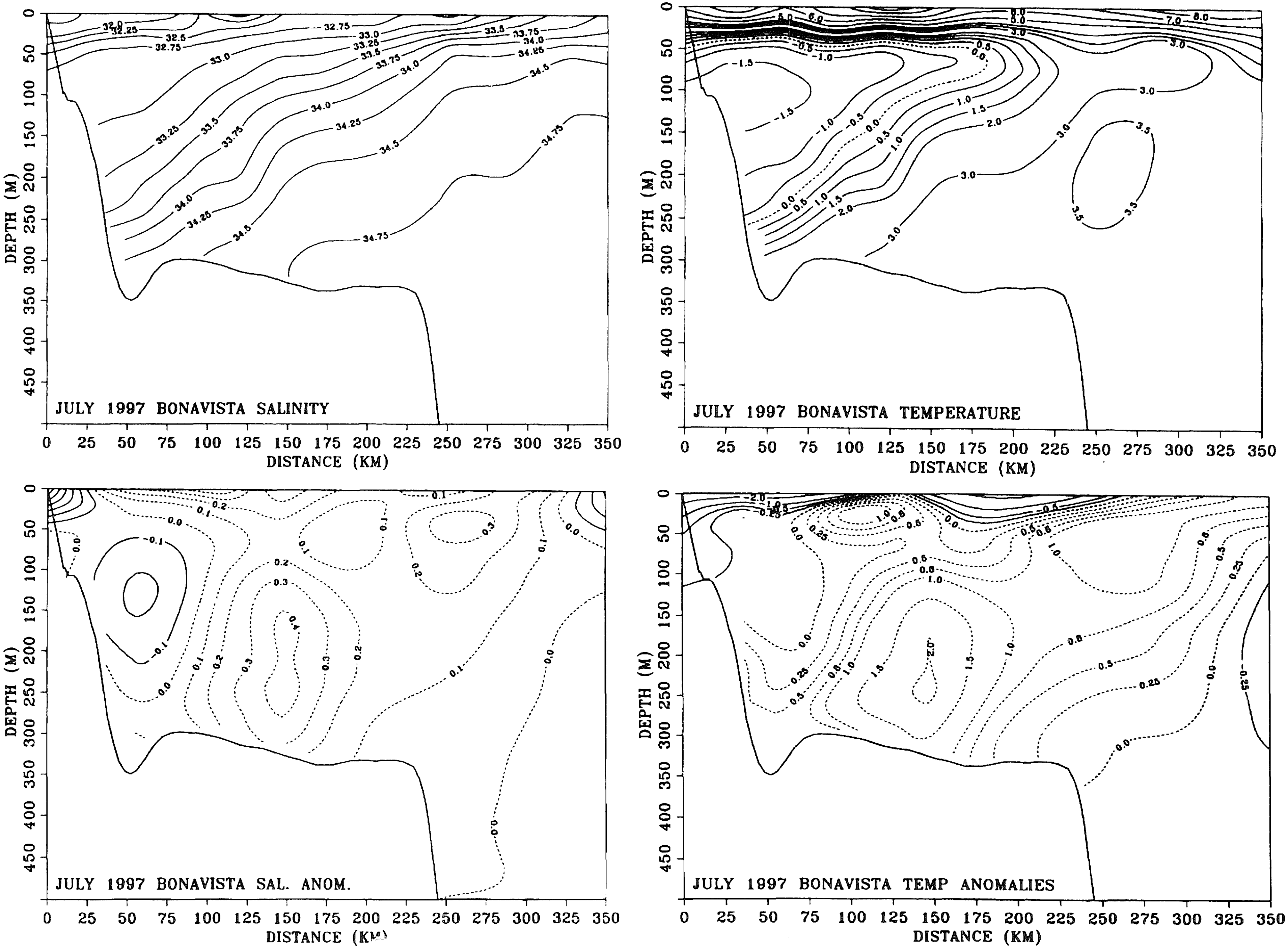


Fig. 8 Temperature and salinity transects - Bonavista

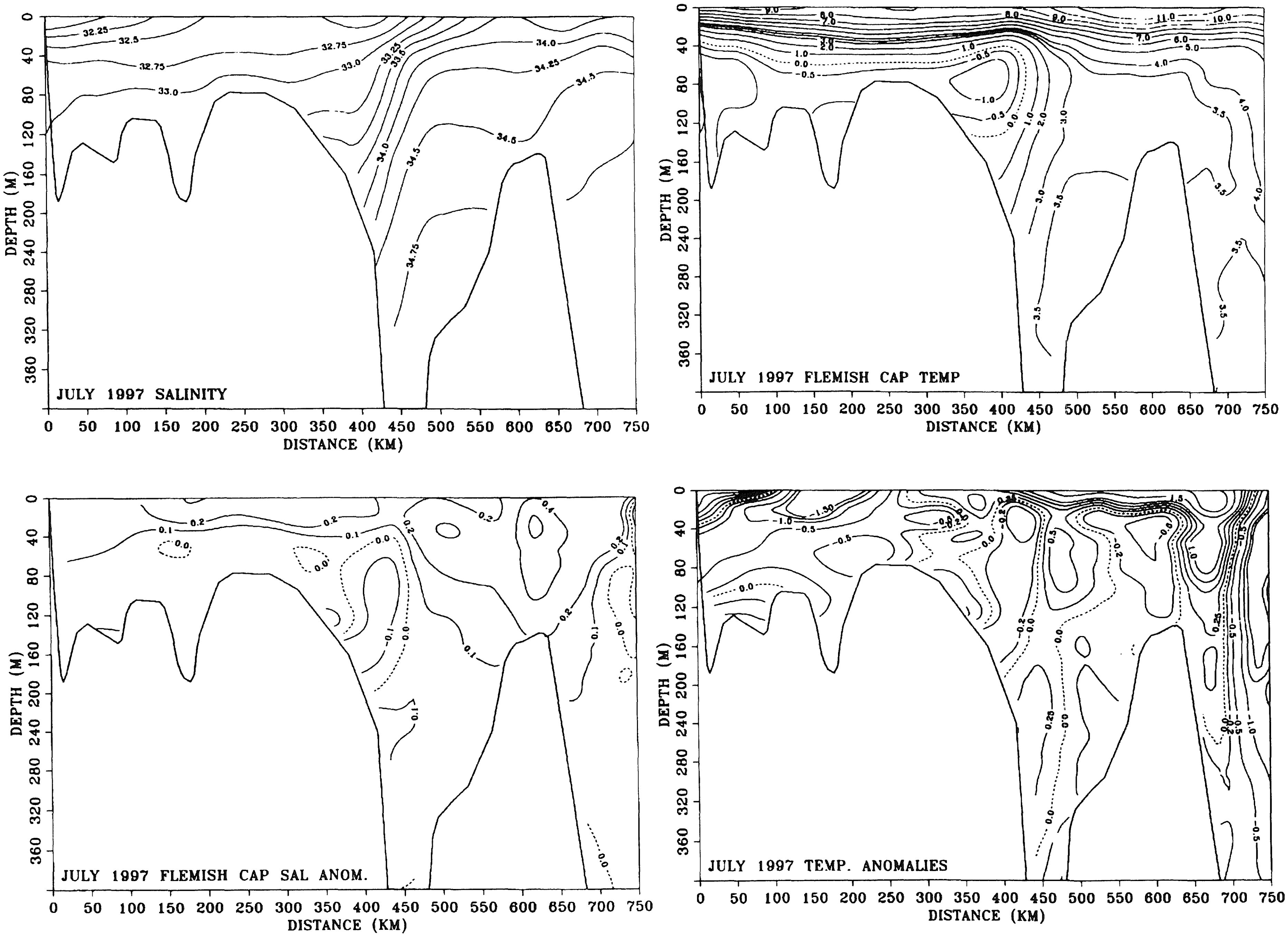


Fig. 9 Temperature and salinity transects – Flemish Cap

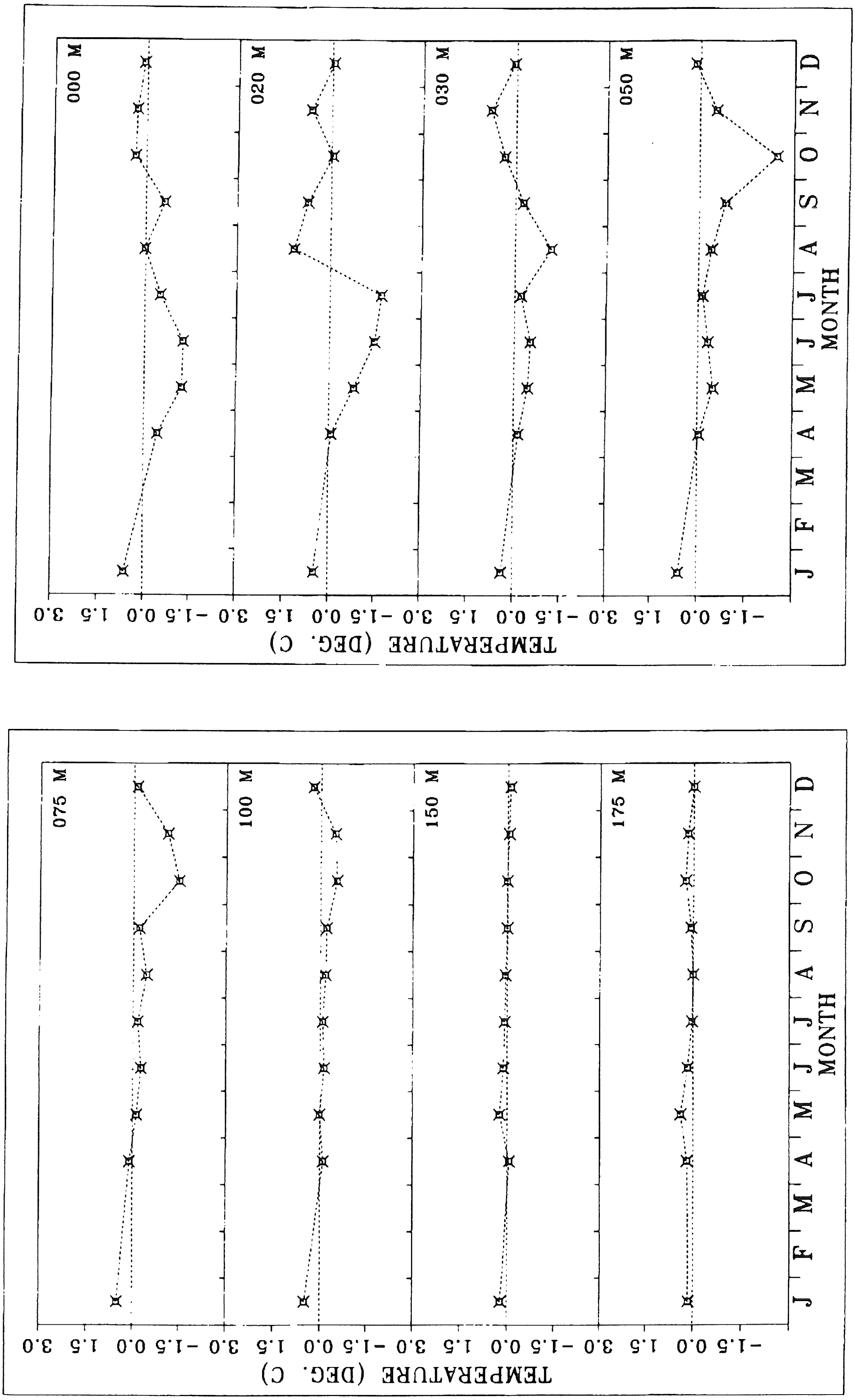


Fig 10a Time series of monthly temperature anomalies at Station 27 at selected depths during 1997

