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REPORT OF THE

WORKING GROUP ON OCEANIC HYDROGRAPHY

Sopot, Poland
10–13 April 2000

International Council for the Exploration of the Sea

Conseil International pour l'Exploration de la Mer

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1 SUMMARY OF WGOH 2000

1) The 1999 ICES Annual Ocean Climate Status Summary was prepared from regional climate reports. This is available at http://www.ices.dk/status/clim9900/
2) 1999 was characterised by warming conditions throughout the North Atlantic. Although there was a positive NAO index during the winter of 1998/1999, the actual pattern of the NAO was anomalous, which meant that cooling in the NW Atlantic did not take place as expected.
3) WOCE and CLIVAR were reviewed. ICES involvement is sought in the compilation of an inventory of hydrographic sections. Future ICES involvement in CLIVAR / ARCFLUX will be investigated.
4) The Nuka Arctica ship-of-opportunity program was reviewed. The vessel has been equipped with an ADCP, and sails regularly between Denmark / Norway and Greenland. It crosses key areas of the Nordic Seas, and will establish a unique data set. The Working Group recognised the importance of such new monitoring initiatives.
5) The major drifting float program ARGO was reviewed. 3000 floats will be deployed in the Atlantic by 2005.
6) New sources of long-term data were examined by the Working Group which might add to the IAOCSS and climate advice the Working Group can offer in the future. The described significant wave height, SST and surface fluxes.
7) Radioactive contamination in the Nordic Seas was discussed. Presently this offers no danger to the environment, but may be used as a tracer of circulation. Such studies have the potential for underpinning advice on dispersion of other forms of contamination in the area.
8) A new method of measuring ocean currents using a Pressure Inverted Echosounder (PIES) was discussed.
9) Planning for the Symposium on Hydrobiological Variability in the ICES Area, 1990-99, (the 2nd ICES Decadal Symposium, Edinburgh, 8 - 10 August 2001.) was discussed. An ICES flier will soon be issued calling for papers (deadline January 2001) and will contain registration details. The WGOH prepared a resolution proposing that ICES co-sponsor a one day workshop to be held prior to the decadal symposium to celebrate the 75th anniversary of the start of the Continuous Plankton Recorder survey.
10) Data archaeology was discussed, with respect to the potential loss to the community of old data sets. The Working Group urged scientists to consider data sets in their institutes that are not archived in national / international data centres. The Working Group also encouraged WGMDM to produce a web link to all national / international data centres to facilitate easy communication.
11) ICES involvement in GOOS was discussed. ICES progress with GOOS is slow, and the SGGOOS needs to stimulate inter-sessional activity.
12) The WGOH can contribute to GOOS by the generation of repeated, regular data, the dissemination of this data in a timely way and the generation of data products such as the IAOCSS.
13) The Working Group discussed its own remit and future with respect to the ICES Strategic Plan. The Working Group would like to see more inter-Working Group activity, with joint workshops and an annual meeting of Working Group Chairs. The Working Group did not support the idea of a joint Working Group meeting in Copenhagen in 2002, as this would be impracticably large.
14) ICES products accessible through the Internet were discussed. The ICES web page was generally criticised as being static, unattractive and uninformative. The IAOCSS is a major contribution by the Working Group to the ICES web site. The educational role of the ICES website was highlighted. The Working Group should consider developing educational information sheets answering "Frequently Asked Questions".
15) The new review process of Working Group reports at the ASC was seen as a good initiative and should be maintained.
16) The Working Group will meet next year in Reykjavik, Iceland, 19-21 March.

Action Points

1) Membership: Write to P. Holliday and G. Reverdin asking them to seek nomination to the Working Group [Turrell]
2) Membership: Identify possible active members from Portugal and Sweden [All]
3) CLIVAR: Input to J. Gould's inventory of hydrographic sections. Send him the ICES list of SSS [Dooley]
4) CLIVAR and ARCFLUX: Contact these communities to discuss possible role of ICES Working Group and Secretariat. [Meincke and Dooley]
5) Nuka Arctica: Can the Working Group support / encourage this project by a relevant letter etc ? [Rossby]
6) Decadal Symposium: A resolution is to be prepared proposing that ICES act as co-sponsor of the CPR one day meeting [Dickson / Dooley]

7) Decadal Symposium: The ICES Oceanography Secretary is to invite IOC to co-sponsor the Symposium, through the ICES General Secretary. [Dooley]
8) Inter Working Group communication: A short summary of the 2000 WGOH will be circulated to all other OCC Working Groups [Turrell]
9) Review of Report: When the review is available at the 2000 ASC it will be circulated to all members. [Turrell]

2 OPENING

The WGOH met at the Polish Academy of Sciences Institute of Oceanology (IOPAN) in Sopot, Poland between 10–13 April 2000. The Working Group was welcomed to the Institute by the Director, Professor J. Dera, and by the Working Group's local member, Professor Jan Piechura. After a brief introduction to the Institute the business of the meeting began. During the second day of the Working Group, two scientists from IOPAN presented some of their work to the Working Group. This was greatly appreciated.

3 REVIEW OF MEMBERSHIP

In the review of membership, it was noted that some members had retired from their member institutes. While their participation in the Working Group is welcomed, new active members from those countries should be nominated by their national delegates. Two people were identified by the Working Group as being able to contribute to the work of the Working Group. These were P. Holliday (UK) and G. Reverdin (France). They will be asked to contact their national delegates in order to obtain nomination to the Working Group. Active membership from France, Portugal, Sweden and Denmark should be encouraged.

4 UPDATE AND REVIEW OF RESULTS FROM STANDARD SECTIONS AND STATIONS (TOR A)

This is a standard item of the WGOH, and is the basis for the main work of the Working Group, and its product the ICES Annual Ocean Climate Status Summary (IAOCSS). Unlike previous years, it is not intended that a detailed account of the national reports be presented here. All national reports are reproduced as Annexes to this report, and hence a detailed account of each regional presentation would be a duplication, especially as the national reports are also summarised in the 1999/2000 IAOCSS (Annex S) and are available on the ICES web site, linked to the web version of the IAOCSS. This agenda item was covered by a single full day of presentations, in which an overview of North Atlantic ocean climate during 1999 emerged. A brief summary of the day's discussions is presented below.

Dickson (UK) and Meincke (Germany) introduced a context setting description of changes in the NAO and of North Atlantic hydrography (Annex D). One main point brought out was that the simple "two-point" NAO index should not be used alone when examining changes in North Atlantic climate, but the distribution of the first mode in SLP should also be examined, as anomalous patterns can be very influential in certain areas of the North Atlantic system. The physics underlying the NAO and its influence on the ocean needs to be addressed, and not just its statistical inter-annual evolution. If the NAO continues to show spatial variability on small scales, the classical NAO index may become less useful.

Fahrbach (Germany) presented German results from the Fram Strait and Greenland Sea (Annex F). This complimented a report on Danish activities west of Greenland, submitted to the Working Group by Buch (Denmark - Annex E). Fahrbach discussed particularly the difficulty of estimating long term transports in a regime with great mesoscale variability. Averaging periods and spatial resolution of moorings have to be considered. Hendry (Canada) presented results from the Labrador Sea (Annex H), and noted how presently many aspects of the area are undergoing change compared to conditions there over the last decade. Convective activity in particular is presently weak. Fishery concerns are driving the need for long term monitoring in the area. Colbourn (Canada) presented the Canadian report (Annex G). The anomalous pattern of the NAO is being felt particularly in this area, and conditions there do not correspond to what would have normally been expected for a positive NAO index year.

Malmberg (Iceland) went on to present the Icelandic report (Annex I) which emphasised the changes which have occurred before, during and after the "ice years". Meincke (Germany) presented results from the SW Ireland - Cape Farewell pan-Atlantic section. Bacon (UK) presented results from the Rockall Trough section (Neither of these presentations are available as Annexes). In the discussions that followed, the long-term funding of such sections was highlighted, and it was noted that the usefulness of time-series from such sections increases almost exponentially with the age of the section.

Lavín (Spain) presented the Spanish national report (Annex J). A useful study has commenced relating in-situ SST measurements with pathfinder satellite data. An examination of the development of SST anomalies with latitude along the NW European shelf edge showed how anomalies appeared to have little time lag along the slope, suggesting a non-advective mechanism. Turrell (UK) presented the Scottish report (Annex L). The Faroese report sent in by Hansen (Faroe) was also discussed (Annex K). Becker (Germany) presented German results from the North Sea (Annex N), which emphasised how the 1990s had the six warmest years in a 30 year record. The ICES Oceanographic Secretary subsequently submitted an Annex (Annex M) describing results from the IBTS in the North Sea.

Loeng (Norway) described results from the Norwegian and Barents Seas (Annex O). The summer of 1999 was one of the warmest on record. Polish results from the Barents Sea were presented by Piechura (Poland - Annex P), and Ozhigin presented Russian results from the same area (Annex Q).

A general discussion then followed concerning the overall view of 1999 in the North Atlantic area. This discussion enabled the draft IAOCSS to be prepared for the followings day.

5 CONSOLIDATION OF MEMBER COUNTRY INPUTS INTO THE ICES OCEAN CLIMATE STATUS SUMMARY (TOR B)

The draft IAOCSS (Annex S) was discussed by the Working Group, and its contents agreed. For the first time this year the web version will contain links to each of the detailed Annexes listed above. Thus the web product presents both a brief overall summary of conditions in the ICES area, but also access to detailed information when this is required.

6 REVIEW OF PROGRESS IN NATIONAL AND INTERNATIONAL PROJECTS IN THE NORTH ATLANTIC (TOR C)

Two major projects concerning North Atlantic hydrography were reviewed by J. Meincke (Germany). These are WOCE and CLIVAR, both being run under WCRP auspices.

WOCE: WOCE is now in its analysis phase. The one time hydrography data set is available, although some tracer results are still not submitted. Present efforts focus on collecting and editing the repeat section data. A comprehensive summary of who measured what, where and when is being compiled and will be published by the end of 2000. An updated set of data CD-ROMs will be issued in late 2000.

The interpretation of WOCE data focuses on the questions of (i) how well did WOCE measure the seasonal/interannual variability and (ii) how well does the WOCE data set describe the mean state of the ocean. These questions will be pursued during the WOCE variability/representatives workshop in Fukuoka (Japan) in October 2000.

CLIVAR: CLIVAR is in its implementation phase. The Atlantic Implementation Panel is chaired by Allyn Clarke. It is concerned with the whole Atlantic as a coupled ocean/ice/atmosphere system. Close links are established with the Working Group on Ocean Model Development (C. Boening, Chair). Key observational elements for CLIVAR are: a) Repeated hydrographic sections (eg 48ºN, Labrador Sea, UK-Rockall-Iceland); b) Profile and velocity data from ARGO-floats; c) Time series stations and sections; d) Altimeter/Scatterometer winds; e) VOS-XBT-lines. First compilations of national contributions will be carried out by the Atlantic Observation Panel during early May 2000.

Issues Related to WOCE and CLIVAR: The International CLIVAR Project Office (J. Gould, SOC, UK) will compile an inventory of hydrographic sections, and the WGOH is asked to contribute to this inventory. ARGO data will be available via the GTS. CLIVAR plans to develop a data system which initially builds on WOCE and the planned GOOS/GCOS operational centre, with the aim of securing the quality of, and access to, ocean data sets. Input is required to the planning process for this data system. CLIVAR was also asked to link up with IGBP programmes in order to plan surveys of oceanic CO_2.

Links to Arctic Programmes: The Arctic programme under WCRP is ACSYS/CLIC. Although its framework connects into the global ocean (as CLIVAR connects to the Arctic), the observational communities were lacking joint programmes in the past. The interaction is improving because of the following projects/initiatives: a) SEARCH: a US-driven, long-term study of Arctic variability, including fluxes between the Arctic and the Atlantic. The programme is in its implementation phase; b) ARC FLUX: an initiative of pan-Arctic, long-term ocean flux measurements across the boundaries between the Arctic and the global ocean. A strawman document is available from a workshop on Arctic Fluxes held in Cambridge 7 April 2000 (R. Dickson, initiator), jointly between scientists, programme managers and representatives from funding organisations. The planning will continue during the Sverdrup Symposium in Tromsö (Norway), 22/23 September 2000: c) VEINS: an EU-funded study of exchanges between the Arctic and the North Atlantic through the Nordic Seas. If a continuation is funded (submitted as OPEC-proposal to the EU), then this project could contribute a major component to the ARCFLUX-initiative; d) MAIA: an EU-funded study of the feasibility of using coastal sea level changes as a proxy for the influx-variability of Atlantic water from the Faroes to the Arctic Ocean; e) Following a high-level political agreement there is a joint planning initiative between UK and Norway to enhance studies on the climate role of Nordic Seas processes and exchanges.

Discussion of ICES involvement: In the discussion of possible ICES involvement in the larger scale Atlantic/Arctic programmes it was stressed that ICES hydrography is known for its North Atlantic/Nordic Seas time-series data base. The ICES Annual Ocean Climate Status Summary (IAOCSS) is an excellent example of this activity. It was furthermore stressed that ICES has the means and facilities to successfully act as project data centre. While ICES primary role is related to fisheries, it still has an important function with oceanography, and this must be upheld. The Working Group decided to seek contact to the CLIVAR and ARCFLUX communities to discuss the possible future role of ICES in these large-scale programmes.

Also during the discussions it was noted that a “Global” label attached to a national commitment to long-term monitoring can be extremely useful in defending such a commitment to national funders. Such international recognition of national programs should be encouraged by programs such as CLIVAR, WOCE etc.

7 DISCUSSION OF THE NUKA ARCTICA SHIPS-OF-OPPORTUNITY PROGRAMME (TOR D)

Rossby (USA) introduced this agenda item. In order to obtain a quantitative assessment of the northward flows of mass and heat and their variability in the northern North Atlantic, a program to measure upper ocean currents on a regular basis from a container vessel “Nuka Arctica” was initiated in July 1999, and is being run by the University of Bergen. The ship is also equipped with a thermosalinograph operated by Dr Gilles Reverdin, CNES, France. Pending approval, an XBT system has been delivered to the ship and is awaiting installation. The University of Rhode Island, the Faroes Fisheries Research Institute and the Wallenberg Foundation in Sweden have contributed to the start-up of the program and additional funding for an initial period is being sought from the Norwegian Research Council.

The combination of repeat sections of velocity, surface temperature and salinity and XBTs will be used to establish upper ocean mean velocities and eddy variability, and their spatial structure, particularly near the regions of inflow towards the Nordic Seas, over the Reykjanes Ridge, around Greenland and across the West Greenland Current. A multi-year program will allow an assessment of the sensitivity of the circulation patterns to interannual variations in atmospheric forcing (wind driven as well as thermal) over the northern North Atlantic to be obtained. Changing wind patterns may influence the patterns of flow whereas heat losses in different regions may affect the strength of the flow since northward flux towards the regions of intermediate and deep convection are clearly demand-driven.

In addition to information on the circulations and fluxes of the upper ocean, the ADCP measurements can provide data on zooplankton biomass distributions and their variability in space and time.

The WGOH agreed that such programs using ships of opportunity were important and should be supported whenever possible. The Nuka Arctica initiative is particularly worthy of support, because of its valuable scientific objectives, and national funding of the program should be encouraged.

8 REVIEW OF INFORMATION ON SURFACE AND SUB-SURFACE DRIFTING BUOY INITIATIVES (TOR E)

A short report on ARGO was presented by Lavín (Spain), based upon the Report of the ARGO Science Team 2nd meeting. ARGO is planned to be a global array of temperature/salinity profiling floats, designed to give a quantitative description of the evolving state of the upper ocean and the patterns of ocean variability. Measurements of subsurface vertical structure of T(z), S(z) and reference velocity will be obtained. Floats will cycle to 2000 m depth every 10-14 days, with 4-5 year lifetimes for individual floats. ARGO data will be used by CLIVAR and GODAE. Some national ARGO projects in France, USA, Canada, Japan, Australia, Korea, UK and Germany are on-going or close to being approved. An ARGO-related proposal (GyroScope) has been presented to the EU by Y. Desaubies (France) involving 4 countries and 9 institutions. USA and France are now developing the ARGO DATA SYSTEM in parallel. Data will be provided in real time (less than 12 hours), with automatic Quality Control, via the GTS network, in a relaxed real-time mode after a few days with more complex QC, and in a deferred mode after some delay for High Quality Scientific data. Great effort is being applied to achieve 0.01 psu salinity sensor stability for periods of up to 4 or 5 years. In addition power consumption, communication, and parking depth stability is being examined as well as problems at high and low latitudes. The number of floats to be deployed will be 3000 by the end of 2005.

Sv. A. Malmberg reported on a recent WOCE drifter program in Icelandic waters 1995-1999. It was a joint project of the Marine Research Institute, Reykjavik (Iceland) and Scripps Oceanographic Institute. 120 drifters were deployed seasonally and annually at 10 locations in the Iceland Sea. The results from 1995-1999 have been published

(Valdimorsson and Malmberg 1999, Rit Fiskideildar, 16), and reveal many aspects of the accepted view of the surface circulation system in northern Icelandic waters and adjacent seas. However, in south Icelandic waters (Iceland Sea) some differences occur, with a deviation of the north going Atlantic flow into branches both west and east of Iceland. The topographic effect of the Reykjanes Ridge deflected the mean current (Irminger current) south-westwards along the ridge before it turned cyclonically into the Iceland Basin, with flow also crossing the Reykjanes Ridge into the Irminger Sea. Work is underway analysing the whole observational period 1995-1999, including the statistics of the observations.

In ACCE approximately 200 PALACE and 150 isopycnal RAFOS floats (sigma-t = 27.5) were deployed in the Labrador and Irminger Seas and the Subpolar front region in order to map out the upper ocean circulation. These observations are now in the process of been analysed. The high density of floats permit quite detailed descriptions of the main flow and eddy activity. As a general observation the flow measurements reveal distinct patterns: offshore and within the boundary currents in the Subpolar gyre (Labrador and Irminger Seas) counter currents can be identified; waters in the Subpolar Front spread along two principal pathways across the Icelandic Basin, NE past the Rockall Plateau or retroflected to the NW towards the Reykjanes Ridge and into the Irminger Sea. Floats deployed along the eastern margin spread north past the Rockall Plateau and curve west and then south along the Reykjanes Ridge. Although not all data have been processed it appears to be quite significant that not a single float has approached and crossed the Iceland-Faroe Ridge into the Norwegian Sea. This raises the very interesting question of which waters do cross the Ridge. The baroclinic shear (shoaling density surfaces to the north) clearly favour on approach from the west. But perhaps the westward bottom currents due to the overflow prevent this, forcing the surface waters to approach the Ridge from the SE. The value of the floats program has been to identify in some detail the circulation patterns in the NE Atlantic. The two types of floats are quite complementary, one focussing on mean flow patterns and the vertical T/S structure, the other highlighting mean flows and eddy activity along isopycnals.

9 REVIEW OF NORTH ATLANTIC CLIMATOLOGIES; THEIR AVAILABILITY AND USAGE (TOR F)

Bacon (UK) explained that the intention of this agenda item was to present to the WGOH surface data sources which may be useful supplements to the annual reports of North Atlantic Ocean climate status presently available to the Working Group. However, these data sources are not yet prepared in the style or frequency to be useful on an annual basis, so the presentation made was a preliminary one.

Significant wave height: From the early 1960's to the late 1980's, surface waves were measured by the UK at various sites in the NE Atlantic and North Sea. These surface measurements have been superseded by satellite radar altimeter measurements. Satellite data coverage is global from 1985 to the present (with a gap around 1990). Products such as monthly means in 2x2 degree bins are available. In the NE Atlantic, significant wave heights are strongly correlated to the NAO.

The SOC surface flux climatology: Global surface flux estimates are obtained from over 30 million ship meteorological reports contained in COADS 1A (1980-1993), using empirical formulae. The COADS data set has been updated with data to the end of 1997. Metadata from the WMO47 list of ships allows corrections for observational bias. The climatology contains fields of air-sea heat fluxes, wind stress and precipitation in a 1x1 degree grid. Time series information 1980-1997 can be extracted from this data set. One example is the series of Ekman flux (wind-driven surface transports) at 60N, which follows the NAO to some extent, with southward transport up to 6 Sv.

SST: The MCSST satellite data set (JPL) covers Jan 1984 - Dec 1999. Its original resolution is 10"x10" in 8-day means, its accuracy is ca. 0.3°C. This data set has been converted to 2x2 degree monthly mean fields. Missing values are interpolated where possible. Remaining areas of reduced data are the northern Labrador Sea and generally north of 60N, due to cloud cover. Annual and semi-annual cycles have been removed to produce anomaly fields.

10 DISCUSSION OF THE RESEARCH PROJECT ON RADIOACTIVE TRACERS IN THE NORDIC SEAS (TOR G)

Malmberg (Iceland) described a Nordic Project, BOK 2, which is currently underway over the period 1998-2001. It deals with environmental consequences with respect to radioactivity, and includes the following two sub-projects; Important Nordic food chains (BOK 2.1) and radioactive tracers in the Nordic Seas areas (BOK 2.2). This second component is divided into a further two sub-components, dealing with the use of Tc-99 as a tracer for transport from the Irish Sea to Nordic waters, including the Baltic Sea, and radionuclide processes in the Baltic Sea, catchment and adjacent areas. The first sub-component focuses on the re-evaluation of transfer factors for Tc-99 from Sellafield to the Nordic marine area, and the study of uptake mechanisms and concentration factors for Tc-99 to living marine resources. The second sub-component aims at a comprehensive assessment of processes in the Baltic Sea and its catchments and adjacent areas. This wide scope is made possible by using already available data to a large degree (Cs-137 etc.).

This project is of great interest to the Nordic countries. It is not only the direct hazards of radioactivity in the Nordic Seas which are of concern (these are minimal at least up to present time), but knowledge of the situation is very important as regards the quality of these waters in connection with fish export. Certainly knowledge of the oceanic circulation and the pathways of the contaminants are also important, and provide a tool to deal with possible concerns arising from more accidental situations.

Iceland, together with other Nordic countries, is to organise sampling on their research vessel cruises with special regards to different water masses and circulation. As such, the project is of general interest for tracing ocean circulation in time and space and its variability. Sampling commenced in February 1999 and went on through out the year 1999.

The next meeting of the Nordic group will be in Norway in March 2000.

In the discussions which followed this agenda item, it was questioned what advice should be sent to ACME concerning radioactive tracers in the Nordic Seas. While such tracers may be used to examine the pattern of distribution in the area, and hence reflect circulation and mixing in some ways, they can not inform about circulation mechanisms. However, through a knowledge of the circulation of an area gained in other ways, oceanographers can advise when plans are needed to sample pollution of an area. This is important background information which physical oceanographers can supply to environmental managers and Governments.

11 REVIEW OF THE OPERATIONAL USE OF NEW OCEANOGRAPHIC EQUIPMENT (TOR H)

Rossby (USA) described a simple yet remarkably efficient technique for studies of ocean dynamics and transports. Although the technique uses established technology, it does so in a new way. It has now been in use for a few years in frontal systems such as the Gulf Stream, and would be very effective for studies of northward transport in the North Atlantic as well as changes in circulation patterns.

The new instrument, the Pressure Inverted Echosounder (PIES), measures the round trip acoustic travel time between the sea bed and sea surface. It is most accurately interpreted as a measure of heat storage, but can also be used as a measurement of dynamic height and Fofonoff potential energy anomaly with a threshold sensitivity of about 0.1 millisecond which translates into 10^8 J/m^2, 1-3 dyn. cm and 2-3 x 10^5 J/m^2, respectively. The last number ($\tilde{x}$2) can also be interpreted as the uncertainty in baroclinic transport between two PIES (ie 3-4 Sv). The pressure measurement is stable to 0(1)dep cm/year at full ocean depths.

A new method of interpreting the acoustic travel line, known as GEM for 'gravest empirical mode' allows one to reconstruct the whole column temperature/salinity/density profile in areas where vertical displacements (T-variations) are simply-behaved in the vertical as is typically the case when the low-frequency variability can be described in terms of a barotropic and simple baroclinic mode.

The PIES lends itself very effectively to studies of full water column transport such as by the sub-polar front, gyre boundary variability, studies of mesoscale processes such as Gulf Stream meandering. Arrays of PIES along standard sections such as AIE or the Nuka Arctica route would greatly strengthen the value of these sections by providing continuous coverage between section occupations. Besides giving information on variability these data would provide a more accurate background for interpreting the individual transects.

12 REVIEW OF PROGRESS IN THE PLANNING OF THE SECOND DECADAL SYMPOSIUM (TOR I)

Dickson (UK) reviewed preparations for the Symposium on Hydrobiological Variability in the ICES Area, 1990-99, (the 2nd ICES Decadal Symposium). The design and content of the draft flier was finalised and approved and is now ready for artwork, printing and distribution by ICES. The ICES Oceanography Secretary suggested that ICES might also act as co-sponsors of the companion CPR Achievements Symposium and will draft a Resolution to that end. Possible additional sponsors were discussed and suggestions will be followed-up by the co-conveners. A deadline of January 2001 was agreed for submission of applications for talks and posters, and a firm deadline of Easter 2001 was approved for the booking of accommodation and events by participants. A booking office will be set up at IFM Hamburg for this purpose, and booking forms and other details will be posted on the ICES website. Further planning by the scientific Steering Group will be conducted by e-mail without the need for meetings, though final arrangements will be reviewed by the WGOH at its 2001 meeting in Reykjavik.

In reviewing the list of co-sponsors for the Symposium, it was considered that IOC should be encouraged to be included in this list, given the close relevance to a number of IOC Programmes (OSLR-LMR, GOOS) and reflecting the IOC's active support of the CPR programme. The Oceanography Secretary was asked to ensure that such an invitation is sent to IOC via the ICES General Secretary. In addition, the co-conveners will seek other potentially interested financial co-sponsors.

13 CONSIDERATION OF OCEANOGRAPHIC DATA SETS IN DANGER OF BEING LOST (TOR J)

Hendry (Canada) introduced this agenda item with a brief review of the rationale for data archaeology and data rescue. Long time-series are required for studies of climate variability. The costs associated with data rescue are often small compared to the cost of collecting new data, so the approach is also cost-effective.

It was recognised that there are highly-organised ongoing efforts to recover lost oceanographic data at both national and international levels. The Working Group on Marine Data Management is active in this area. However, individual scientists can play a role by identifying specific data sets in danger of being lost.

In the discussion that followed, it was emphasised that the recovery of metadata was a key part of data recovery, and that it is often the most expensive part in terms of time and effort. Individual scientist and project leaders constrained by finite resources may find it difficult to give high priority to data rescue. One way of supporting such efforts is to include a data rescue component at the scientific project level where appropriate. Dickson (UK) reported that the Arctic Ocean Science Board has adopted this approach in an ongoing study of the sudden mid-1900's warming of the North Atlantic.

Another point raised in discussion was that future data needs can not be predicted, making it important to rescue all types of oceanographic data, including data sets with limited resolution or accuracy.

It was also recognised that significant amounts of oceanographic data are not available for general use because of commercial, military, and proprietary considerations at national levels. Although these data are not lost in the strict sense, their full value cannot be realised until they are preserved in national and world data centres and made freely available for scientific use.

The agenda item was not fully addressed in the sense that no list of specific data sets in danger of being lost was produced. There was a general feeling that the problem is more complex than suggested by such an approach. However, the discussion was valuable in reinforcing the importance of such efforts. Recommendations reached during the discussion were:

(1) Individual ICES scientists are urged to recognise the importance of data archaeology and data rescue. Scientists and project leaders should contribute by helping to identify data sets in danger of being lost, by involving themselves in such efforts within their individual and institutional limits, and by cooperating with national and international data recovery efforts.

(2) Since data rescue opportunities can be enhanced by good communication between individual scientists, project leaders, and institutional data specialists on the one hand, and national data committees and data centres on the other hand, it is recommended that the Working Group on Marine Data Management consider producing an up-to-date list of contact persons within national oceanographic data centres and/or national oceanographic data committees of ICES member states and others where appropriate to facilitate this communication.

14 ASSESSMENT OF DEVELOPMENTS IN GOOS OF RELEVANCE TO ICES (TOR K)

Loeng (Norway) presented ideas on GOOS and ICES. GOOS had been on a number of Working Group’s agendas, but many of them are still unclear about the objectives of GOOS. At the 1999 GOOS Commitments Meeting (Paris), ICES submitted the IBTS as a contribution to the initial observing system. A workshop was held in Bergen in 1999 to consider ICES/GOOS interactions. The meeting recommended that ICES / IOC form a joint Steering Group, under an ICES/IOC co-chair. The SG was assigned several tasks, such as the development of an ICES North Sea GOOS observational network (incorporating the IBTS), and the further development of the IAOCSS. The SG was due to meet in February, but due to several factors this meeting did not take place. It was noted that presently there are only 6 nominated members of the SG. A postponement to May clashed with the IOC LMR meeting, so now the SG will meet in October 2000. A concern was expressed that the SG was not moving rapidly enough, and that there was little intersessional activity. A ICES GOOS flier is being prepared to introduce ICES Working Groups to the concepts of GOOS.

The IAOCSS was then reviewed by Turrell (UK) with respect to improving its relevance to GOOS. Members of the WGOH can firstly contribute to GOOS by the generation of data in repeat, regular surveys whose results are available in a timely fashion. Such data comes from the ICES Standard Sections and Stations. ICES and the WGOH could improve the visibility of this work by creating a ”brand” name or image for this work. Secondly ICES can contribute to

GOOS by the dissemination of data in a rapid form. The ICES Oceanographic Data Centre can participate in this activity. Finally ICES and the WGOH can generate relevant products. The IAOCSS is the first of these. It should be used as the context setting product, beneath which other WGOH develop their own status summaries, either regionally based or summaries of non-0climate related ICES data (e.g., HABs).

15 CONSIDERATION OF POSSIBLE FUTURE DIRECTIONS FOR THE OCEANOGRAPHY COMMITTEE (TOR L)

At the 1999 Annual Science Conference the Oceanography Committee decided different actions in order to meet the requirements of the ICES Strategic Plan. The Oceanography Committee suggested that there should be an inter-sessional review of the objectives and purpose of all Working Groups with the goal of addressing the needs, benefits and disadvantages of merging Working Groups and forming new ones. It is important that the Committee and its working groups are pro-active in specifying what they want in the way of products to meet the strategic needs, and that they can contribute to developing and creating products.

The topic was introduced by Loeng (Norway), and he described his view of the way forward. It is important that the WGOH discuss oceanographic issues that are relevant for the ICES advisory groups/committees. An example is the ICES Annual Ocean Climate Status Summary (IAOCSS). In that way the Working Group justifies its existence. Working groups may work together in preparing/proposing workshops, e.g., an Ocean Climate variability. Workshops on topic of joint challenges between two or more working groups could be one way to go in order to solve problems that concerns more than one working group. The WGOH should formulate their remit and a justification for its future existence.

The Working Group had a lengthy discussion on different aspects of its future role. There was a broad agreement that the WGOH should serve other working groups with information on the physical environment and continue the work of improving the IAOCSS. The IAOCSS should be more focussed towards its customers, and should follow up demands from other bodies within the ICES System. The WGOH should improve the presentation of the IAOCSS on the web (see ToR m) and improve methods for ocean monitoring by being updated on new technology. It should play an advisory role in climate related questions, including preparing for long-term prediction and search for explanations on climate variability in order to improve predictions. The Working Group should expand the cooperation with other working groups, (also working groups under other Committees).

At the last ASC a question was raised of having all working groups (of the Oceanography Committee) to meet in Copenhagen at the same week in 2002. Based on experience from earlier joint meetings, WGOH did not support this idea. The Working Group was more in favour of organising workshops in order to solve problems of common interest between working groups. The Working Group did not point at any specific theme, but impact of climate variability on different components of the ecosystem could be an example.

The Working Group felt it was important to improve the communication between the different working groups within the Oceanography Committee. An annual meeting between working group chairs at the ASC would be a step in the right direction.

16 CONSIDERATION OF DATA PRODUCTS THAT CAN BE PROVIDED VIA THE ICES WEBSITE (TOR M)

Dooley (ICES) led the discussion of this item. He reminded the Working Group that this item was placed on the agenda on the recommendation of the ad hoc group of Oceanography Committee Chairs, which met informally during the 1999 Statutory Meeting.

Until now, this Working Group has taken the lead in developing web-based products on the ICES web-site via its "ICES Annual Ocean Climate Status Summary". It is this product which has stimulated the Oceanography Committee to enquire amongst all of the groups it parents concerning appropriate products relating to their respective activities.

The Working Group sees various possibilities for improving and further developing the ICES web-site on matters under its remit. Clearly the two main elements that could be developed further is the IAOCSS, and the current administrative pages maintained by the Secretariat. Future expansion may include elements of specific relevance to the ICES Strategic Plan, for example, by improving the visibility of ICES and improving communication within the organisation. The future structure of the Working Group's web pages may therefore include education material for interested lay people/marine and fisheries administrators; information relevant to other working groups of the Committee; information for "customer" working Groups, especially the fish stock assessment groups. This could include information specifically targeted to individual groups; private (internal) information in connection with Working Group business.

The above information might consist of both graphical and textual products, and some may be presented as "Frequently Asked Questions". The Working Group considered that the current static implementation of the ICES web site restricted its ability to develop its ideas further and hoped that ICES could address the need for the implementation of a more sophisticated and dynamic site with some urgency.

In concluding this item, Dooley (ICES) drew the Working Group's attention to various oceanographic products that had been placed on the ICES web site in the inter-sessional period. In particular the entire oceanographic data bank for the period 1900-1989 was now on line, approximately 1 million stations. The implementation is a static one and is updated at about 6 monthly intervals. Data are available in 5 degree squares for the Northeast Atlantic, and the North and Baltic Seas. A huge reduction in the number of requests for data has been noted, and it is assumed that this is the direct result of this implementation. In addition to these data, underway temperature and salinity data for the 1990s acquired from the currently developing ships of opportunity programmes are now available on line. It was hoped that this would stimulate the submission of additional underway data to ICES, which had been decreasing in volume since the peak years of the 1960s and 1970s.

17 EXAMINATION OF THE 1999 OCEANOGRAPHY COMMITTEE WORKING GROUP REPORTS AND THE TERMS OF REFERENCE (TOR N)

Loeng (Norway) introduced this agenda item. He explained that a new initiative to improve communications between OCC Working Groups had begun in 1999, with a meeting of all Working Group chairs at the 1999 ASC. The intention is to improve cross-Working Group working and identify areas where the work of Working Groups may underpin one another. This is the first year of this initiative, and the Working Group expressed its opinion that it should be continued. The exchange of ToR between Working Group chairs was insufficient. The Chairs should meet, at least once per year, and more information should be fed back to the Working Group members. Working Group reports should include executive summaries which are rapidly circulated between Working Groups to enhance communication. The Working Group recommended that the Secretariat provide facilities at the ASC so that Working Group chairs may meet and exchange ideas and concerns. The new initiative started by the OCC to have all Working Group reports reviewed should be encouraged, and the results of these reviews circulated amongst members. While joint Working Group meetings are thought to be too cumbersome to work, it was suggested that individual Working Group members could attend other Working Groups to aid inter-group communication.

18 ANY OTHER BUSINESS

Loeng (Norway) introduced an item concerning a Norwegian program linking climate and fisheries. This concludes in 2004, and there may be a requirement for an ICES Theme Session to present the results of the program. A ToR for the Working Group's 2001 meeting will be prepared on this topic by Norway.

The new initiative by the Oceanography Committee in getting the Working Group's report reviewed was discussed. The Working Group considered this development to be useful. In future the review should be circulated amongst Working Group members.

19 DATE AND PLACE OF NEXT MEETING

Dr Malmberg (Iceland) kindly extended to the Working Group an invitation to Reykjavik in 2001. The Working Group will meet there during 19-21 March 2001.

20 RECOMMENDATIONS

<u>A</u> The WGOH recommends the following recurring theme session for the Annual Science Conference:

North Atlantic Processes co-conveners for 2001 Loeng (Norway) and Turrell (UK)

<u>B</u> The WGOH (Chair Dr W. R. Turrell) should meet at IMR, Reykjavik, Iceland, 19-21 March 2001 to:

1) Update and review results from Standard Sections and Stations;
2) Consolidate inputs from Member Countries into the ICES Annual Ocean Climate Status Summary (IAOCSS);
3) Examine the potential predictability of ocean climate.
4) Re-analyse the 1920-1950 warm period in the North Atlantic.
5) Review new climatologies for inclusion in the ICES Annual Ocean Climate Status Summary (IAOCSS)

6) Evaluate relevance of climatological and time series products prepared by the ICES Oceanographic Data Centre as potential input to the Ocean Climate Status Report.
7) Review progress during 2000 / 2001 of the ICES SGGOOS
8) Loeng - discuss Norwegian fisheries and climate program
9) Prepare educational / information material for the ICES WGOH web site.

Justifications

A Theme Session: North Atlantic Processes

This recurring Theme Session has the intention of encouraging young scientists involved in national and international oceanographic projects to make scientific contributions to ICES, and hence help to constantly rejuvenate the science ICES presents. Each year a different “flavour” will be placed on the Theme Session, although all physical oceanographic research from the North Atlantic and Nordic Seas will be welcomed. The 2001 Theme Session will emphasise ocean climate change, the predictability of ocean climate change and its consequences.

B Agenda

1. This is a repeating task established by the Working Group to closely monitor the ocean conditions in the ICES area. The materials presented under this item will be utilised to prepare an overview of the state-of-the-environment in the North Atlantic for 1999.
2. The Working Group recognises the need for disseminating climate information in a timely and appropriate manner. The Steering Group on ICES-GOOS has also identified the climate summary as an essential contribution from WGOH. This agenda item will allow WGOH members to prepare the document during the meeting, thus avoiding delays in the dissemination of the information.
3. Environmental observations have generally been used in an indirect and limited way in fishery stock assessment. The priorities in order to improve upon this situation are a) to understand ocean climate and its variability and b) to use this understanding for predictions in fish stock assessments. There are difficulties in predicting climate, but marine living resources are closely dependent upon it. The task of predicting ocean climate is presently a pressing challenge in the further development of fish stock assessment, and the Working Group will discuss a review of this subject by Iceland (Malmberg).
4. The observed hemispheric warming of the past Century took place in two distinct episodes, from 1925 to the 1950s and from the late 1970s to the present. The latter which appears to be associated with a long-term amplification of the NAO has received much attention, and this attention is justified because of the general consensus among climate models that CO_2-warming will tend to favour NAO-positive conditions. However though the earlier warming episode was more widespread and prolonged, its causes remain largely unknown. In view of the influence of this apparently-localised warming on the global temperature trend, the Arctic Ocean Science Board has recently recommended its re-analysis.
5. Climatologies of the sea surface are being developed for many different parameters, some of which are remotely obtained via satellite, some from in-situ measurements such as the Voluntary Observing Ships programme. These climatologies contain data derived over more than a decade and thus are building into useful time series. At the 2000 WGOH meeting, examples of these time series were presented, including surface wave height (global), SST and wind-driven surface (Ekman) flux. In the view of their wide area coverage, including the ICES area, these data sets have the potential to be presented as useful material, possibly on an annually updated basis, to the WGOH, in the context of the ICES Annual Ocean Climate Status Summary.
6. The ICES Data Centre is used as a source of oceanographic products to some non-oceanographic working groups. Currently the ICES Ocean Climate Status Report is based on data compiled by individual institutes, and may be based on differing climatologies. It is the intention now of the Oceanographic data centre to test to see the extent to which it can reproduce the products prepared by the Working Group with a view to developing a more operational and timely approach to the production of the Status Report.
7. The ICES SGGOOS will meet in October 2000 in order to progress ICES involvement in GOOS. Intersessional activities are also planned. The WGOH should remain informed about this work, and may contribute to ICES / GOOS initiatives.
8. During the 2000 WGOH it was suggested that one role of the WGOH might be to generate educational / information material for the ICES web site in order to make this of more use to the ICES and marine science communities. The Working Group will consider drafts of such material and discuss possible future developments.

21 DRAFT RESOLUTION

a) The Working Group on Oceanic Hydrography recommends that

ICES co-sponsor the "Conference on the 70th Anniversary and Achievements of the Continuous Plankton Recorder (CPR)" to be held in Edinburgh, UK on 7 August 2001. The ICES representative at the Conference will be Dr R. Dickson (UK)

Priority:	This draft resolution is a logical consequence of C Res 1997/2:2 concerning the 2001 ICES symposium on hydrobiological variability (Decadal symposium). If the resolution is not approved then ICES will lose the opportunity to develop closer ties with the other organisations that are likely to be involved.
Scientific Justification:	This Conference is being held at the same location and on the day prior to the start of the ICES Decadal symposium (Edinburgh, 8-10 August 2001).It is being organised by the Scottish Association for Marine Sciences (SAMS) and the Sir Alister Hardy Foundation for Ocean Sciences (SAHFOS). The Conveners of the ICES Symposium have already established a close working relation with the Conference organisers and are already assisting each other with logistical arrangements. Given the very close relevance of the CPR programme to may ICES activities, and also the fact that the ICES Symposium expect to be hosting an exhibition of water colours by Sir Alister Hardy to commemorate the 70th anniversary of the CPR, the relevance of this co-sponsorship should be obvious..
Relation to Strategic Plan:	This resolution is consistent with Institutional Goal 4 (Establish and maintain partnerships that are mutually beneficial in fulfilling the ICES Vision)
Resource Requirements:	No additional costs to ICES will be incurred, but ICES will additionally provide the usual secretariat support for the extra CPR day, and information about the CPR will be (is) included in the flier for the Decadal symposium, and on the symposium web site
Participants:	The co-sponsorship will benefit the Symposium and Conference in terms of the number of contributors. Participation in the Symposium will certainly be enhanced.
Secretariat Facilities:	Nothing beyond what is already covered by C.Res 1997/2:2
Financial:	Ca 5000 DKr to cover extra staff costs for one additional day's attendance
Linkages To Advisory Committees:	N/A
Linkages To other Committees or Groups:	N/A
Linkages to other Organisations	This resolution is about linkages to SAMS and SAHFOS. It also makes it clear that IOC should be invited to participate as co-sponsor to the ICES Symposium. It is hoped that IOC will also wish to co-sponsor this Conference - the General secretary should approach IOC with a view to IOC co-sponsoring the Decadal symposium.

b) The Working Group on Oceanic Hydrography recommends that

The 2000 / 2001 ICES Annual Ocean Climate Status Summary, edited by Dr W. Turrell (UK) as reviewed and approved by the Chair of the Oceanography Committee will be published in the *ICES Cooperative Research Report* series. The estimated number of pages is 35.

Priority:	This draft resolution enhances the development of the IAOCSS, and make sit an official and citable ICES product.
Scientific Justification:	Presently the IAOCSS is an Annex to the report of the Working GroupOH, and is a ICES web product. As such it can not be easily cited, or recoognised as an official ICES publication. The Cooperative Research Report series offers a good venue for its annual publication.
Relation to Strategic Plan:	This resolution will contribute towards Scientific Objectives; 1a (Describe, understand and quantify the state and variability of the marine environment in terms of its physical chemical and biological processes.); 1b (Understand and quantify the role of climate variability and its implications for the dynamics of the marine ecosystems); 5c (Co-ordinate international, monitoring and data management programmes which underpin ongoing ICES core science.); 4c (To publicise the work of ICES and the contributions that ICES can make for its stakeholders, and for the wider public audience, regarding the understanding and the protection of the marine environment), and Institutional Objective 6 (Make ICES' scientific products more accessible to the public.)
Resource Requirements:	Cost of production and publication of a 10 page CRR
Participants:	The co-sponsorship will benefit the Symposium and Conference in terms of the number of contributors. Participation in the Symposium will certainly be enhanced.

Secretariat Facilities:	Help with document preparation / publication
Financial:	Ca 5000 DKr to cover extra staff costs for one additional day's attendance
Linkages To Advisory Committees:	
Linkages To other Committees or Groups:	Publications Committee
Linkages to other Organisations	N/A

c) The Working Group on Oceanic Hydrography recommends that

2COH The **Working Group on Oceanic Hydrography** (Chair: W. Turrell, UK) will meet in Reykjavik, Iceland from 19-21 March 2001 to:

a) update and review results from Standard Sections and Stations;

b) consolidate inputs from Member Countries into the ICES Annual Ocean Climate Status Summary (IAOCSS);

c) examine the potential predictability of ocean climate;

d) re-analyse the 1920-1950 warm period in the North Atlantic;

e) review new climatologies for inclusion in the ICES Annual Ocean Climate Status Summary (IAOCSS);

f) evaluate relevance of climatological and time series products prepared by the ICES Oceanographic Data Centre as potential input to the Ocean Climate Status Report;

g) review progress during 2000 / 2001 of the ICES SGGOOS;

h) discuss underway ADCP measurements;

i) review progress towards the 2nd ICES Decadal Hydrobiological Variabilty Symposium;

j) prepare educational / information material for the ICES WGOH web site;

WGOH will report to the Oceanography Committee at the 89th Statutory Meeting.