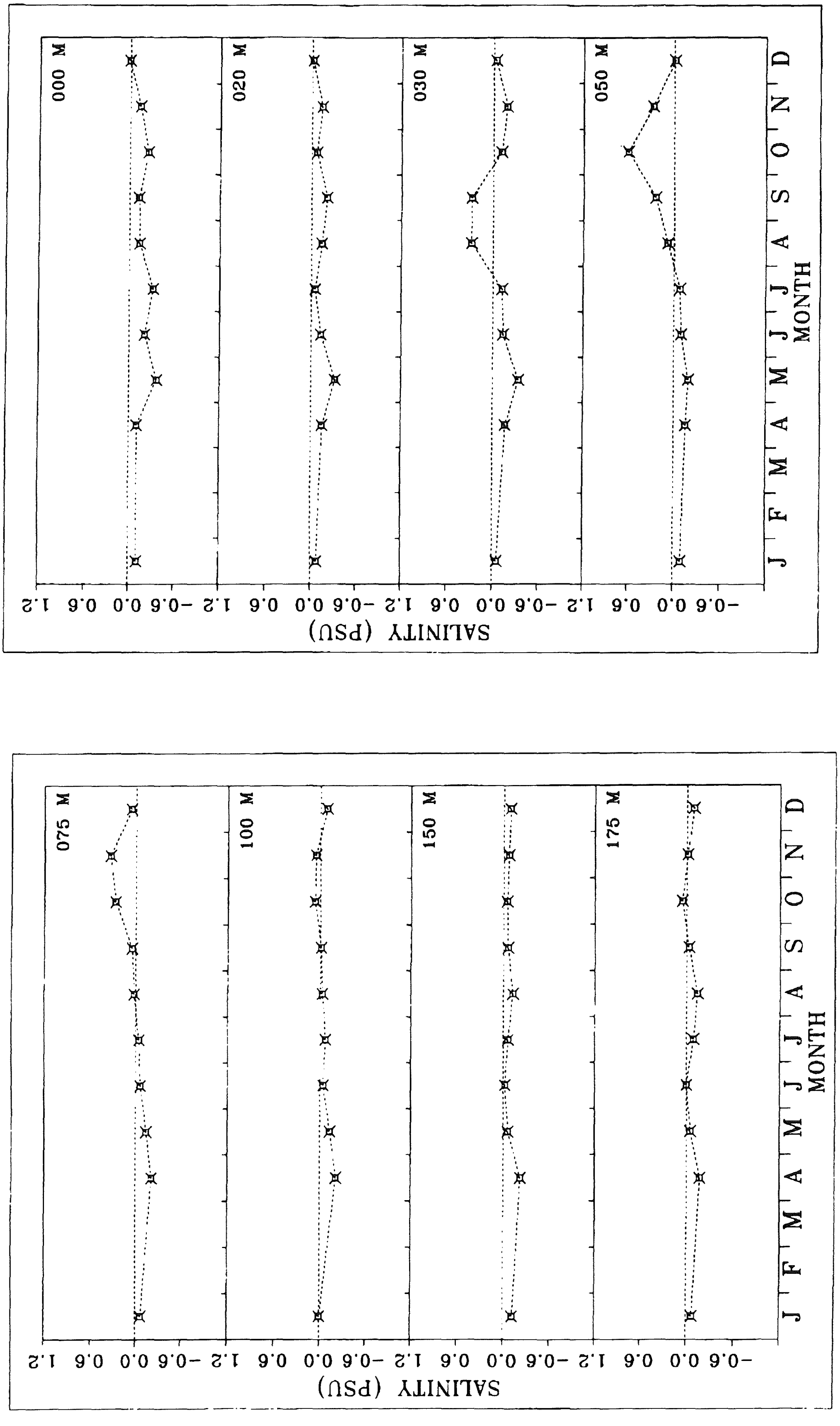


Fig 10b Time series of monthly salinity anomalies at Station 27 at selected depths during 1997

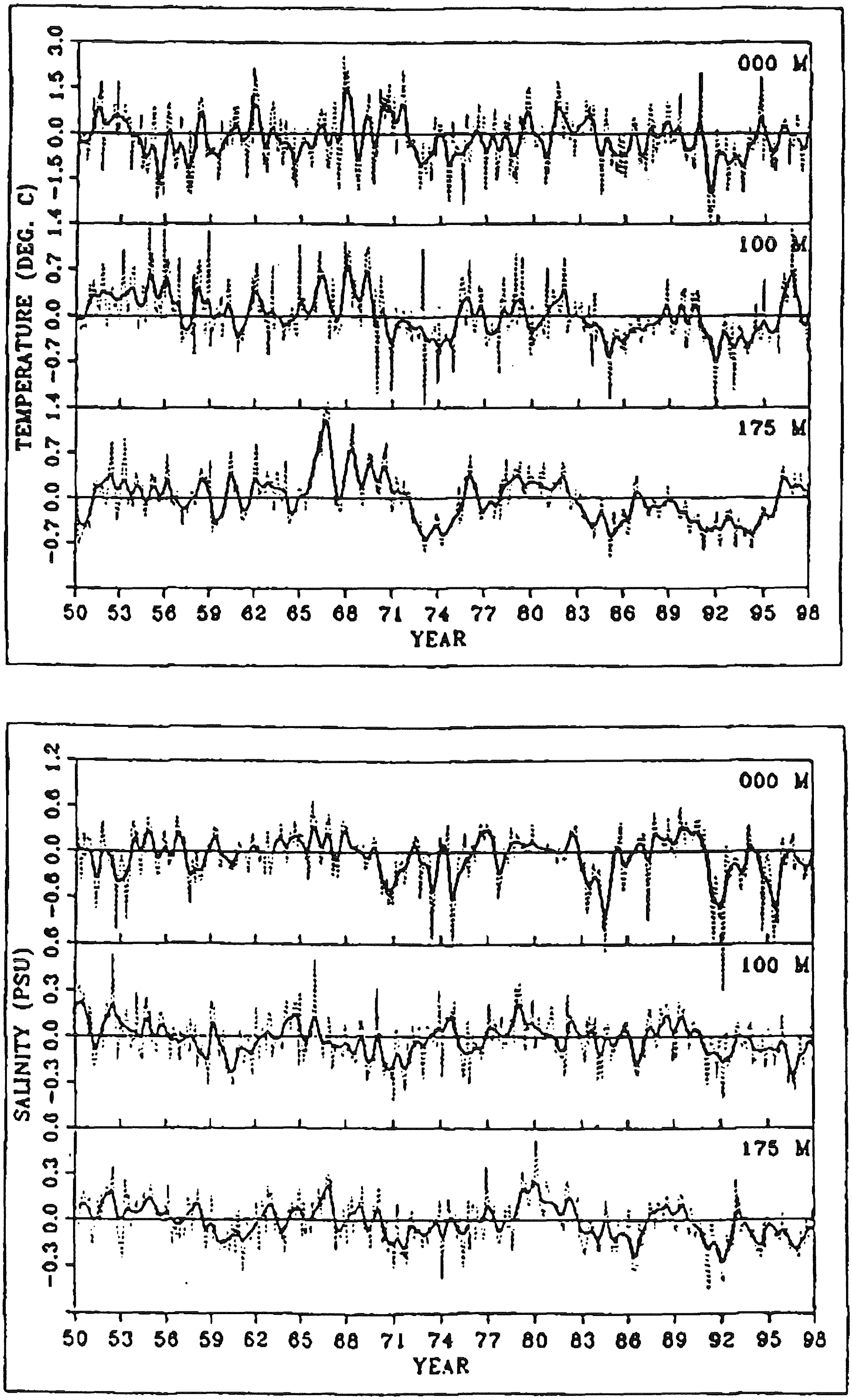
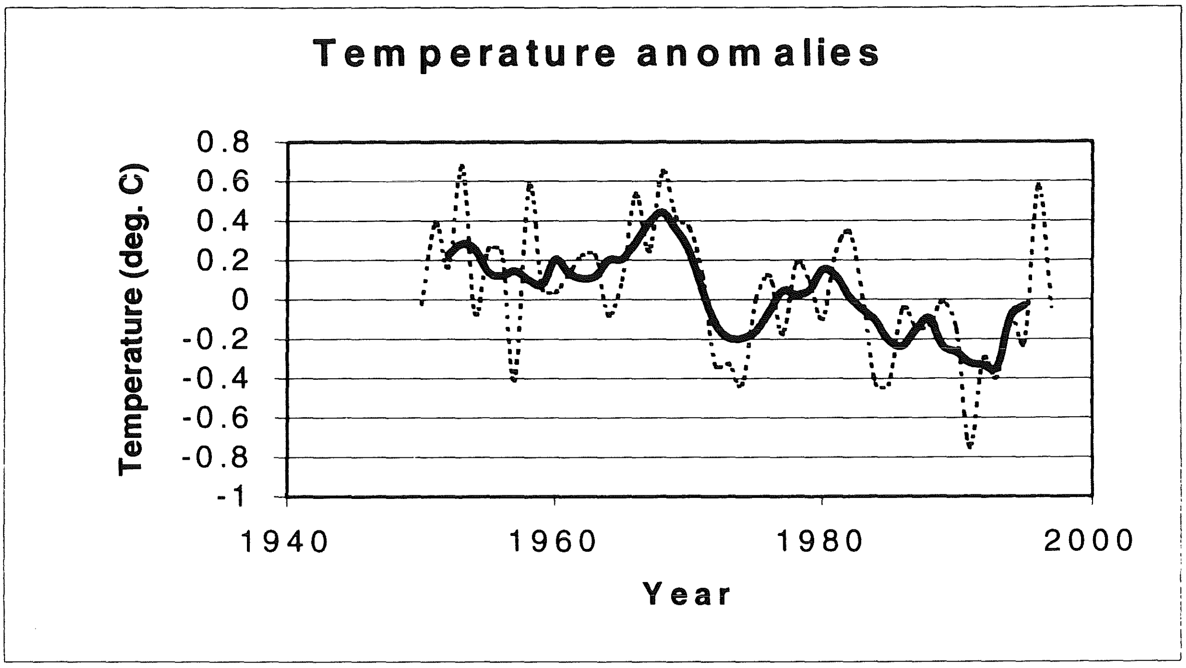


Fig 11 Low pass filtered time series of temperature and salinity anomalies at standard depths at Station 27



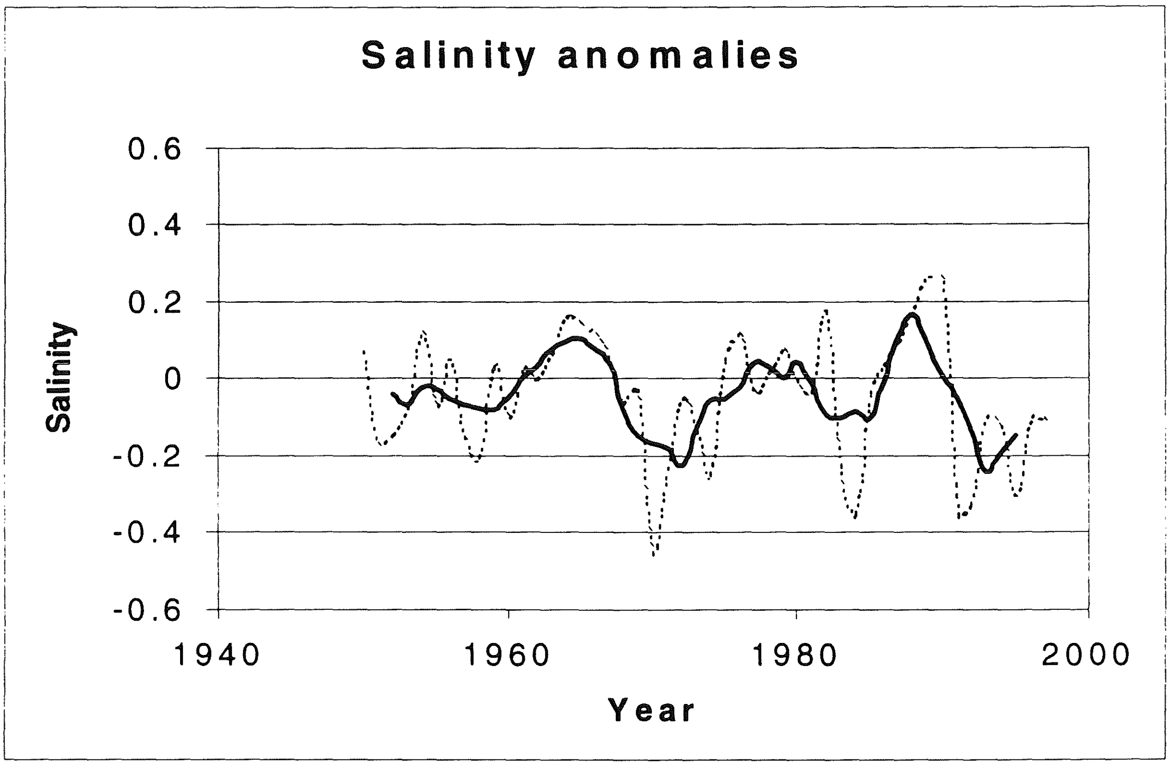


Fig 12 Time series of the annual vertically averaged temperature (0-176m) and salinity (0-50m) anomalies at station 27. The solid lines are the 5 year running means.