Supporting Information

Priority:	
Scientific Justification:	a) This is a repeating task established by the Working Group to closely monitor the ocean conditions in the ICES area. The materials presented under this item will be utilised to prepare an overview of the state-of-the-environment in the North Atlantic for 2000. b) The Working Group recognises the need for disseminating climate information in a timely and appropriate manner. The Steering Group on ICES-GOOS has also identified the climate summary as an essential contribution from Working GroupOH. This agenda item will allow Working GroupOH members to prepare the document during the meeting, thus avoiding delays in the dissemination of the information. c). Environmental observations have generally been used in an indirect and limited way in fishery stock assessment. The priorities in order to improve upon this situation are i) to understand ocean climate and its variability and ii) to use this understanding for predictions in fish stock assessments. There are difficulties in predicting climate, but marine living resources are closely dependent upon it. The task of predicting ocean climate is presently a pressing challenge in the further development of fish stock assessment, and the Working Group will discuss a review of this subject by Iceland (Malmberg). d). The observed hemispheric warming of the past Century took place in two distinct episodes, from 1925 to the 1950s and from the late 1970s to the present. The latter which appears to be associated with a long-term amplification of the NAO has received much attention, and this attention is justified because of the general consensus among climate

	models that CO_2-warming will tend to favour NAO-positive conditions. However though the earlier warming episode was more widespread and prolonged, its causes remain largely unknown. In view of the influence of this apparently-localised warming on the global temperature trend, the Arctic Ocean Science Board has recently recommended its re-analysis. e). Climatologies of the sea surface are being developed for many different parameters, some of which are remotely obtained via satellite, some from in-situ measurements such as the Voluntary Observing Ships programme. These climatologies contain data derived over more than a decade and thus are building into useful time series. At the 2000 Working GroupOH meeting, examples of these time series were presented, including surface wave height (global), SST and wind-driven surface (Ekman) flux. In the view of their wide area coverage, including the ICES area, these data sets have the potential to be presented as useful material, possibly on an annually updated basis, to the Working GroupOH, in the context of the ICES Annual Ocean Climate Status Summary. f) The ICES Data Centre is used as a source of oceanographic products to some non-oceanographic working groups. Currently the ICES Ocean Climate Status Report is based on data compiled by individual institutes, and may be based on differing climatologies. It is the intention now of the Oceanographic data centre to test to see the extent to which it can reproduce the products prepared by the Working Group with a view to developing a more operational and timely approach to the production of the Status Report. g) The ICES SGGOOS will meet in October 2000 in order to progress ICES involvement in GOOS. Intersessional activities are also planned. The Working GroupOH should remain informed about this work, and may contribute to ICES / GOOS initiatives. h) Increasingly underway ADCP measurements are being aquired from research vessels (eg Canadian vessels on the Newfoudland shelf) and ships of opportunity (eg Nuka Arctica). The Working Group wishes to consider these measurements, and the techniques involved, as they will lead to valuable time-series in the future. i) The 2nd ICES Decadal Symposium will be held in Edinburgh during August 2001. This will be the last chance for the Working GroupOH to review progress towards the meeting, and discuss any final aspects of the scientific program and the subsequent publication of results in an ICES Journal j) During the 2000 Working GroupOH it was suggested that one role of the Working GroupOH might be to generate educational / information material for the ICES web site in order to make this of more use to the ICES and marine science communities. The Working Group will consider drafts of such material and discuss possible future developments.
Relation to Strategic Plan:	a) Towards Scientific Objectives; 1a (Describe, understand and quantify the state and variability of the marine environment in terms of its physical chemical and biological processes.); 1b (Understand and quantify the role of climate variability and its implications for the dynamics of the marine ecosystems); 5c (Co-ordinate international, monitoring and data management programmes which underpin ongoing ICES core science.) b) Towards Scientific Objective 4c (To publicise the work of ICES and the contributions that ICES can make for its stakeholders, and for the wider public audience, regarding the understanding and the protection of the marine environment), and Institutional Objective 6 (Make ICES' scientific products more accessible to the public.) c) Towards Scientific Objectives; 1a (Describe, understand and quantify the state and variability of the marine environment in terms of its physical chemical and biological processes.); 1b (Understand and quantify the role of climate variability and its implications for the dynamics of the marine ecosystems d) Towards Scientific Objectives; 1a (Describe, understand and quantify the state and variability of the marine environment in terms of its physical chemical and biological processes.); 1b (Understand and quantify the role of climate variability and its implications for the dynamics of the marine ecosystems e) Towards Scientific Objectives; 1a (Describe, understand and quantify the state and variability of the marine environment in terms of its physical chemical and biological processes.); 5a (To take an active role in the design, implementation and execution of global and regional research and monitoring programmes.) f) Towards Scientific Objectives; 1a (Describe, understand and quantify the state and variability of the marine environment in terms of its physical chemical and biological processes.); 5c (Co-ordinate international, monitoring and data management programmes which underpin ongoing ICES core science.)

	g) Towards Scientific Objectives; 5a (To take an active role in the design, implementation and execution of global and regional research and monitoring programmes.); 5c (Co-ordinate international, monitoring and data management programmes which underpin ongoing ICES core science.) h) Towards Scientific Objectives; 5a (To take an active role in the design, implementation and execution of global and regional research and monitoring programmes.) i) Towards Instituional Objectives; 1c (Develop a plan of stimulating symposia) j) Towards Instituional Objectives; 1b (Broaden the scope and readership of publications); 6 (Make ICES' scientific products more accessible to the public); 6d (Maximize the use of electronic media to distribute ICES scientific products, including electronic publications and the ICES Website as a source for "living documents" that are updated as soon as new information is produced.)
Resource Requirements:	a) 1 day Working GroupOH meeting. Pre-prepared national reports from members. b) 5 days Chairman's time to edit. Agenda item discussion (2-3 hours Working GroupOH meeting) c) Pre-meeting preperation (Malmberg, Iceland). Agenda item discussion (1-2 hours Working GroupOH meeting) d) Pre-meeting preperation (Dickson, UK). Agenda item discussion (1-2 hours Working GroupOH meeting) e) Pre-meeting preperation (Bacon, UK). Agenda item discussion (1-2 hours Working GroupOH meeting) f) Pre-meeting preperation (Dooley, ICES). Agenda item discussion (1-2 hours Working GroupOH meeting). g) Pre-meeting preperation (Loeng, Norway). Agenda item discussion (1-2 hours Working GroupOH meeting) h) Pre-meeting preperation (Colbourn, Canada. Rossby, USA). Agenda item discussion (1-2 hours Working GroupOH meeting) i) Pre-meeting preperation (Dickson, UK). Agenda item discussion (1-2 hours Working GroupOH meeting) j) Pre-meeting preperation (Turrell, UK). Agenda item discussion (1-2 hours Working GroupOH meeting). Total = 3 days meeting time
Participants:	) All members b) Turrell (UK) lead. All members. c) Malmberg (Iceland) lead. All members. d) Dickson (UK) lead. All members. e) Bacon (UK) lead. All members. f) Dooley (ICES) lead. All members. g) Loeng (Norway) lead. All members. h) Colbourn (Canada) and Rossby (USA) lead. All members. i) Dickson (UK) lead. All members. j) Turrell (UK) lead. All members.
Secretariat Facilities:	a) 1 day Oceanography Secretary to prepare IBTS / Skaggerak report b) 2 days Oceanography Secretary to put report onto ICES web site f) 2 days Oceanography Secretary to prepare report for Working GroupOH j) 12 days Oceanography Secretary to place information on ICES web site
Financial:	None apart from b) Publication / reproduction costs
Linkages to Advisory Committees:	b) ICES Annual Ocean Climate Status Summary available to ACFM and ACME
Linkages to Other Committees or Groups	b) Publications Committee; Consultative Committee g) Consultative Committee, SGGOOS i) Publications Committee; Consultative Committee
Linkages to Other Organisations:	g) IOC, GOOS

ANNEX A - AGENDA AND TERMS OF REFERENCE FOR 2000 WGOH MEETING

The Working Group on Oceanic Hydrography [WGOH] (Chair: Dr W. Turrell, UK) met in Sopot, Poland from 10–13 April 2000

Agenda

a) update and review results from Standard Sections and Stations;
b) consolidate inputs from Member Countries into the 'North Atlantic Climate Summary';
c) review progress in national and international projects in the North Atlantic such as WOCE, VEINS, CLIVAR/ACSYS, TASC, ESOP2, Trans-Atlantic Section of Currents, and others;
d) discuss the management of the Nuka Arctica ships-of-opportunity programme and of GOOS;
e) update and review the surface and sub-surface drifting buoy initiatives;
f) review North Atlantic climatologies and their availability and usage, and additional data sources for the ICES Annual Ocean Climate Summary;
g) discuss the early results from the current Research Project on Radioactive Tracers in the Nordic Seas and Baltic Sea;
h) review present status of the operational use of new oceanographic equipment;
i) review progress in the planning of the Second Decadal Symposium (C.Res.1997/2.2);
j) compile a list of oceanographic data sets in danger of being lost and consider means for their rescue;
k) assess developments in GOOS of relevance to ICES in the wake of the I-GOOS IV and the Agreements meeting, taking into account the work of the Steering Group on GOOS;
l) consider possible future directions for the Oceanography Committee and the Annual Science Conference with specific regard to the part physical oceanography must play in ICES;
m) consider, and where feasible, develop data products and summaries that can be provided on a routine basis to the ICES community via the ICES website;
n) examine the 1999 Oceanography Committee Working Group reports and the Terms of Reference for 2000 to identify where inter-group input could be provided or required with the view to formulating key questions requiring inter-disciplinary dialogue during concurrent meetings of the Committee's Working Groups in 2002.

Justifications

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

b) The Working Group recognises the need for disseminating climate information in a timely and appropriate manner. The Steering Group on ICES-GOOS has also identified the climate summary as an essential contribution from WGOH. This agenda item will allow WGOH members to prepare the document during the meeting, thus avoiding delays in the dissemination of the information.

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

d) ADCP and other underway instruments mounted on Nuka Arctica will become operational in 1999. The WGOH wishes to discuss the progress on this installation and the end-to-end data management as well as potential installations on other commercial ships crossing the North Atlantic.

e) Under GOOS, there is a major thrust in the development, instrumentation and deployment of drifting buoys. These provide new challenges and new opportunities. Large volumes of data from these buoys are now available in real-time and more will be there in future. The WGOH wishes to examine the opportunities for research using these data.

f) Even though the WGOH reviews and discusses data from standard sections and stations, it is conscious of the fact that there exist other climatologies that are of potential use for the Working Group. WGOH members will compile lists of such known data sets and discuss them at the next meeting.

g) There is a Nordic Project presently in place dealing with environmental consequences as regards radioactivity. It includes the following two components: Important Nordic food chains and Radioactive tracers in Nordic Seas areas including the Baltic Sea and its catchment and adjacent areas. There is a significant field component which is of interest to the WGOH particularly since it will also address water masses and circulation and the use of these tracers to identify the time and space scales and its variability. The WGOH will discuss this program and proposes to invite Henning Dahlgaard, Denmark, a specialist in this field to the next year's meeting.

h) 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.

i) This item is to review the progress on the Second Decadal Symposium planning.

j) The WGOH is concerned about the data sets that are at risk of loss due to retirements and restructuring in the Member Countries and around the world. WGOH members will compile lists of such known data sets and discuss them at the next meeting.

k) The GOOS Agreements meeting will take place during the IOC General Assembly this year, and most ICES Member Countries by then will have their national GOOS plans formulated. The ICES Bureau will also have had a chance to review the recommendations of the SGGOOS and decide on them. The WGOH will discuss both the national plans and ICES plans with respect to GOOS. All members will provide GOOS status reports.

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

m) and n) were formulated during discussions of Working Group Chairs at the 1999 ASC.

ANNEX B: LIST OF PARTICIPANTS

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ANNEX D: CONTEXT SETTING ATLANTIC HYDROGRAPHY 1999-2000

ATLANTIC HYDROGRAPHY IN 1999-2000: ONLY PARTIAL RECOVERY TOWARDS A PAN-ATLANTIC NAO PATTERN.

By

Bob Dickson (CEFAS, Lowestoft) and Jens Meincke (IFM Hamburg).

1. Background:

The North Atlantic Oscillation (NAO) is the dominant recurrent mode of atmospheric behaviour across the North Atlantic sector accounting in normal years for more than one-third of the total variance in winter sea-level pressure (Figure 1a). The conventional index of NAO activity is the mean pressure difference between the two main cells and various station pairs have been used in its calculation. Here we use the Lisbon-Stykkisholmur winter (DJFM) index of Hurrell (1995; 1996).

The characteristics of the NAO and many aspects of the ocean's response were described in the equivalent context-setting section of last year's report. Following a long period of amplification from its most extreme and persistent negative phase in the 1960s to its most extreme and persistent positive phase during the late-1980s-early 1990s, the winter NAO index underwent a rapid and extreme decrease in 1995-96 (Figure 1b) and the 1999 WGOH report attempted to describe the recovery to more positive values since then. Parameters covered included a basin-wide change in sea level, the northward heat transport through 48N, the westward shift of the sub-Arctic front in mid-Atlantic, the reversal of the precipitation regime over Europe, the ice flux through Fram Strait, and the effect of warming sea temperatures on cod recruitment in the North Sea.

Here we attempt a more detailed analysis of the recovering NAO. By comparing the Atlantic composite mean sea level pressure anomaly for the three winters (1993-5) which preceded the 1996 extreme drop in the index with that of the three years (1997-9) which followed, we show that the recovery of the index to more positive values has not yet been accompanied by a complete recovery of the full-ocean pattern of δ-slp that in "normal" years would typify the winter NAO. The distinction is important in understanding the climatic status of the North Atlantic in 1999 since it explains why reports from the eastern Atlantic may seem already to be typical of the ocean's response to the positive NAO while those from parts of the west Atlantic may remain far from typical.

Thus while the 2-point pressure difference that forms the NAO Index may offer a convenient indication of atmospheric behaviour and ocean response, we are liable to be misled if we rely on its use alone without reference to the specific configuration of slp-anomaly that gives rise to it, or to the local physics which determine the Ocean's response.

2. Configuration of the "recovering" NAO.

Figure 2 shows the composite pattern of the winter pressure-anomaly field in 1995-7 (winters are djfm unless otherwise stated, are dated by the year of the January and are extracted from the NOAA NCEP data set (http://www.cdc.noaa.gov/composites)]. Since the NAO was then at its most extreme positive state, on average, in a 135-year instrumental record, it is unsurprising that the pressure-anomaly distribution resembles that of the NAO itself, with a deeper than normal Iceland Low, an amplified Azores High, a chill and strong north-westerly airflow promoting cooling in the NW Atlantic and West Greenland together with intense and deep-reaching convection (to >2300m) in the Labrador Sea, but with an intense south-westerly airflow (not shown) spreading abnormal warmth along the eastern boundary from south of Britain to the Barents Sea and Arctic Ocean.

By contrast, the pressure anomaly composite for the three years that followed the 1996 NAO deep-minimum is highly atypical of the winter pressure field (Figure 3). A north-south pressure-anomaly gradient in the east Atlantic is sufficient to increase the NAO Index but this is far from indicative of the re-establishment of the NAO pattern itself. Although something resembling the NAO dipole may occupy the east Atlantic, this does not extend far to the west of Iceland, and the north-west Atlantic is instead occupied by a large positive pressure-anomaly cell, with light or southerly anomaly winds replacing the chill dry north-westerly airflow more typical of NAO-positive conditions (Dickson et al 1996). By subtracting the 1993-5 composite from the 1997-9 anomaly pattern (Figure 4), the full extent of the contrast is revealed, with the main change being a drastic weakening of the NAO-positive signal between one 3-year composite and the next.

To some extent, the 1997-9 composite is an artificial construct, reflecting an evolving field in which none of the winters may resemble the composite. We therefore add a separate description of the winter slp anomaly distribution for 1999 which forms the main focus for this Report (Figure 5). As shown, the recovery of the NAO Index to high positive values (+ 1.89) has been accompanied by a pattern of winter slp which much more closely resembles the NAO-positive field. Crucially however, the δ-slp pattern has still a rather easterly distribution and the Atlantic-wide pattern has still not fully developed.

Thus although in the reports that follow we will find evidence of the warming in the subtropical gyre and along the eastern boundary to the Fram Strait (e.g. Figure 6) that we have come to expect from NAO-positive conditions, the northwesterlies in the west Atlantic flow from south-east Greenland rather than across the Labrador Sea and Davis Strait (see Figure 5) so that reports from the West Greenland Banks will be of continued warmth rather than cooling, and convection in the Labrador Sea remains weak and shallow compared with the norm for NAO-positive conditions (Dickson et al 1996, Dickson 1997). And with anomalous warmth developing in its expected locations but with cooling *failing* to develop where expected in the subpolar gyre, the composite SST anomaly pattern for the winter of 1999 is understandably one of general warmth (Figure 7, from NOAA data).

It remains to be seen whether continued re-amplification of the NAO will be accompanied by the full re-extension of the NAO pattern into the West Atlantic. The slp-anomaly pattern for winter 2000 (Figure 8) appears very similar to conditions in 1999. Once again, the main pressure anomaly gradient in the North Atlantic is strongly NAO-positive, but once again the pattern is displaced a little to the north and east so that weak southwesterlies rather than strong northwesterlies occupy the Labrador Sea.

The climatic simulations of the Bonn Group (Paeth et al, 1999) using the ECHAM (Hamburg) model scenarios and observations suggest that one accompaniment of CO_2 warming will be an eastward shift in the centres of the two cells that form the NAO dipole. So it is conceivable (but not yet “likely”) that the more-easterly distribution we have experienced in winters 1999 and 2000 may be part of that shift.

4. References.

Dickson, R.R., Lazier, J., Meincke, J., Rhines, P. and Swift, J. 1996. Long-term Coordinated Changes in the Convective Activity of the North Atlantic. Prog. Oceanogr., 38, 241–295

Dickson, R.R 1997. From the Labrador Sea to Global Change. Nature, 386, 649–650.

Hurrell, J.W. 1995. Decadal trends in the North Atlantic Oscillation: regional temperatures and precipitation. *Science, 269,* 676–679.

Hurrell, J.W. 1996. Influence of variations in extratropical wintertime teleconnections on Northern Hemisphere temperature. Geophys. Res. Lttrs., 23 (6) 665–668.

Paeth, H., A. Hense, R. Glowienka-Hense, R. Voss, and U. Cubasch, 1999. The NAO as an indicator for greenhouse gas induced regional climate change. Clim. Dyn., 15, 953– 960.

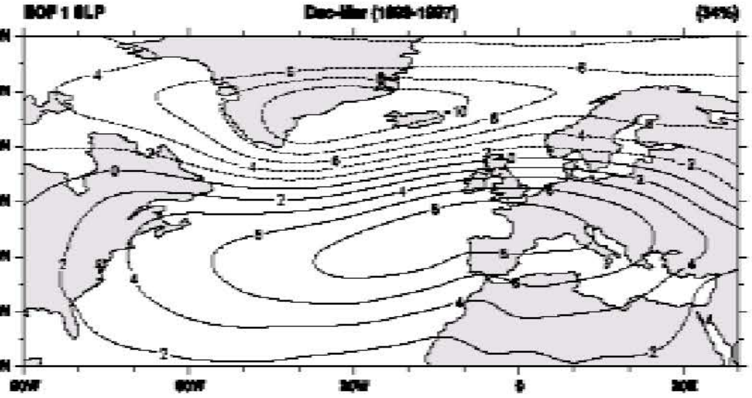


Figure 1a

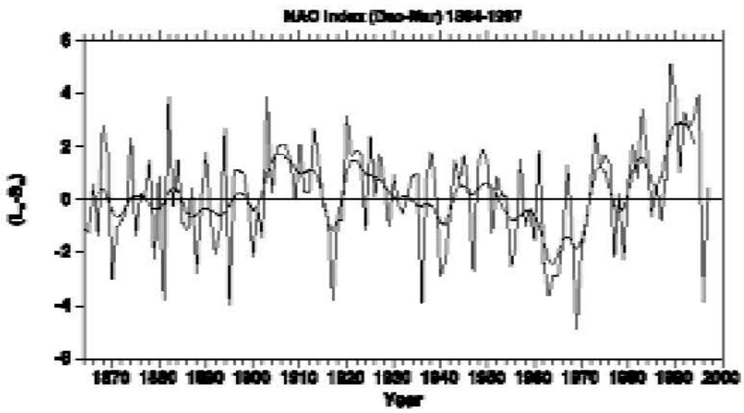


Figure 1b

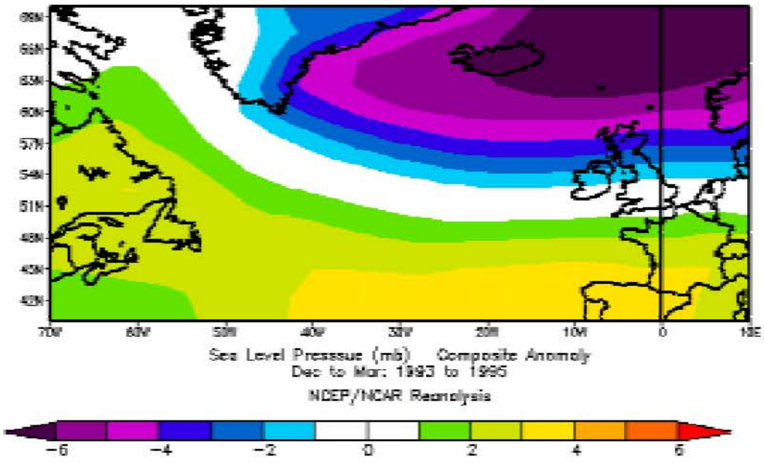


Figure 2

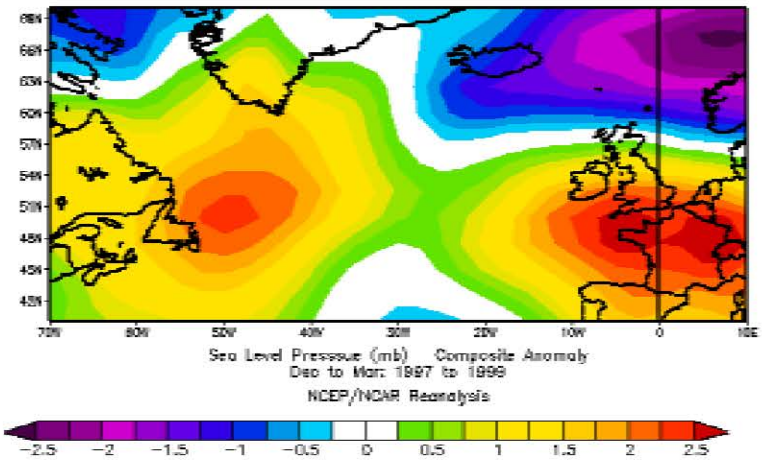


Figure 3

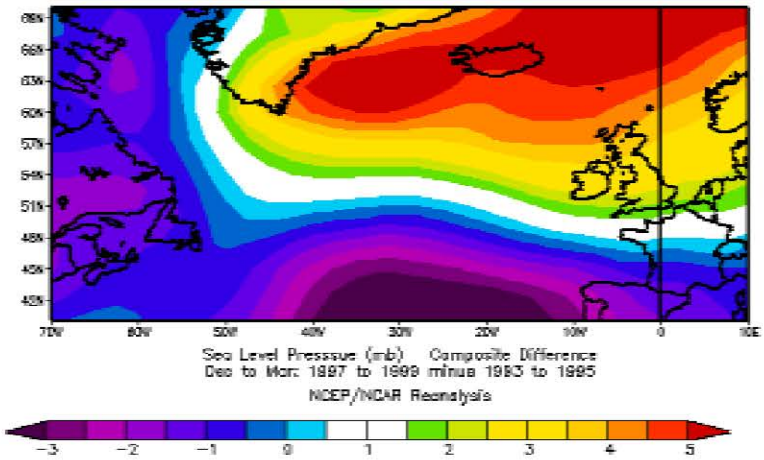


Figure 4

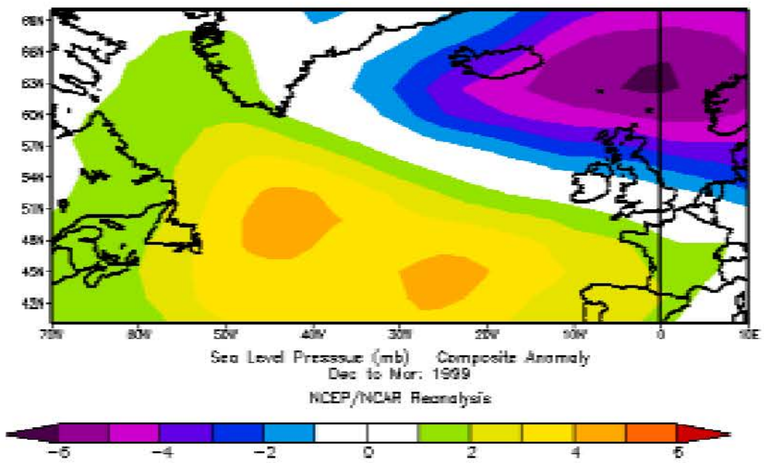


Figure 5

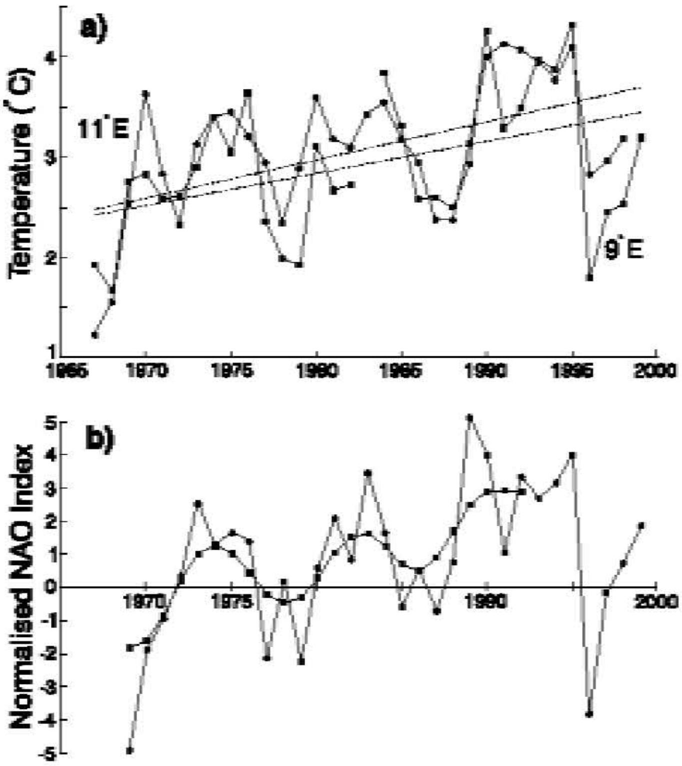


Figure 6

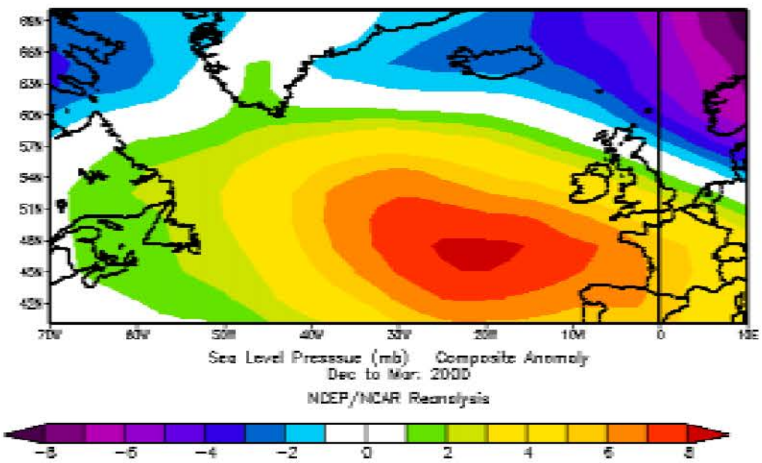


Figure 8

Oceanographic Investigations off West Greenland 1999

By

Erik Buch

Division for Operational Oceanography
Danish Meteorological Institute

February 2000

1. Introduction

The climatic conditions at West Greenland has been relatively mild in the second half of the 1990s. The annual mean air temperature anomalies at Nuuk, the capital of Greenland, have shown positive values since 1995, Figure 1.

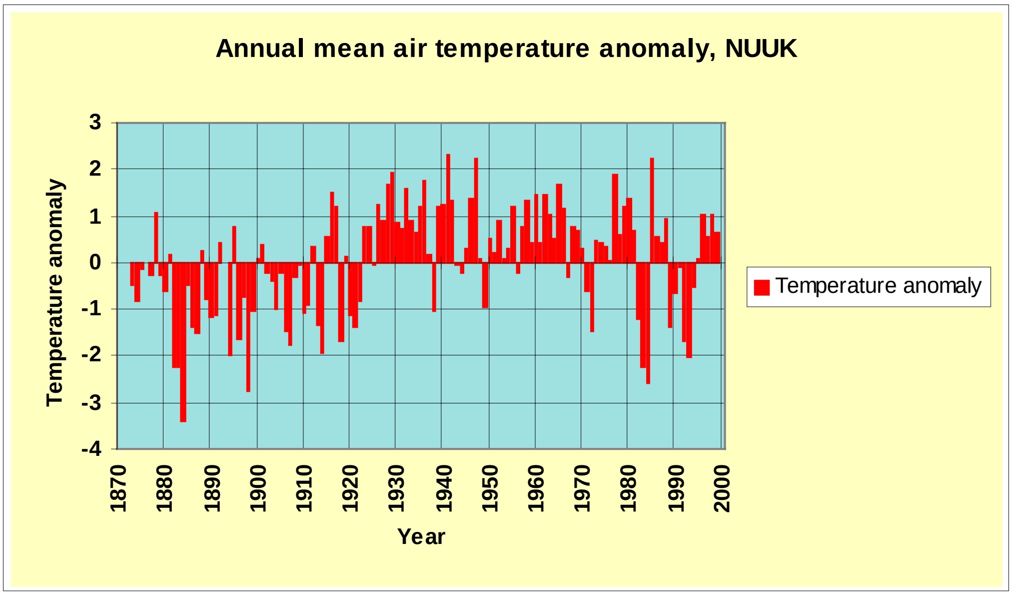


Figure 1. Anomaly in the annual mean air temperature observed at NUUK for the period 1873 to 1999. The anomaly is taken relative to the mean temperature for the whole period

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

The NAO index has been high since 1980, the values observed in 1983, 1989 and in 1990 being the highest recorded since 1863, and these years were some of the coldest ever experienced in Greenland. In 1996, however, the NAO index shifted from high to low values and a milder climate is therefore now present in the Greenland region, Figure 2.

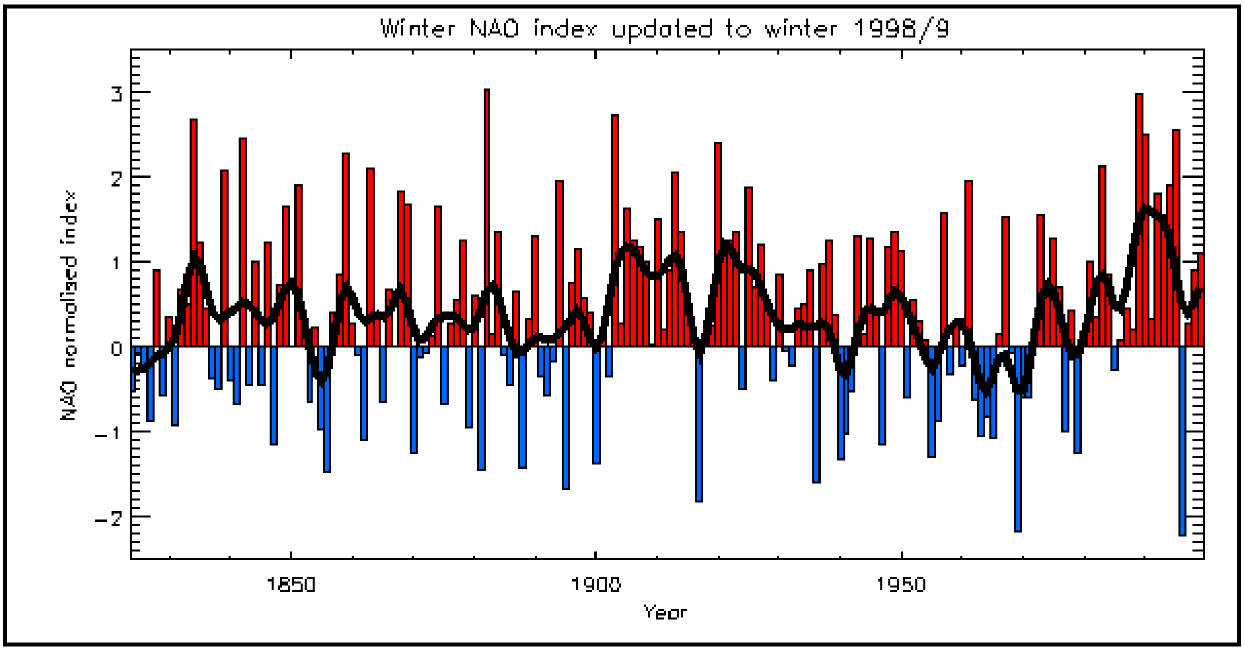


Figure 2. Timeserie of the winter NAO index (December to March average), after Jones *et al.* (1997).

The relatively mild climatic conditions is reflected in the SST anomalies for the water surrounding South Greenland. Figure 3, shows monthly mean SST anomalies for the month of July 1999 - the period of the cruise with TULUGAQ.

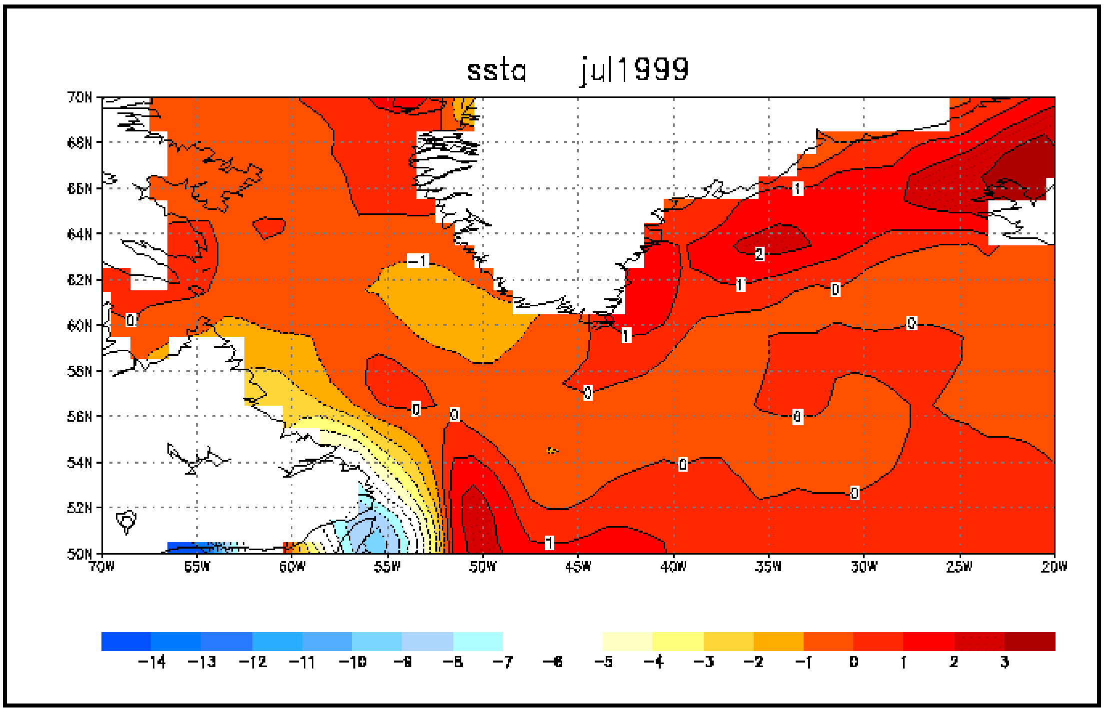


Figure 3. Monthly mean SST anomalies in the water around South Greenland.
From the NOAA AB/CPC Data Page: Servers (Climate, Weather Analyses, Weather Forecasts)

2. Measurements

The 1999 cruise was carried out according to the agreement between the Greenland Institute of Natural Resources and Danish Meteorological Institute during the period July 01-July 10, 1999 onboard the Danish naval ship **"TULUGAQ".** Observations was performed on the following stations:

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

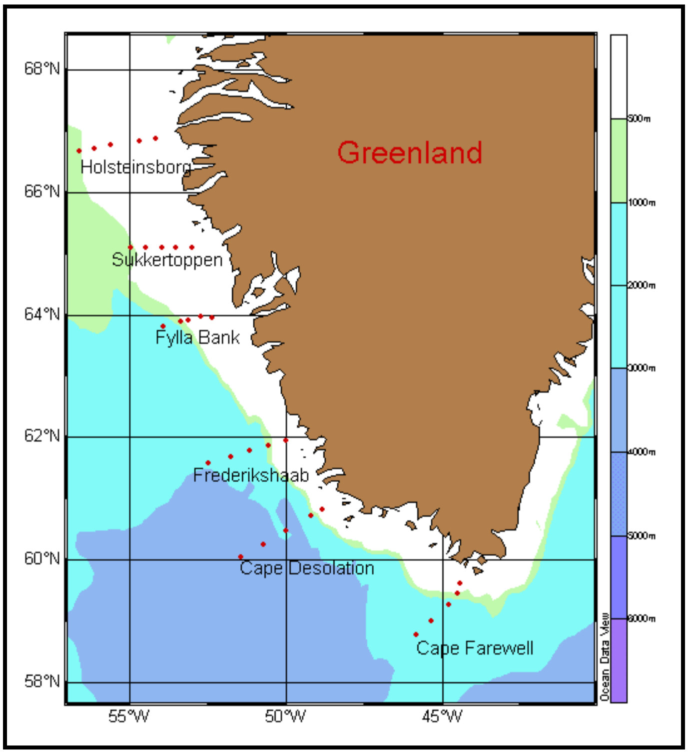


Figure 4. Position of the standard sections off West Greenland

On each station the vertical distributions of temperature and salinity was measured from surface to bottom, except on stations with depths greater than 700 m where 700 m was the maximum depth of observation.

The cruise was blessed with favourable weather and ice conditions. "Vestice" was not present at the Holsteinsborg section. At the innermost 3 station of the Cape Farewell section "Storis" was present; but fortunately not in quantities preventing the measuring program being carried out except for the innermost station, which was observed approximately 9 nm to the north of its position.

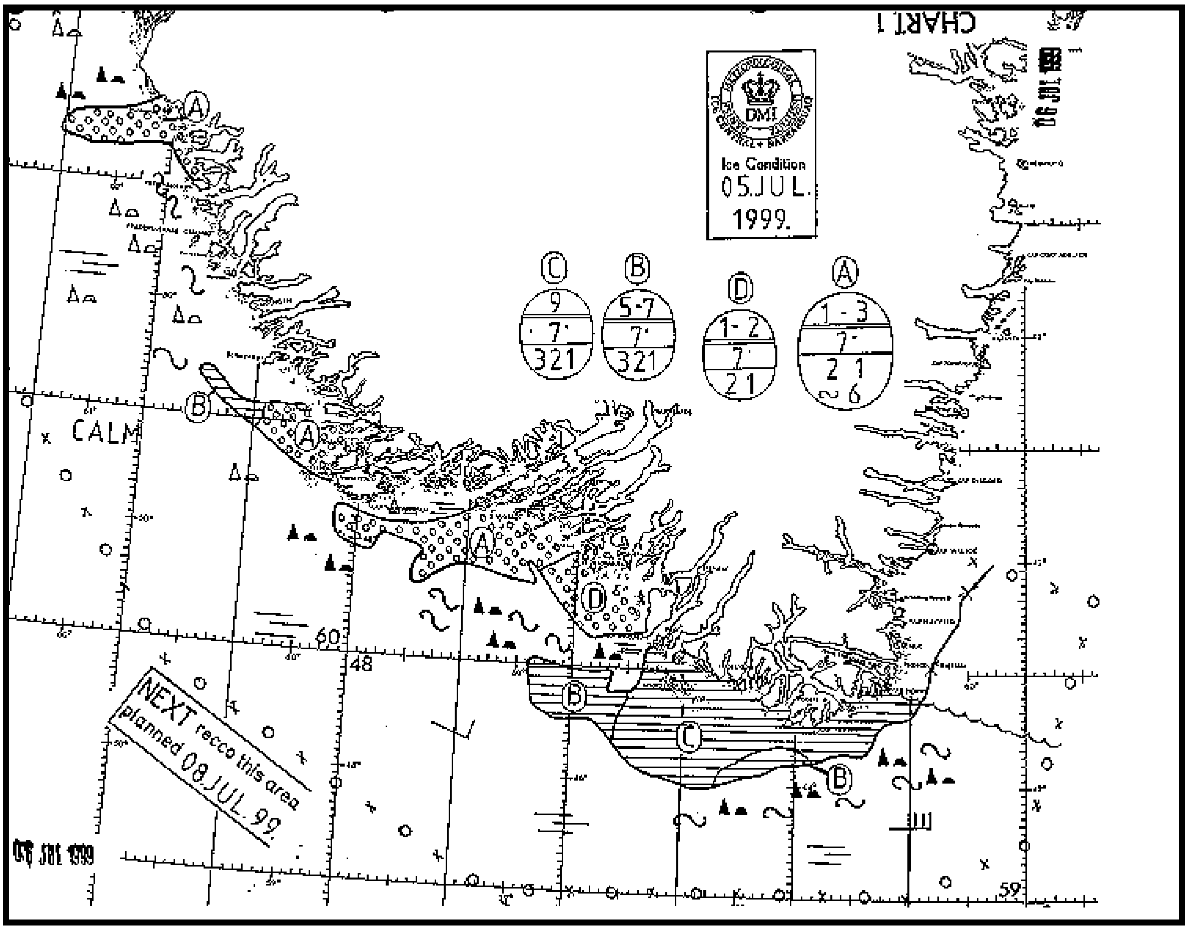


Figure 5. Distribution of sea ice in the Cape Farewell region July 5, 1999.

3. Data handling

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

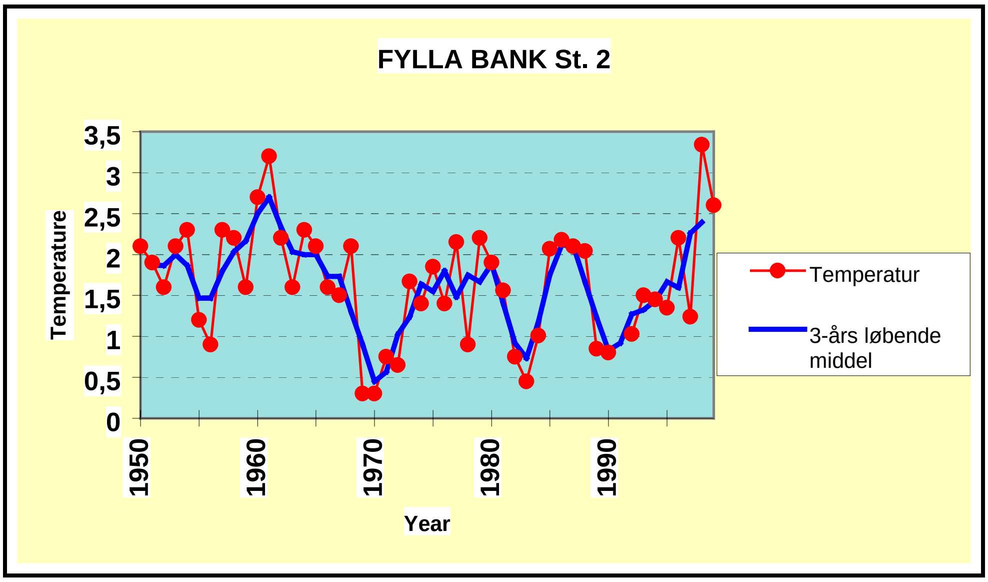
The CTD data were analysed using SEASOFT 4.217 software provided by SEABIRD.

All quality controlled data are stored in the Marine Database at the Danish Meteorological Institute from where copies have been sent to ICES and MEDS.

4. Oceanographic conditions off West Greenland in 1998

The mean temperature and salinity on top of Fylla Bank in the middle of June are shown in Fig. 6 a,b. The 1999 value was well below the 1998 the record high value observed in 1998; but the 1999 temperature (2.6°C) is, however, among the highest 5 temperatures observed since the start of the time series in 1950, and thereby also well above the average value of 1.67°C for the whole 50 year period.

a)



b)

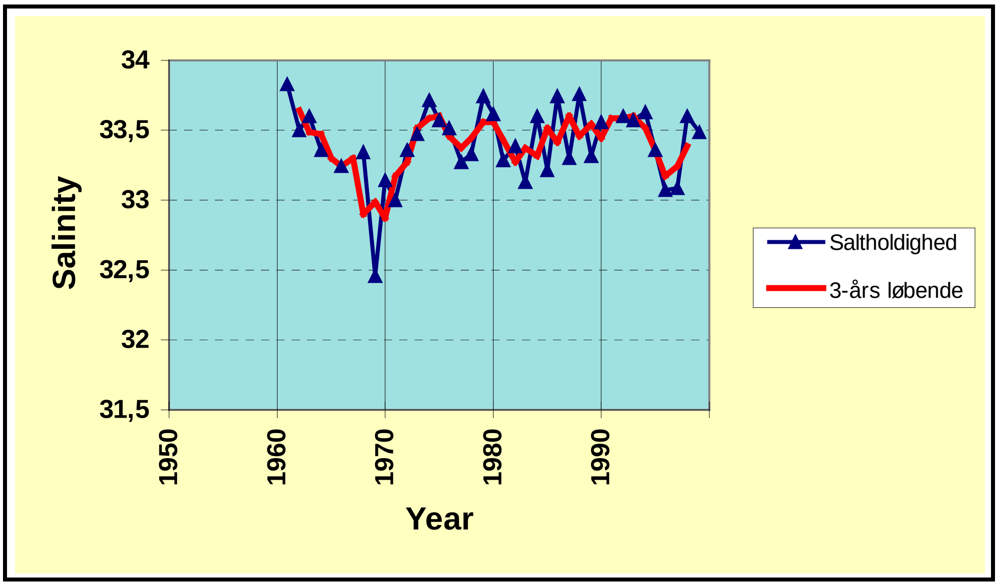


Figure 6. Timeseries of

a) mean temperature (observations and 3 year running mean)

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

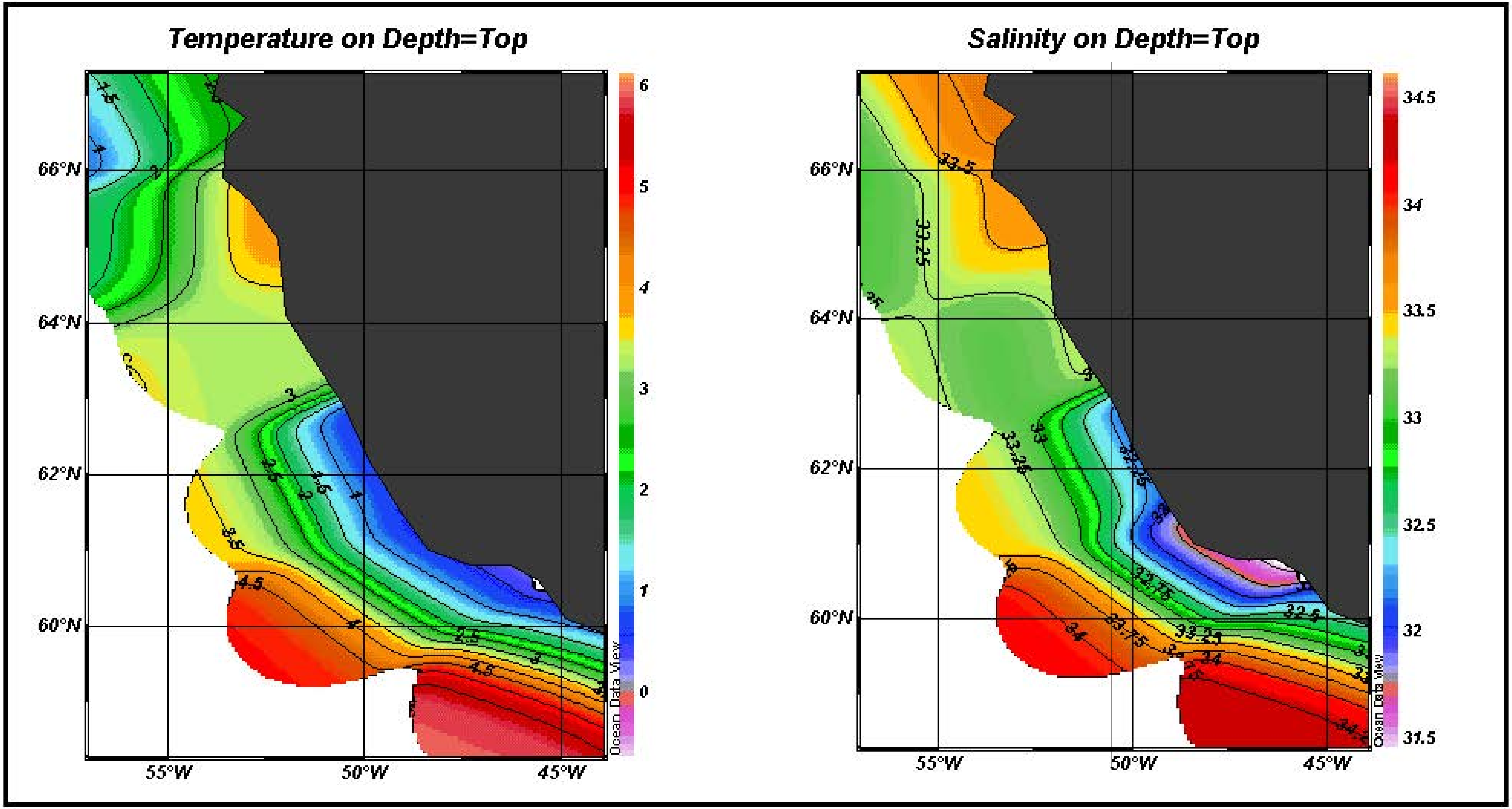


Figure 7. Surface temperature and salinity, early July 1999

The 1999 mean salinity value (33.48 psu) on top of Fylla Bank (Fig.6b) was slightly lower than in 1998, but still slightly above the average value of 33.40 psu.

The surface temperatures and salinity's observed during the 1999 cruise are shown in Figs. 7. The cold and low salinity conditions observed off south-west Greenland indicates a inflow of Polar Water carried to the area by the East Greenland Current. The low temperatures found in the north-western corner (off Holsteinsborg) indicates melting of Westice just prior to the observations. Water of Atlantic origin (T> 3^{o}C; S> 34.5 psu) are found at surface only at the outermost station on the three southernmost sections.

The vertical distribution of temperature, salinity and density as well as TS-relations at the six observed sections are given in Figs. 8 - 13.

In the surface layer relatively strong gradients between the cold, low-saline Polar Water and the warm, high-saline water of Atlantic origin was observed from Fylla Bank and southward. North of Fylla Bank cold, low saline water was found at the westernmost stations indicating recent melting of Westice. The normally observed core of Polar Water just west of Fylla Bank at a depth of 50 - 150 m was almost absent in 1999.

Temperature and salinity observations at greater depth showed a relatively weak inflow of pure Irminger Water (T ~ 4.5^{o}C, S > 34.95 psu) took place in 1999. The tongue of Irminger Water did in 1999 just reach as far north as the Cape Desolation section. The core of inflowing Irminger Water was found at around 200 m's depth at Cape Farewell, where salinity values just above 35.0 psu was observed. The TS-plots show that the Irminger Water (S>34.95) in 1999 had temperatures between 5 and 6^{o}C in the Cape Farewell region, while it further north had values just above the normal 4.5^{o}C, indicating a relative high heat content in the Irminger Water off Southeast Greenland, which can serve as an explanation to the positive SST anomalies observed in this region, Fig. 3.

Modified Irminger Water (34.88 < S < 34.95) was observed as far north as to the region between Lille Hellefiske Bank and the Holsteinsborg section.

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

References

Buch, E. (1997). Oceanographic conditions in the West Greenland Waters 1981 - 1997. NAFO Ser. Doc.

Jones P. D., Jonsson T. and Wheeler D. (1997). Extension to the North Atlantic Oscillation using early instrumental pressure observations from Gibraltar and South-West Iceland. Int. J. Climatol. 17, 1433-1450.

van Loon,H. and J.C.Rogers (1978). The Seesaw in Winter Temperatures between Greenland and Northern Europe. Part 1: General Description. Mon. Wea. Rev. 106, 296-310.

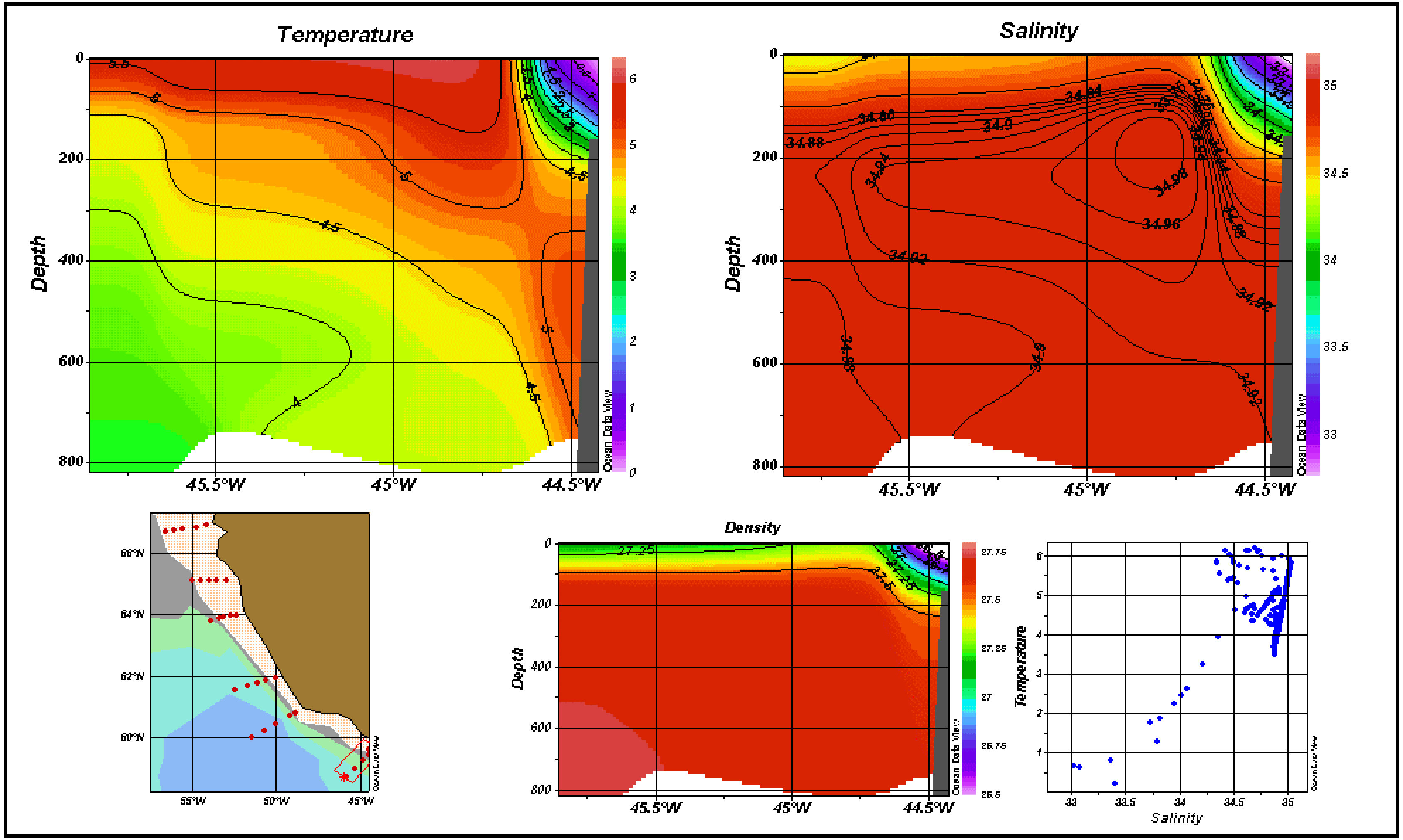


Figure 8. Vertical distribution of temperature, salinity and density at the Cape Farewell section, July 10, 1999

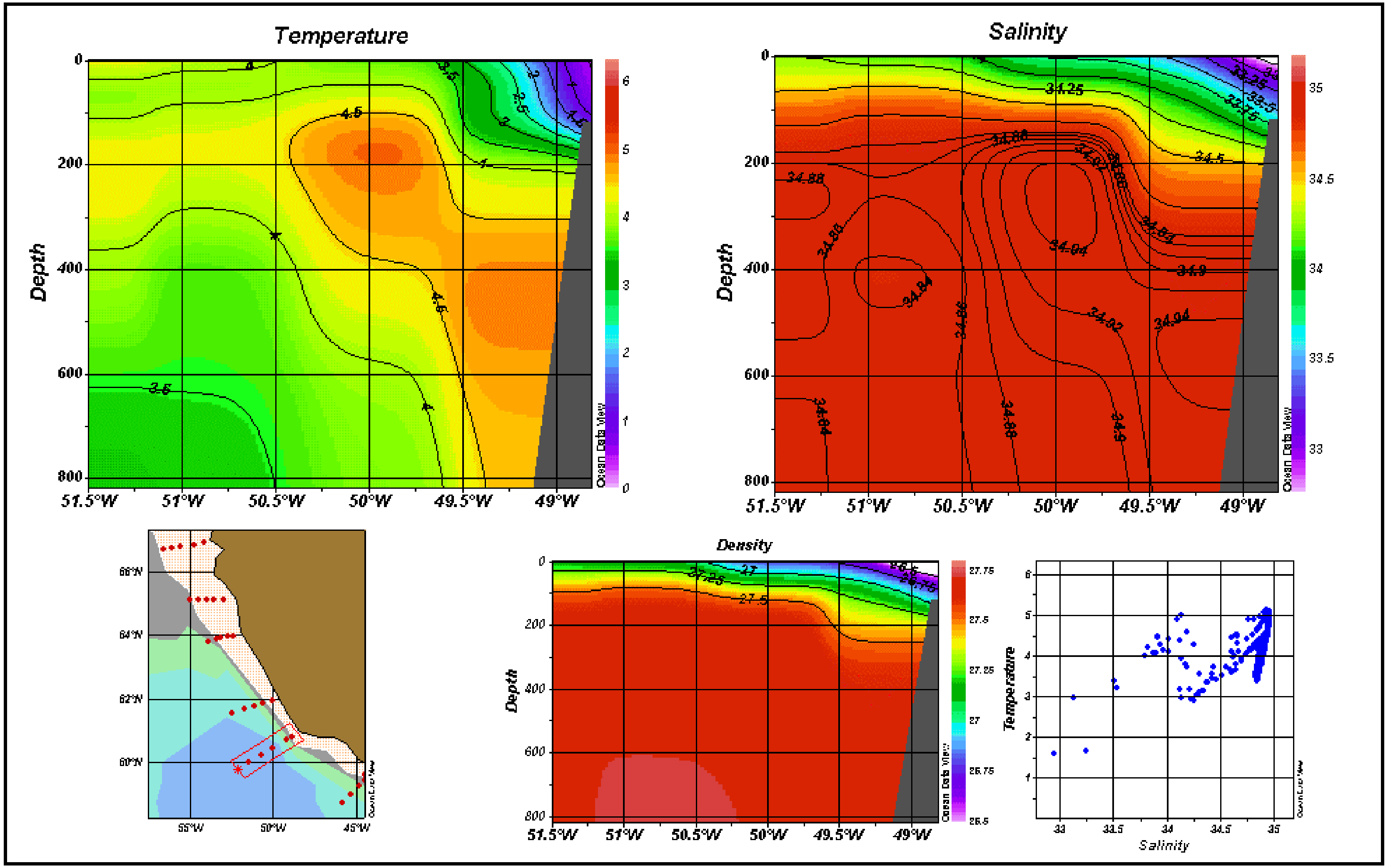


Figure 9. Vertical distribution of temperature, salinity and density at the Cape Desolation Section, July 5, 1999.

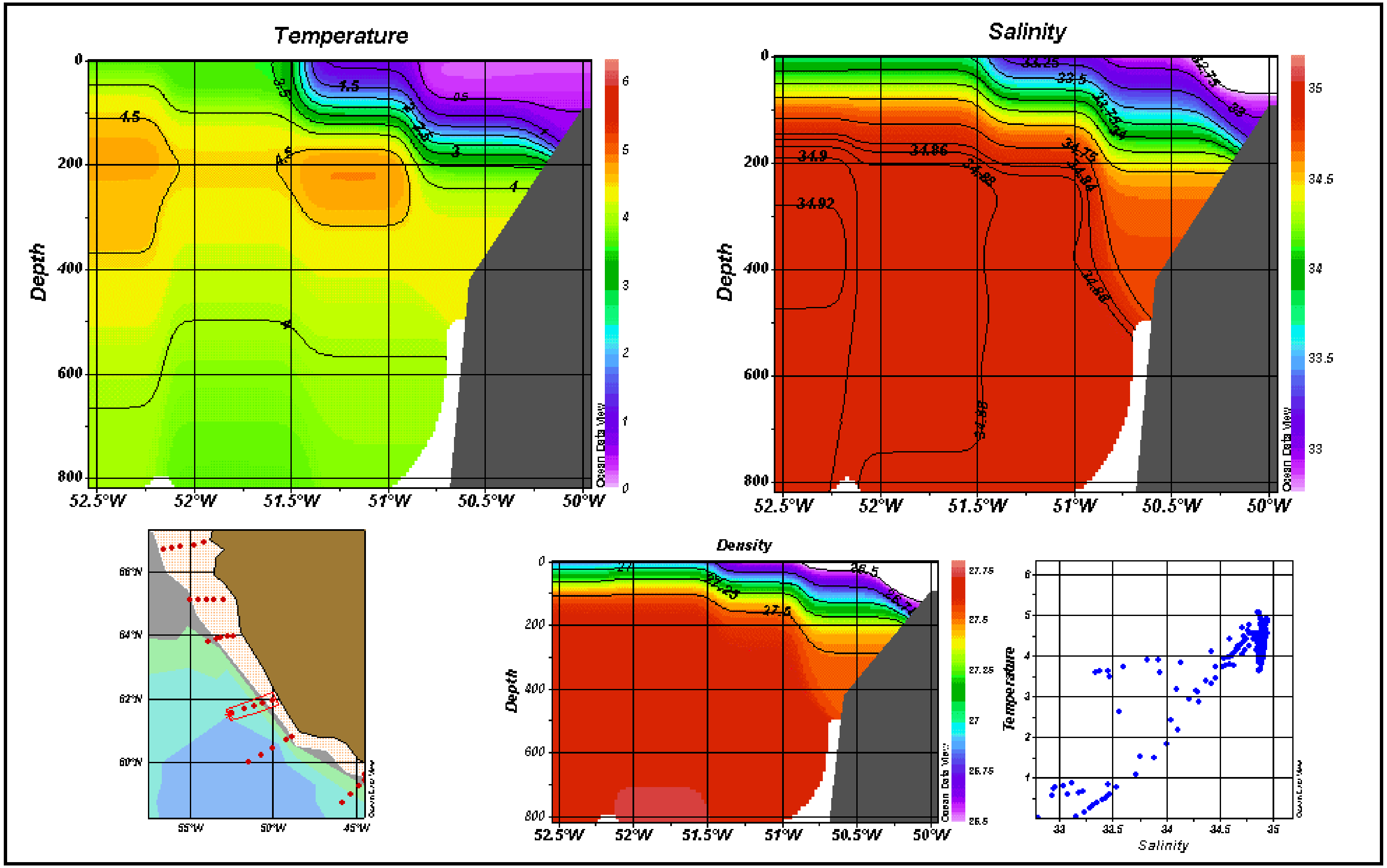


Figure 10. Vertical distribution of temperature, salinity and density at the Frederikshaab Section, July 4, 1999.

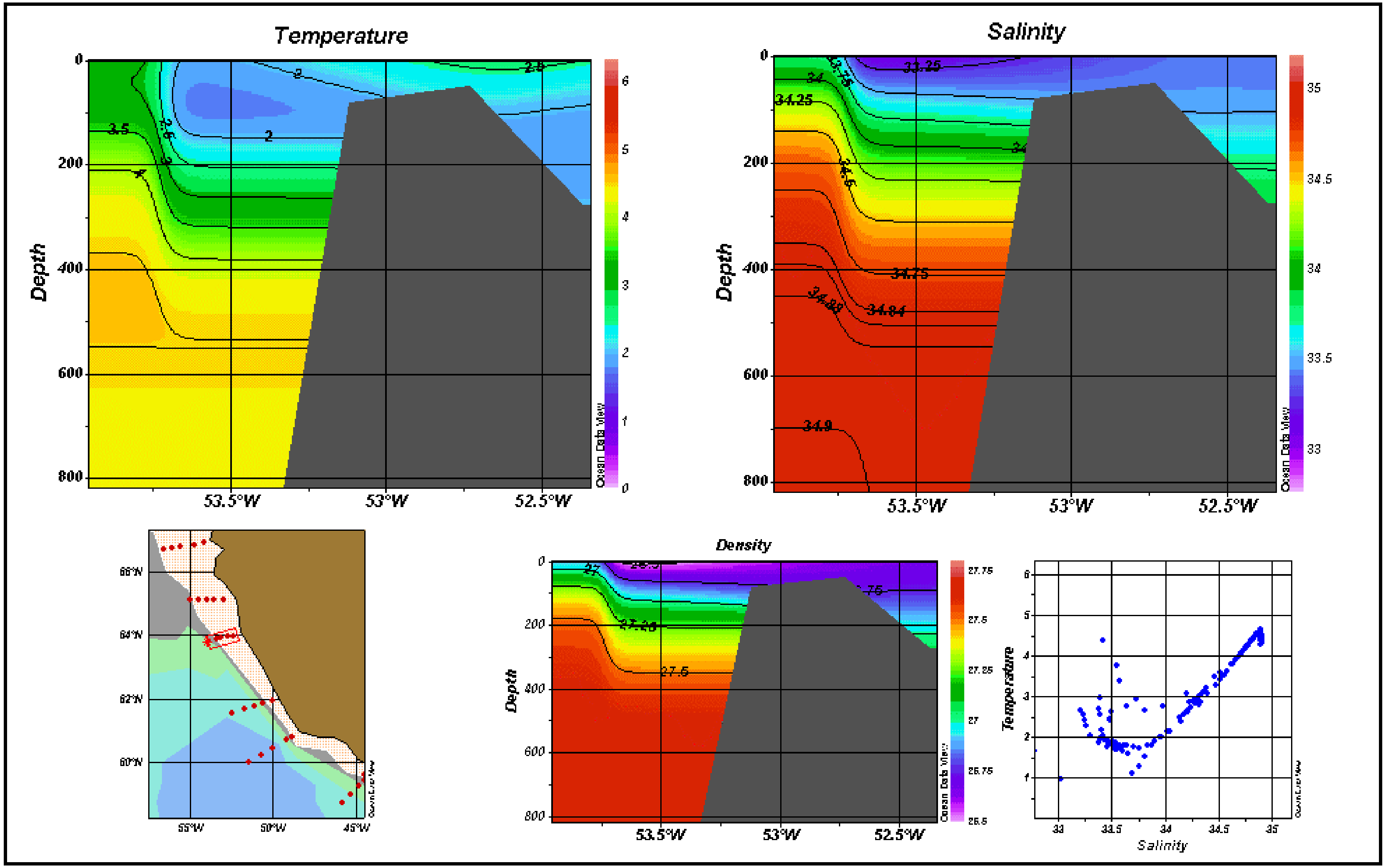


Figure 11. Vertical distribution of temperature, salinity and density at the Fylla Bank Section, July 2, 1999.

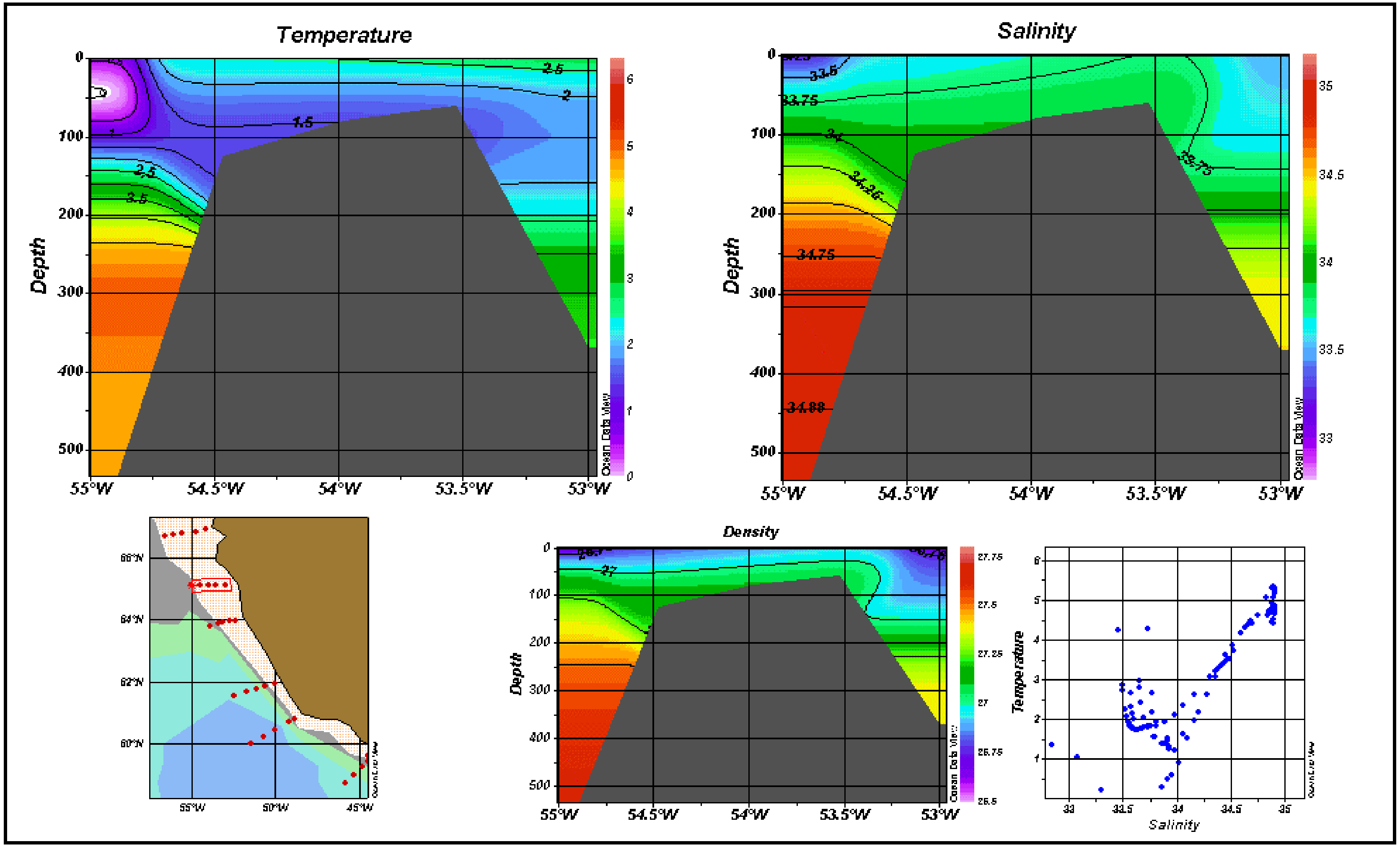


Figure 12. Vertical distribution of temperature, salinity and density at the Lille Hellefiske Bank Section, July 2, 1999.

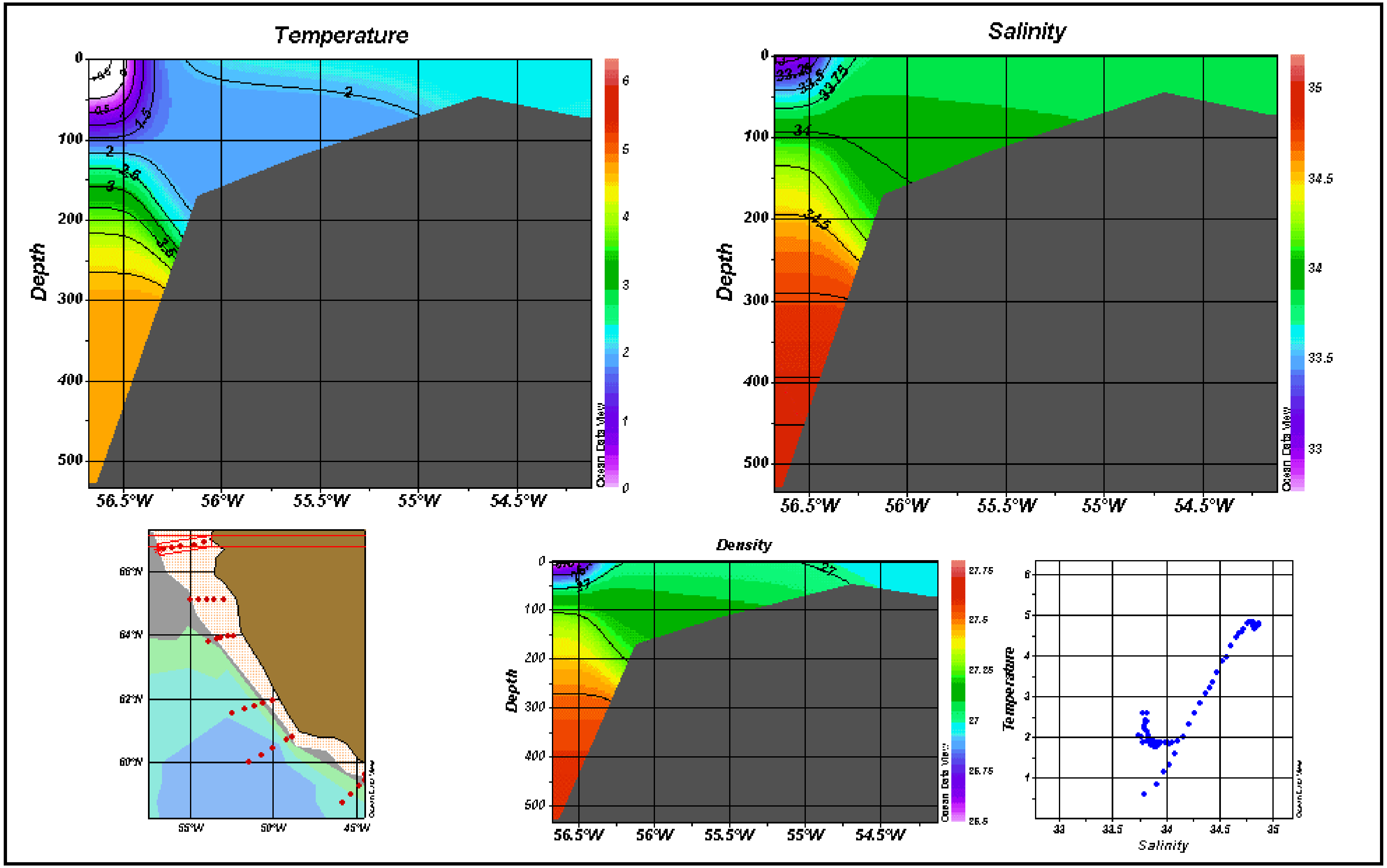


Figure 13. Vertical distribution of temperature, salinity and density at the Holsteinsborg Section, July 1, 1999

ANNEX F: AREAS 1 AND 12 (WEST GREENLAND) GERMAN REPORT

Oceanographic results from cruise WH211 East and West Greenland (10 October – 8 November 1999)

Investigations performed by FRV "Walther Herwig III" in October/November 1999 at NAFO Standard Oceanographic Sections Fyllas Bank, Little Halibut Bank, and Holsteinsborg indicate that warm, saline water reached the northern parts of the West Greenland bank areas. Along the Holsteinsborg Section water temperatures in the depth layer 300-400m were well above 5°C (Figure 2). At the Little Halibut Bank Section temperatures above 6°C were measured, a value which is seldom reached at this section (Figure 3).

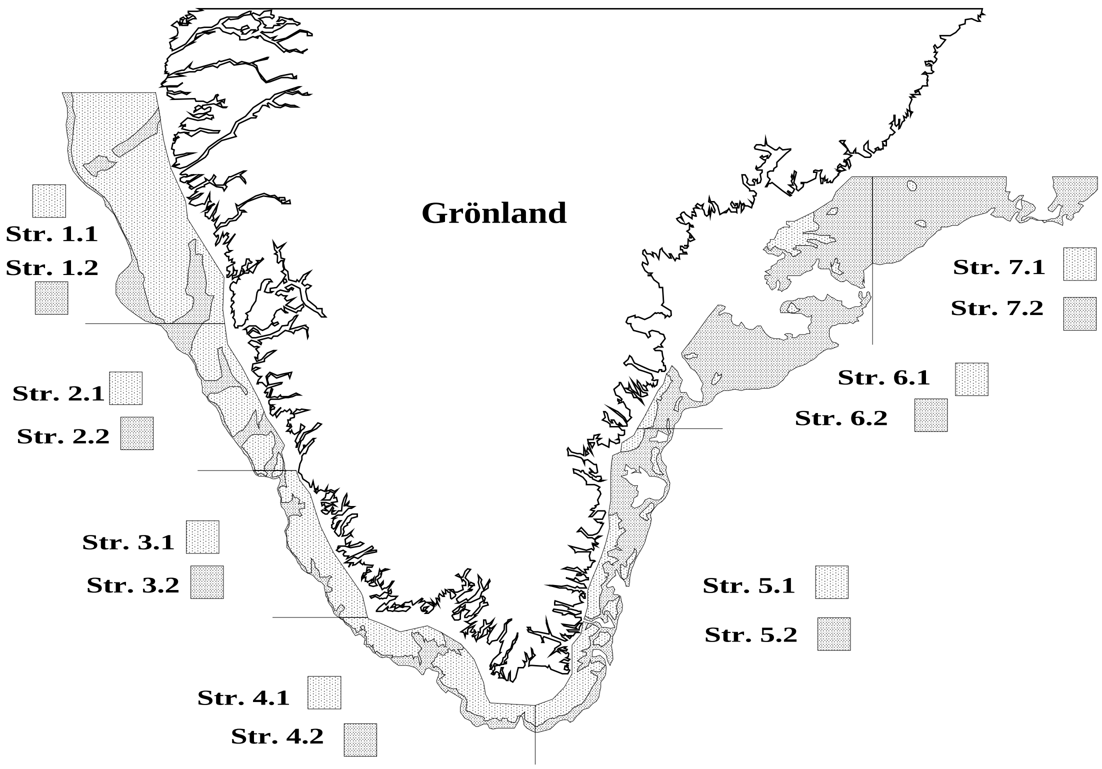


Figure 1. Area of investigation during WH 211, and individual survey strata (10 October – 8 November 1999)

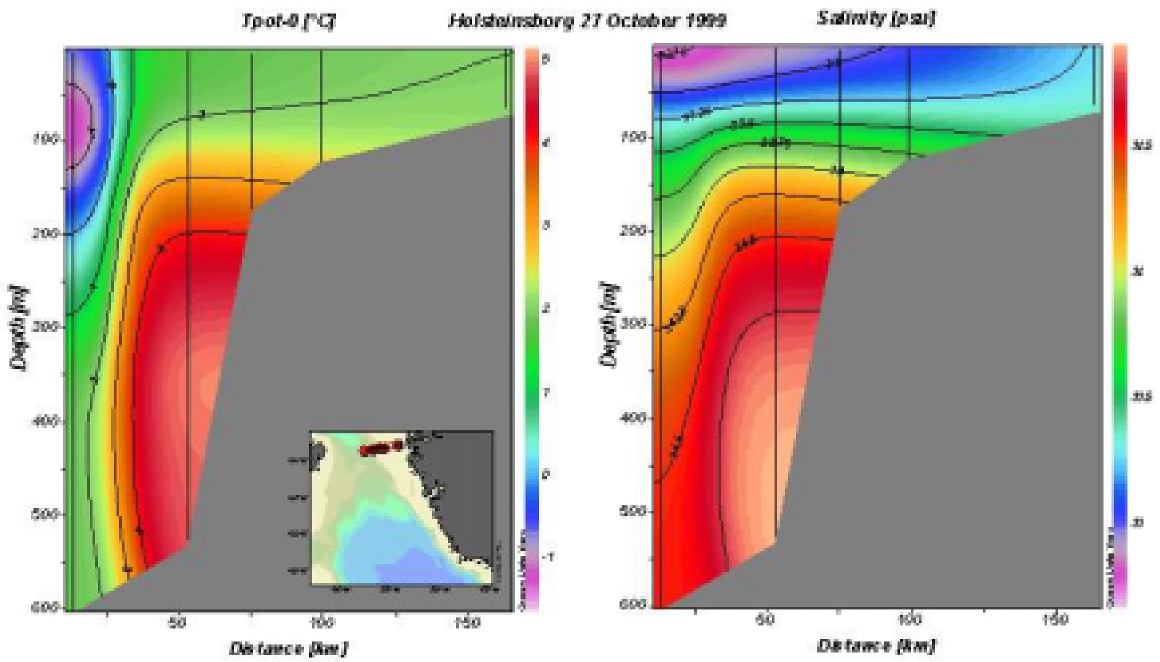


Figure 2. Potential temperature and salinity along Holsteinsborg Section (27 October 1999)

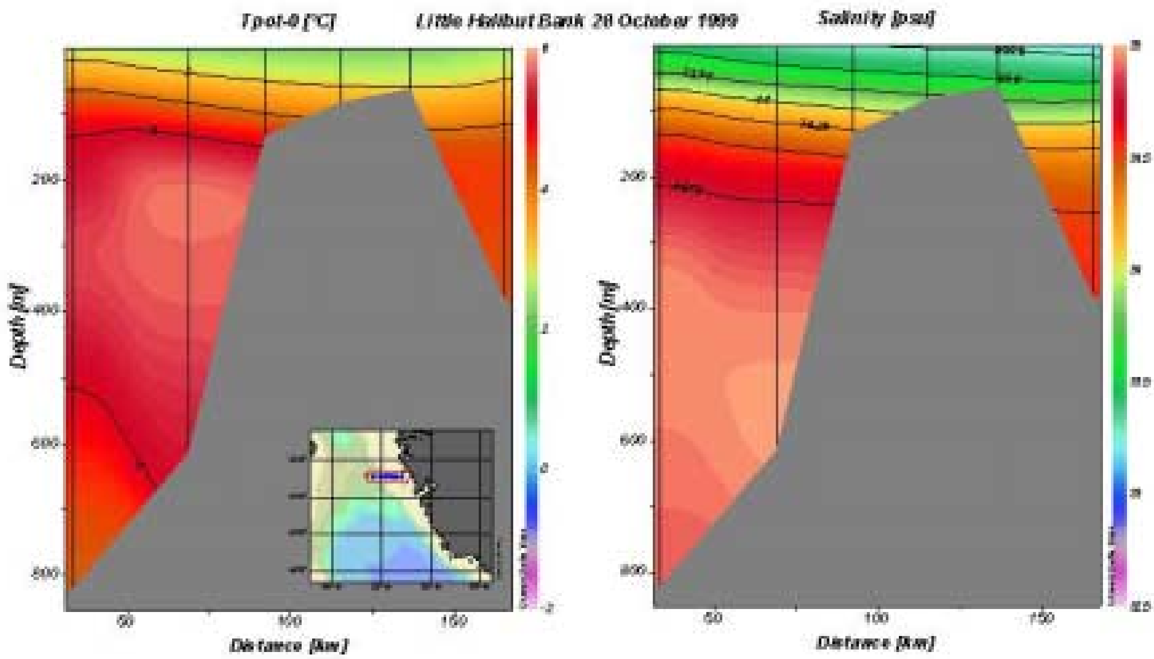


Figure 3. Potential temperature and salinity along Little Halibut Bank Section (28 October 1999)

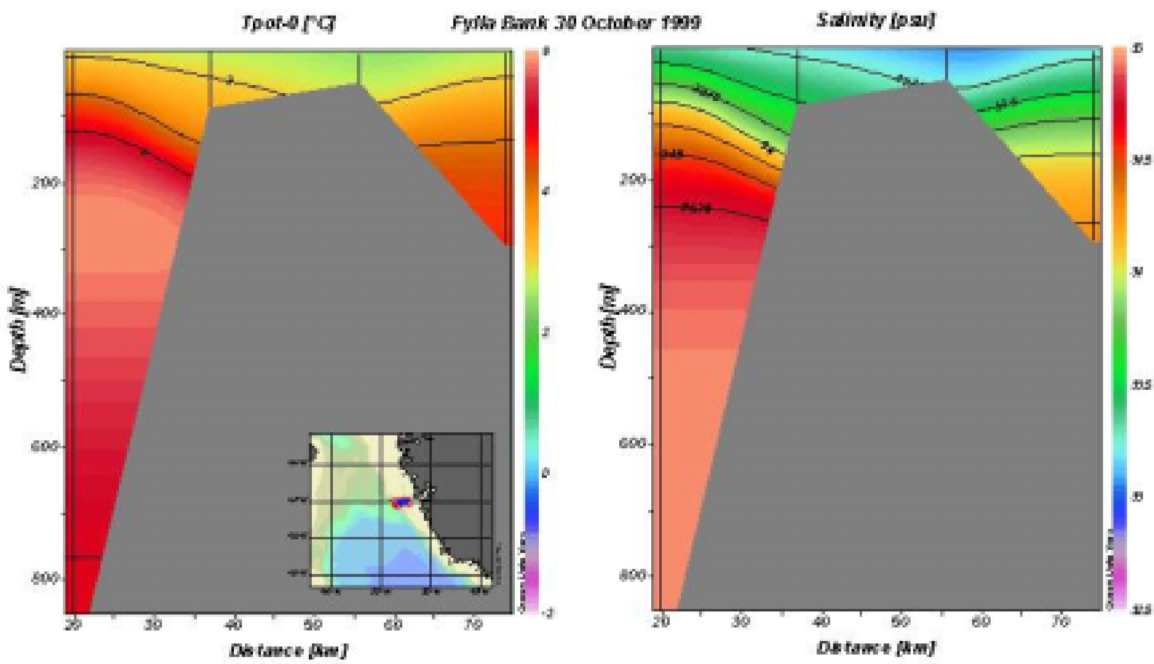


Figure 4. Potential temperature and salinity along Fylla Bank Section (30 October 1999)

The results from Fylla Bank are given in Figures 4 and 5. Accordingly, mean temperature anomalies of water layers 0-50m, 0-200m, and 200-300m are +1K above the 1963-90 mean value.

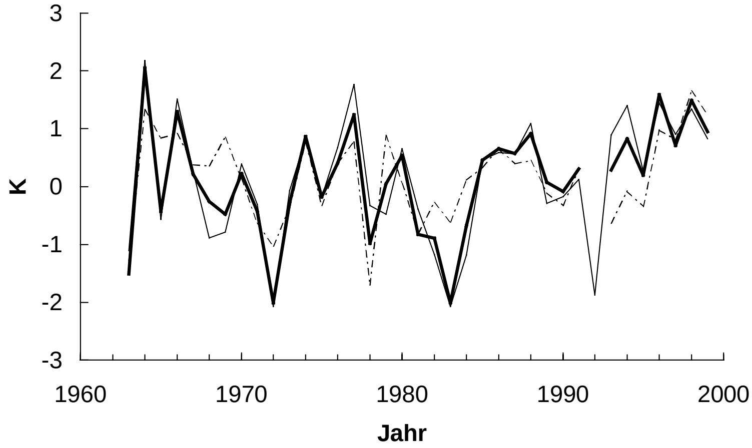


Figure 5. Mean temperature anomalies of water layers at station 4 of the Fylla Bank Section (0-50m: thin; 0-200m: bold; 200-300m: dashed)

Comparison between the mean stratum weighted temperature index of the entire area under investigation (East and West Greenland), and the results of station 4 of the Fylla Bank Section (Fig. 6) reveal for the depth layers 0-200m, and 200-400m, i.e. the depth layers of the surveyed strata, significant correlation:

0-200m /Temperatur-Index $r^2 = 0.82$ ($p << 0.001$)
200-400m /Temperatur-Index $r^2 = 0.78$ ($p << 0.001$).

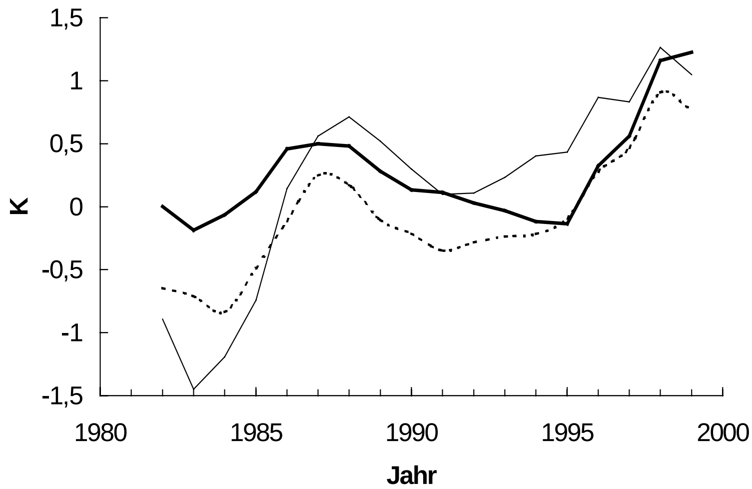


Figure 6. Mean temperature anomaly of water layers 0-200m (thin), 200-400m (bold) at station 4 of Fylla Bank Section, and stratum weighted mean temperature index (dotted) of entire research area as given in Figure 1.

These results indicate that both methods, the observation at a standard station, and the area integrated temperature index give similar results on the climatic situation in the near-bottom water layer of the bank system East and West Greenland. This points at advective processes which seem to play an important role in this bank system.

After passing Cape Farewell, an XBT transect was performed between 12 and 16 November 1999 until reaching the European continental shelf break off the Pentlands (inter station distance 30nm). It must be noted that more than 20% of the XBT profiles could not be used for analysis (due to signal wire of bad quality; XBT-type Deep Blue, 05205).

The results of this project (1989-1999 XBT observations along 60°N) will be presented at the 2001 symposium in Edinburgh.

Literature cited: Ratz, H.-J. 1999. Structures and Changes of the Demersal Fish Assemblage off Greenland, 1982-96. NAFO Sci Coun. Studies, 32: 1-15.

ANNEX G – AREA 2 (NORTHWEST ATLANTIC) CANADIAN REPORT

Results from the standard stations and sections in the Northwest Atlantic.

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Introduction

The meteorological and oceanographic conditions during 1999 are presented referenced to a standardised base period from 1961-1990 in accordance with the convention of the World Meteorological Organization. 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). The meteorological and sea ice data and analysis were provided by Drinkwater, Prinsenberg and Peterson at Bedford Institute of Oceanography in Dartmouth Nova Scotia Canada.