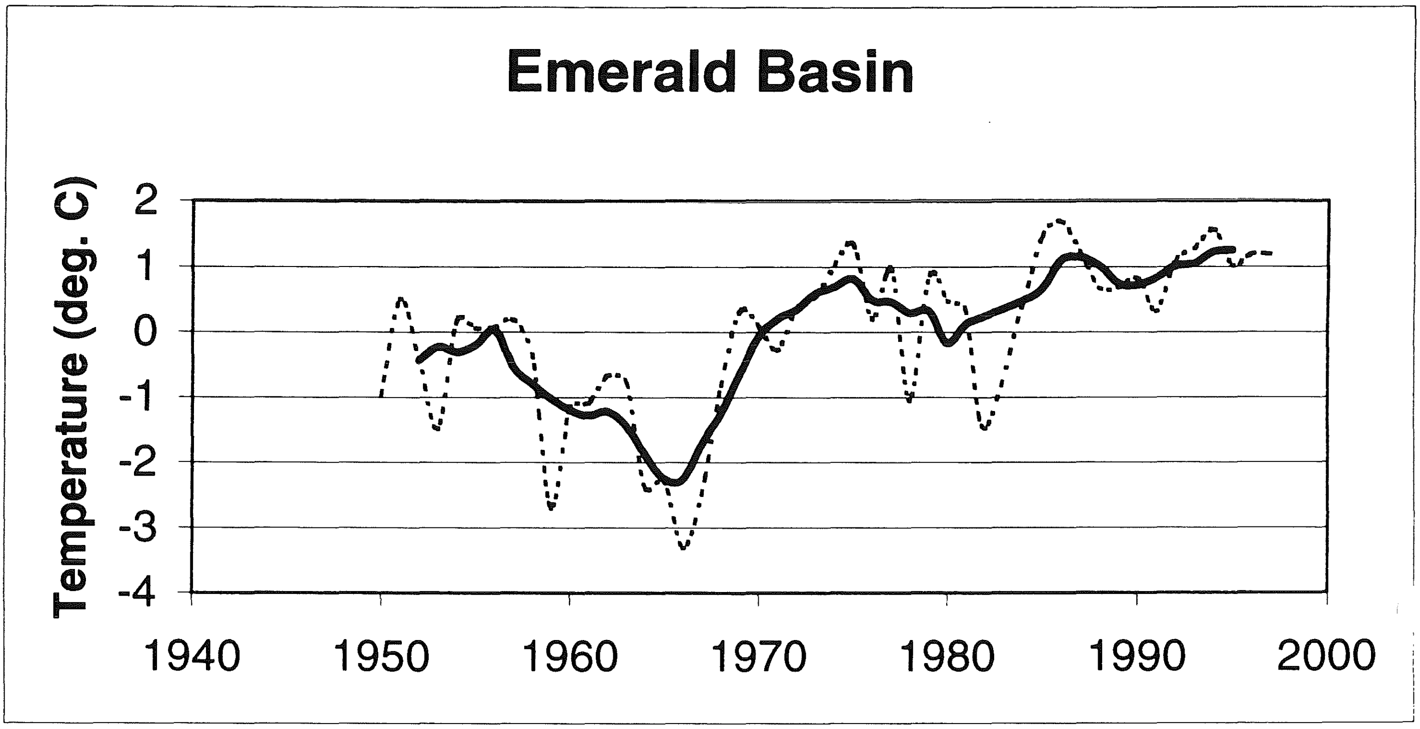


Fig 13 Temperature anomalies (relative to 1961 – 1990) at 250 m in Emerald Basin

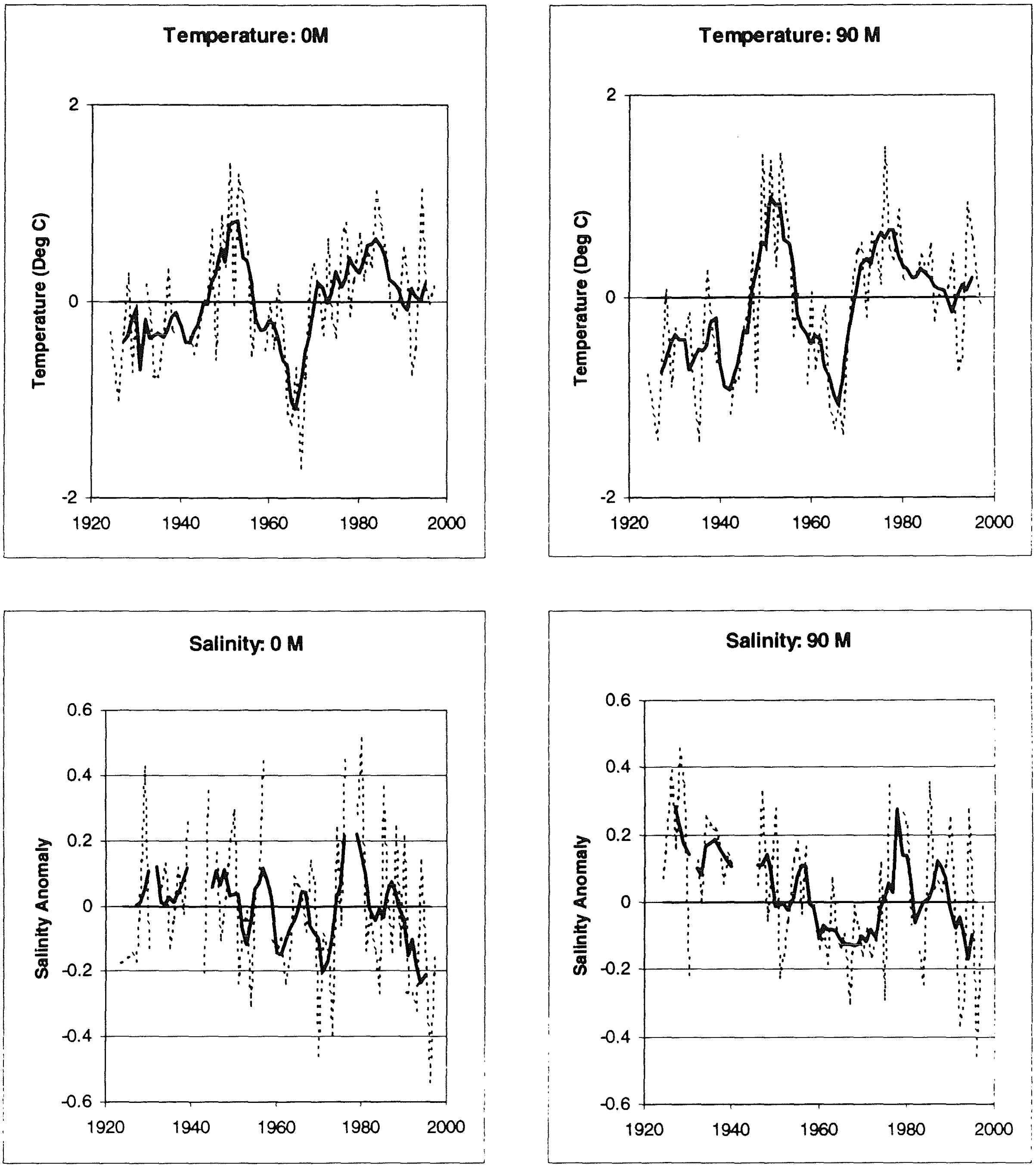


Fig 14 The annual 5 year running means of temperature and salinity anomalies for Prince 5

Annex L: Occurrence of High Salinities in the Southern Bight and Channel

Johan Van Bennekom, NIOZ, P. O. Box 59, 1790 AB, Texel, Holland

In February and March 1998 salinities in the central Southern Bight, presumably originating from the Channel, were high, 35.180 at about 52° N and 35.293 at 53°N respectively. These are not very local phenomena as shown by the underway salinity samples, taken on March 2-4 and 25-26 in the framework of the MERLIM program (Courtesy Dr Timmermans, NIOZ). Calibration of the underway sensor gave an accuracy of better than 0.02 PSU. Fig. 1 shows that salinities were substantially higher than long term averages as published in ICES atlases for 1905-1973: 0.5 higher in the central Southern Bight, 0.4 higher in the Eastern Channel and 0.25 PSU higher in the western approaches to the Channel. In many cases they are close to the maxima recorded in these atlases. Data recorded by the North Sea Directorate (Dutch Rijkswaterstaat) showed that high salinities in the central Southern Bight started in January 1998; in December 1997 they were about 35.0 (Courtesy M. Bontenbal). However, the present data set did not allow an estimation of the duration of this high salinity occurrence in the Bight.

It is difficult to select and interpret “real” maxima from archived material. An attempt has been published in the Quality Status Report (Fig 2-3, North Sea Task Force, Oslo arid Paris Commission, London, 1993), showing the salinity maxima from 1905 to 1991, ranging from 35.1 to 35.6 in the central Southern Bight (2-4°E and 52-54°N), selected from the ICES data centre. The years 1970-74 and 1990-92 give even higher values than ours in 1998. Water discharge of the Rhine River was below average during 1971-73, 1976 and 1989-93. The timing of these periods does not coincide with the periods of high salinity in the North Sea in Fig 2-3 and therefore the river discharge is not the dominating factor in the variation of the salinity maxima in the Southern Bight. "Oceanic climate" in the western approaches to the Channel and water flow through the Channel seem to be more important

Other observations

The report by Malmberg to the 1998 OHWG meeting noted a salinity increase in the waters south of Iceland, while Turrell noted cyclicity superimposed on a salinity increase since 1994 in N. Atlantic water.

There are problems with both spatial and temporal distributions in this area, which makes statistics troublesome and that he used only clusters (Harry Dooley, personal communication). The 1970s values may be suspect, but the 1990 peaks seemed convincing. The 1990s situation also led to a paper by Heath (Nature 352:116, 1991) when the highest ever values were identified in a strip, 3.5-4E; 58-59N, off the Norwegian coast, >35.45. The maximum of 35.471 seemed the highest salinity entering the North Sea in this century.

However, these high salinities are not that exceptional (Becker, personal communication). High salinities were observed in the Channel and southern North Sea in the years from about 1989 to 1991 (Becker and Dooley, Ocean Challenge, Vol.6 (1), 1995). A steady increase in salt since 1993 has been observed by Peter

Koltermann, at around 10°W, 49°N and it extends pretty far west to about 25^{0}W. This increase was not present in the 1957 or 1982 section.

Surface salinity data from CIROLANA which from 31 Jan-16 Feb 1998 passed right through the Southern Bight and Channel and from 2-5 Feb 1998 through the Celtic Sea and Irish Sea, appear to corroborate these observations (Bob Dickson, personal communications). In the western approaches values of 35.56-35.58 were observed.