One of the most widely used and longest oceanographic time series in the Northwest Atlantic is from Station 27 located at latitude 47° 32.8′ N and longitude -52° 35.2′ W. This monitoring station was first occupied 1946, it is located in the inshore region of the eastern Canadian continental shelf about 8 km off St. John's Harbor Newfoundland (Fig. 1), in a water depth of 176 m. The station is occupied on a regular basis mainly by oceanographic and fisheries research vessels at a frequency of about 3 times per month on average, with 45 occupations during 1999.

Recognising the usefulness of standard oceanographic indices for monitoring ocean climate variability the Canadian Department of Fisheries and Oceans started occupying a series of cross-shelf hydrographic transects during mid-summer of every year beginning in the late 1940s. In 1976 the International Commission for the Northwest Atlantic Fisheries (ICNAF) adopted a suite of standard oceanographic stations along transects in the Northwest Atlantic Ocean from Cape Cod (USA) to Egedesminde (West Greenland) (Anon. 1978). Four of these transects are occupied annually during mid-summer on an annual oceanographic survey conducted by the Canadian Department of Fisheries and Oceans, they are: (1) the Seal Island transect on the Southern Labrador Coast crossing Hamilton Bank; (2) the White Bay transect which crosses the relatively deeper portions of the Northeast Newfoundland Shelf; (3) the Bonavista transect off the East Coast of Newfoundland; and (4) the Flemish Cap transect which crosses the Grand Bank at 47°N and continues eastward across the Flemish Cap. In this report the results from the Seal Island, Bonavista and the Flemish Cap transects (Fig. 1) for the summer of 1999 are presented.

Meteorological and sea-ice conditions

Monthly air temperature anomalies for 1998 and 1999 relative to their 1961-90 mean at eight sites in the north-west Atlantic from Godthaab in Greenland to Cape Hatteras on the eastern coast of the United States are shown in Fig. 2. The predominance of warmer-than-normal air temperatures over most of eastern Canadian waters during 1999 is clearly evident with anomalies of +3° to 4°C common. The annual mean air temperature anomalies for 1999 were above normal with new record highs recorded at St. John's (1.9°C; 126-year record), and Cartwright (1.9°C; 65-year record).

The time series of the annual anomalies are shown in Figure 3. The high air temperature anomalies in 1999 are clearly evident. At St. John's the annual anomaly rose above 1998 values by approximately 1°C and at Cartwright by 0.7°C. At the remaining sites they were similar to 1998 except at Godthaab where the anomaly declined by 1.2°C. Note that the interannual variability in air temperatures since 1960 at Godthaab, Iqaluit, Cartwright, and, to a lesser extent, St. John's, have been dominated by large amplitude fluctuations with minima in the early 1970s, early to mid-1980s and the early 1990s, suggesting a quasi-decadal period. Indeed, the recent rise in temperature is consistent with a continuation of this near decadal pattern. Also note that all sites where data are available, cold conditions (relative to the 1961-90 mean) existed throughout the late 1800s and early 1990s. Temperatures rose to above normal values between the 1910s and 1950s, the actual timing being site-dependent.

The North Atlantic Oscillation (NAO) Index as defined by Rogers (1984) is the difference in winter (December, January and February) sea level atmospheric pressures between the Azores and Iceland and is a measure of the strength of the winter westerly winds over the northern North Atlantic. A high NAO index corresponds to an intensification of the Icelandic Low and Azores High which creates strong north-west winds, cold air and sea temperatures and heavy ice in the Labrador Sea and Newfoundland Shelf regions. (Colbourne *et al*. 1994; Drinkwater 1996). In 1999, the NAO anomaly was well above normal (+14.3 mb) and had increased significantly from the 1998 value which was +1.1 mb (Fig. 4). The 1999 index returned to a level similar to that observed during the first half of the 1990s and was above the lower-than-average indices registered in 1996 and 1997. These changes in the NAO index fit the pattern of quasi-decadal variability that has persisted since the 1960s, however during 1999 the colder-than-normal winter conditions usually associated with high NAO index were restricted to the west Greenland side of the Labrador Sea.

Information on the location and concentration of sea ice is available from the daily ice charts published by Ice Central of Environment Canada in Ottawa. The time series of the areal extent of ice on the Newfoundland and southern Labrador shelves (between 45-55°N) show that the peak extent during 1999 was close to but slightly below that observed in 1998 and the lowest since 1978 (Fig. 5). The average ice area during the period of general advancement (January to March) rose slightly relative to 1998 but during the period of retreat (April to June) it declined compared to the previous year. During both advance and retreat periods, the average ice area was below the long-term mean and was much less than the early 1990s (Fig. 5). In general, sea ice coverage was lighter-than-average and of shorter duration than normal during 1999 on the Labrador and Newfoundland shelves.

Oceanographic conditions

Station 27

The cold near isothermal water column off eastern Newfoundland at Station 27 (Fig. 1) during the winter of 1999 has temperatures ranging from 0°C to –1°C. These temperatures persisted throughout the year, in the bottom layers. The surface layer temperatures were near constant at about 0°C from January to early April, after which the surface warming commenced. By late April upper layer temperatures had warmed to 2°C and to near 15°C by August at the surface, after which the fall cooling commenced. These temperatures ranged from 0.25° to 1°C above normal for the winter months over most of the water column and over 2°C above normal at the surface during June and July. By late summer a negative temperature anomaly developed over the upper 100-m of the water column with anomalies exceeding 0.5°C below normal. These cold anomalies may have been caused by the advection of cold water from the Labrador Coast that was observed there during the summer. Bottom temperatures throughout the year ranged from 0.25° to 0.5°C above normal (Fig. 6). Surface salinities reached a maximum of >32.2 by late February and decreased to a minimum of <30.5 by late August. These values ranged from about normal during the winter months to 0.2-0.5 below normal during the summer months. In the depth range from 50 to 100-m, salinities generally ranged from 32.4 to 32.7 and near bottom they varied throughout the year between 33 and 33.5. Except for the positive anomaly during the winter months salinities were generally below normal during most of 1999 (Fig. 7).

The vertically averaged (0-176 m) annual temperature anomaly time series (Fig. 8) shows large amplitude fluctuations at near decadal time scales, with cold periods during the early 1970s, mid-1980s and early 1990s. During the time period from 1950 to the late 1960s the heat content of the water column was generally above the long-term mean. It reached a record low during 1991, a near record high during 1996, near normal in 1997 and 1998 and above normal during 1999. The 0-50 m vertically averaged summer (July-September) salinity anomalies (Fig. 8) show similar behaviour as the heat content time series with fresher-than-normal periods corresponding to the colder-than-normal conditions. The magnitude of negative salinity anomaly on the inner Newfoundland Shelf during the early 1990s is comparable to that experienced there during the 'Great Salinity Anomaly' of the early 1970s (Dickson *et al.* 1988). During 1993 summer salinities started returning to more normal values but decreased again by the summer of 1995 to near record lows, these increased to near normal values in 1997 and 1998 but fell again to below normal values in 1999. In general, data from the fixed stations off the Canadian East Coast confirm the continuation of the warm phase in the north-west Atlantic.

Standard transects

Seal Island

Temperatures along the Seal Island transect (Fig. 9) ranged from 0°C at 30-m depth to between 5°C to 6°C at the surface. Temperatures below 50-m were generally sub-zero °C over most of the shelf except near bottom where they range from 1-3°C. Near the shelf break temperatures increase up to 4°C. Temperature anomalies in the surface layer along the Seal Island transect ranged from 0.25° to 1.0°C below normal near-shore and at the shelf break to 1°C above normal in the offshore region beyond the shelf edge. Below 50-60 m and near bottom, temperatures ranged from 0.25-1.5°C above normal. Surface salinities along the Seal Island transect (Fig. 10) ranged from 31.5 near-shore to greater than 33.25 offshore. Below the surface layer salinities ranged from 32-34.5 near bottom over the shelf. Except for a weak sub-surface negative anomaly near the shelf edge, salinities were above normal along the entire transect during July by up to 0.4.

Bonavista

Temperatures along the Bonavista transect (Fig. 11) in the upper 20-m of the water column ranged from 10°C-12°C in the inshore regions but decreased to 8°C along the offshore portion of the transect. These values were up to 2°C above normal near the coast and up to 1°C below normal at about 100 km from Cape Bonavista and offshore to the edge of the shelf. Most of the intermediate depth temperatures were slightly below normal while deep-water (200-300 m) temperatures were up to 1.5°C above normal. Bonavista transect salinities (Fig. 12) ranged from 31.25 near the surface in the inshore region to

34.25 in the offshore region. Bottom salinities ranged from 32.5 over the inshore portion of the transect, to 34.75 at about 325-m depth near the shelf edge. Salinities were fresher than normal (up to 0.6) in the upper 200-m over the inshore half of the transect and saltier-than-normal (by up to 0.5) in the offshore half of the transect. The fresher-than-normal salinities inshore were also observed at Station 27. Bottom salinities across the shelf in water deeper than 200-m were near to slightly above normal.

Flemish Cap

Summer temperatures along the Flemish Cap transect (Fig. 13) ranged from about 12^{o}C near the surface to sub-zero ^{o}C below 50-m in the Avalon Channel and at the edge of the Grand Bank in the core of the Labrador Current. Over the Flemish Cap temperatures were greater than 12^{o}C at the surface and about 4-5^{o}C at 80-m depth to the bottom. The values were about 2^{o}C above normal in the upper layer near the coast, below normal at mid-shelf and above normal in the offshore areas. Bottom temperatures over most of the Grand Bank were near 0.5^{o}C above normal. Over the Flemish Pass and Cap temperatures ranged from 0.5-1.5^{o}C above normal, except east of the Cap, where temperatures were up to 1^{o}C below normal. Salinities along the transect (Fig. 14) were slightly fresher than normal in the Avalon Channel, at the edge of the Grand Bank and to the east of the Flemish Cap. These are regions where the Labrador Current flows southward indicating fresh-than-normal water being advected from the north.

CIL Time Series

As shown above in the cross-shelf transect plots the vertical temperature structure on the Newfoundland Continental Shelf during the summer is dominated by a layer of cold sub-zero ^{o}C water trapped between the seasonally heated upper layer and warmer slope water near the bottom. This water mass is commonly referred to as the cold intermediate layer or CIL (Petrie *et al.* 1988). The cold, relatively fresh, shelf water is separated from the warmer saltier water of the continental slope by a strong temperature and salinity front near the edge of the continental shelf. The area of cold intermediate water 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.

Figure 15 shows a time series of the CIL cross-sectional area of sub-zero ^{o}C water for the Seal Island, Bonavista and Flemish Cap transects. Along the Bonavista transect during the summer of 1999 the CIL extended offshore to about 190 km, with a maximum thickness of about 175 m (Fig. 11) corresponding to a cross-sectional area of about 20.2 km^2, compared to the 1961-90 average of 26.8 km^2. This value is about 25% below normal compared to 5% below normal in 1998 and 28% below normal in 1997. From 1990 to 1994 the CIL area was above normal reaching a peak of more than 60% in 1991. The CIL area along the Seal Island transect was also below normal by about 49% during 1999, compared to 15% in 1998 and 38% during 1997. During 1994 the CIL along the Seal Island transect was 36% above normal and up to 61% above normal in 1991. Along the Flemish Cap transect the CIL was about 14% below normal in 1999 compared to about normal in 1998 and up to 20% above normal in 1997. During 1995 it was about 18% above normal compared to 12% in 1994 and to 48% during 1991. In general, the volume of sub-zero ^{o}C water on the Canadian continental shelf in 1999 is continuing the below normal trend established in 1995 thus indicating a continuation of the warm phase in the Northwest Atlantic after the severe cold conditions of early 1990s.

References

Anon. 1978. List of ICNAF standard oceanographic sections and stations. ICNAF selected papers #3.

Colbourne, E. B., S. Narayanan, and S. Prinsenberg. 1994. Climatic change and environmental conditions in the Northwest Atlantic during the period 1970-1993. ICES mar. Sci. Symp., 198:311-322.

Dickson, R.R., Meincke, J., Malmberg, S. A., and Lee, A. J. 1988. The "Great Salinity Anomaly" in the northern North Atlantic 1968-82. Progr. Oceanogr. 20: 103-151.

Drinkwater, K.F. 1996. Climate and oceanographic variability in the Northwest Atlantic during the 1980s and early-1990s. J. Northw. Atl. Fish. Sci. 18: 77-97.

Petrie, B., S. Akenhead, J. Lazier and J. Loder. 1988. The cold intermediate layer on the Labrador and Northeast Newfoundland Shelves, 1978-1986. NAFO Sci. Coun. Stu. 12: 57-69.

Rogers, J.C. 1984. The association between the North Atlantic Oscillation and the Southern Oscillation in the Northern Hemisphere. Mon. Wea. Rev. 112: 1999-2015.

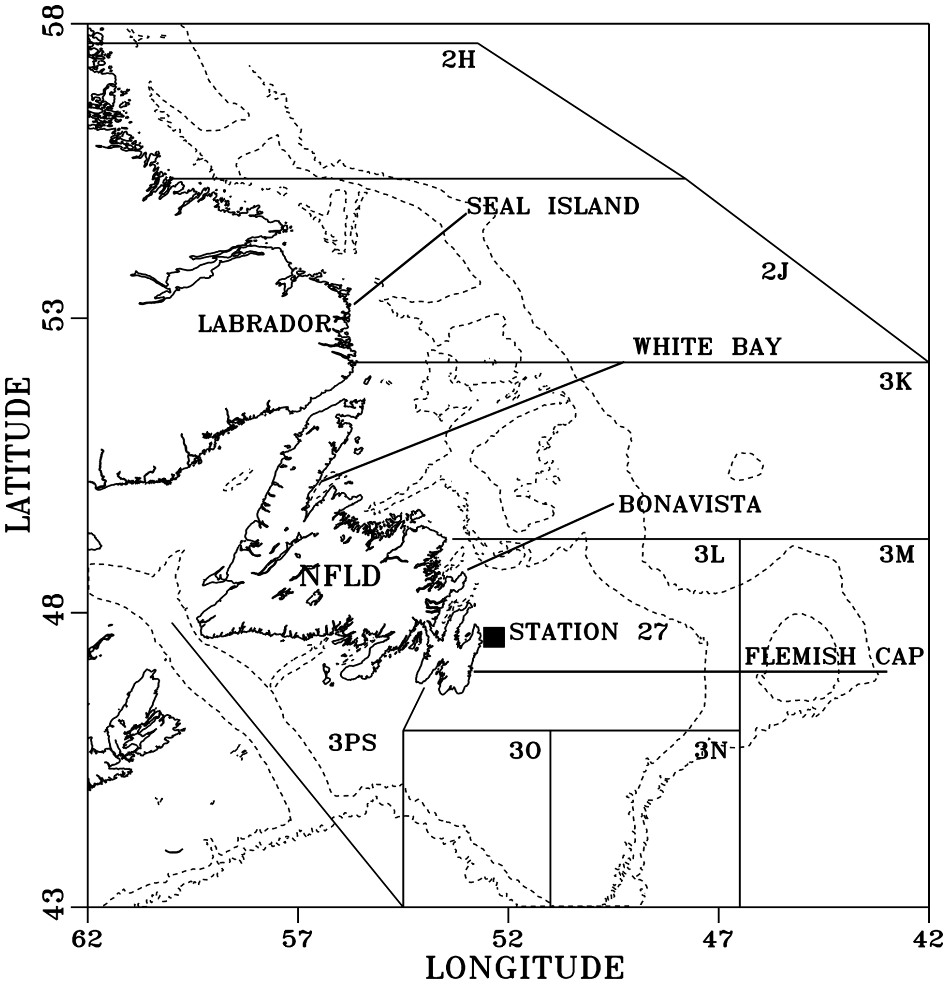


Figure 1. Map showing the standard continental shelf sections and Station 27 in the Newfoundland Region. Bathymetry contours are 300 and 1000 m.

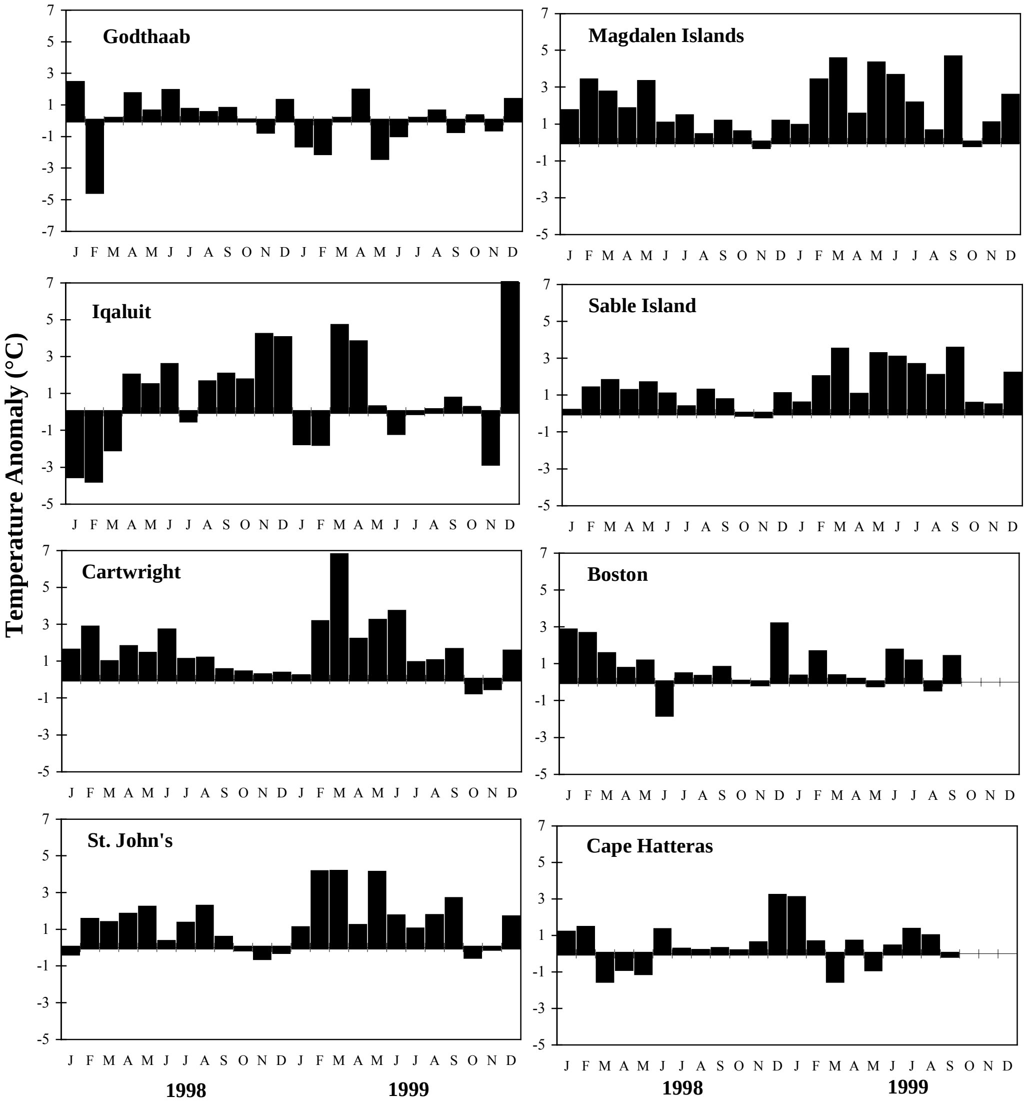


Figure 2. Monthly air temperature anomalies in 1998 and 1999 at selected coastal sites in the Northwest Atlantic.

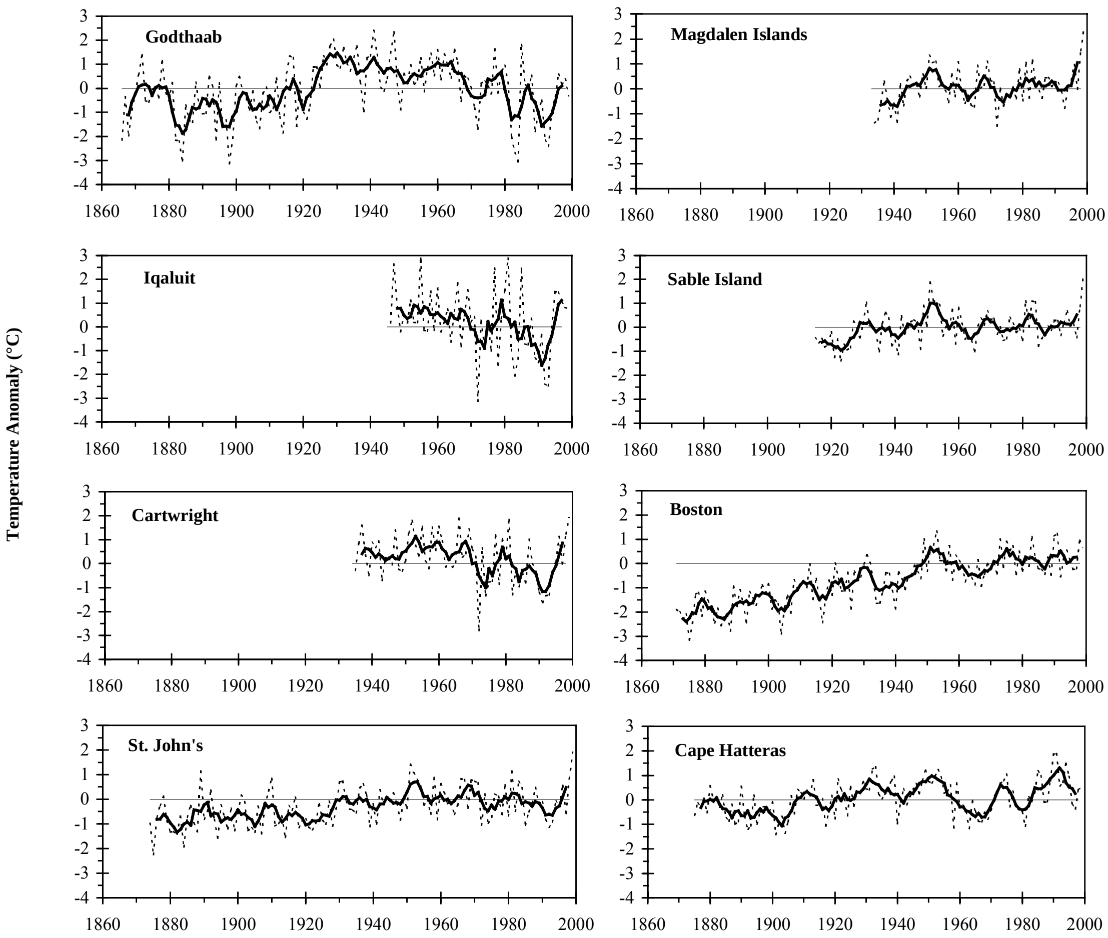


Figure 3. Annual air temperature anomalies (dashed line) and 5-yr running means (solid line) at selected sites in the Northwest Atlantic.

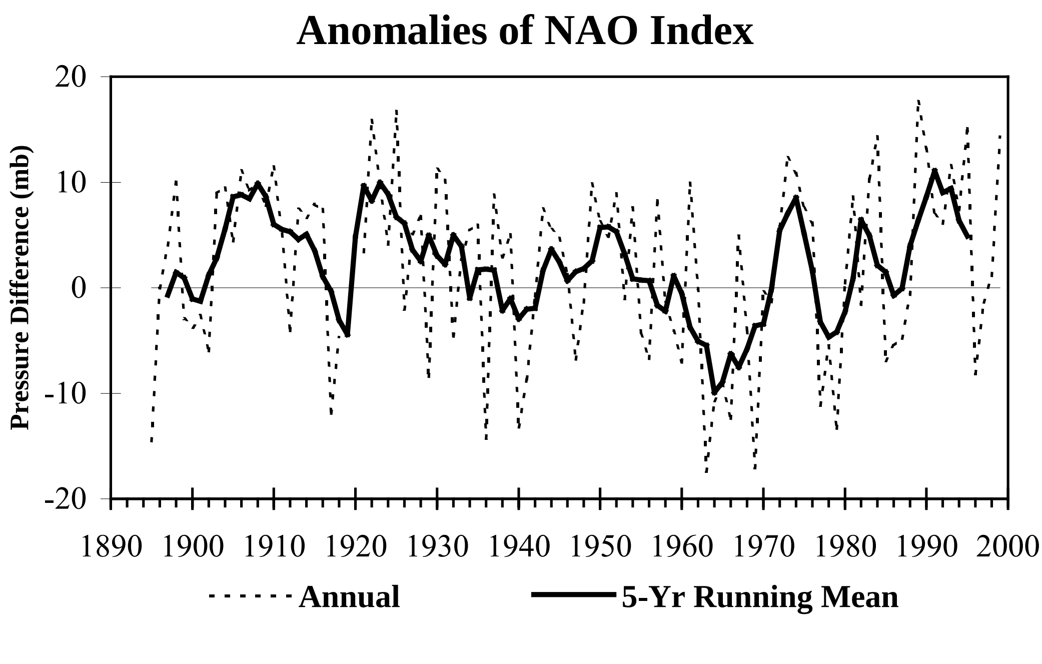


Figure 4. Anomalies of the North Atlantic Oscillation Index, defined as the winter (December, January, February) sea level pressure at Ponta Delgada in the Azores minus Akureyri in Iceland, relative to the 1961-90 mean.

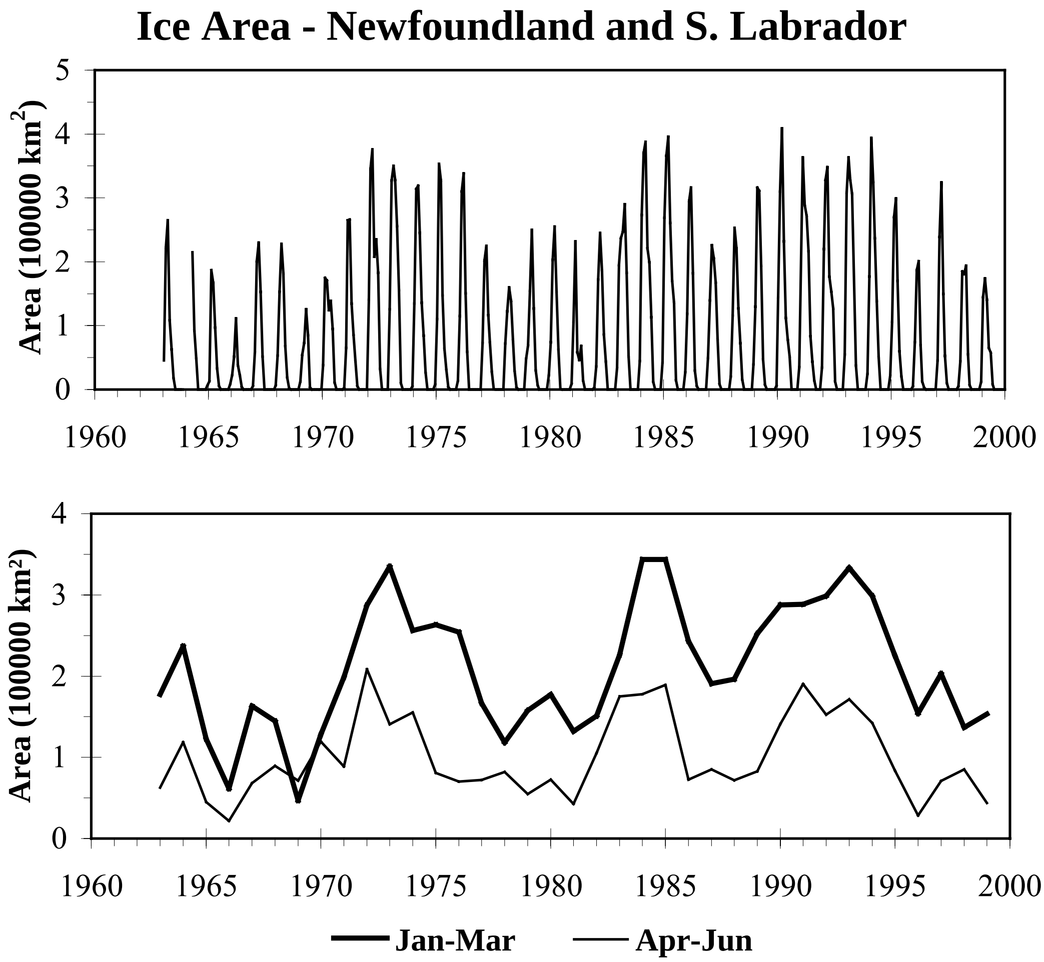


Figure 5. Time series of the monthly mean ice area off Newfoundland and Labrador between 45°N- 55°N (top panel) and the average ice area during the normal periods of advancement (January-March) and retreat (April-June) (bottom panel).

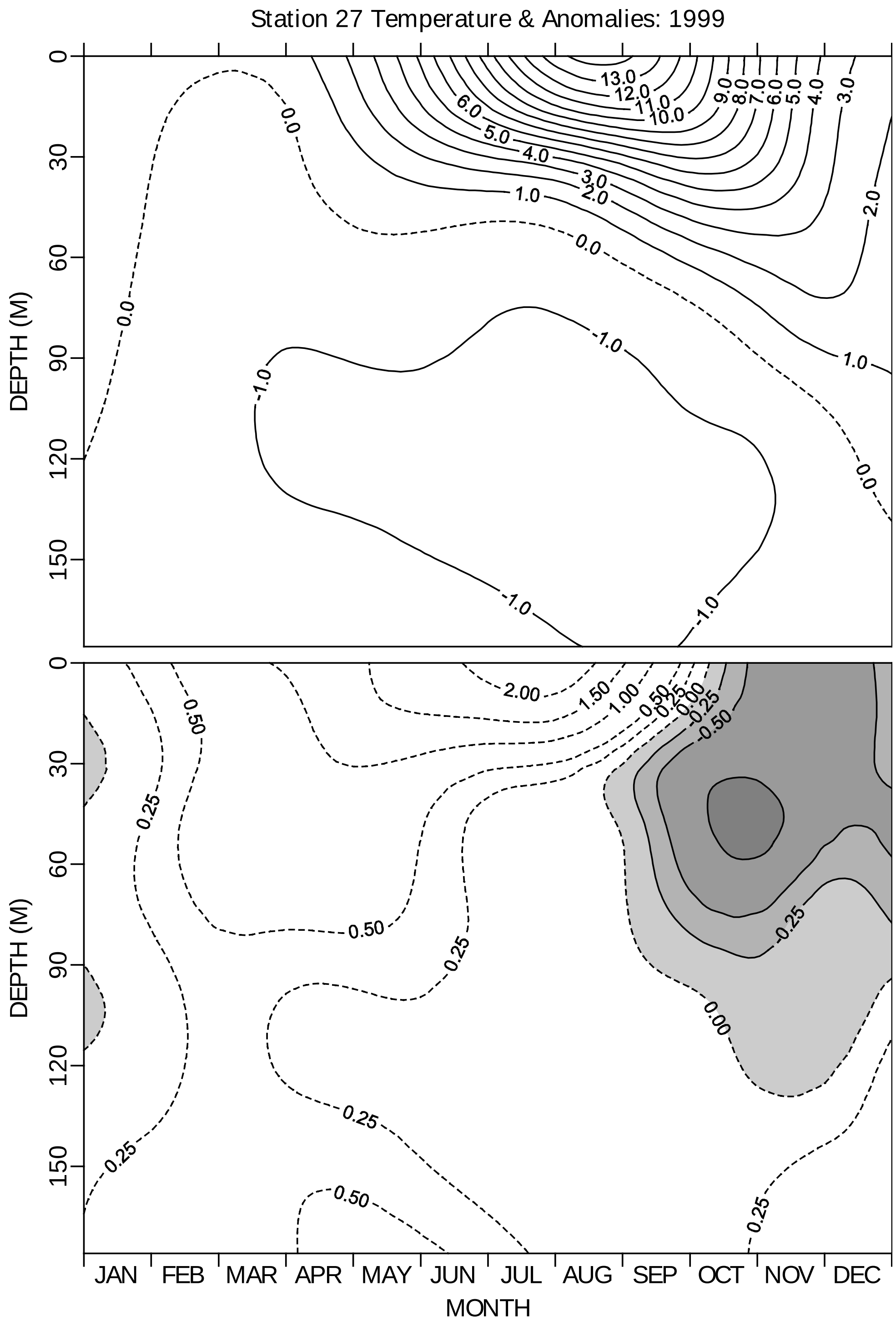


Figure 6. Monthly temperatures (top panel) and anomalies (bottom panel) in °C at Station 27 as a function of depth for 1999.

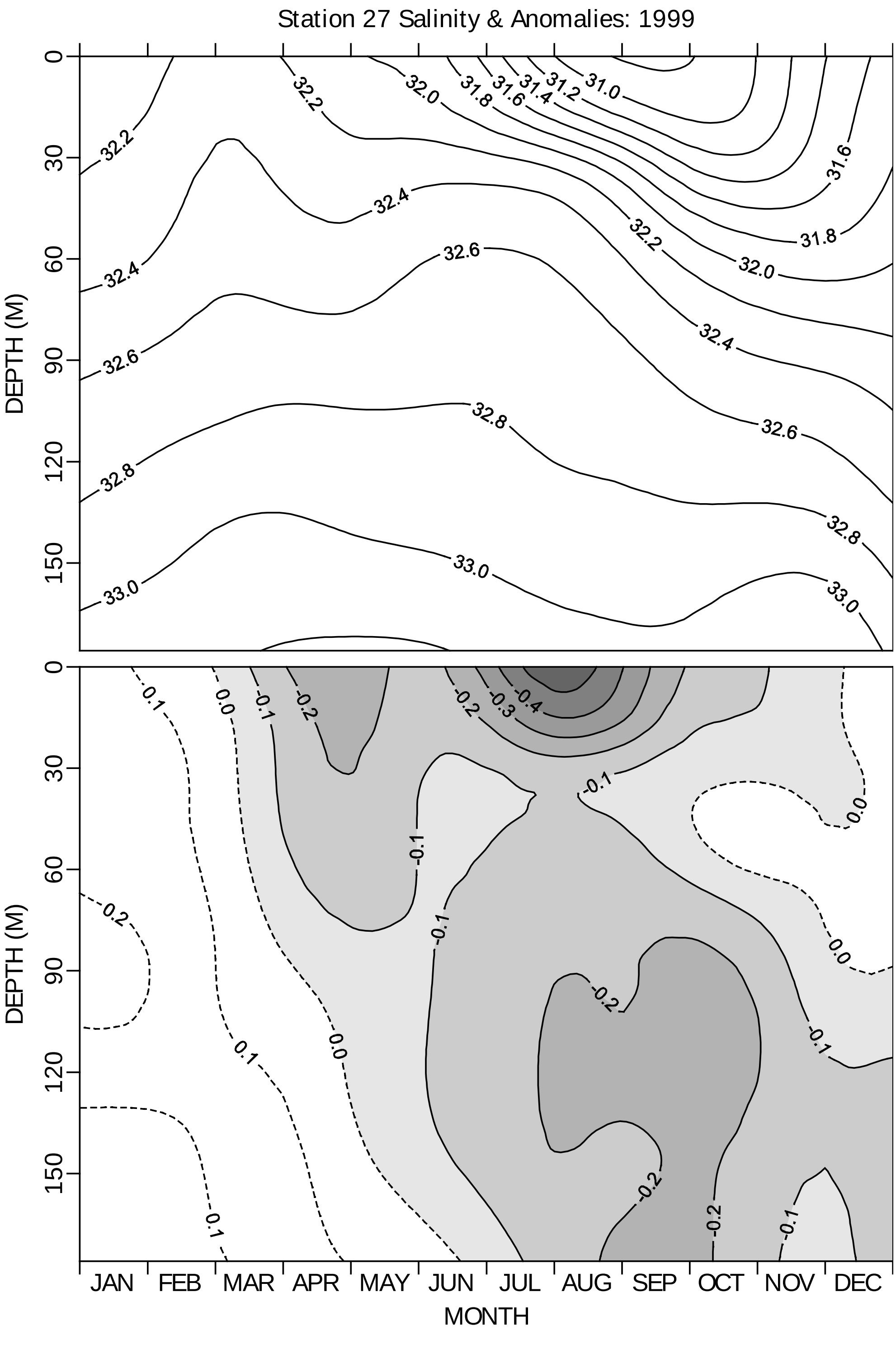


Figure 7. Monthly salinity (top panel) and anomalies (bottom panel) at Station 27 as a function of depth for 1999.

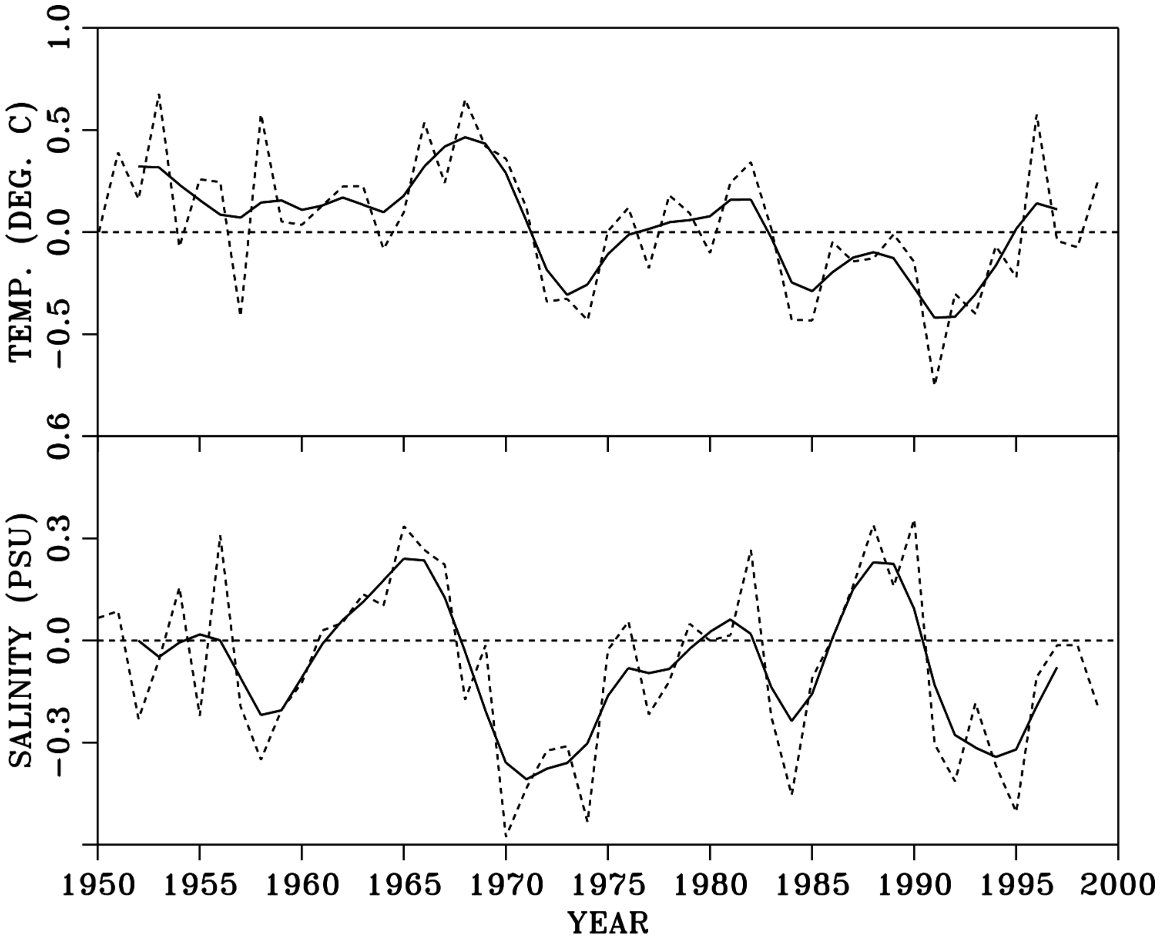


Figure 8. Time series of the annual vertically averaged (0-176 m) Station 27 temperature anomalies and the vertically averaged (0-50 m) summer (July-Sept.) Station 27 salinity anomalies. The heavy lines are the three-year running means.

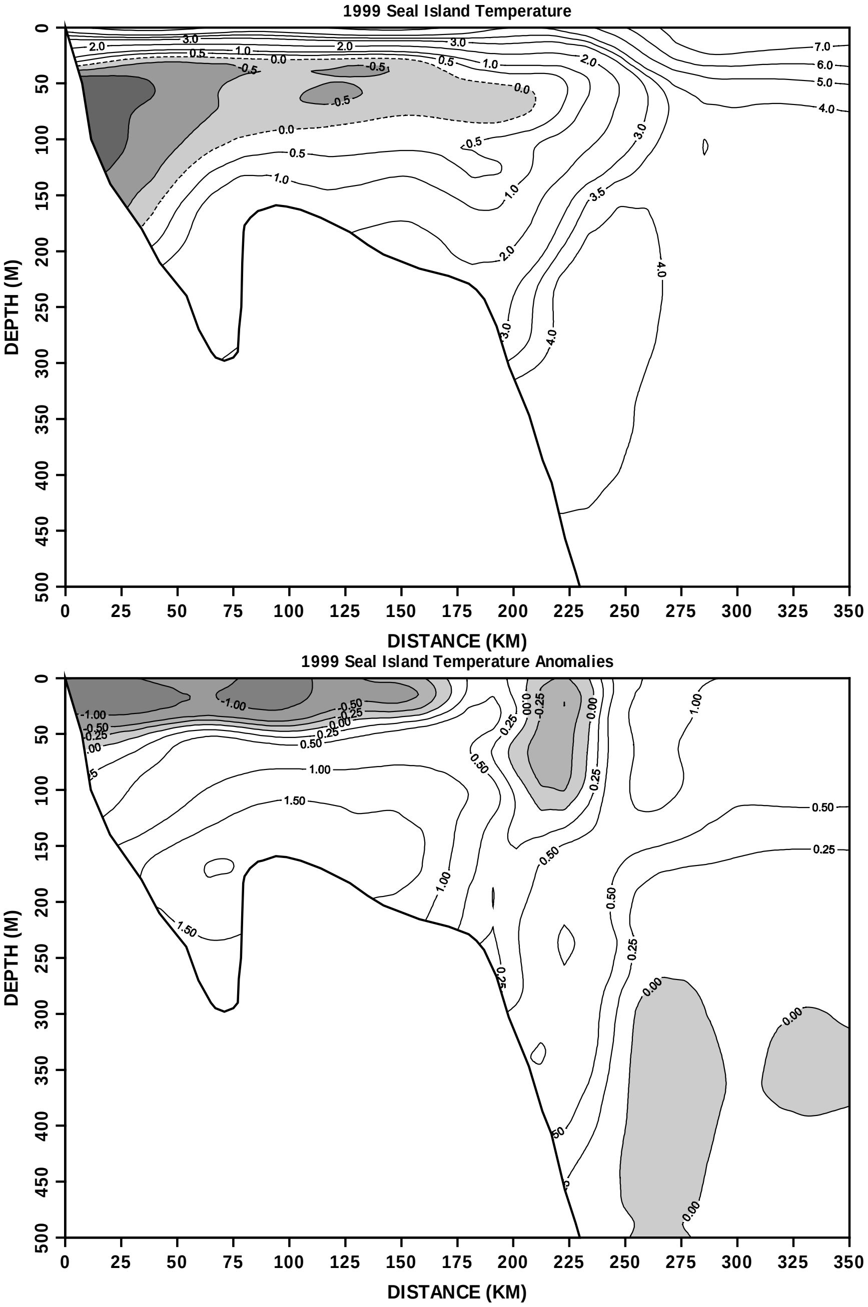


Figure 9. A vertical cross-section of temperature and temperature anomalies in °C along the standard Seal Island transect for the summer of 1999. Negative values are shaded.