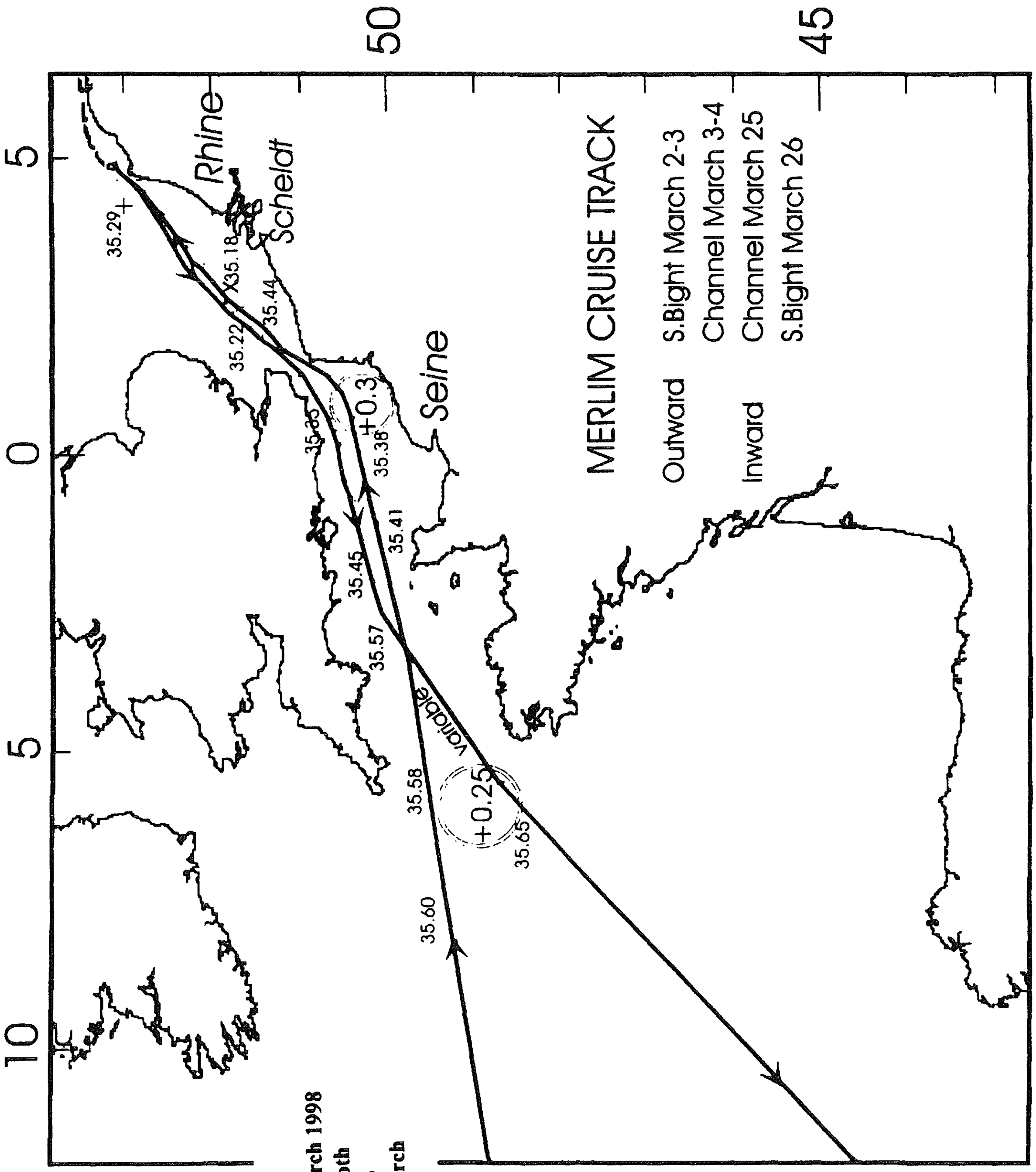


Fig 1.
Salinity Feb -March 1998
at 3 m depth
(x) 17 Feb
(+) 30 March

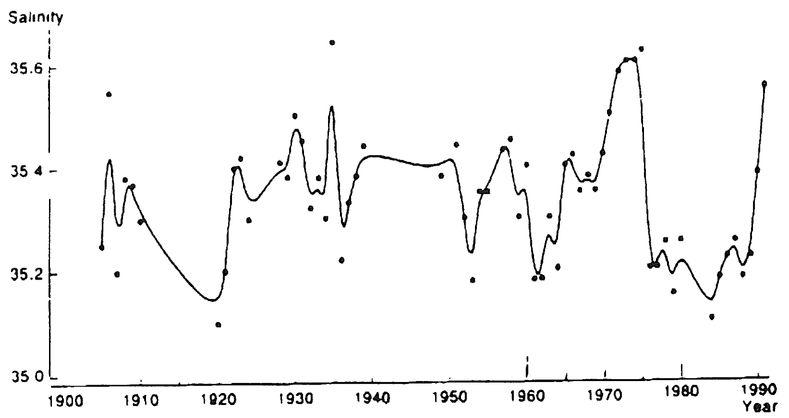
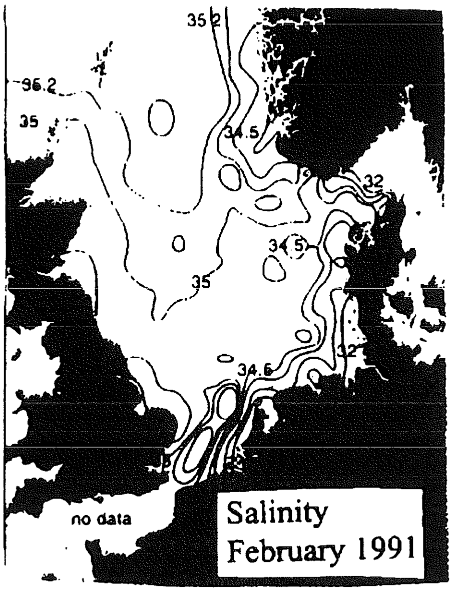
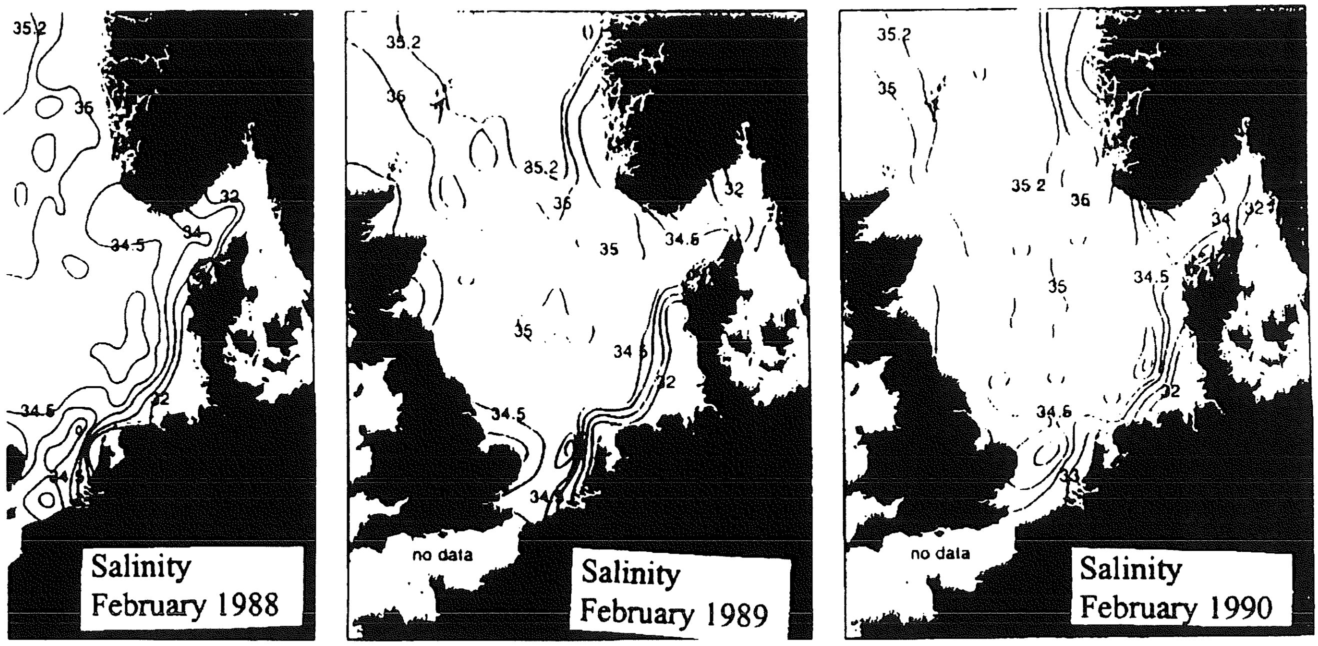


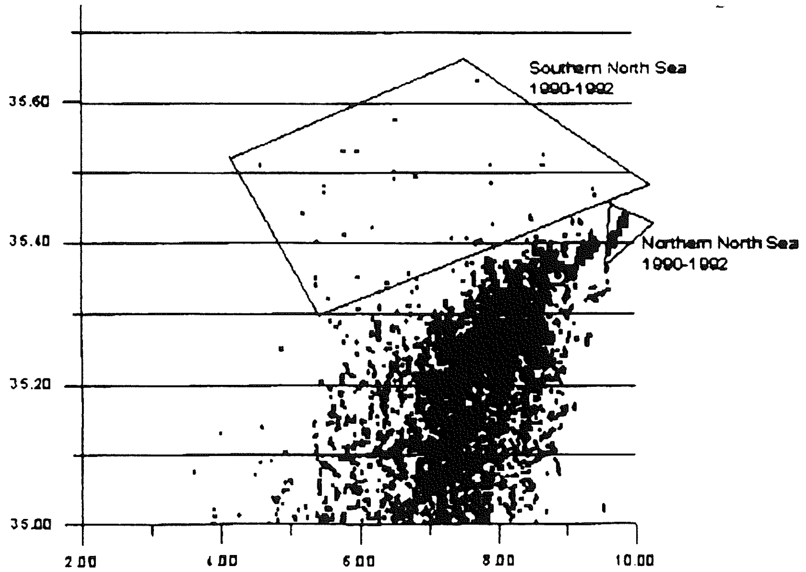
Figure 2-3. Trends in maximum salinity in the southern North Sea (52–54°N 2–4°E), 1905–1991. Source of data: ICES Oceanographic Data Centre.

From North Sea Task Force
Quality Status Report 1993
London and Paris Commission





Surface salinities in the North Sea, 1988–1991. Source of data: ICES Oceanographic Data Centre



FROM DOOLEY

t,S North Sea
IBTS surveys 1990-1997

http://www.ices.dk/committe/occ/johan.jpg

Annex M: Winklers by Colorimetry

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P. O. Box 59, 1790 AB, Texel, Holland

Following a suggestion by Su-Cheng Pai et al (Marine Chemistry 41:343-351, 1993), scientists of various disciplines at NIOZ obtained experience with measuring the amount of Iodine, produced in the Winkler procedure, colorimetrically at a wavelength of 456 nm. Some modern spectrofotometers have sufficiently narrow bandwidths and reproducibility to allow measurements on the slope of the extinction spectrum (Fig 1). Su-Cheng Pai et al. demonstrated the linearity of the calibration curve over the range of oxygen concentrations encountered in seawater. This has been our experience too; moreover, the calibration constant did hardly change over periods of at least half a year. We used a Hitachi U-1000 spectrofotometer (bandwidth 5 nm; reproducibility 0.3 nm), connecting the analog output to a voltmeter (Metex M4650). In this way we obtained 4 significant digits in the extinction, necessary in view of the required accuracy. We found reproducibility's of about 0.2% and excellent agreement between results obtained by titration and by colorimetry. Colorimetry has several advantages (first 4 also mentioned by Su-Cheng Pai):