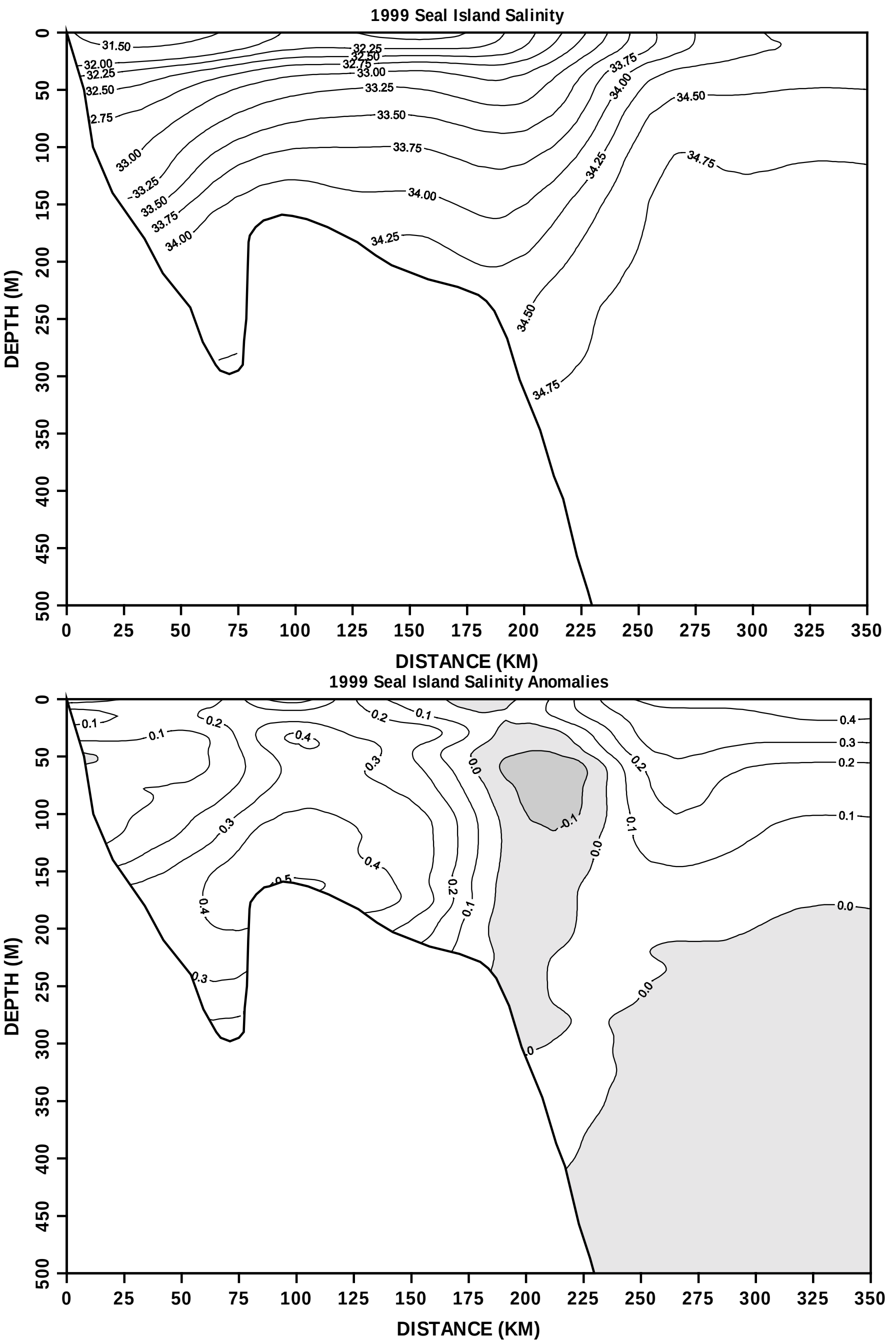


Figure 10. A vertical cross-section of salinity and salinity anomalies along the standard Seal Island transect for the summer of 1999. Negative values are shaded.

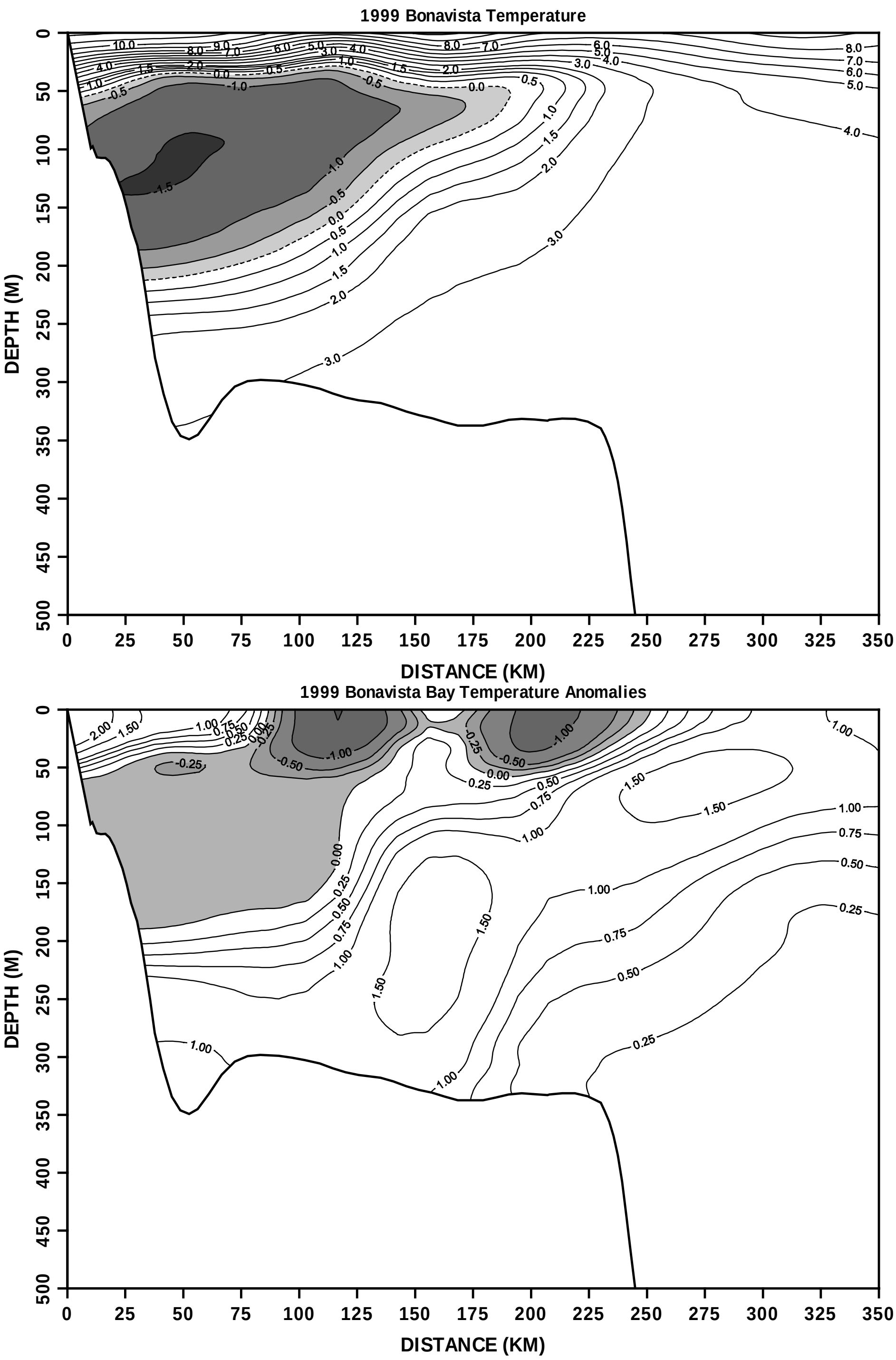


Figure 11. A vertical cross-section of temperature and temperature anomalies in °C along the standard Bonavista transect for the summer of 1999. Negative values are shaded.

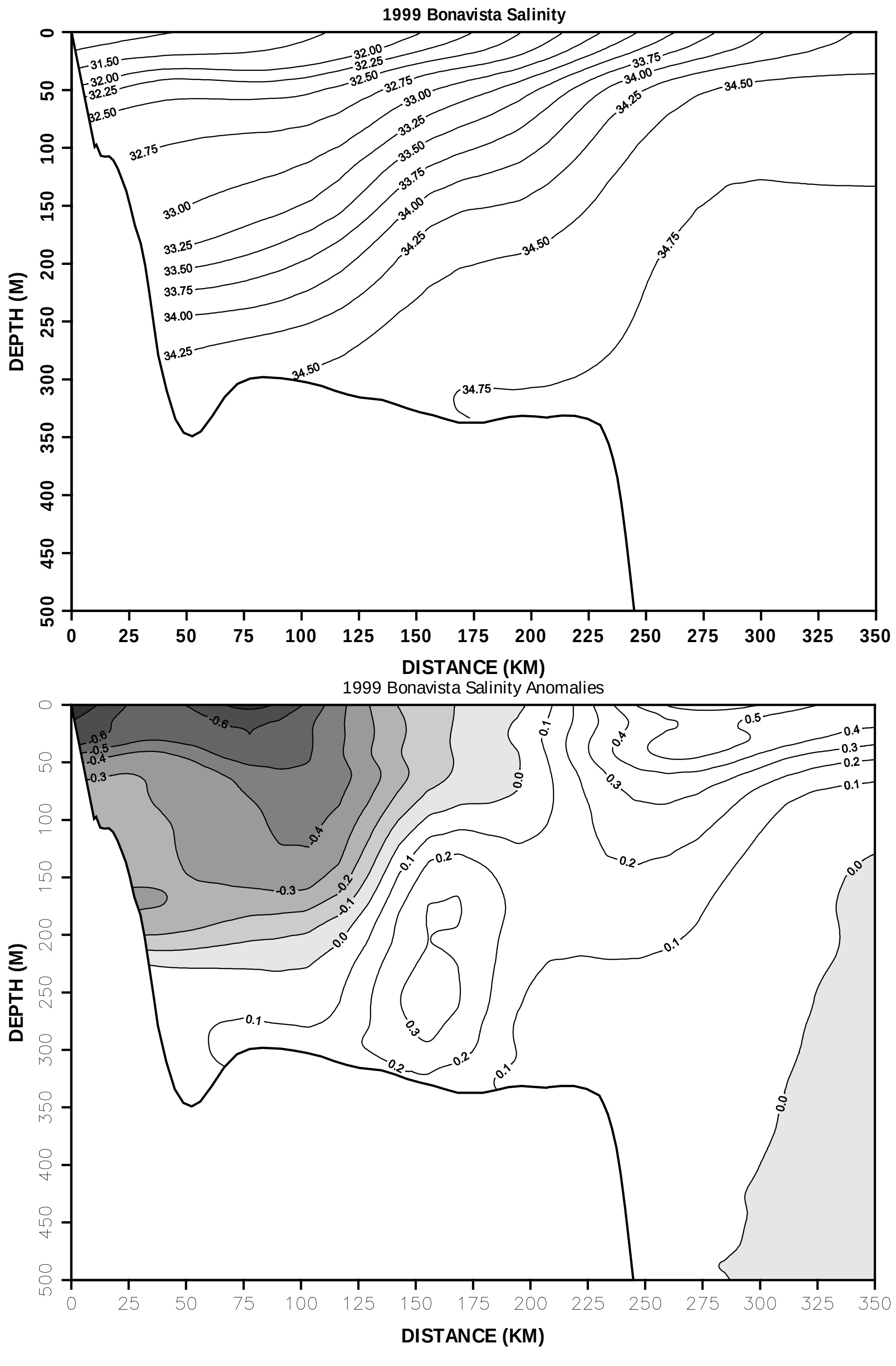


Figure 12. A vertical cross-section of salinity and salinity anomalies along the standard Bonavista transect for the summer of 1999. Negative values are shaded.

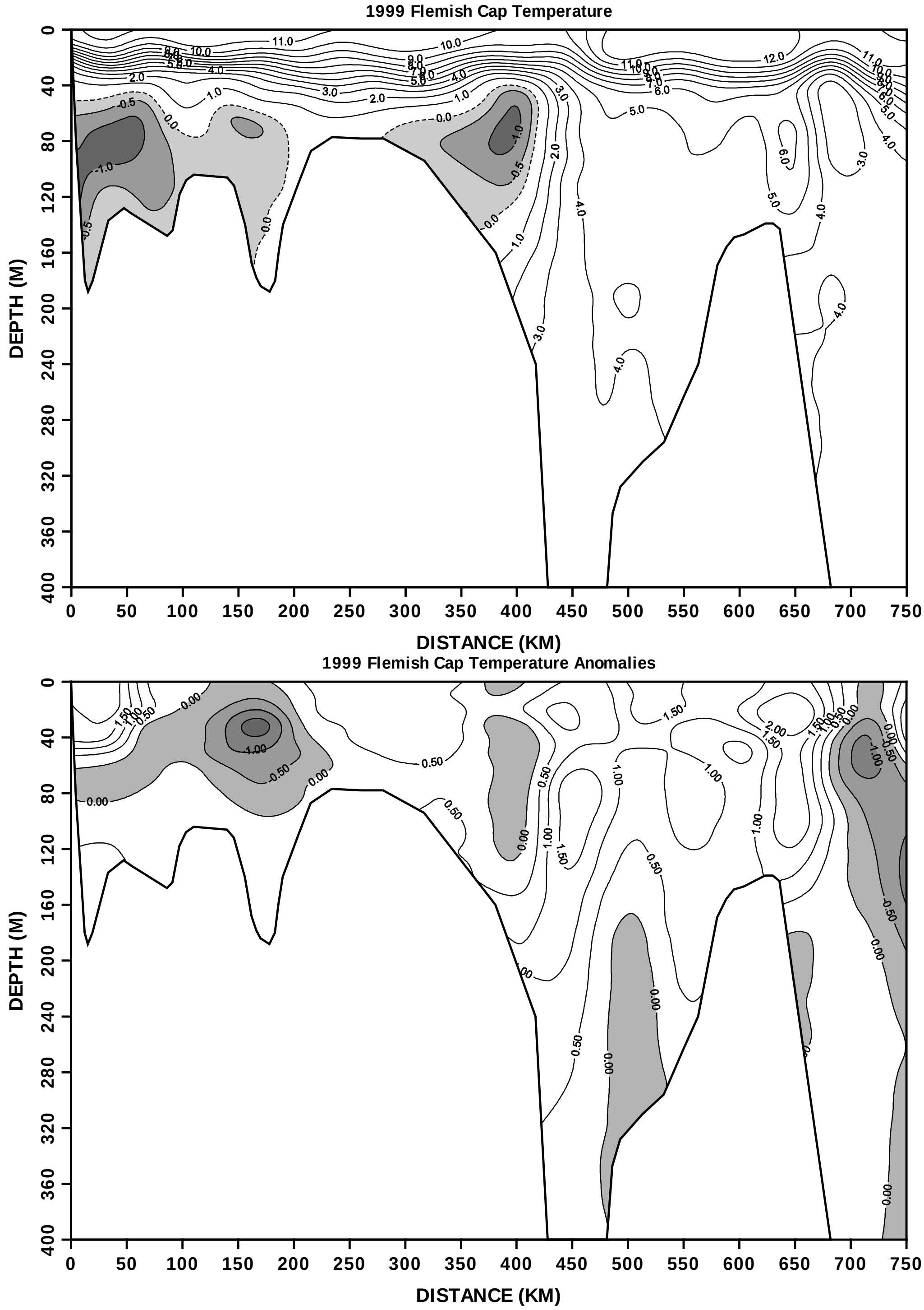


Figure 13. A vertical cross-section of temperature and temperature anomalies in °C along the standard Flemish Cap transect for the summer of 1999. Negative values are shaded.

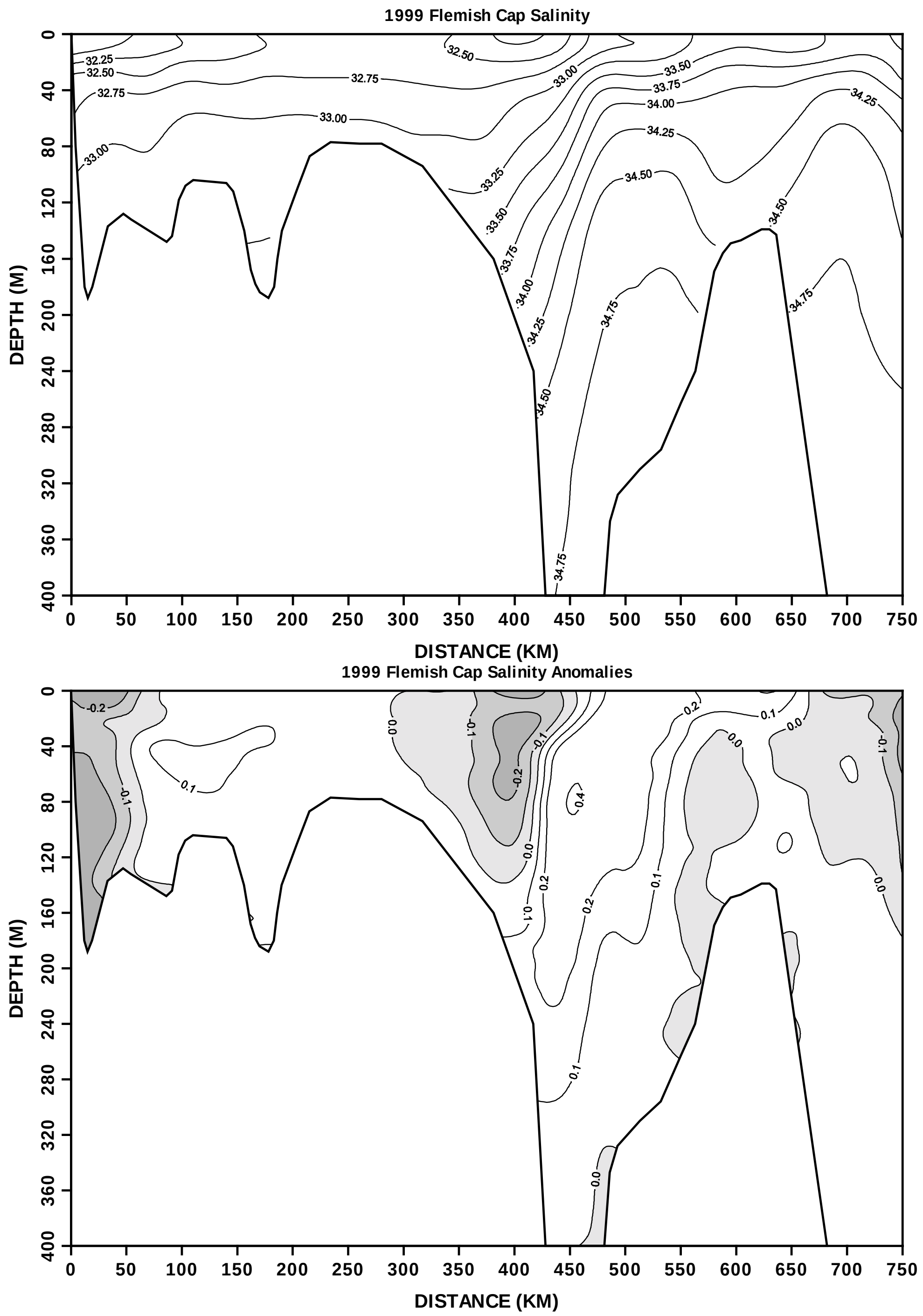


Figure 14. A vertical cross-section of salinity and salinity anomalies along the standard Flemish Cap transect for the summer of 1999. Negative values are shaded.

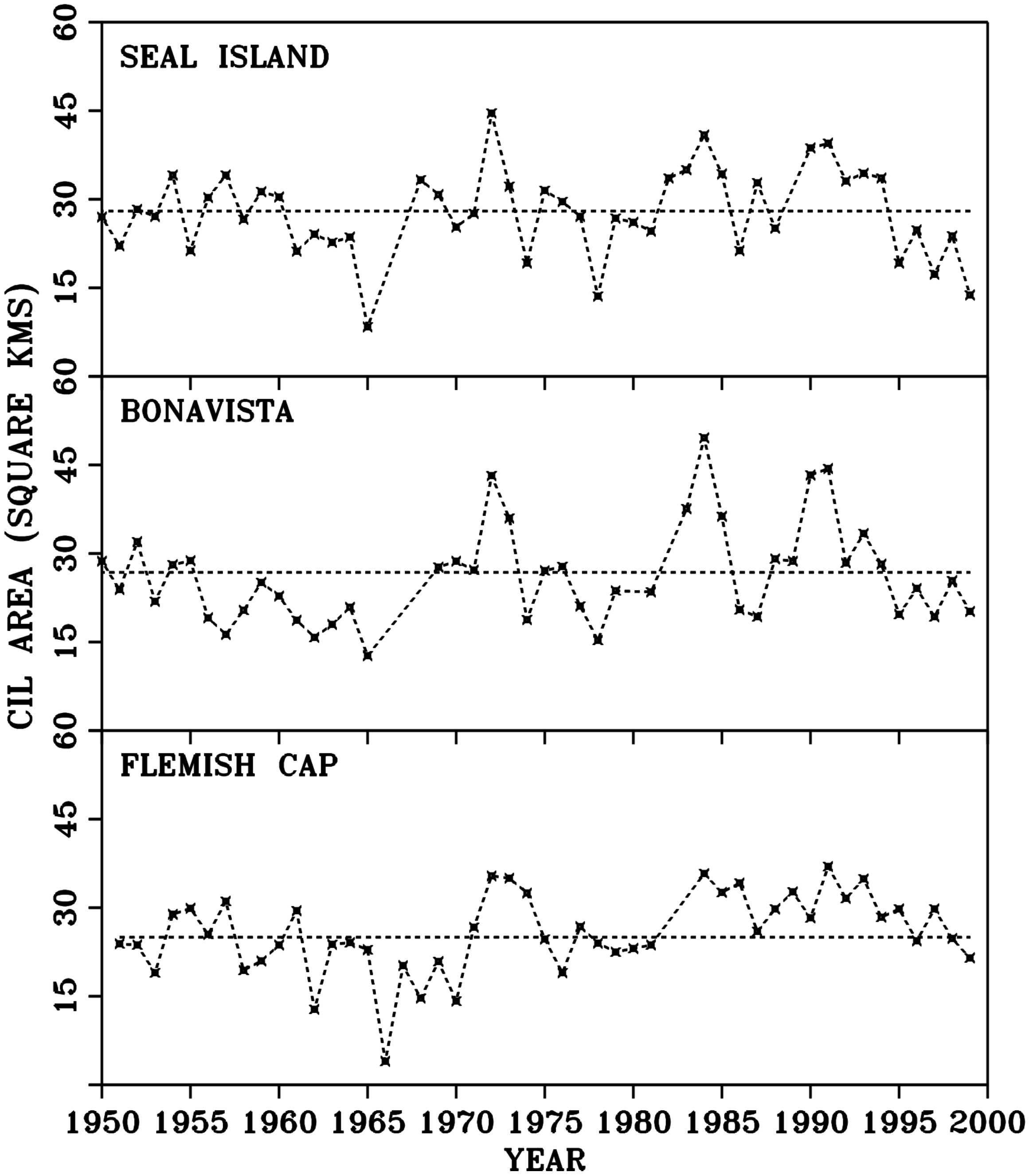


Figure 15. Time series of CIL cross-sectional area along the Seal Island, Bonavista and Flemish Cap transects. The horizontal dashed lines represent the 1961-90 average.

ANNEX H – AREA 2B (LABRADOR SEA) CANADIAN REPORT

Changes in Labrador Sea properties from 1998 to 1999

R.M. Hendry[1], R.A. Clarke[1], J.R.N. Lazier[1], and Igor M. Yashayaev[2]

The most recent transect of WOCE Section AR7W by Ocean Sciences Division (Fisheries and Oceans Canada at the Bedford Institute of Oceanography) was made during 1-11 July 1999 on CGCS Hudson Cruise 99022. Chief scientist was Allyn Clarke. The section included a total of 29 full depth CTD casts with up to 24 small volume rosette bottles.

Figure 1 shows a map of the Labrador Sea with station positions for the 1999 AR7W occupation. Positions for the 1998 occupation of AR7W on Hudson Cruise 98023 during 26 June - 3 July 1998 are also shown. It should be noted that the 1998 Hudson section did not extend all the way to the Greenland slope. Also shown in Figure 1 are Stations 21-25 made on June 30, 1998 on Cruise TU26 of the Royal Danish Navy coastal patrol cutter Tulugaq. Dr Eric Buch was chief scientist on this cruise and the data are used with the kind permission of Mr Helle Siegstad of the Greenland Institute of Natural Resources. Contoured sections of potential temperature and salinity for the entire 1999 section are shown in Figures 2a and 2b. Expanded views of the western end of the section covering the Labrador Current are shown in Figures 3a and 3b. Figures 4a and 4b show potential temperature-salinity diagrams for both 1998 and 1999. Figure 4a combines Hudson and Tulugaq data for the entire section. Figure 4b shows results from the Labrador Current zone with along-section distances in Figures 3a and 3b less than 300 km.

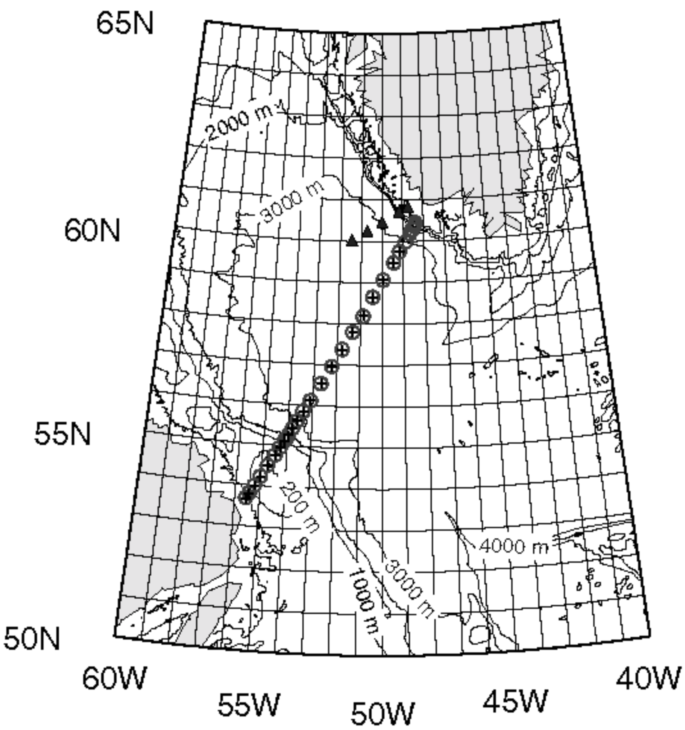
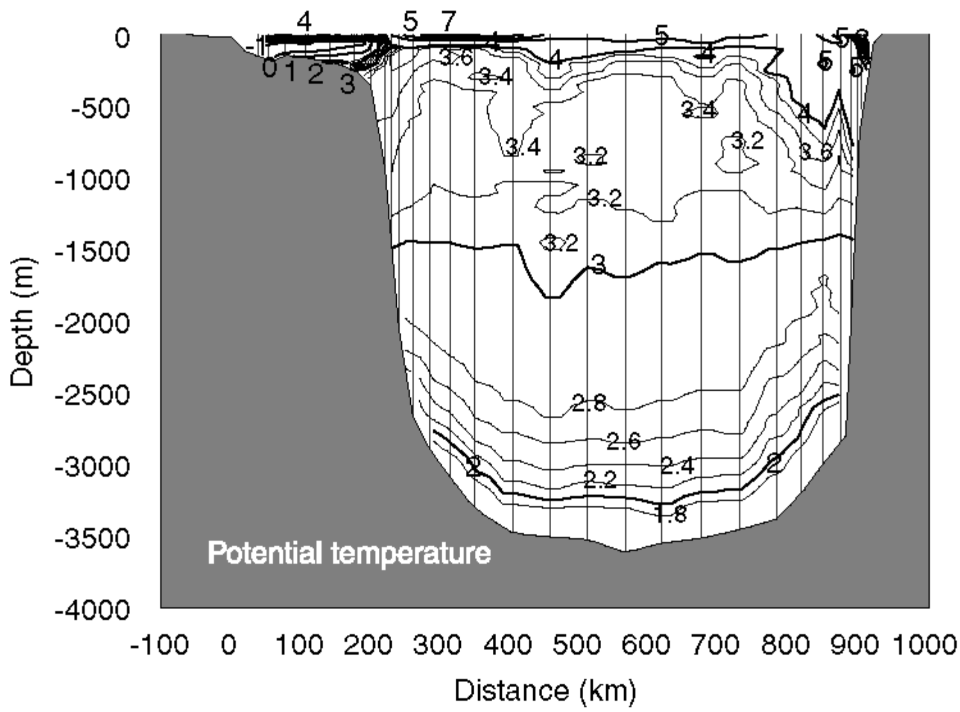


Figure 1. Map of the Labrador Sea showing station positions for Hudson 98023 (crosses), Hudson 99022 (open circles), and Tulugaq 26 (triangles).



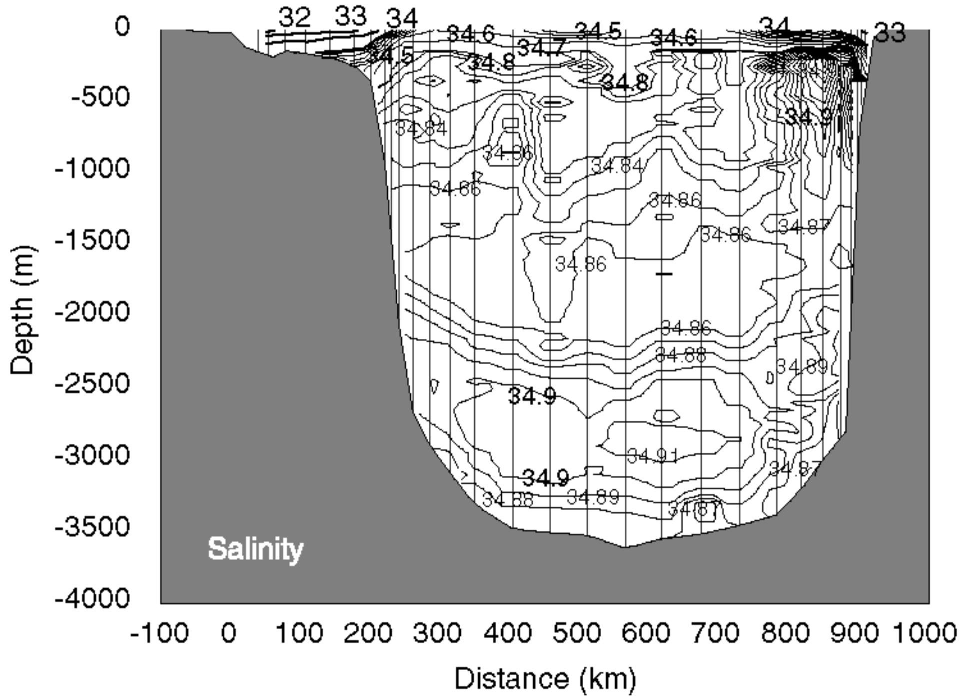


Figure 3a. (upper) Potential temperature section for Hudson 99022, 1-11 July 1999.

Figure 3b. (lower) Salinity section for Hudson 99022.

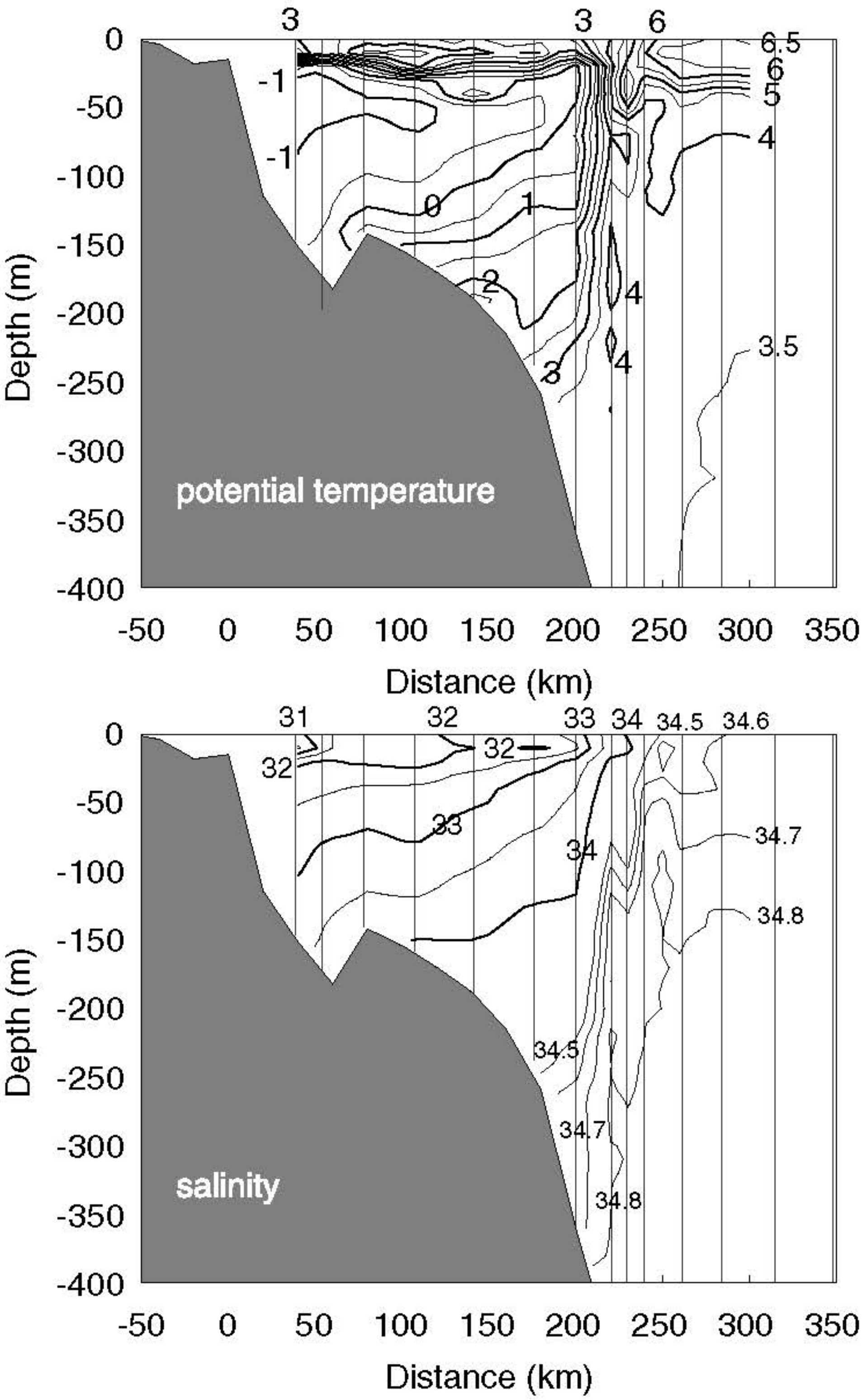
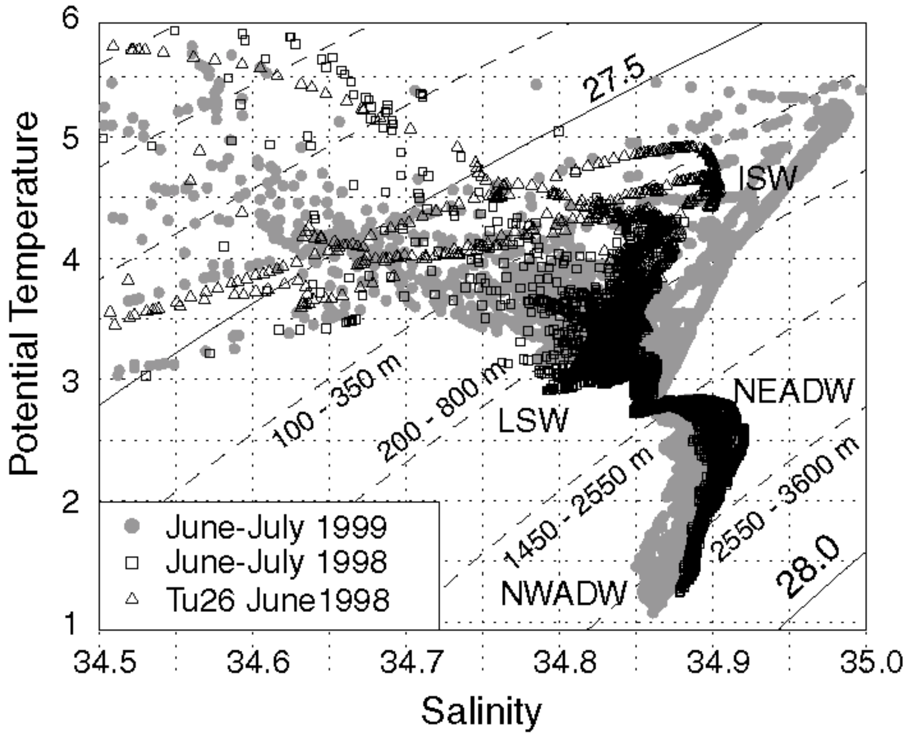


Figure 3a. (upper) Labrador Current potential temperature section for Hudson 99022.

Figure 3b. (lower) Labrador Current salinity section for Hudson 99022.



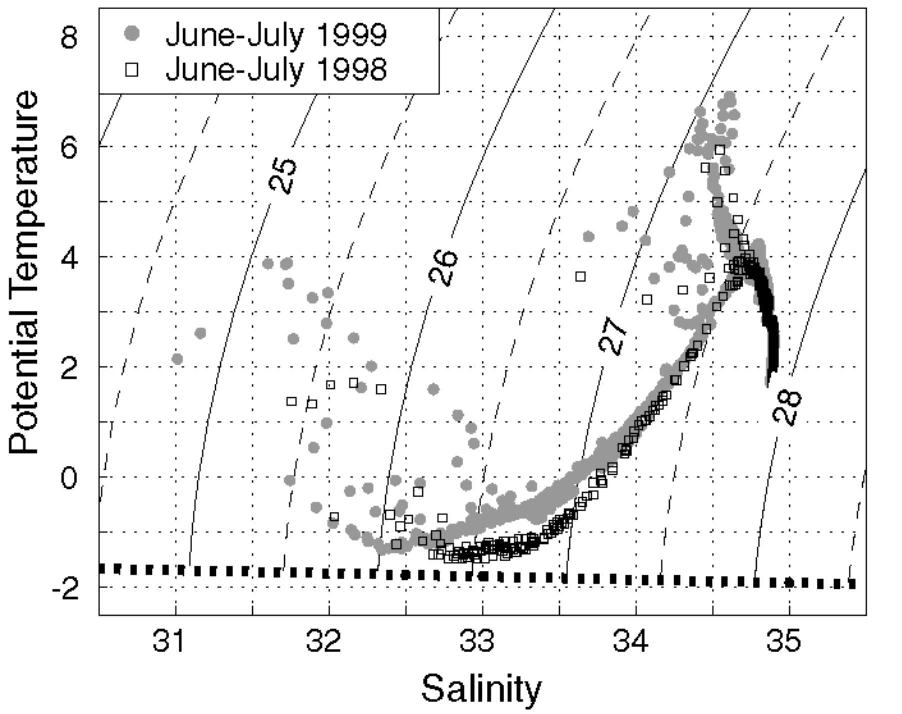


Figure 4a. (above) Potential temperature vs salinity for Hudson (1998 – filled circles, 1999 - open squares) and Tulugaq measurements (1998 - triangles).

Figure 4a. (above) Labrador Current potential temperature vs salinity for 1998 and 1999 Hudson measurements as in Figure 4a.

Figure 4a suggests that Northwest Atlantic Deep Water, found at the deepest levels, was cooler and fresher in 1999 than in 1998. Other analyses show that this tendency was most marked on the Greenland side of the section. Northeast Atlantic Deep Water, characterised by a local salinity maximum in the vertical near 2500-m depths, also shows a slight cooling and freshening tendency. There was apparently little renewal of Labrador Sea Water during the 1998-99 winter. Water at intermediate depths formed during earlier winters had become warmer and more saline by mid-1999, compared to mid-1998 conditions. Warm, saline Irminger Sea Water found in the upper layers off Greenland at the eastern end of the section was warmer and more saline in 1999 than in the summer of 1998.

Figure 4b shows that the Arctic waters transported by the Labrador Current were notably warmer in 1999 than at the same season in the previous year. Salinity increased in the frontal zone of the main branch of Labrador Current (potential density anomaly greater than ~ 26.5 km/m^3) in 1999 relative to 1998. Over the same time period, salinity decreased in the upper 50-100 m on the inner Labrador Shelf. The 1998 measurements showed a minimum temperature of approximately -1.44 C with corresponding salinitiy values near 32.9. The warmer 1999 conditions show a minimum temperature of approximately -1.25 C, with corresponding salinity values near 32.5. The temperature minimum is associated with winter convection on the shelf. As such, it is an index of the severity of the preceding winter. Brine rejection during freezing influences the salinity of this "winter water". For this reason, colder winter conditions should tend to produce more saline winter water, as was observed during the 1998 survey.

A re-occupation of the AR7W section is scheduled for late May 2000. Cruise reports for previous AR7W transect cruises can be found at http://dfomr.dfo.ca/science/ocean/woce/DOGrep.html.

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ANNEX I – AREA 3 (ICELANDIC WATERS) ICELANDIC REPORT

Icelandic section / Svend-Aage Malmberg and Hedinn Valdimarsson

Marine Research Institute, Reykjavik

Iceland is situated at the meeting place of warm and cold currents (Figure1), which meet in this area because of 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 (6-8°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 seas around Iceland, principally the overflow of deep, cold water from the Nordic Seas and the Arctic Ocean south over the submarine ridges into the North Atlandic.

The different hydrographic conditions in Icelandic waters are also reflected in the atmospheric or climatic conditions in and over the country and the surrounding seas, mainly through the Icelandic Low and the Greenland High. These conditions in the atmosphere and the surrounding seas have their impact on biological conditions, expressed through the food chain in the waters including recruitment and abundance of commercial fish stocks.

The hydrographic conditions in Icelandic waters in 1999 as in 1998 revealed in general favourable temperatures and salinities. The salinity in the warm water from the south was in 1999 as since November 1997 higher than was observed over the last decades and even since before the so-called ice-years in Iclandic waters in the sixties (Figure 4). These conditions were evident in a moderate inflow of Atlantic water into North-Icelandic waters in 1998, when there was a low saline surface in the upper 50-100 m above the warm inflow beneath as since 1996 (Figure 2). In 1999 no trace of this low saline surface layer was observed and the Atlantic inflow into North Icelandic waters was more pronounced than decades before as demonstrated by the maximum salinity of the 0-300 m layer (Figure3). High temperatures in North Iclandic waters in 1999 are further demonstrated in continuous recordings of sea-surface temperatures at the island Grímsey 1987-1999 (Figure 5), revealing relatively high temperatures both in winter 1998-1999 and summer 1999.

The warm Atlantic conditions also seemed in 1999 as in 1998 to spread westwards into the Irminger Sea towards Greenland. The cold East Icelandic Current north-east and east of Iceland was also relatively far offshore in 1999 and in general with increasing temperatures and salinities towards the end of the year (Figs. 4 and 6), when salinities reached almost 34.8 or were well above the critical value which prevents convection.

These mild conditions in Icelandic waters follow extremely cold conditions in 1995, improving in 1996 and 1997 and continuing to do so in 1998 and 1999. Furthermore, observations in February 2000 revealed ongoing favourable hydro-biological conditions in Icelandic waters.

Figure1 Main currents and locations of standard hydro-biological section in Icelandic waters. Selected areas and station dealt with in this report are indicated.

Figure 2 a) Main annual air-temperatures in Reykjavík and Akureyri 1950-1999.

Figure 2 b) Temperatures and Salinity at 50 m depth in spring at station 5-3 in North Icelandic waters 1952-1999.

Figure 3 Maximum salinity in the upper 300 m layer in spring at station S-3 in North Icelandic waters 1952-1999 and its 5 - years running means.

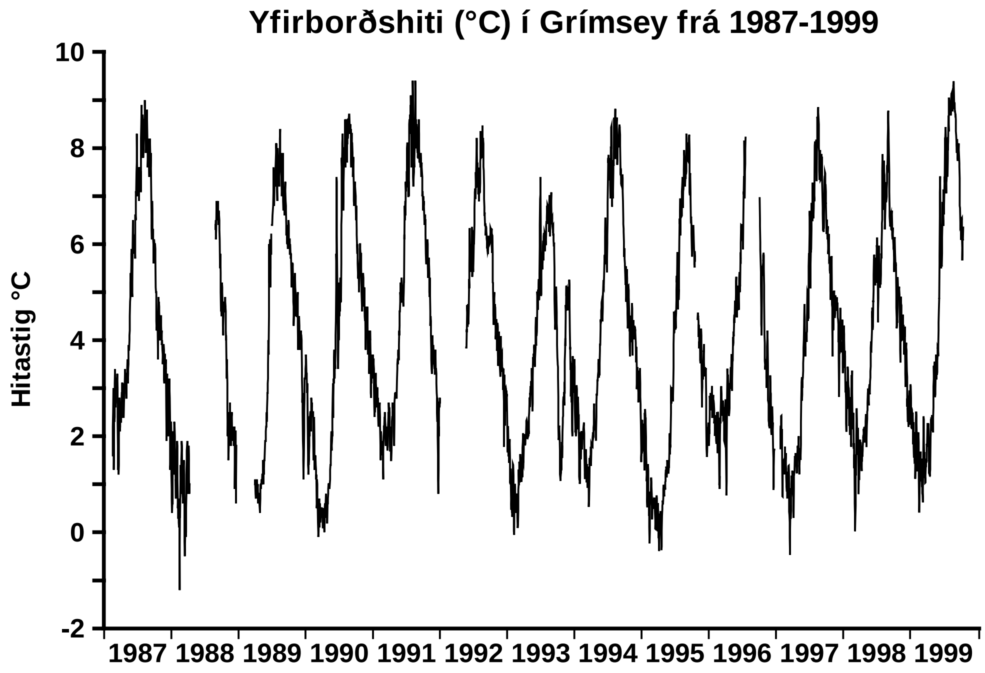
Figure 4 Salinity deviations in spring at:

Figure 4 a) 100 m depth in the Irminger Current south of Iceland (S-5) 1978-1999.

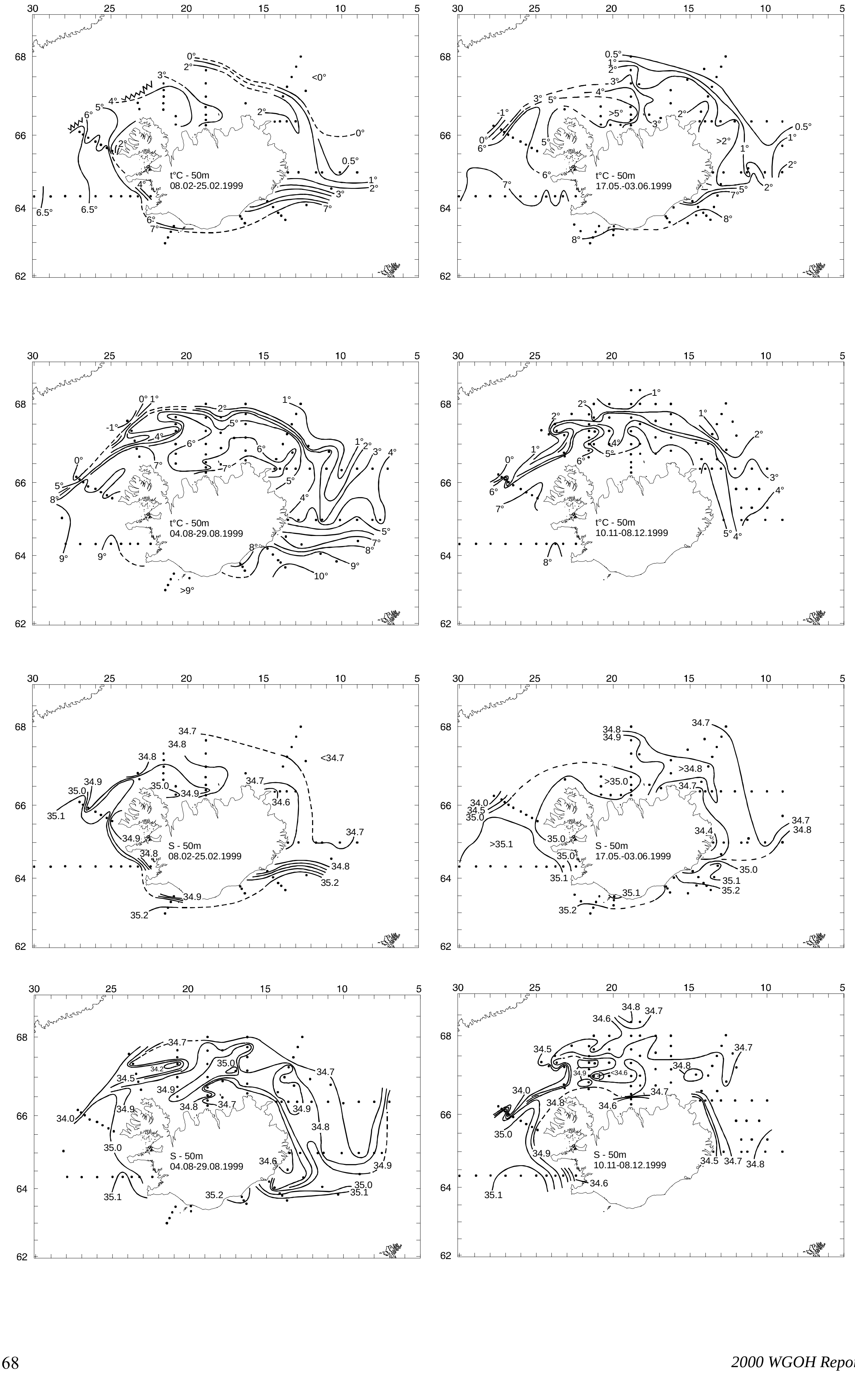
Figure 4 b) 25 m depth in the East Icelandic Current north-east of Iceland 1962-1999.

Figure 5 Annual and seasonal variations in the sea-surface temperatures at Grímsey, North Icelandic waters, 1987-1999.

Figure 6. Temperatures and salinity at 50 m depth in Icelandic waters in February, May/June, August and November/December 1999.



Yfirborðshiti (°C) í Grímsey frá 1987-1999
Hitastig °C
10
8
6
4
2
0
-2
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999



t°C - 50m
08.02-25.02.1999
t°C - 50m
17.05.-03.06.1999
t°C - 50m
04.08-29.08.1999
t°C - 50m
10.11-08.12.1999
S - 50m
08.02-25.02.1999
S - 50m
17.05.-03.06.1999
S - 50m
04.08-29.08.1999
S - 50m
10.11-08.12.1999

ANNEX J – AREA 4 (BAY OF BISCAY AND EASTERN ATLANTIC) SPANISH REPORT

Spanish Standard Sections

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** Centro Costero de Vigo. P.B. 1552, 36280 Vigo Spain

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

Meteorological conditions in the north of the Iberian Peninsula in 1999 are similar to those of 1998, with mean air temperature at 14.8ºC, 0.5ºC above the mean (1961-1999)(Figure 1) (Source: Instituto Nacional de Meteorología). However, anomalies in the annual cycle are quite different. While the winter of 1998 was warm, in 1999 spring and summer were warm and February and November were cold. In Figure 2 anomalies in monthly mean air temperatures are shown over the annual cycle in the Santander Observatory (INM).

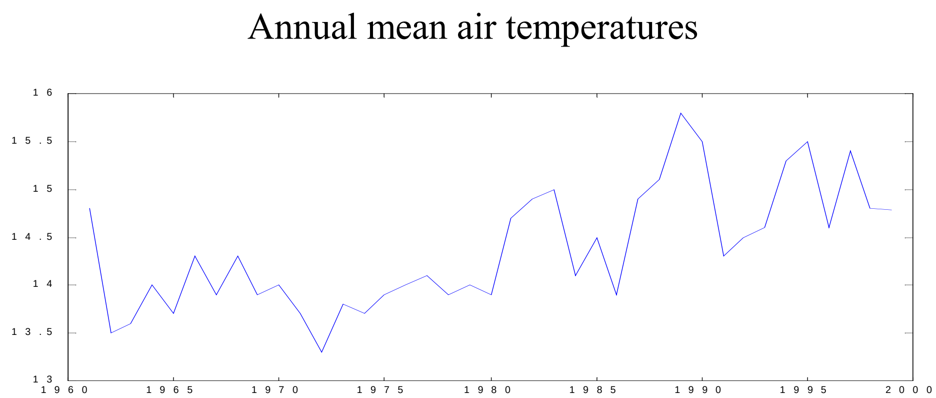


Figure 1

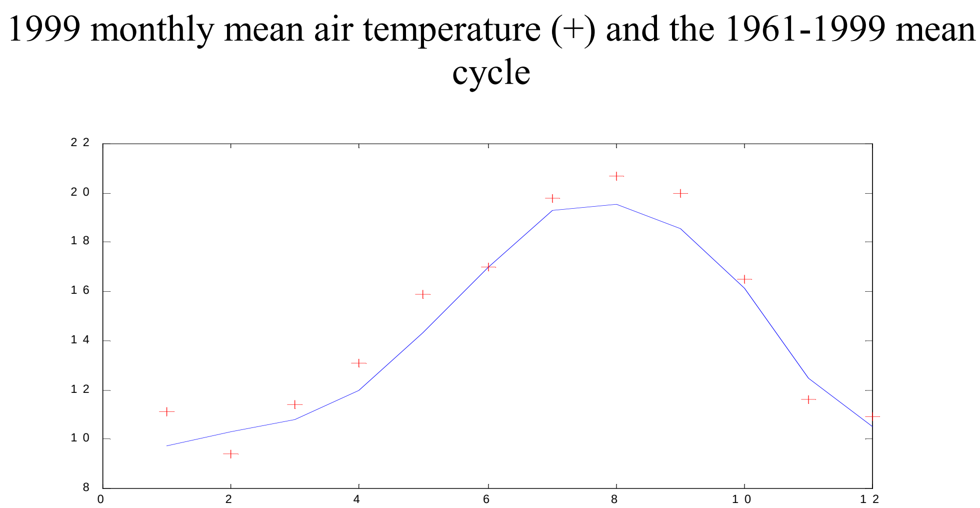


Figure 2 - Months

Contours of temperature, salinity and nitrates over the shelf (100 m depth) in the Santander section are presented in Figure 3. The seasonal cycle in temperature is clearly marked in the upper layers. Stratification develops between April-May and October-November, and during the rest of the period the water column is mixed. Salinity contours show high salinity at the beginning of the winter due to the poleward current and sporadically in spring-summer due to seasonal upwelling events. Low salinity appears in autumn when the seasonal pycnocline is broken, in summer in the upper layers, due to the advection of warm surface water, and in spring, due to river overflow. With regard to nitrate distributions, high values appear in the mixed period and, due to upwelling events, in the stratified part of the year. 1998 has a very low influence of upwelling, and only after June nitrate does nitrate concentration reach around 6µmol/l below 40 m.

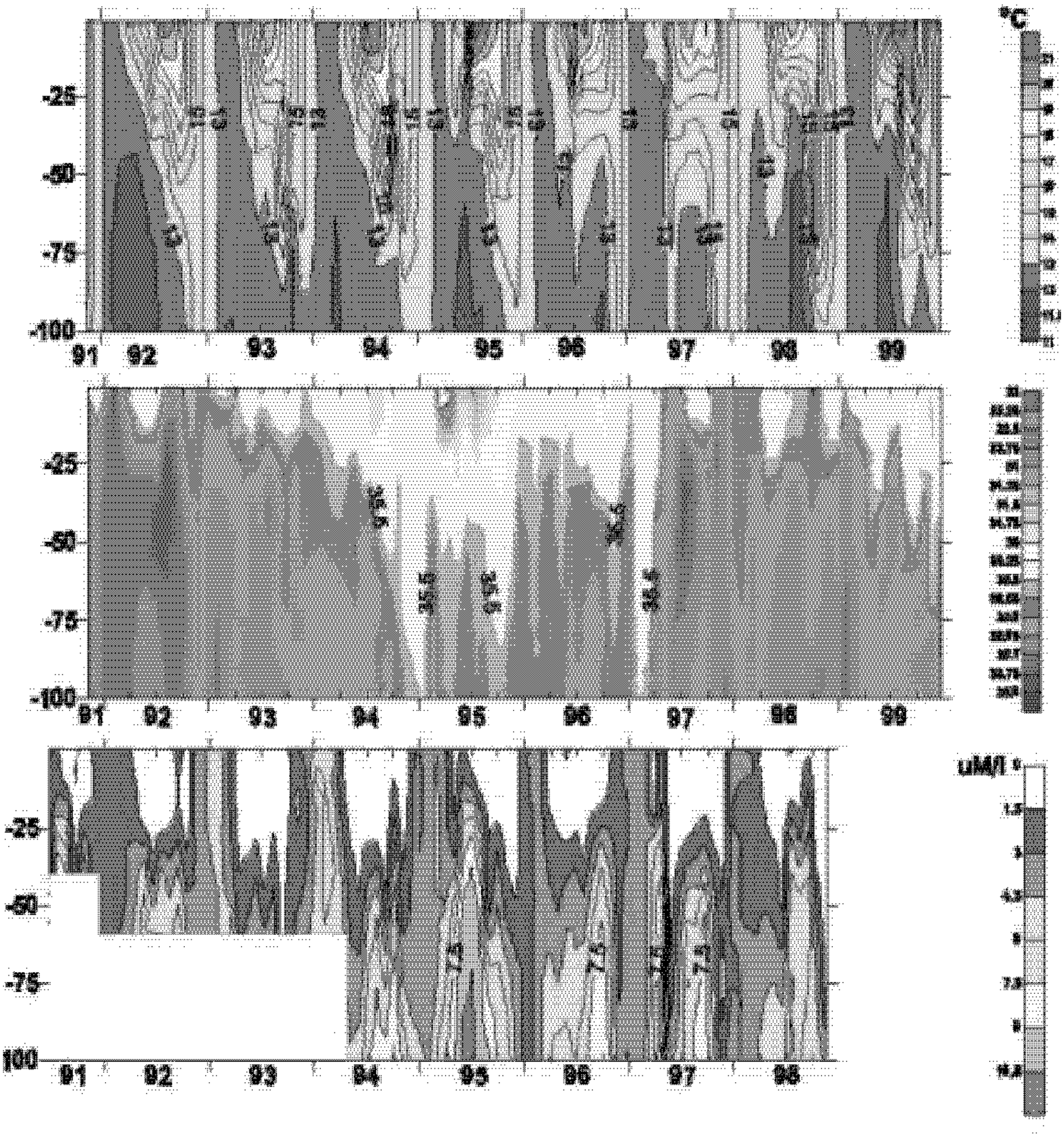


Figure 3

Contours of temperature, salinity and nitrates over the shelf-break (600 m depth) in the Santander section are presented in Figure 4. During the first period (1992-1995) only upper layers were sampled. The seasonal cycle in temperature is clearly marked in the upper layers. The period of low salinity in the uppers waters (1994-1995) is clearly displayed, the increase until 1997 and the reduction in 1999. Stratification develops between April-May and October-November, mainly reaching 100 m depth, and during the rest of the period the water column is mixed. Salinity contours show high salinity after the end of the mixing period at the beginning of the winter extending the warm period at those depths due to the poleward current. Winter 1996 is a good example and 1998 looks strong. With respect to nitrate distributions, high values appear in summer due to upwelling events over the shelf mainly during 1994 and 1995. After those years, nitrate content has reduced considerably.

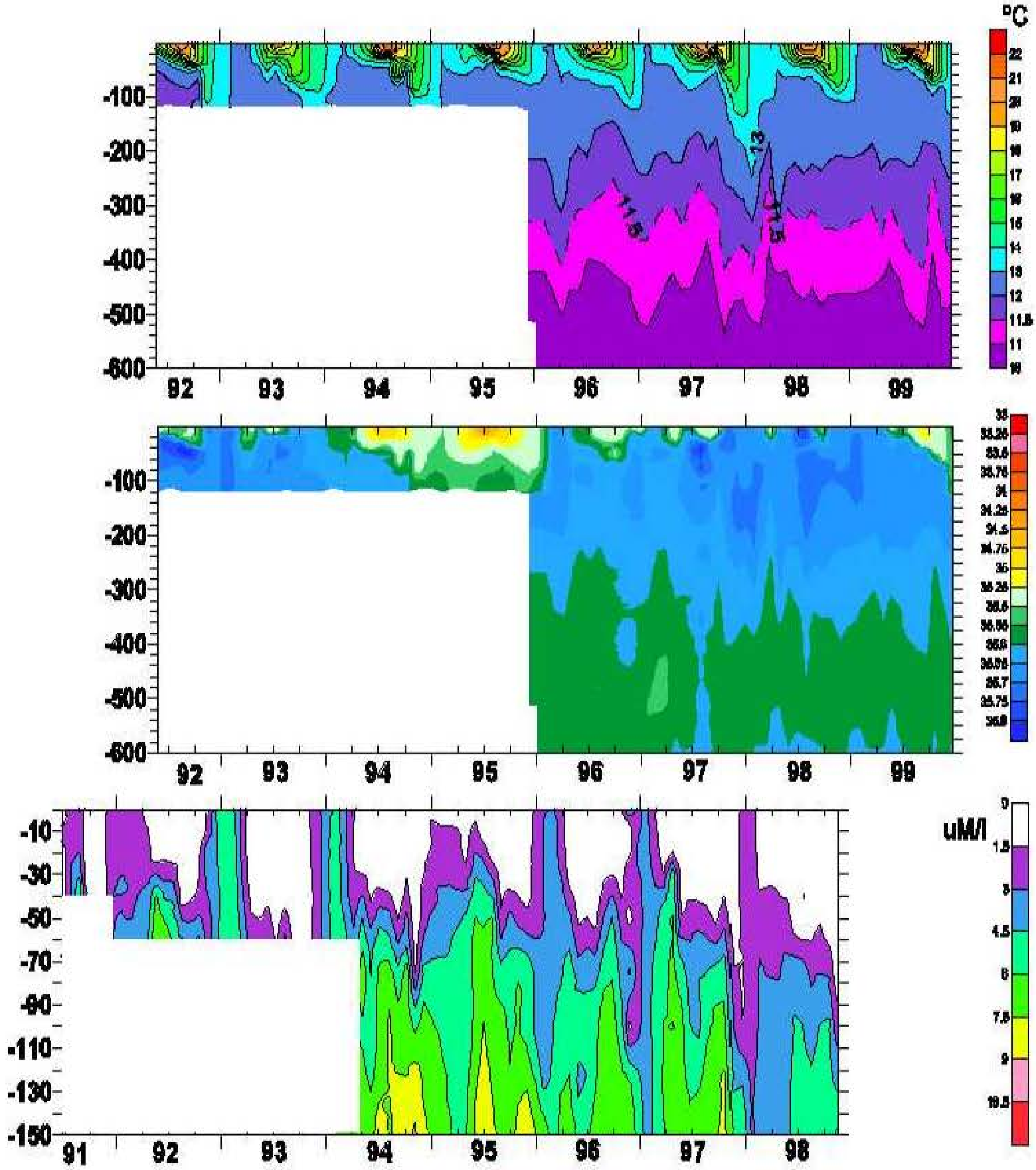


Figure 4

Sea temperature

During 1999 air temperatures were higher than the mean during spring and summer, but sea temperatures at 10 m were above the mean from June to October, being more than 1ºC over the mean in the last three months (Figure 5). Sea temperatures at the surface layer (10 m depth) show that the amplitude of the seasonal cycle between winter and summer was 8.9ºC, the largest in the sampled period, with a yearly mean temperature of 16.1ºC (Figure 6). This behaviour is similar to that of 1995. The only difference is that while 1995 was the warmest atmospheric year in the period sampled and with the highest NAO index of the decade, 1999 was a standard atmospheric year for the last decade, without such strong atmospheric forcing and a positive NAO index. Using the 12 month running mean, we have plotted the final series, filtering the annual cycle as well as the annual mean value of temperature for both series. The rate of warming amounts to 0.04ºC/year at 10m depth at station 4 between 1992 and 1999 (Fig 7) and 0.07ºC/year at station 6 also at 10 m depth from 1994 to 1999 (Fig 8).

Seasonal cycle of temperature at 10 m depth (-) with monthly standard deviation, and 1999 values (+).

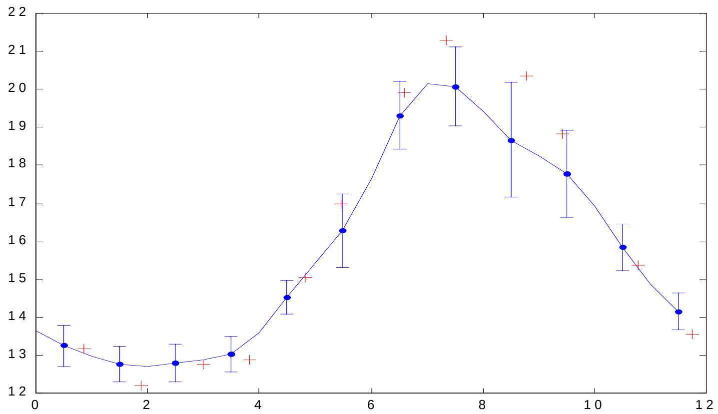


Figure 5

Temperature at 10 m. Monthly values (1991-1999)(x), and 12 month running mean mid-year value (*)

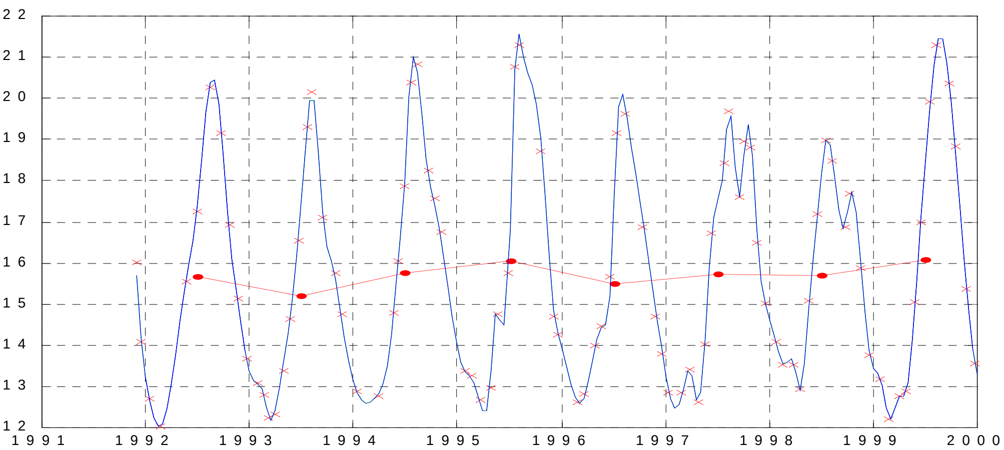
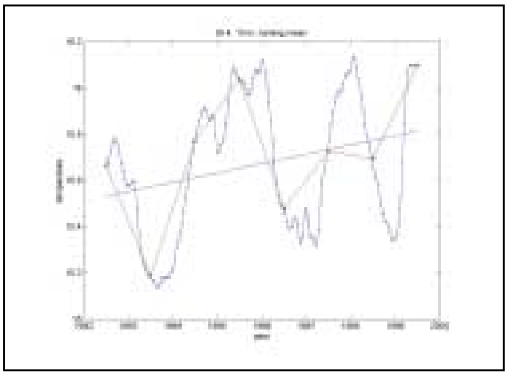


Figure 6



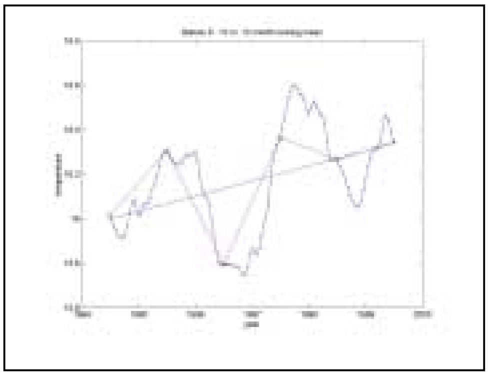


Figure 7 **Figure 8**

In a detailed study of winter/spring temperatures (Figure 9), we found 1998 to be the warmest in the sampled period, while 1999 was one of the coldest years, together with 1992 and 1993. This winter-spring period has a large influence on egg and larval survival.

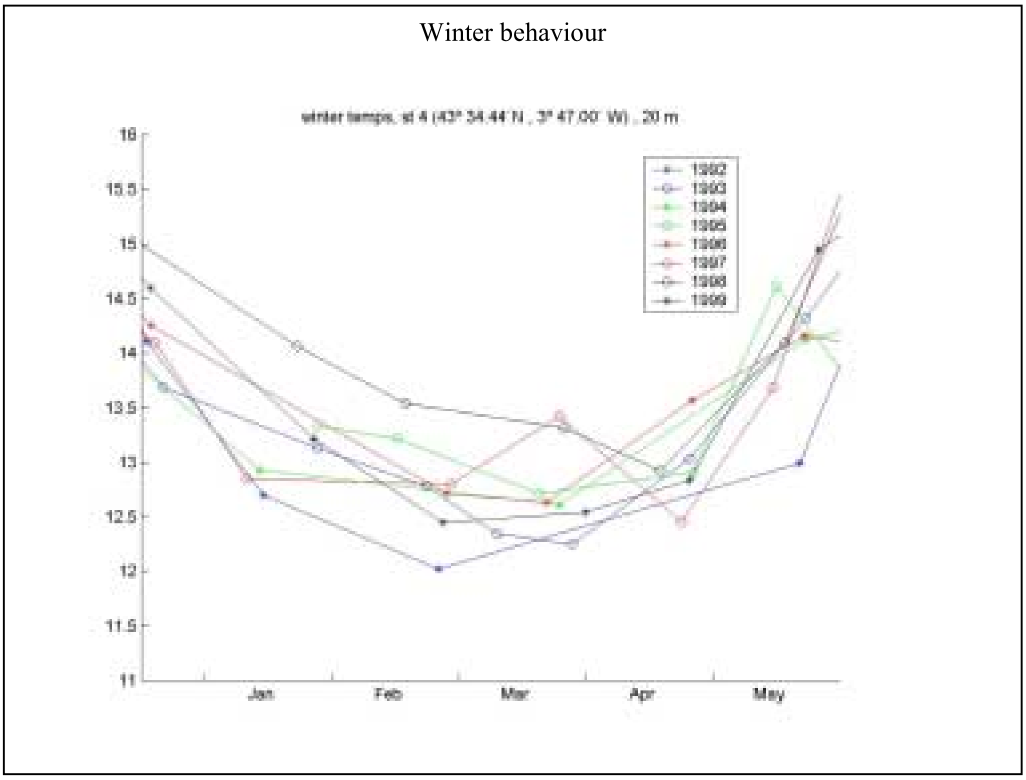


Figure 9

Salinity

Salinity behaviour in the form of monthly values during the period is presented in Figure 10. Salinity in the Bay of Biscay, which had been increasing from a low salinity event in 1995, reached its maximum during 1997/98 and began to fall in 1999. This occurs throughout the water column of station 4 (10, 50, and 90 m depth).

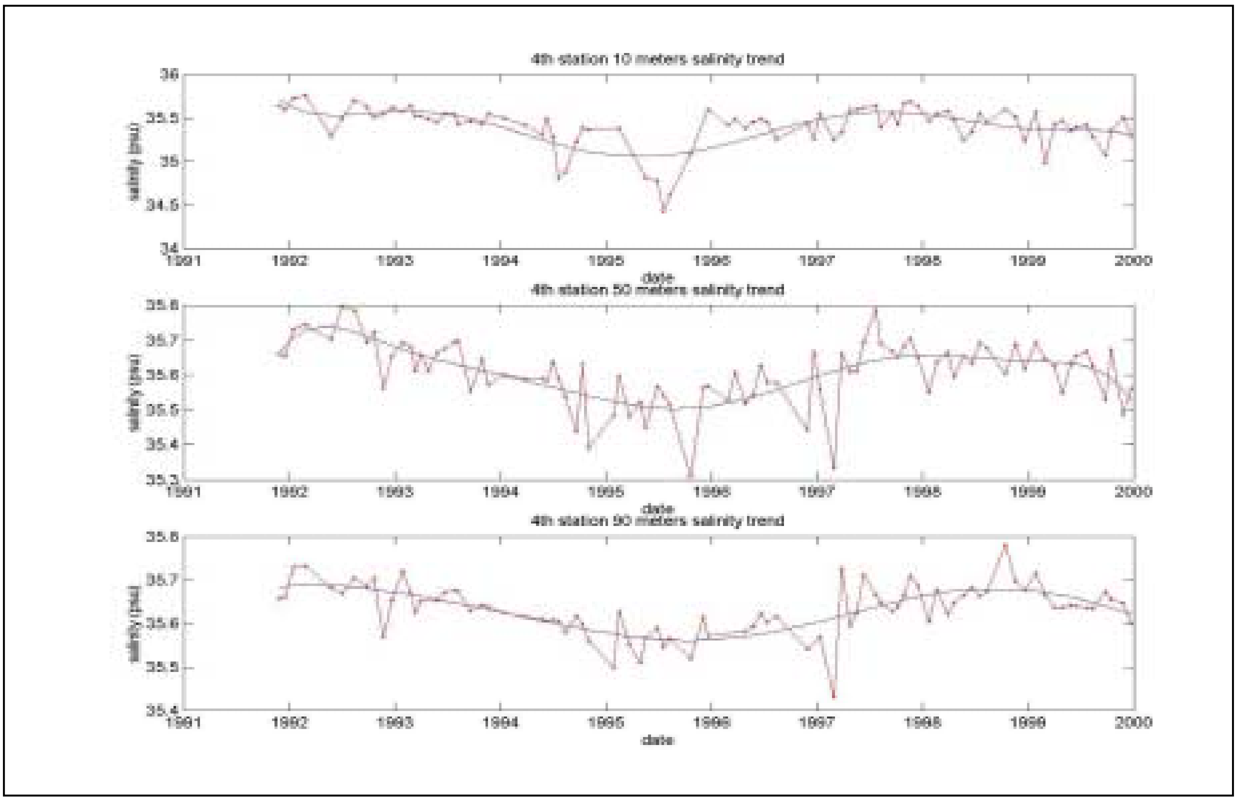


Figure 10

1999 EXTREME EVENTS

At 50 m depth, the seasonal temperature cycle was more than 5ºC. There were upwelling signals between May and July and in September temperature reached 17.3ºC, the highest of the decade.

At 90 m, November/December were the warmest months, but autumn mixing hardly reached this depth, indicating moderate or a lack of strong winds.

The advection of low salinity water of high temperature occurred again, as in the early 90's, but salinity decreased to a lesser extent.

The annual mean air temperature over the Bay of Biscay followed the ongoing warming trend. In Santander, the mean value for 1998 of 14.8ºC was maintained in 1999, 0.5ºC over the 1961-1999 mean.

1999 presents the widest amplitude in the seasonal cycle of sea water temperature at 10 m (8.9ºC) with summer/early autumn temperatures more than a degree above the 1992-1999 mean (between August and October). At this depth, the 1999 annual mean was 16.1ºC, the warmest year of the time series. The trend obtained from this series over the shelf was 0.04ºC/year.

Sea surface salinity in the Bay of Biscay, which had been increasing from a low salinity event in 1995, reached its maximum during 1997/98 and began to fall in 1999.

Heat content

To study the heat content over the surface and NACW, we have observed two parts of the water column separately: the upper part between 0 and 100 m and from 100 to 500 m. (Figure 11) The upper part shows the seasonal cycle in heat content, but the deep part shows a high signal in late autumn or early winter. This signal is stronger in 1995, 1996 and above all in 1998. Late 1997/early 1998 was the warmest period throughout the water column and marked the strongest event of the decade (See also Fig 4).

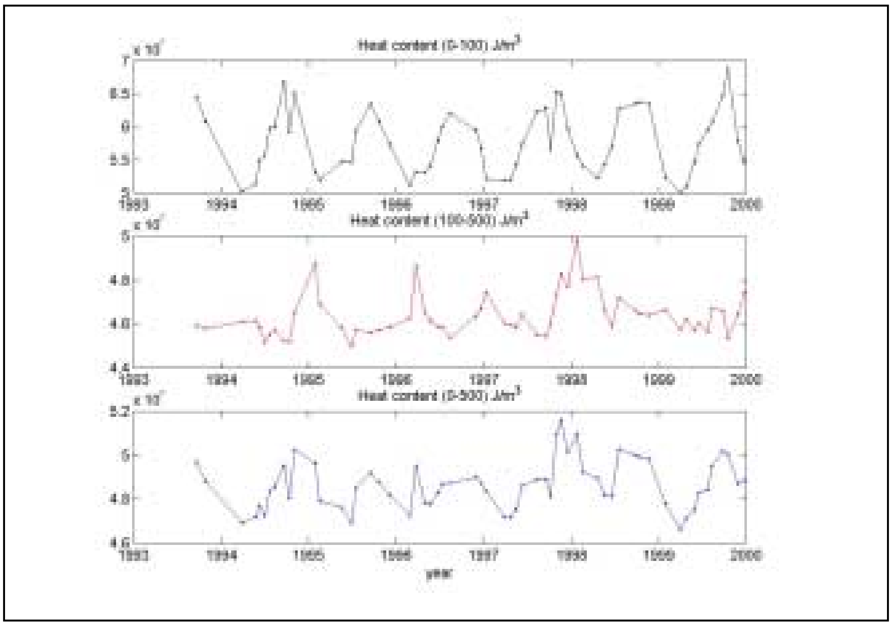


Figure 11

Comparison of satellite and 'in situ' data.

To cross check the SST of station 6 and work backwards, we have compared two time series with data from 9 km resolution Pathfinder data pixels for the period January 1987-October 1999 (courtesy of PML) and 'in situ' 10 m data from station 6. A monthly mean of satellite data was calculated at the location of the station (Figure 12). A strong parallelism in both series is observed with small deviations due to monthly sampling (at 10 m depth) and the mean monthly value for the satellite data. Deviations were found in the warmest and coldest parts of the year. The deviation in the warmest part of the year may have been due to very superficial warming in August or because the day sampled 'in situ' was not representative of this period. In winter, it may also have been due to an inversion of temperatures with colder temperatures at the surface. Most of the work was done to see whether the shortage of samples occurring at the end of 1993 and early 1994 would give an unrepresentative picture of the year. Due to this data shortage for autumn/winter we used the station 6 time series from spring 1994.

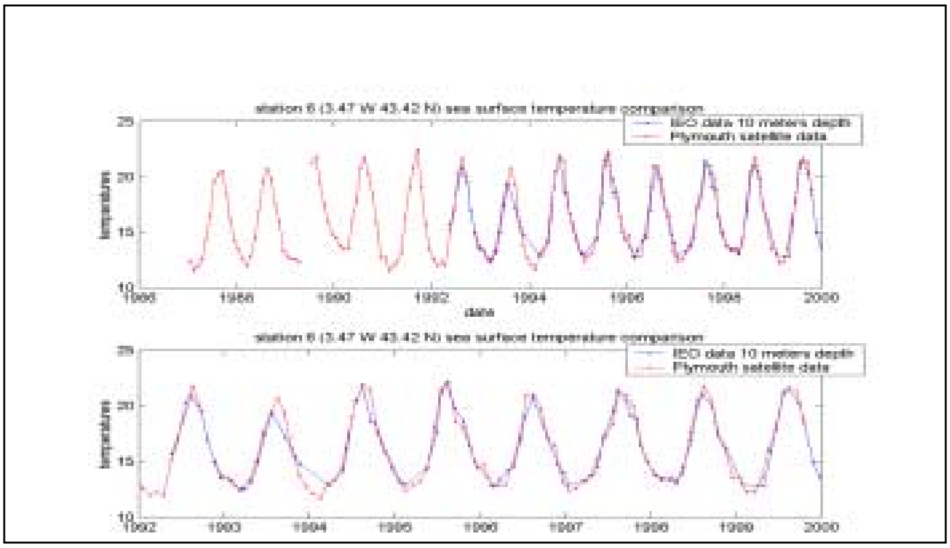


Figure 12

Vigo Standard Section

Contours of temperature, salinity and nitrates over the shelf (94 m depth) in the Vigo section from 1994 to 1999 are presented in Figure 13. The seasonal cycle is marked in temperature in the upper layers and remains during the autumn, usually interrupted by summer upwelling events. Stratification develops between April-May until October-November when warmer water covers the shelf. During the rest of the period the water column is mixed. Salinity contours show high salinity at the beginning of the winter in 1995 and 1996 due to the poleward current and sporadically in spring-summer due to seasonal upwelling events. The highest values were found during spring-summer 1997 spreading into the rest of the year. Autumn 97/ winter 98 was the warmest period in the time series, which may indicate a strong poleward current, even when salinity was high from the middle of the year. Salinity was so high that the upwelling events (marked by low temperature) present lower salinity than in the surrounding area. From summer 1998 the main part of the water column was cold, which seems to be due to strong upwelling. The poleward current during autumn 98 was weak, and in winter 99 the water remains as cold as it was during 1994. Salinity decreased in 1999 from the previously high levels, and values are now similar to those of 1994.

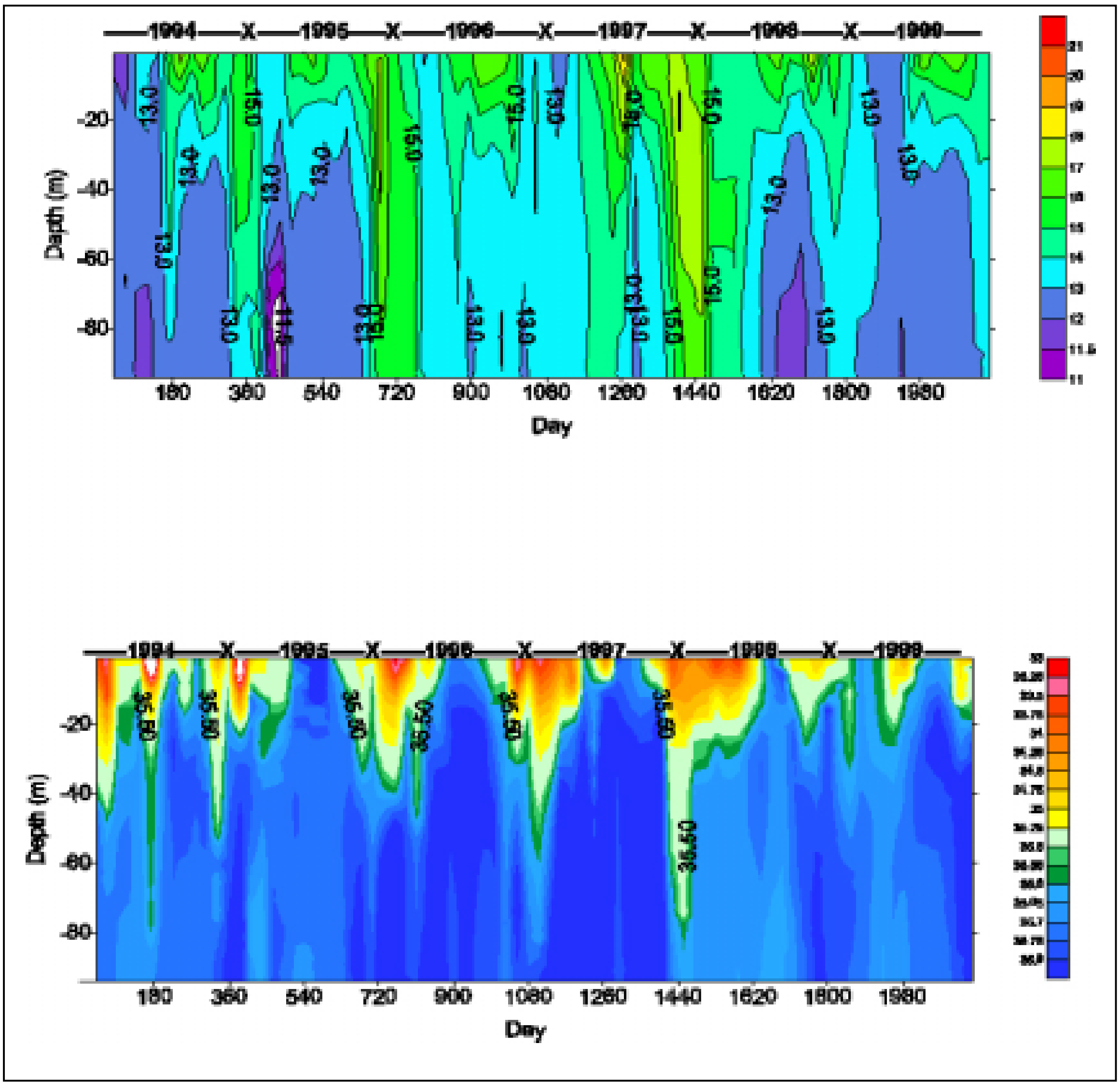


Figure 13

ANNEX K – AREA 6 (FAROE BANK CHANNEL) FAROESE REPORT

In the mid-1990s the Atlantic water in the Faroe Bank Channel was relatively cold and fresh. Since then, temperature and salinity have increased. The first half of 1999 was fairly cold; but towards the end of the year, the 100-300 m layer in the FBC was again warm.

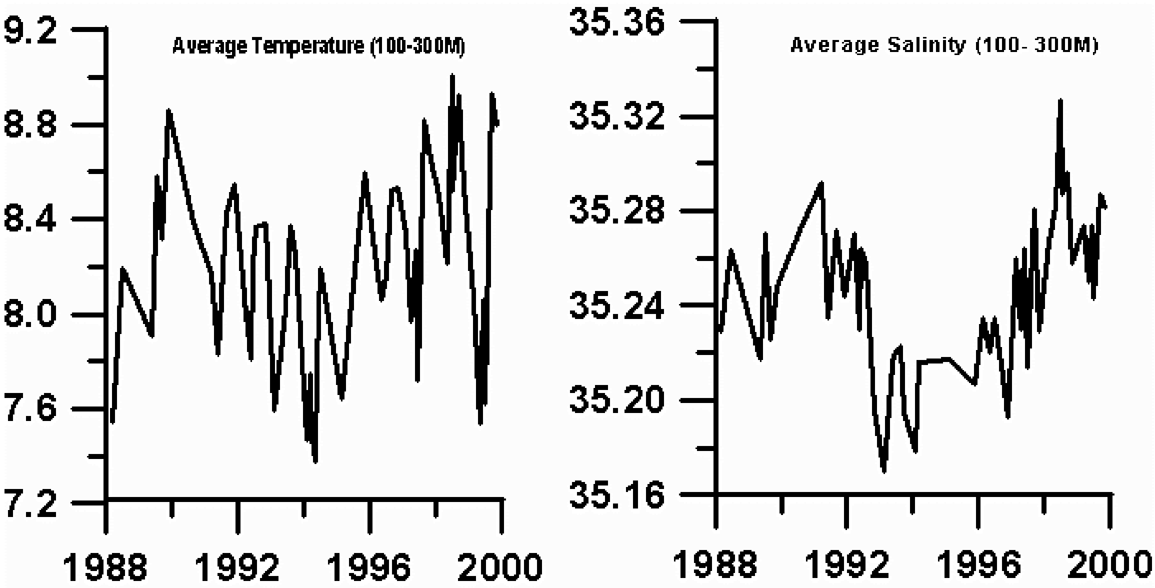


Figure above: Temperature (left) and salinity (right) averaged over the 100-300 m depth interval and over the two deepest stations on the Faroe Bank Channel standard section.

ANNEX L – AREA 7 (NORTHWEST EUROPEAN SHELF EDGE AND NORTHERN NORTH SEA) SCOTTISH REPORT

Scottish Ocean Climate Status Report 1999

W.R. Turrell, Marine Laboratory Aberdeen

Weather

Monthly mean weather data has been obtained at 5 sites around Scotland (Figure 1). They characterise the west coast (Abbotisinch - 1, Stornoway - 2), east coast and North Sea (Dyce - 3, Leuchars - 4) and the north coast and Faroe Shetland Channel (Lerwick - 5). Hourly data at Lerwick is also available since 1960 to examine trends in parameters. Wind data is only available for this report at Lerwick.

Air temperatures were slightly above the 1961-1990 mean throughout the year (Figure 2). This was particularly evident in minimum air daily temperatures. Sunshine hours also were close to average, except for a few exceptions (eg August on the west coast). The year was generally wetter on the west coast and drier on the east coast compared to the 1961-1990 mean. The west coast was particularly wet at the start and end of the year. The east coast was drier than normal throughout.

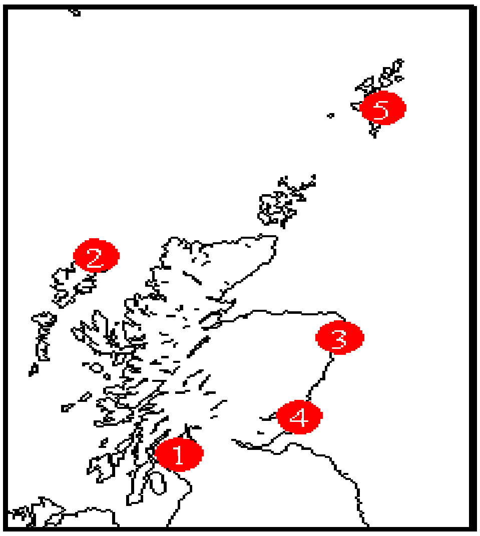


Figure 1. Location of the five representative weather stations; Abbotsinch in the Clyde (1), Stornoway in the Hebrides (2), Dyce near Aberdeen (3), Leuchars near St Andrews (4) and Lerwick (5).

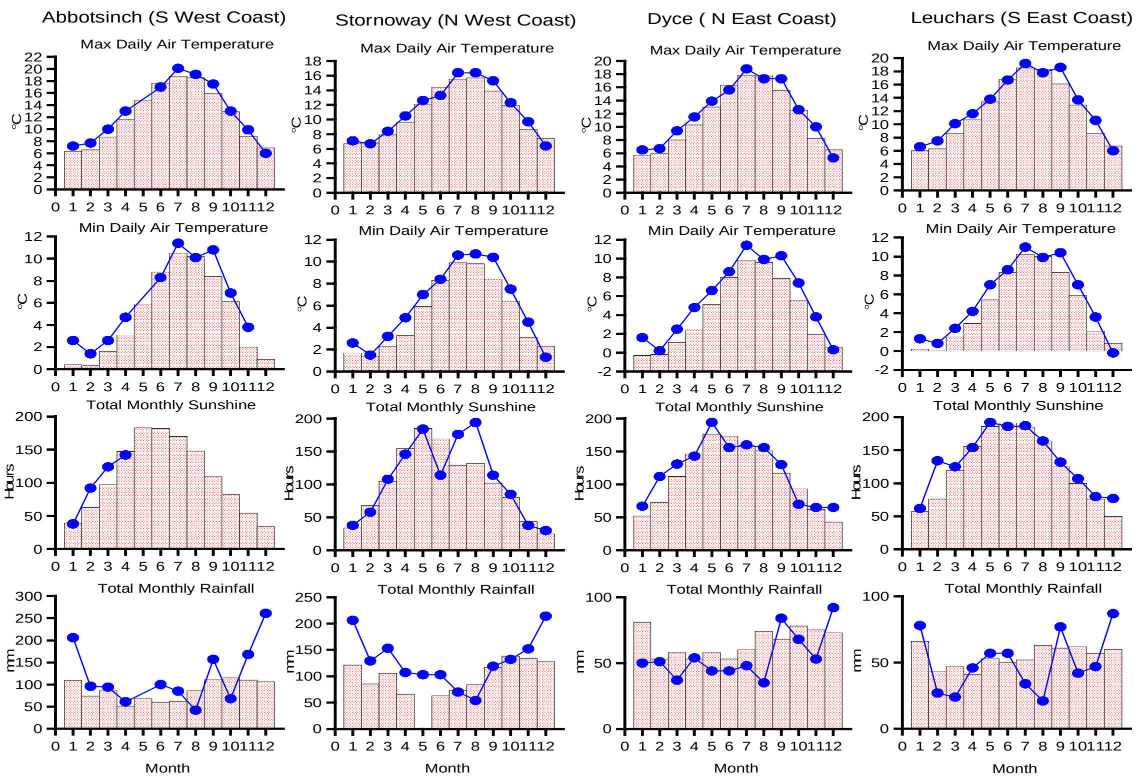


Figure 2. Monthly average air (maximum and minimum) temperature, total sunshine (hours) and total rainfall (mm) at four representative Scottish coastal locations (See Figure 1). The blue line indicates 1999 values. The red bars indicate the 1961-1990 averages.