- It is simpler and at least 3 times quicker than titration.
- No standardised thiosulphate is needed.
- Bottle volumes have to be known only with 1% accuracy instead of 0.1% in titration's. Small bottles do not require much adaptations
- Interference by turbidity, a nuisance in titration's with photometric endpoint, is corrected by subtraction of the extinction after adding drops of a sulphite solution.
- Measurements can be repeated in the same bottle

The procedure for sampling, pickling and storage is the same as for titration. Calculation of oxygen concentrations from extinctions follows the procedure by Su-Cheng Pai. The volume of acid added to dissolve the precipitate also dilutes the colour. Extinctions are first recalculated to the entire bottle volume by multiplication with

$$({}^{v}\text{bottle} - {}^{v}\text{reagents}) / ({}^{v}\text{bottle} + {}^{v}\text{acid})$$

Corrected extinctions are multiplied with an apparent extinction coefficient ($\mu M^{-1}\ d^{-1}$), where d is the optical path, determined from calibration with Potassium Iodate solution. We do not add the Iodate to samples as Su-Cheng Pai does, but weigh different quantities of iodate solution into calibrated 100 ml volumetric flasks, add the acid and alkaline iodide solutions and fill up to the mark with bidest. The oxygen equivalents of the iodate quantities in µmol are divided by 0.1 and the reagent blank is subtracted to get µM. With our apparatus the apparent extinction coefficient in 1 cm cuvettes varied less than 0.2% over periods of at least half a year. Variations are probably larger when changing to a different batch of reagents.

Reagent blanks and "Sea water blanks" are also determined colorimetrically at 352 nm (maximum absorption of the triiodide complex, where the extinction coefficient is about 25 times higher), by adding first acid and, after stirring, the alkaline iodide solution. Under these circumstances dissolved oxygen does not produce iodine but other oxidizing components do. The amount of oxygen in the reagents is determined by multiple additions of reagents to de-oxygenated water.

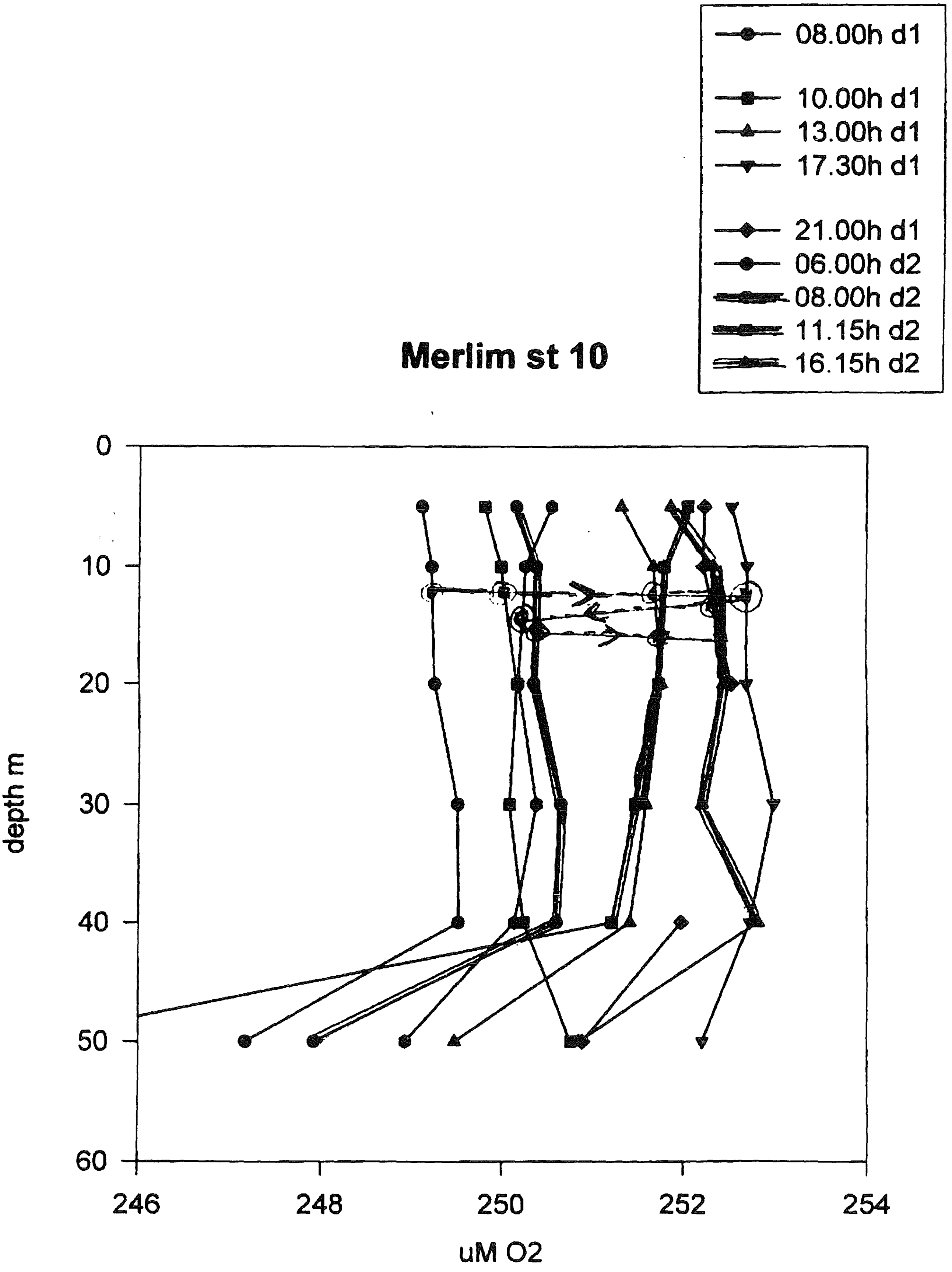
Some results

In a few samples of deep water from the NE Atlantic dissolved oxygen was determined both by titration with automated photometric endpoint, and by colorimetry:

Sample	**µM titration**	**µM colorimeter**	**Titration-Colorimetry**
1	270.95	270.80	0.15
2	276.65	276.44	0.21
3	277.73	277.35	0.38
4	271.90	271.90	0.00
5	277.95	277.83	0.12
6	264.65	264.40	0.25
Difference	**0.18+0.14 µM or 0.07+0.05%**		

The method has been investigated further (R. Manuels, NIOZ) with similar results.

Another example gives recent unpublished results on the dissolved oxygen content of the surface mixed layer over a period of 32 hours. The increase during the day and decrease during the night are easily seen. Of course these results could have determined by titration too, but that would have been much more time-consuming. We recommend the colorimetric method.



Merlim st 10
08.00h d1
10.00h d1
13.00h d1
17.30h d1
21.00h d1
06.00h d2
08.00h d2
11.15h d2
16.15h d2
depth m
0
10
20
30
40
50
60
246
248
250
252
254
uM O2

Fig. 1