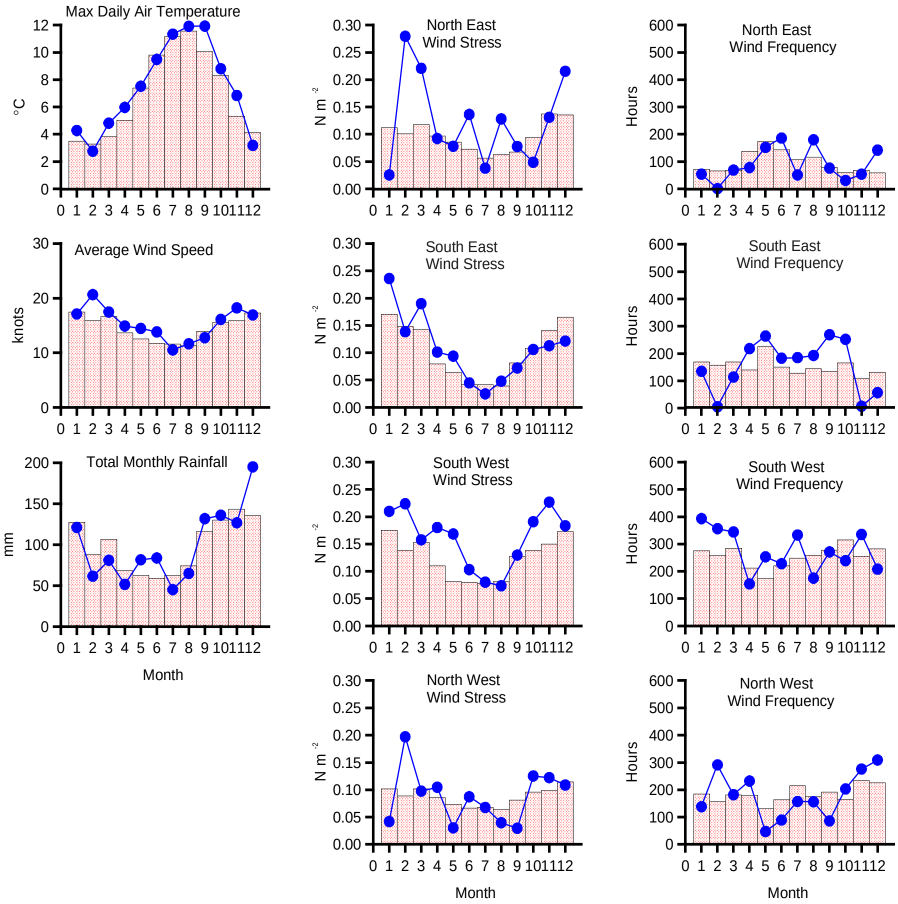
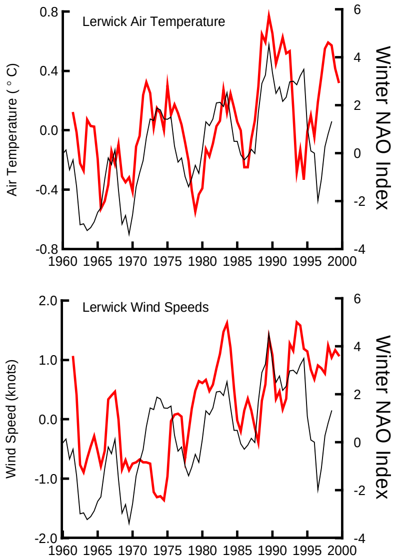


Figure 3. Left - the monthly average air temperature, average wind speed and total rainfall at Lerwick. Centre - the average force of the wind (wind stress) from 4 quadrants of the compass. Right - the total time (hours) during which the wind blew from each quadrant. The blue line shows the 1999 values. The red bars are the 1961-1990 averages.



North of Scotland (at the southern boundary of the Faroe Shetland Channel) air temperatures were also normal throughout the year (Figure 3). Wind speed was above the 1961-1990 mean in all months except July to September. May, June and December were wet, while the remainder of the year rainfall was normal.

In terms of wind stress, wind stress and frequency of winds from the SW was stronger than average throughout the year. NE wind stress was also abnormally strong at the start and end of the year.

Trends at Lerwick are particularly notable in air temperatures and wind speed (Figure 4). Air temperatures are steadily rising, although multi-decadal variability which appears to be related to the NAO is evident. Wind speeds are steadily increasing since 1975. Although there seems some relation to the NAO, the recent switch in the NAO was not repeated in wind speed, which continues to increase.

Figure 4. Long-term changes in the monthly average air temperature and wind speed at Lerwick (Figure 1). The seasonal changes have been removed from the measurements so that the long term trend can be seen better. The thin black line shows the changes in the North Atlantic Oscillation (NAO) during this period.

Water Masses

Figure 5 shows the location of the Modified North Atlantic Water (MNAW), North Atlantic Water (NAW), Fair Isle Current (FIC) and Cooled Atlantic Water (CAW) monitoring stations. Figures 6 to 9 show the time series of temperature and salinity anomalies for these water masses. Figure 10 shows the temperature and salinity at 800 dbar in the Faroe Shetland Channel.

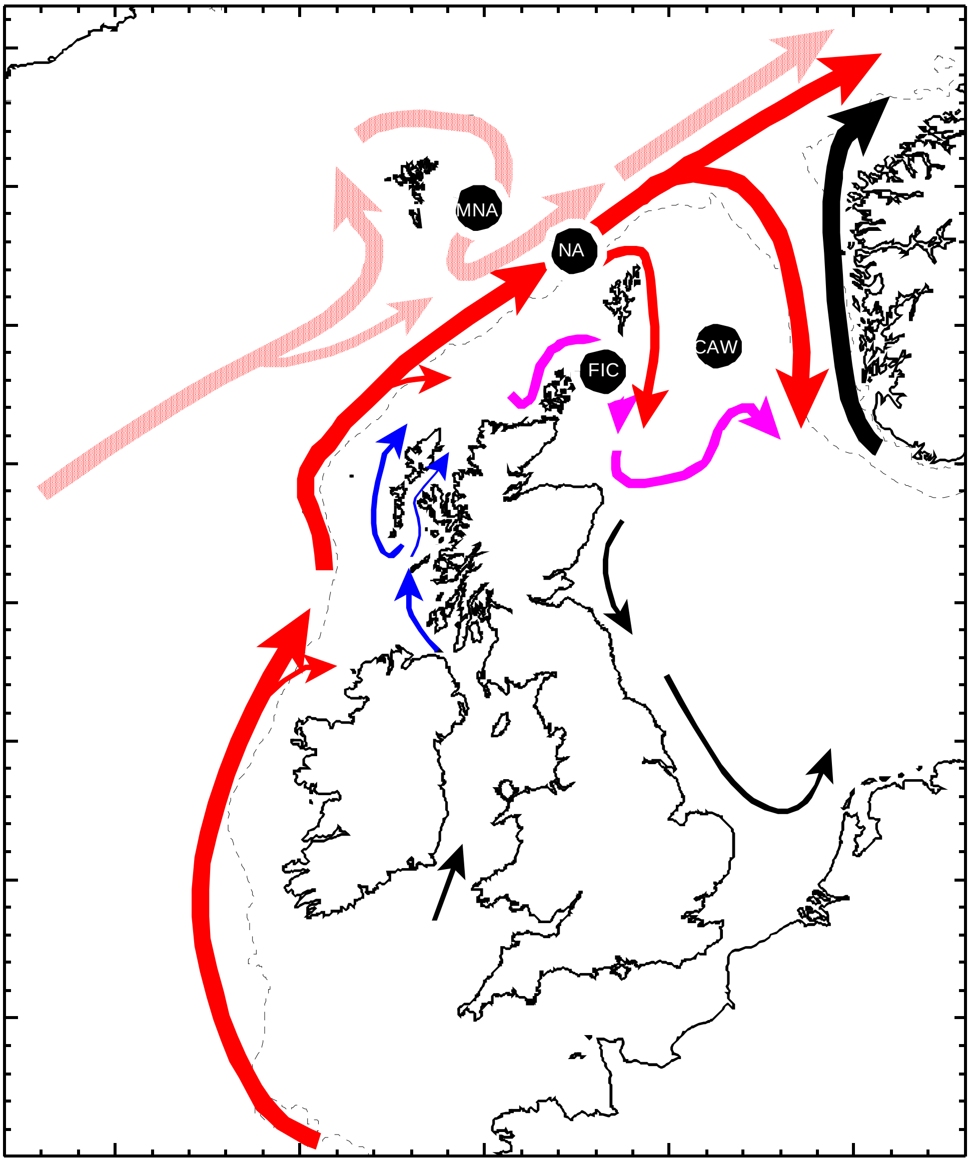


Figure 5. The circulation of surface waters around Scotland. The red arrow is the flow of warm, salty Atlantic water along the shelf edge (the Shelf Edge Current). The blue and black arrows show the flow of coastal waters. The purple arrow shows the inflow of mixed coastal / oceanic water past Fair Isle. The light red arrow shows the flow of water from the middle of the Atlantic around the Faroe Islands. The thin broken line marks the edge of the continental shelf. The location of the time series MNA, NA, FIC and CAW are shown.

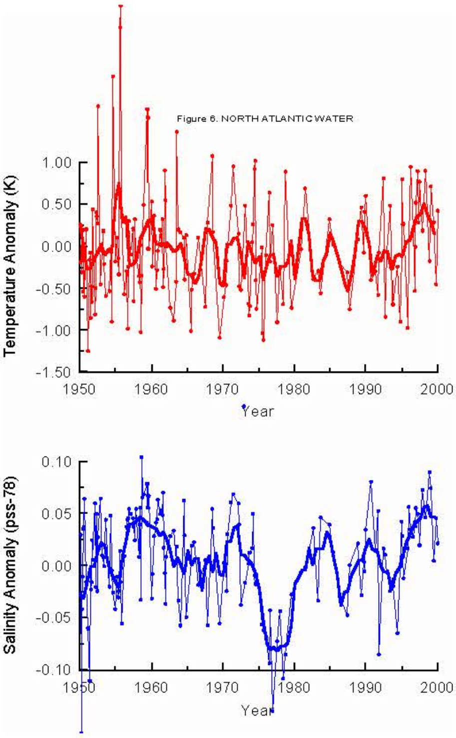


Figure 6. NORTH ATLANTIC WATER
Temperature Anomaly (K)
Salinity Anomaly (pss-78)
Year

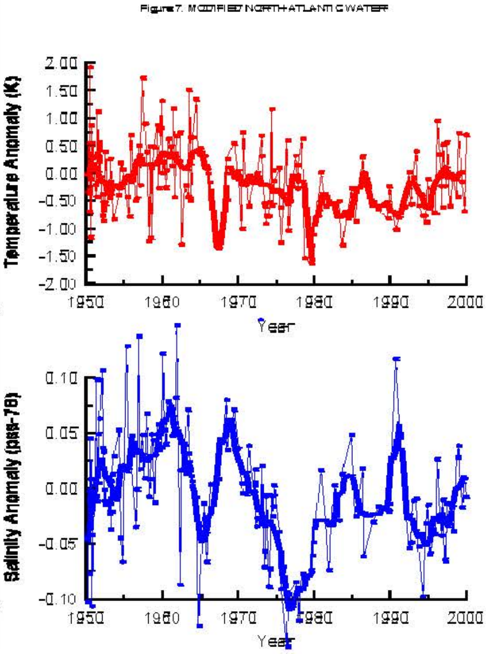
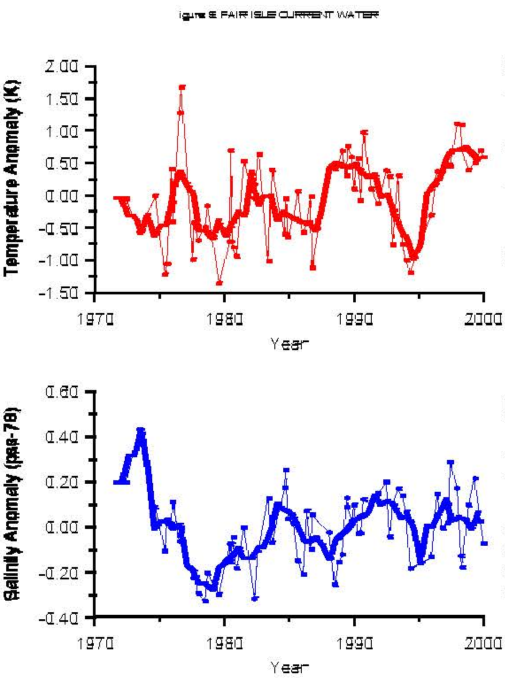


Figure 7. MODIFIED NORTH ATLANTIC WATER
Temperature Anomaly (K)
Salinity Anomaly (pss-78)
Year


FAIR ISLE CURRENT WATER
Temperature Anomaly (K)
Salinity Anomaly (pss-78)
Year

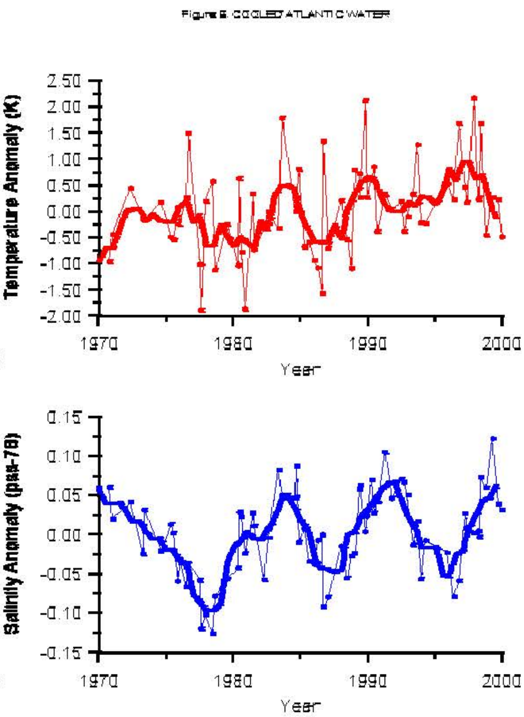
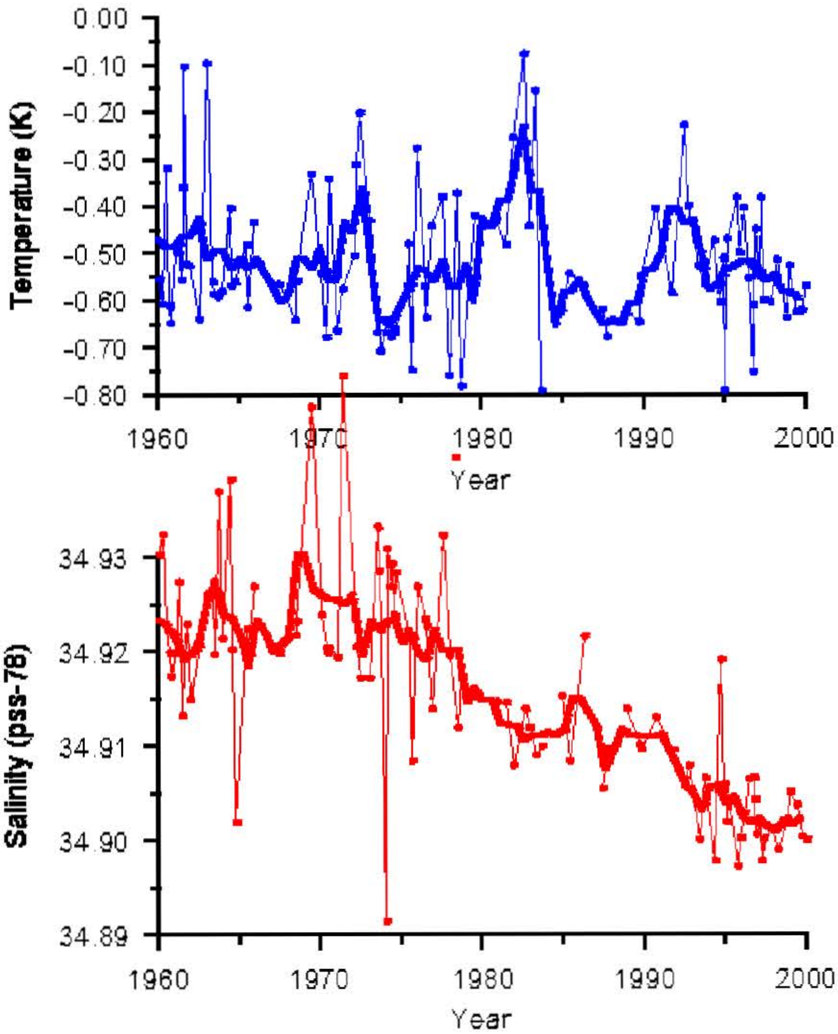

COOLED ATLANTIC WATER
Temperature Anomaly (K)
Salinity Anomaly (pss-78)
Year

Figure 10. FAROE SHETLAND CHANNEL BOTTOM WATER – 800 dbar



ANNEX M – AREA 8 AND 9 (NORTHERN AND SOUTHERN NORTH SEA) IBTS SURVEY

Hydrographic Report of the 1999 IBTS Survey

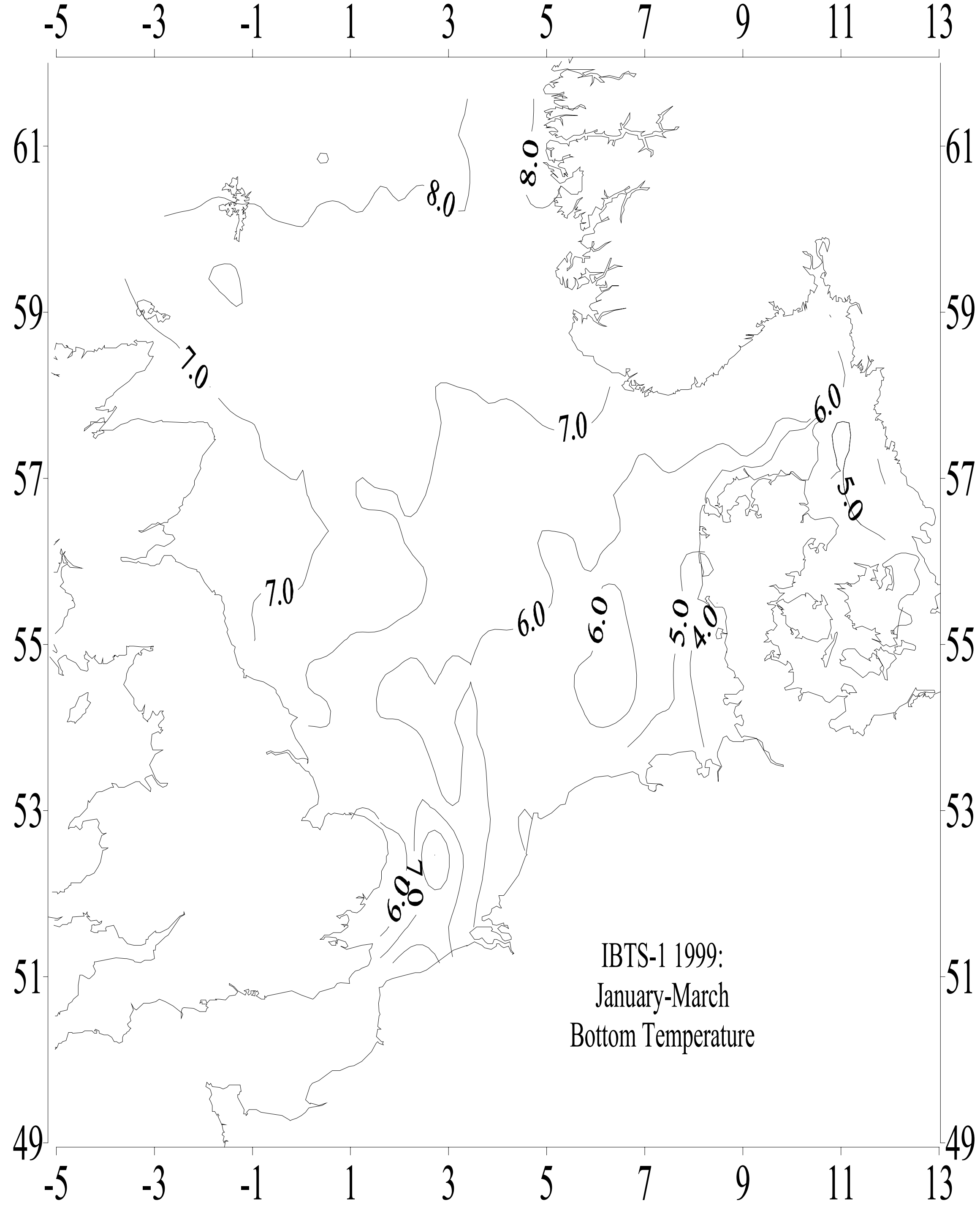
Seven ships contributed hydrographic data to the 1999 dataset. These consist of 435 stations worked between 9 January and 26 February. Nutrient data were supplied from 66 stations, contributions being received from two ships (Argos and Scotia). Data quality was good. The supplied Michael Sars dataset, includes data in addition to those at which IBTS trawls were undertaken.

Charts of the distribution of bottom temperature and salinity are given in Figs 7.1 and 7.2. An updated table, giving the time series of temperature and salinity at 10 locations in the North Sea during IYFS/IBTS (1) surveys from 1970 to 1999 is provided as Table 7.1. The Figures and Table show that North Sea conditions were very similar to recent years, with sustained levels of relatively high temperature and salinity, especially in the northern North Sea. In Fig 7.3 5-year running mean temperature reveal the high spatial coherence in the temperature time series, based on the ten locations given in Table 7.1. In particular the sustained cooling around 1980 and the warming around 1990 is clearly demonstrated.

Charts from the 1999 IBTS-1 survey are also published on the ICES website on

www.ices.dk/ocean/project/datasets/iyfs.htm, along with corresponding charts since 1970. The website also includes charts showing station locations. Charts of phosphate, silicate, nitrate and nitrite will follow later, after more data have been received.

Figure 7.3. Five-Year averages of temperature at each of the ten locations in Table 7.1



-5
-3
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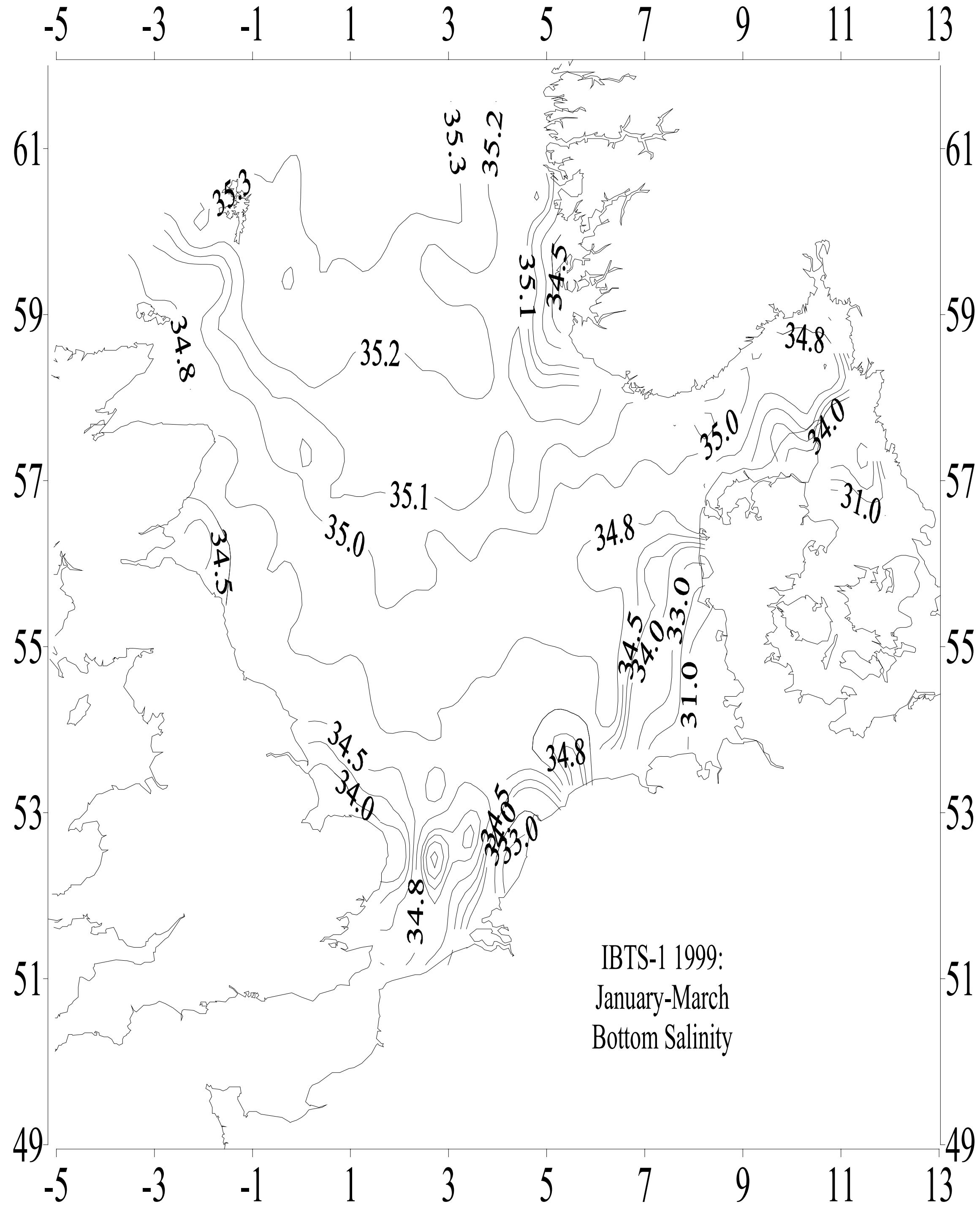
IBTS-1 1999:
January-March
Bottom Temperature

Figure 7.1


-5
-3
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5
7
9
11
13
61
59
57
55
53
51
49
35.3
35.2
35.3
35.1
34.5
34.8
35.2
34.8
35.0
34.0
35.1
31.0
35.0
34.8
34.5
34.5
34.0
33.0
31.0
34.5
34.8
34.0
34.5
34.0
33.0
34.8
IBTS-1 1999:
January-March
Bottom Salinity

Figure 7.2

Time series data of bottom temperature and salinity during IYFS/IBTS(1) 1970-1999

Location	1		2		3		4		5		6		7		8		9		10	
Position	60° 0'N 2°E		57° 30'N 0°E		57° 30'N 2°E		57° 30'N 4°E		55° 0'N 0°E		55° 0'N 2°E		55° 0'N 4°E		55° 0'N 8°E		54° 0'N 3°E		52° 30'N 3°E	
Year	t°C	Sal	t°C	Sal	t°C	Sal	t°C	Sal	t°C	Sal	t°C	Sal	t°C	Sal	t°C	Sal	t°C	Sal	t°C	Sal
1970	5.5	35.08	5.8	34.95	5.3	35.00	4.7	34.92	5.9	34.75	4.5	34.82	4.0	34.72	0.5	33.00	4.0	34.72	4.0	34.62
1971	7.1	35.15	7.0	35.05	6.9	35.15	6.0	35.10	7.0	34.82	6.2	34.88	5.5	34.80	3.5	33.00	5.9	34.55	7.0	34.95
1972	5.8	35.22	6.9	35.08	5.9	35.20	4.5	34.78	6.5	34.91	4.8	34.86	5.2	34.80	2.5	33.80	5.2	34.70	6.9	35.10
1973			7.4	35.02	7.2	35.20	6.7	35.10	7.0	35.05	6.1	35.00	6.0	34.86	5.0	33.00	6.4	34.80	6.5	35.05
1974	6.9	35.28	6.5	35.11	6.5	35.08	6.3	35.04	6.5	34.90	6.0	34.90	5.6	34.90	4.7	33.00	6.1	34.78	8.0	35.20
1975	7.3	35.20	6.6	35.05	6.6	35.15	6.4	35.13	6.6	34.95	6.4	34.90	6.1	34.85	5.2	33.50	5.9	34.62	6.9	34.62
1976	6.7	35.20	6.5	35.00	6.5	35.15	5.6	35.12	6.1	34.81	4.9	34.95	4.9	34.85	2.2	31.00	5.1	34.78	5.1	34.80
1977	6.0	35.18	6.2	35.02	5.1	35.00	4.8	34.92	6.0	34.98	4.9	34.85	5.0	34.80	3.1	33.60	5.6	34.78	7.1	35.22
1978	6.4	34.88	6.6	35.00	6.0	34.90	4.7	34.88	5.6	34.78	4.9	34.88	4.2	34.80	2.2	32.50	4.6	34.68	5.5	34.90
1979	6.4	35.15	6.0	34.80	4.1	34.88	4.0	34.98	4.5	34.64	2.8	34.62	2.8	34.62	-1.5	32.00	3.0	34.62	4.2	34.95
1980	5.9	35.12	6.6	35.00	5.5	35.00	4.5	34.70	6.1	34.60	3.8	34.65	4.5	34.50	3.1	33.50	5.1	34.70	6.1	35.11
1981	6.9	35.22	6.6	34.90	6.2	35.05	5.8	35.15	6.5	34.80	5.8	34.82	5.1	34.82	3.4	32.50				
1982	6.6	35.28	6.1	35.02	5.9	35.05	5.5	35.10	5.5	34.72	4.8	34.82	4.5	34.62	2.8	32.50	4.7	34.30	6.0	34.65
1983	6.9	35.22	6.5	35.00	6.4	35.10	6.2	35.15	5.6	34.62	6.1	34.95	5.2	34.90	3.0	33.00	5.2	34.80	6.4	34.70
1984	6.3	35.18	6.4	35.10	6.4	35.10	5.2	35.12	5.9	34.80	5.0	34.84	4.9	34.90	3.5	33.00	4.9	34.65	7.4	34.95
1985	6.9	35.17	6.8	35.10	6.5	35.18	5.9	35.05	6.5	34.70	4.7	34.91	5.0	34.90	1.0	32.50	4.0	34.70	6.0	34.80
1986	6.6	35.25	5.8	35.05	5.4	35.08	5.2	35.05	5.2	34.65	3.9	34.72	3.6	34.60	0.0	32.50	4.0	34.60	4.0	34.65
1987	6.5	35.28	6.1	34.90	5.9	35.08	4.9	35.00	5.0	34.75	4.2	34.80	4.3	34.60	0.8	30.00	4.9	34.60	4.8	34.90
1988	7.6	35.18	7.6	34.95	7.4	35.03	7.0	34.96	7.1	34.70	6.6	34.80	6.5	34.50	5.9	33.50	6.9	34.60	7.7	34.90
1989	8.5	35.29	8.0	34.85	7.8	34.89	7.6	35.05	7.5	34.76	7.1	34.81	6.8	34.80	6.0	34.10	6.5	34.68	7.5	34.62
1990	8.5	35.29	7.6	35.00	7.6	35.12	7.6	35.15	7.5	34.70	7.5	34.85	7.5	34.80	6.5	34.10	7.4	34.70	7.4	34.60
1991	7.9	35.30	6.7	35.10	7.1	35.22	6.1	34.97	6.6	34.65	5.8	34.85	5.5	34.80	3.0	34.00	5.8	34.60	6.1	35.30
1992	8.1	35.29	7.6	35.10	7.1	35.16	7.1	35.19	7.4	34.80	6.6	34.80	6.5	34.80	6.6	32.00	4.5	34.80	6.0	35.20
1993	7.4	35.31	6.5	34.92	6.4	35.18	6.5	35.30	6.5	35.05	6.2	35.00	5.4	34.95	4.3	33.50	5.6	34.80	6.0	35.00
1994	6.2	35.20	6.5	35.05	5.5	34.93	4.3	34.80	6.3	34.90	5.4	34.90	5.2	34.80	4.0	32.00	5.5	34.70	7.0	35.00
1995	7.5	35.23	7.0	34.92	7.1	35.00	6.7	35.09	6.7	34.71	6.0	34.87	5.6	34.81	4.0	30.03	6.0	34.65	7.9	34.51
1996	7.1	35.24	6.5	34.91	5.0	34.94	4.7	34.87	6.0	34.59	4.6	34.71	3.0	34.44	-0.2	32.12	3.4	34.71	3.8	34.83
1997	7.6	35.21	7.3	34.92	6.2	34.92	6.4	35.09	6.5	34.72	5.8	34.80	4.9	34.72	2.9	32.93	5.2	34.67	5.2	34.96
1998	8.2	35.29	8.5	35.14	7.8	35.16	7.0	35.00	7.5	34.79	6.3	34.84	6.1	34.62	3.5	31.78	6.3	34.56	7.2	35.25
1999	7.6	35.30	7.1	35.00	7.4	35.16	6.7	35.10	7.2	34.79	6.4	34.94	5.5	34.80	4.1	31.02	5.8	34.73	8.3	35.14

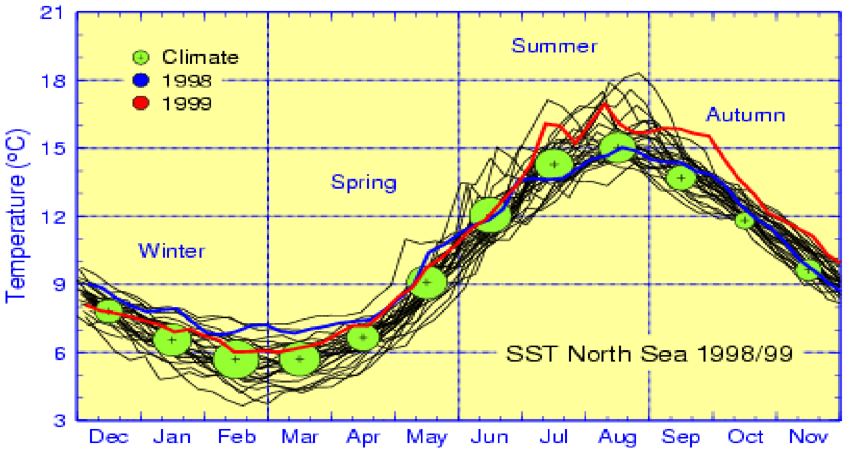
Table 7.1

ANNEX N – AREAS 8 AND 9 (NORTHERN AND SOUTHERN NORTH SEA) GERMAN REPORT

BSH Hamburg Report

Gerd Becker, Peter Loewe, BSH Hamburg and Rostock

Based on weekly SST maps of the North Sea which have been analysed regularly since 1968, the annual evolution of the area averaged gridded monthly SST data and its anomalies from the 1971-93 climatology are presented. Although SSTs were above normal throughout the year, departures from the climatology (Figure 1) averaged only 0.5°C until June and thus may be qualified as only moderately strong. The subsequent temperature jump of 3.2°C to an average of 15.5°C led to the second warmest July after 1997. While seasonal cooling usually sets in round mid-August, SSTs in 1999 remained at about 16°C throughout September. This prolonged summer season is considered the most anomalous feature of the seasonal cycle in 1999. During September, with average departures of 2°C and even beyond 3°C in the continental coastal waters (Figure 2a-d), new record SSTs were set. The basin wide extreme warm anomaly by and large persisted through to the end of the year and continued also in the first quarter of the year 2000.



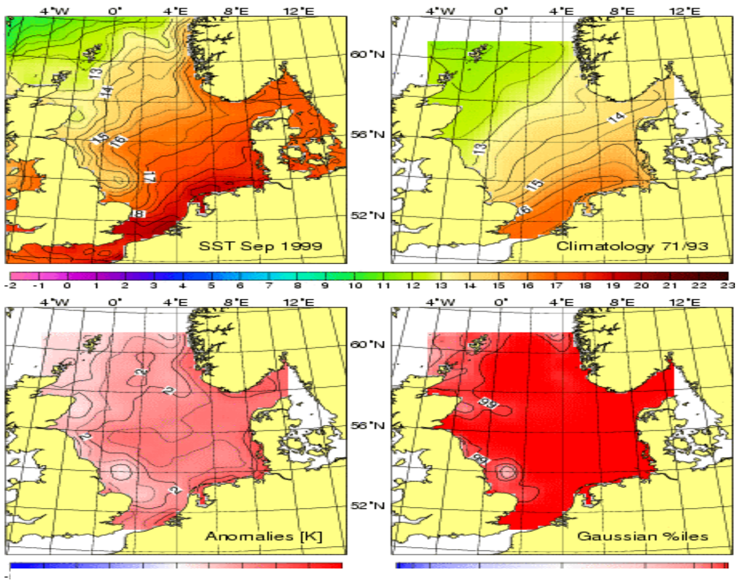


Figure 3

An annual mean SST of 10.7°C made 1999 the 2nd warmest year after 1990 (10.8 °C) in the record dating to 1971. Thus 6 of the warmest 7 years occurred during this 30-year period chanced to occur in the 1990s. The heat content not only depends on the SST, but in a sea with pronounced seasonal stratification such as the North Sea, the thickness of the mixed surface layer and the temperature of the layer below the thermocline determines the heat content. The temperature of the layer beneath the thermocline depends very much on the temperature of the annual minimum temperature in February/March as well as the onset and strength of the seasonal thermocline.

The minimum temperature in February/March 1999 was normal to slightly above the climatology. Therefore it was expected that summer bottom layer temperatures would also be above climatology. A cruise in the summer of 1999 (RV "GAUSS", 2-15 July 1999), sampling the whole North Sea on E-W sections between 52°N and 60°N using a towed CTD-System (Delphin), gave the first estimates of the overall heat content of the North Sea. The Delphin is towed between surface and about 70 to 100 m depths.

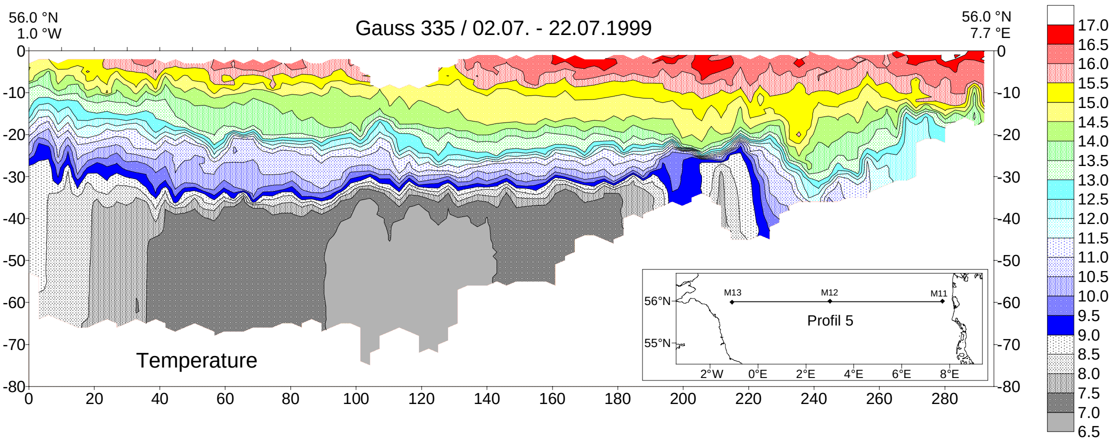


Figure 4

As an example the temperature section at 56°N given in Figure3 shows a thermocline at depths of about 30 to 35 m, separating the homogenous bottom layer with temperatures between 6.5°C and 7.5°C. The temperature of the bottom layer therefore is about 0.5°C to 1°C above climatology. Due to the weaker kinetic energy input, the surface layer is not well mixed; from the surface down to the thermocline and a temperature gradient is observed.

So far the 1999 data have not been compared with a new North Sea and Baltic Sea climatology (Janssen, Schrum and Backhaus, 1999; Supplement 9 to DHZ). This will be undertaken during the next months. However, the general judgement of the data set gained in 1999 results in an anomalous high heat content of the North Sea in the summer and even in the autumn of 1999. The causes are probably the high recovering NAO index with an increased heat flow from the atmosphere into the water column and lower than normal winds during the summer and early autumn. The role of advective heat transports from the North Atlantic into the North Sea in the year 1999 is not known.

The surface salinity distribution (Figure4), taken from hourly thermosalinograph data (Seabird) shows a rather normal salinity in the whole North Sea, although the Baltic outflow extends more to the west. This was caused by a rather shallow halocline separating the Baltic outflow from the inflowing Atlantic water at depths of only 5 to 10 m.

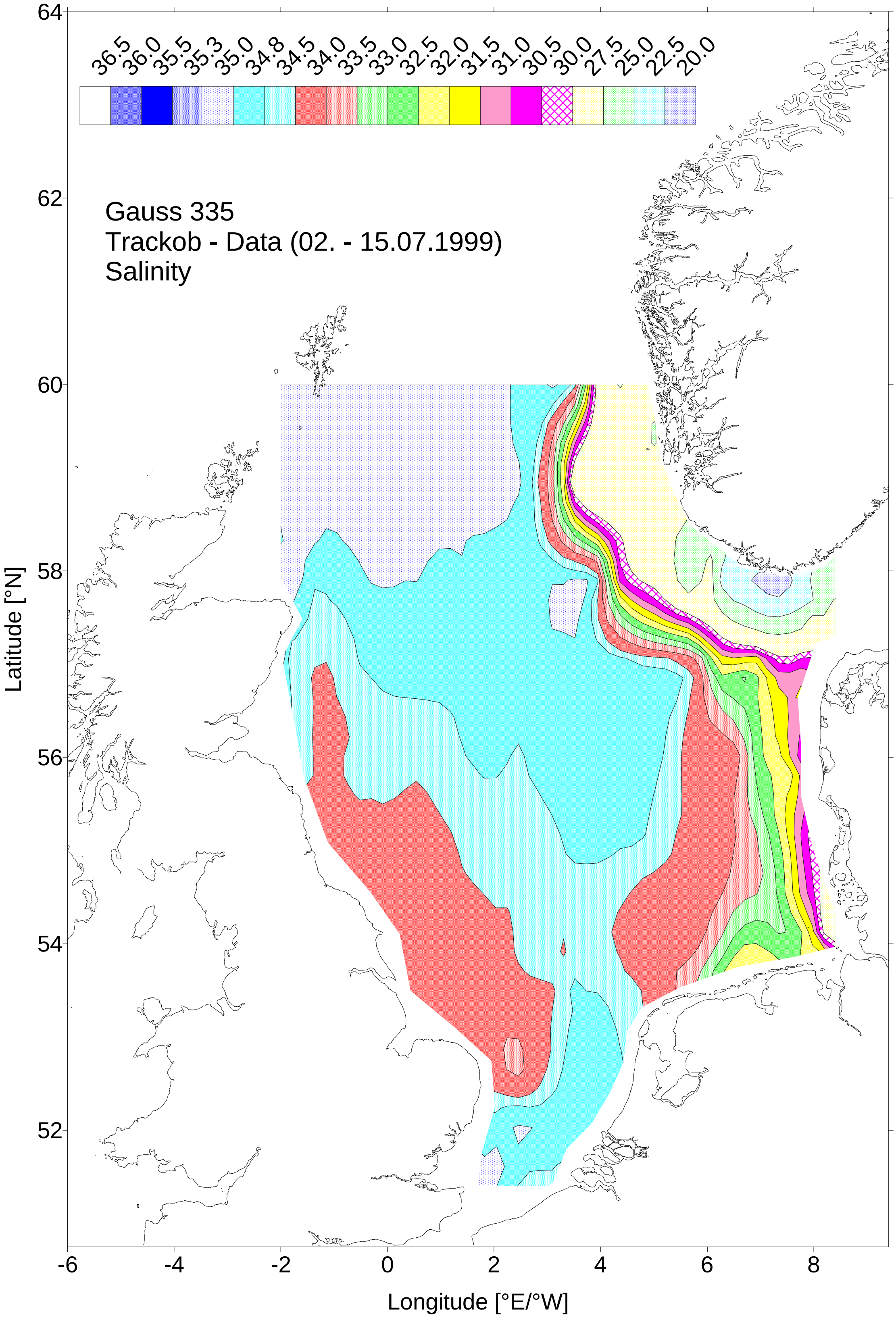

36.5
36.0
35.5
35.3
35.0
34.8
34.5
34.0
33.5
33.0
32.5
32.0
31.5
31.0
30.5
30.0
27.5
25.0
22.5
20.0
Gauss 335
Trackob - Data (02. - 15.07.1999)
Salinity
64
62
60
58
56
54
52
Latitude [°N]
-6
-4
-2
0
2
4
6
8
Longitude [°E/°W]

Figure 5

ANNEX O – AREAS 8, 10 AND 11 (NORTHERN NORTH SEA NORWEGIAN AND BARENTS SEAS) NORWEGIAN REPORT

Norwegian Sections
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Summary

Increased inflow of Atlantic water combined with a warm summer and autumn lead to temperatures above normal in the eastern Norwegian Sea, in the Barents Sea and the North Sea. The central and western parts of the Norwegian Sea are dominated by relatively rich inflow of Arctic water with low temperatures and salinity.

Figure 1 shows all Norwegian standard sections and fixed oceanographic stations.

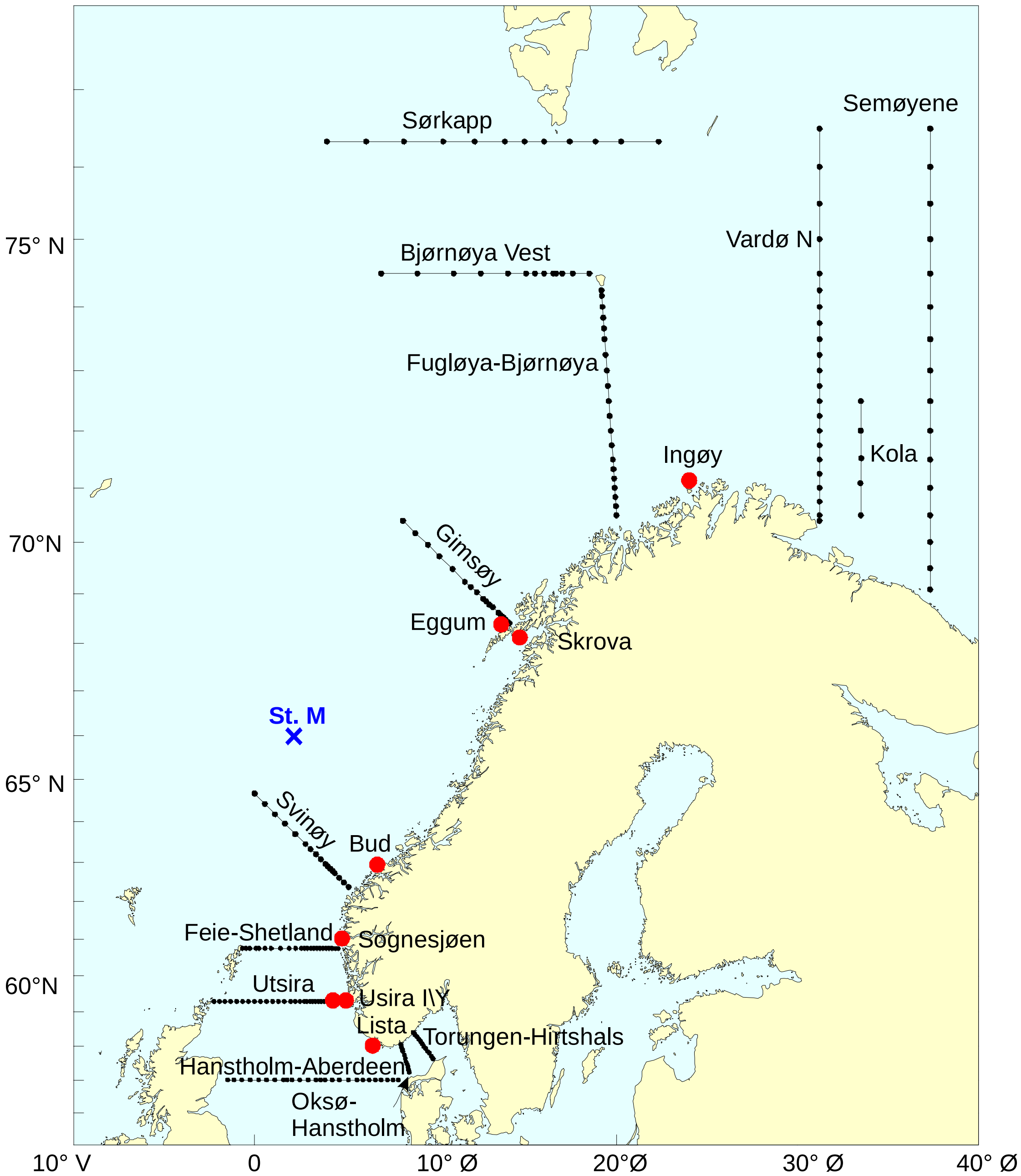


Figure 1. Standard sections and fixed oceanographic station worked by Institute of Marine Research, Bergen. The University of Bergen is responsible for station M, while the Kola section is operated by PINRO, Murmansk (ANON 2000)

The Norwegian Sea

In the Atlantic water flowing into the Norwegian Sea through the Faroe-Shetland Channel the temperature has gradually increased since 1995. In 1999 the average temperature was about 0.4°C above the long-term average, which is the highest registered since the beginning of the 1980s. In the core of the Atlantic water off the Norwegian coast the temperature decreased to around normal in 1999.

Figure 2 shows the development in temperature and salinity from south to north in the Norwegian Sea. Since the late 1970s, there has been a trend both in the temperature and salinity. The temperature shows a slight increase while the salinity has a decreasing trend. The considerable temperature increase in the southeastern Norwegian Sea during 1997 and 1998 did not continue in 1999. The temperature decreased to below the trend-line both in the Svinøy-section and the Gimsøy-section. In the Sørkapp-section, however, the temperature was slightly higher in 1999 compared with the previous year, but it was still below the trend-line. However, the temperature here has been close to the long-term mean since 1996.

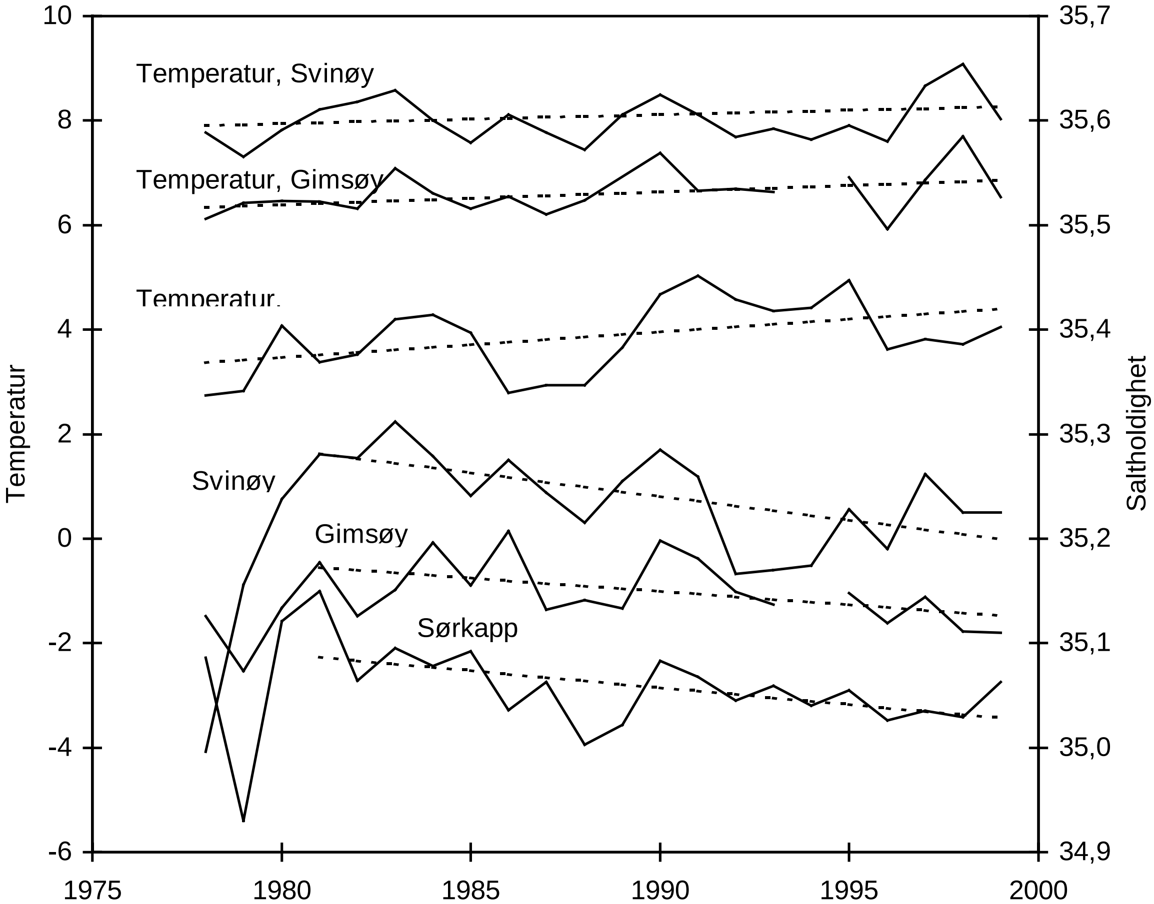


Figure 2. Temperature and salinity, observed in July/August in the core of Atlantic water in the sections Svinøy-NW, Gimsøy-NW and Sørkapp-W, averaged between 50 and 200 m depth. (ANON 2000)

Also the salinity decreased in the two southernmost sections, most in the Svinøy-section. This may be due to reduced salinity in the Atlantic inflow, but more likely it is because of increased influence of water from the East-Icelandic Current (ANON. 2000). During spring 1999 there was a large transport of Arctic water from the East-Icelandic Current into the southern part of the Norwegian Sea. This is water with temperature between 1°C and 3°C and relatively low salinity that is found at intermediate layer between 300-600m. In August 1999, the temperature in the intermediate layer of the inner part of the Svinøy section was up to 2°C lower than the long-term mean.

The Barents Sea

The Barents Sea is a shelf area, receiving an inflow of Atlantic water from the west and demonstrating considerable interannual fluctuations in water mass properties, particularly in heat content which influence on winter ice conditions. The variability in the physical conditions is monitored in three sections. Fugløya-Bear Island is situated where the inflow of Atlantic water takes place, the Vardø-N section represents the central part of the Barents Sea while Sem Islands-N represent the eastern Barents Sea. In all sections there are regular hydrographic observation, but in addition, there are also current measurements in the Fugløya- Bear Island section.

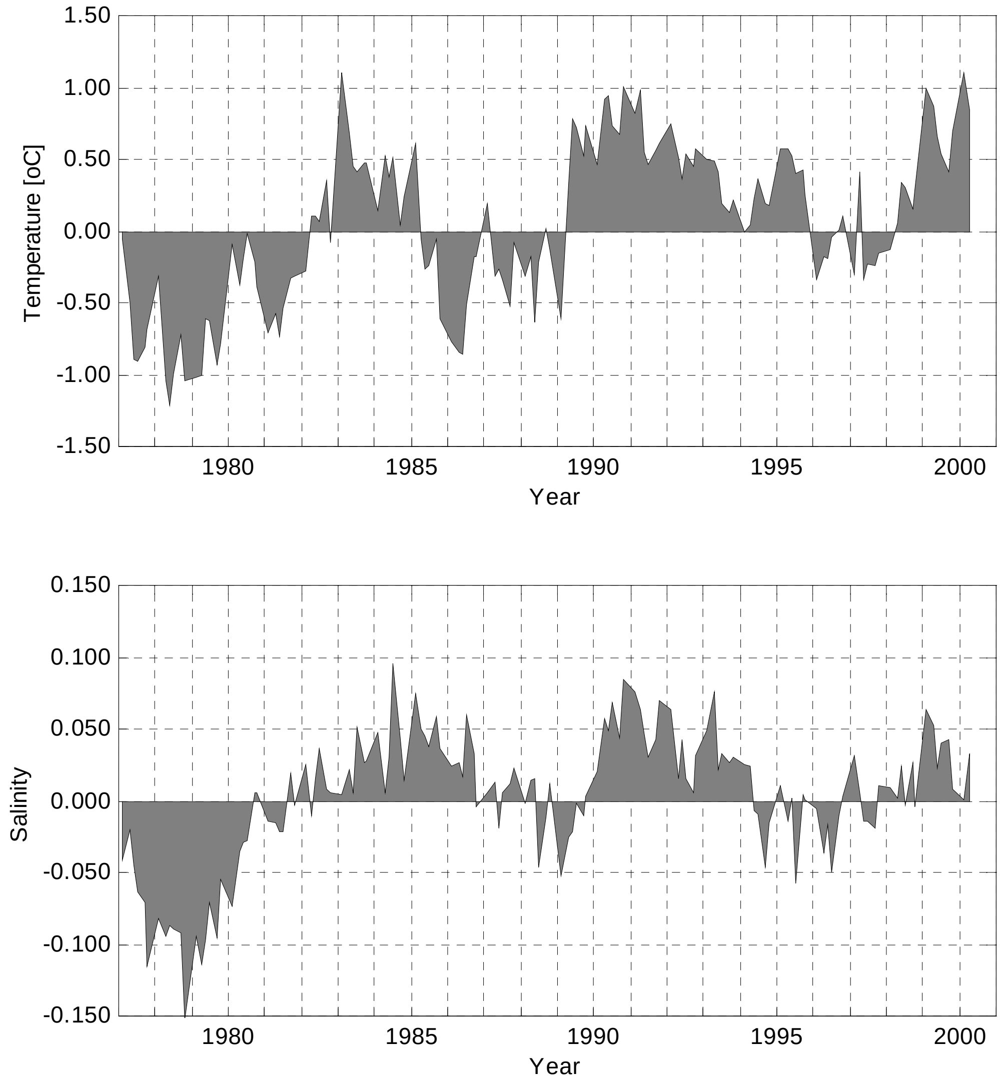


Figure 3. Temperature anomalies (upper panel) and salinity anomalies (lower panel) in the section Fugløya – Bear Island (ANON 2000).

Figure 3 shows the temperature and salinity anomalies in the Fugløya-Bear Island section in the period from 1977 to March 2000. Temperatures in the Barents Sea have been relatively high during most of the 1990s, and with a continuous warm period from 1989-1995. During 1996-1997, the temperature was just below the long-term average, while it has been some sudden changes during the last couple of years. In January 1999 the temperature increased rapidly to 0.7°C above the average, and thereafter dropped to be just above the average during spring and summer. In autumn 1999, the temperature increased slowly again, while there was a new rapid and large increase in the temperature around New Year 2000. In January the temperature was 1.1°C above the average, and we have to go back to 1983 to find a higher temperature at that time of the year. In March 2000, the temperature anomaly again decreased slightly.

Figure 4 shows the ice index for the Barents Sea. The variability in the ice coverage is closely linked to the temperature of the inflowing Atlantic water. The ice has a relatively short response time on temperature change, but usually, the sea ice distribution in the eastern Barents Sea respond a bit later than in the western part.

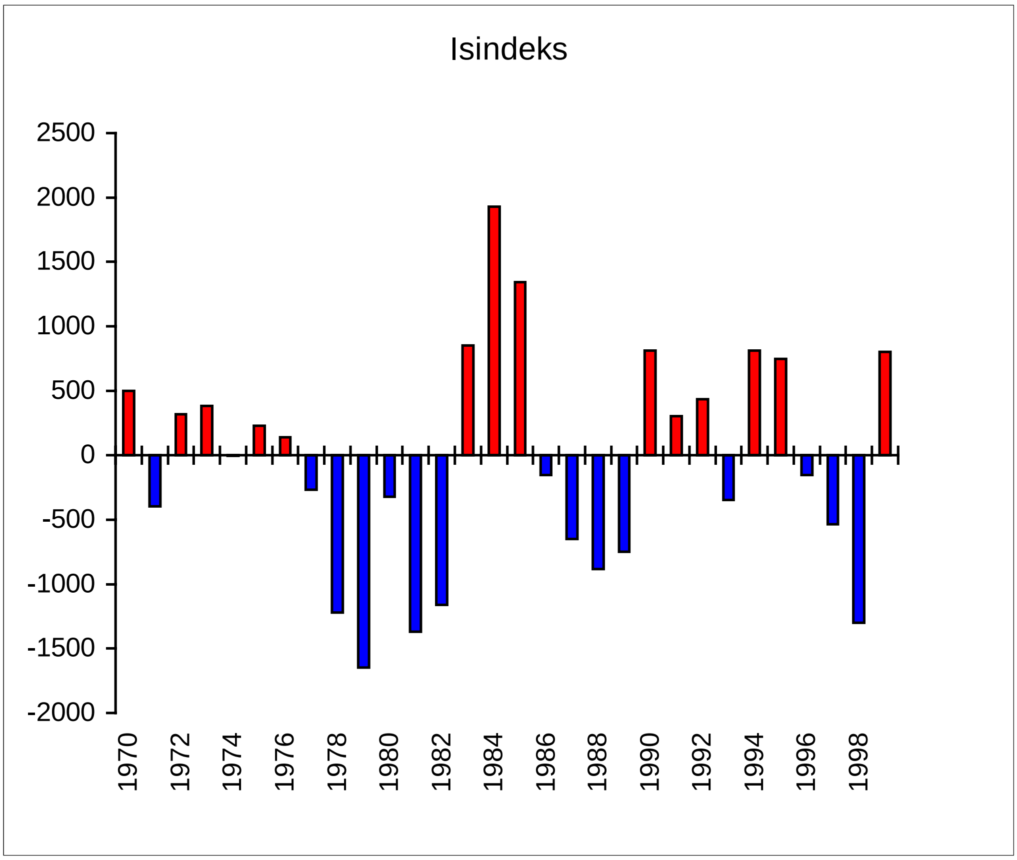


Figure 4. Ice index for the period 1970-1999. Positive values means less ice than average, while negative values show more severe ice conditions (ANON 2000).

The observed current in the section Fugløya-Bjørnøya is predominantly barotropic, and reveals large fluctuations in both current speed and lateral structure (Ingvaldsen *et el.,* 1999, 2000). Based on several years of hydrographic observations, and also by current measurement from a 2-month time series presented by Blindheim (1989), it was believed that the inflow usually take place in a wide core located in the area 72°30'-73°N with outflow further north. The long-term measurements that started in August 1997 (as part of the VEINS-project) showed a more complicated structure of the current pattern in the area. The inflow of Atlantic water may also be split in several cores. Between the cores there might be a weaker inflow or a return flow. The outflow area may at times be much wider than earlier believed, stretching from 73°30'N south to 72°N. This phenomenon is not only a short time feature; it might be present for a whole month. These patterns are most likely caused by horizontal pressure gradients caused by a change in sea-level between the Barents Sea and the Arctic or the Norwegian Sea either by accumulation of water or by an atmospheric low or high.

There seems to be seasonality in the structure of the current. During winter the frequent passing of atmospheric lows, probably in combination with the weaker stratification, intensify the currents producing a structure with strong lateral velocity-gradients and a distinct, surface-intensified, relatively high-velocity, core of inflow. During the summer, when the winds are weaker and the stratification stronger, the inflowing area is wider, and the horizontal shear and the velocities are lower. In the summer season there is in inflow in the upper 200 m in the deepest part of the Bear Island Trough.

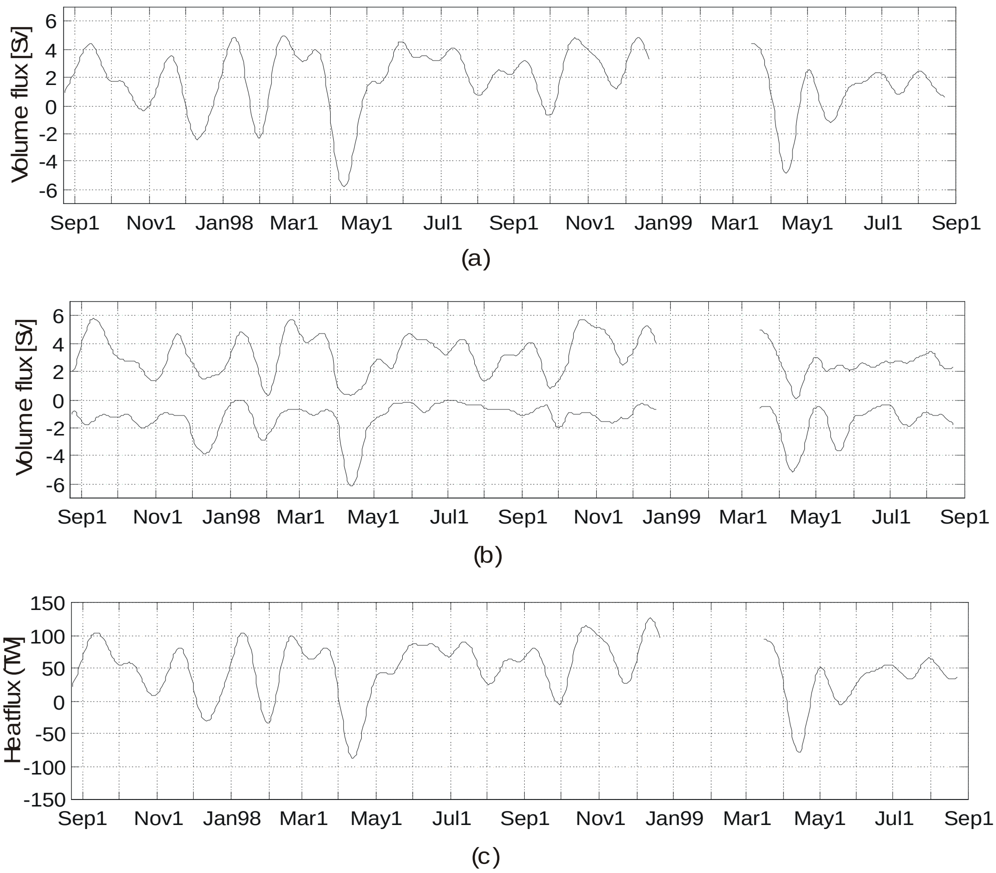


Figure 5. Total volume flux (a), volume flux separated inn inflow (positive) and outflow (negative) (b), and total heat flux across the section (c). All data have been lowpass filtered over 30 days (Ingvaldsen et al. 1999).

The time series of volume and heat transports reveal fluxes with strong variability on time scales ranging from one to several months (Figure 5). The monthly mean volume flux is fluctuating between about 5.5 Sv into and 6 Sv out of the Barents Sea, and with a standard deviation of 2 Sv. The strongest fluctuations, especially in the inflow, occur in late winter and early spring, with both maximum and minimum in this period (Figure 5 b). The recirculation seems to be more stable at a value of something near 1 Sv, but with interruptions of high outflow episodes. A very surprising result is the high outflows occurring in April both in 1998 and 1999.

A seasonal variation with higher inflow of Atlantic water during winter was anticipated for this region. For the first year of the measurement programme (September 1997-August 1998) this was not the case. Although the variability was higher during winter, there was no significant difference in mean flux between summer and winter. However, this was the period when the temperature in the Atlantic layer changed from a below to above the long-term mean (Figure 3). The transition from one climatic state to the other is likely to be enforced externally by variations in the larger scale oceanic and atmospheric circulation (Ådlandsvik and Loeng, 1991). The first year may therefore not be representative for the general seasonal cycle.

These results are consistent with results from our numerical model, which show that the seasonal cycle during 1997-1998 was weaker than the long-term mean. The measurements taken during the second year (September 1998-August 1999) show the anticipated seasonal cycle with significant higher inflow during winter. Considering the last year to be representative for the long-term mean we obtain for the winter season about 4 Sv going into the Barents Sea, whereby about 1 Sv recirculate. For the summer season the figures are 2 and 1 Sv respectively. The net heat flux is about 70 TW during winter and 35 TW during summer.

North Sea: The temperature in the upper layer of the Skagerrak and in the great parts of the North Sea stayed between 0.5 and 2.0°C above the long-term average during 1999. In the autumn 1999, the temperatures were particular high because of the warmest autumn in 100 years.

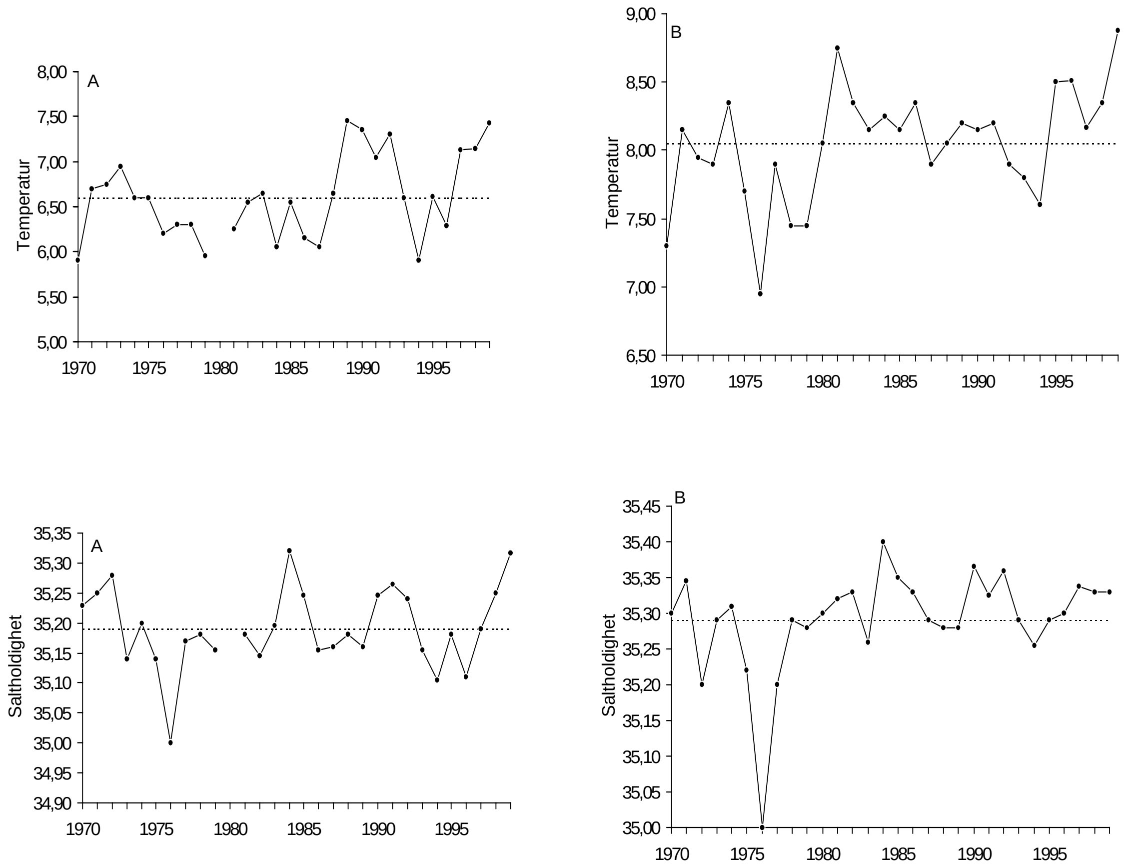


Figure 6. Temperature and salinity near bottom in the north-western part of the North Sea (A) and in the core of Atlantic water at the western shelf edge of the Norwegian Trench (B) during the summers of 1970–1999 (Anon. 2000).

Figure 6 shows the development of temperature and salinity at two positions, one near bottom in the northwestern part of the North Sea and in the core of Atlantic water at the western shelf edge of the Norwegian Trench. The measurements are carried out during summer and represent the last winter situation. On the plateau, there has been a continuous increase both in temperature and salinity since 1996. The development is relative similar in the core of the Atlantic inflow. The main difference is that the temperature and salinity values are a bit higher in the core of the Atlantic inflow. The temperatures observed in the core of the Atlantic inflow is the highest observed since measurements started in 1970.

References

Anon. 2000. Havets Miljø 2000. FiskenHav. Særnr. 2, 2000. Institute of Marine Research, Bergen, Norway.

Blindheim, J., 1989. Cascading of Barents Sea bottom water into the Norwegian Sea. Rapp. P.-v. Réun. Cons. int. Explor. Mer 188, 49-58.

Ingvaldsen, R., Asplin, L., and Loeng, H., 1999. Short time variability in the Atlantic inflow to the Barents Sea. ICES C.M. 1999/L:05.

Ingvaldsen, R., Loeng, H., and Asplin, L., 2000. Monthly to seasonal variability in the Atlantic inflow to the Barents Sea. Continental Shelf Research, submitted. Loeng, H., Ozhigin, V., Ådlandsvik, B., 1997. Water fluxes through the Barents Sea. ICES Journal of Marine Science, 54, 310-317.

Parsons, A.R., 1995. On the Barents Sea Polar Front in summer and interpretations of the associated regional oceanography using an arctic ocean general circulation model. Ph.D. Thesis. Naval Postgraduate School Monterey, California, 185pp.

ANNEX P – AREA 11 (BARENTS SEA) POLISH REPORT

1999 Summer condition at the Norwegian-Barents Sea opening

Data

During regular summer cruises of r.v. "Oceania" (since 1987) to the GIN Seas the CTD and ADCP measurements in the area between Norway and Spitsbergen were made. Sea Bird and Guideline CTDs and shipmounted RDJ 150 KHz ADCP were used. Figure 1 shows location of hydrographic stations and transects.

Results

At the southern most station A both temperature and salinity of the core of Atlantic Waters (7.2^{o}C and 35.18 psu) were higher then previous year by about 1.2^{o}C and 0.04 psu. Similar high values were recorded here during summer 1992 (Figure 2). High temperature was also recorded in 1989. The lowest temperature (5.3^{o}C) and salinity (35.09) were observed in 1988.

At station H located against the mouth of Bjornoya Trough Atlantic Water was also warmer (≈ 6.3^{o}C) and saltier (35.13 psu) then year before. Temperature was also high in 1992 and 1989 and low in 1988 and 1993. The highest and lowest salinity was recorded in 1989 and 1988 respectively.

At this location as well as at the more northerly located station K (75^{o}N) temperature and salinity were increasing since 1997. At the station K temperature (6.6^{o}C) was even higher then at more southerly located station H (6.3^{o}C). Except extreme values of temperature in 1999 (high) and 1997 and 1988 (low) and salinity in 1989 (high) and 1988 (low) both parameters do not show big variations. At the most northerly station M opposite to the mouth of Storfjordrenna in 1997 and 1999 the Atlantic Water was not presents. The main stream of Atlantic Waters was located to the west of this station. In years 1988-1996 and 19998 temperature and salinity was rather stable with the tendency to decrease. 1988 and 1998 show very low values of both parameters.

Baroclinic transport across 15^{o}E transect (Figure3) was generally increasing since 1993 with interrupting decreases in 1996 and 1998.

Atlantic Water layer thickness, its mean temperature and salinity along 15^{o}E transect for 12 summers (1988-1999) (Figure8) show bigger volume, lover temperature and higher salinity at the end of 80 th, low volume at 1990-97, higher volume, higher salinity and temperature during 1992-96, lower values at 1996-97 and higher again during last 2 years.

In the Sorkapp region three different water masses collide: warm, saline Atlantic Water carried by WSC, cold and fresh Barents Sea/Polar Water of East Spitsbergen and next Sorkapp Current and very cold (below – 1.5^{o}C) and saline (over 35.2 psu) brine origin water produced during winter freezing on the East Svalbard shelf and cascading down the slope of Storfjord and Storfjordrenna (Figure 6) close to the bottom.

Instability at the fronts between this currents plus influence of bottom topography causes complicated circulation pattern, mesoscale eddies in particular. Both cyclonic and anticyclonic eddies are found. Rarely seen elsewhere, cold water lense in the cyclonic eddy is observed here very often.

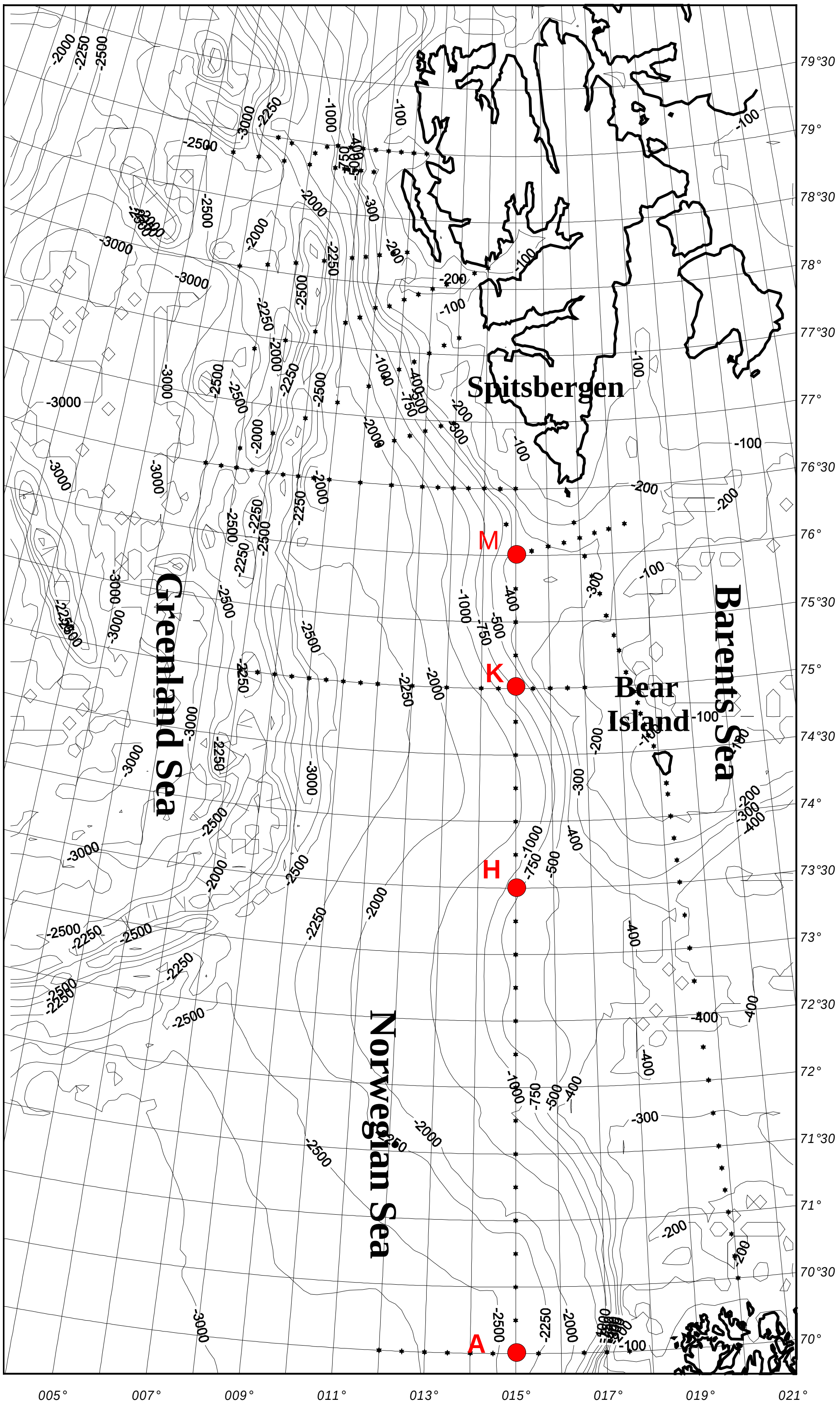


Fig.1 Location of CTD stations and transects

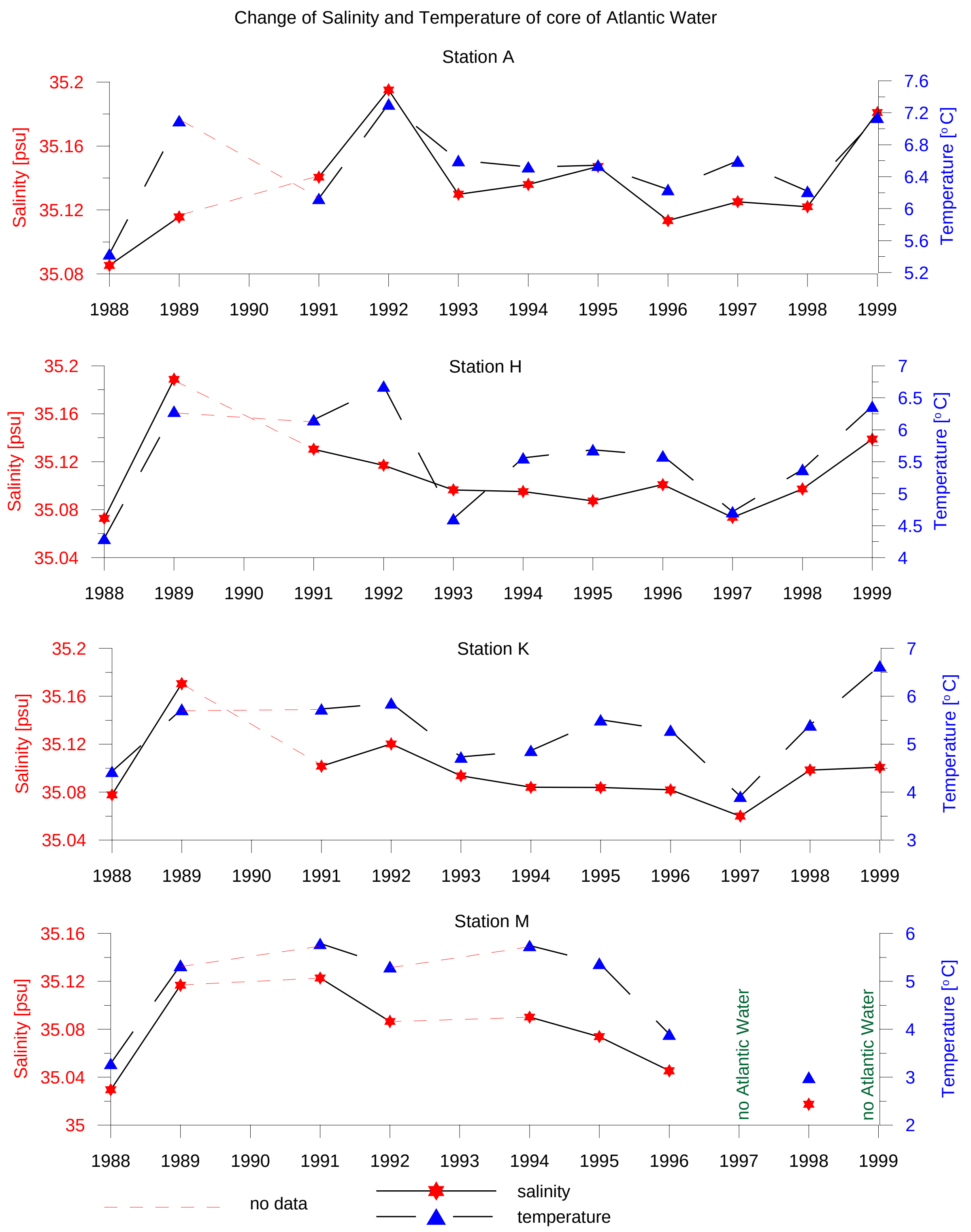
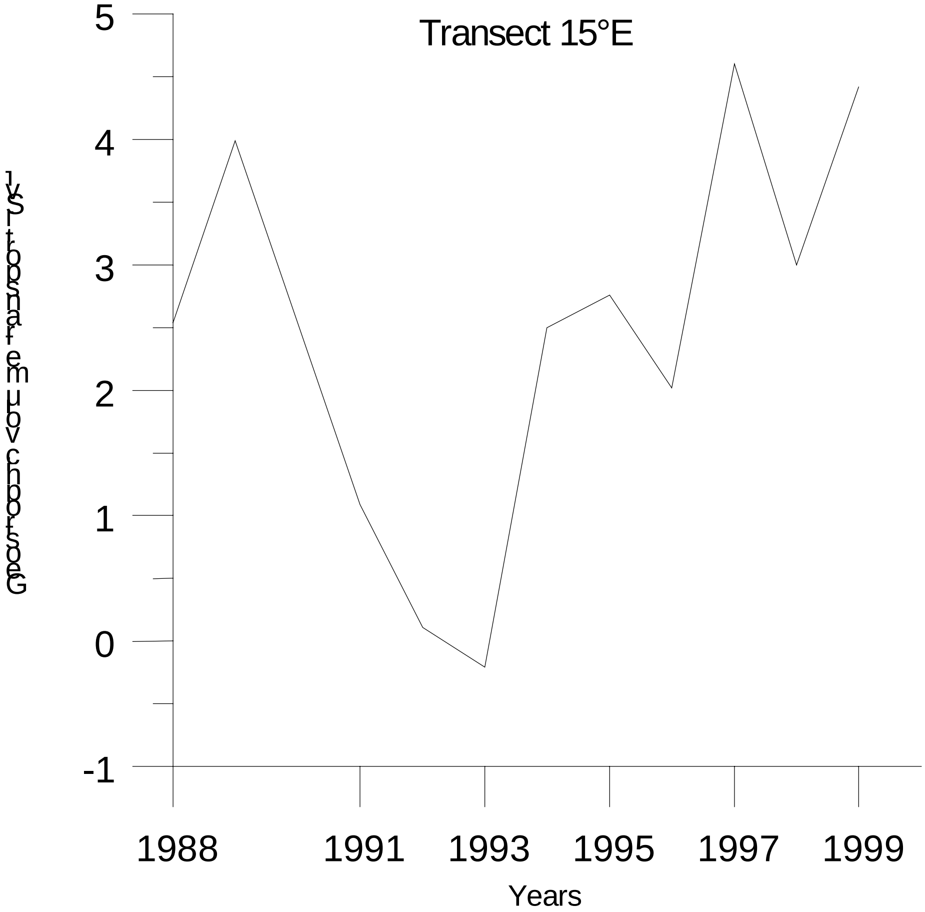


Fig.2 Temperature and salinity of Atlantic Water core layer at choosen stations



year	Vol. (E) [Sv]	Vol. (W) [Sv]	Vol. total [Sv]
1988	3.69	1.15	2.54
1989	8.92	4.93	3.99
1991	4.32	3.23	1.09
1992	5.21	5.10	0.11
1993	2.65	2.86	-0.21
1994	4.62	2.12	2.5
1995	11.26	8.5	2.76
1996	9.72	7.7	2.02
1997	10.87	6.28	4.6
1998	10.6	7.6	3
1999	8.38	3.96	4.42

Fig.3 Volume of geostrophic transport (upper 1000m) across the 15°E transect.

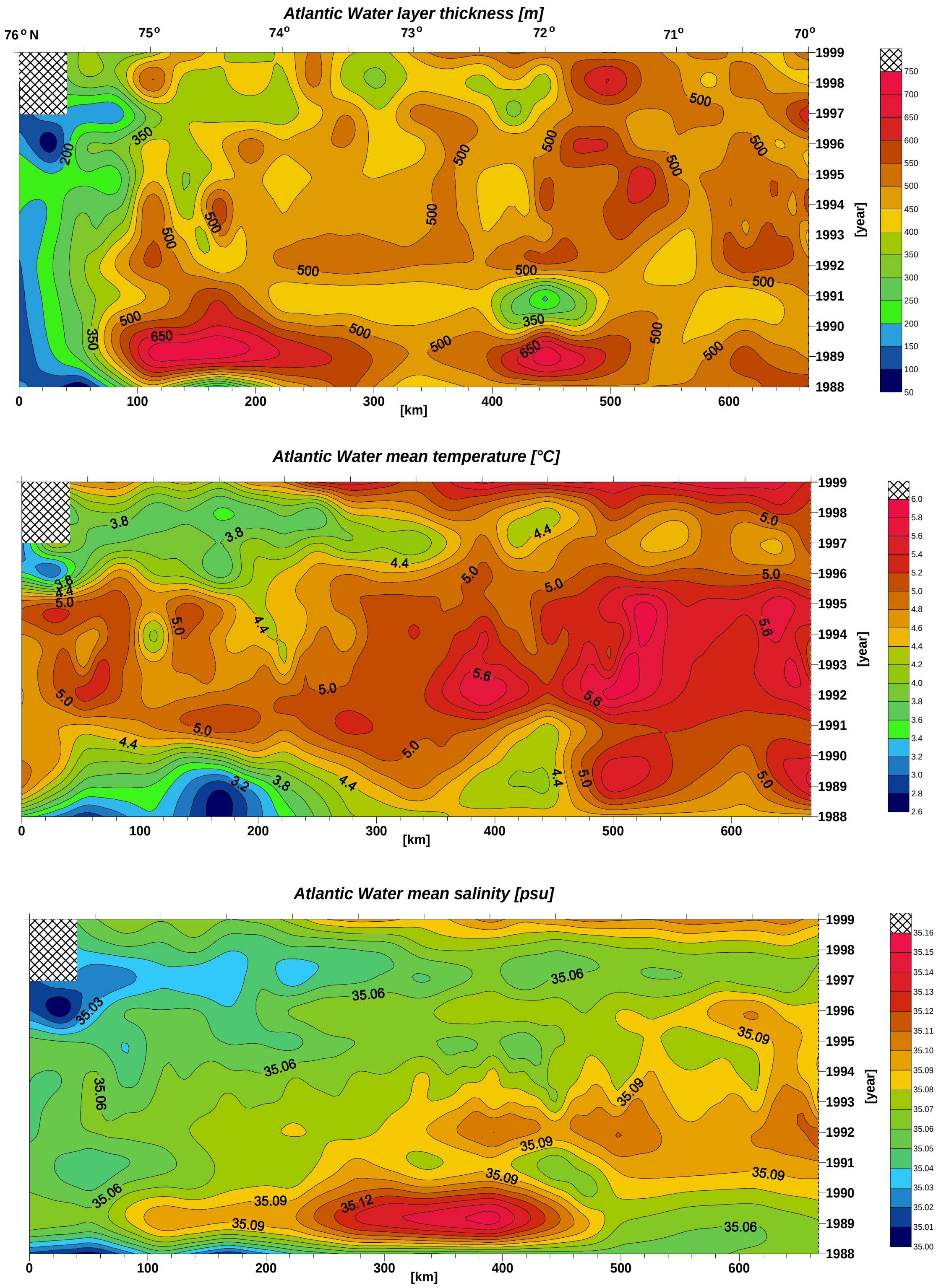


Fig4. Atlantic Water layer thicknes, its mean temperature and salinity along 15°E transect.

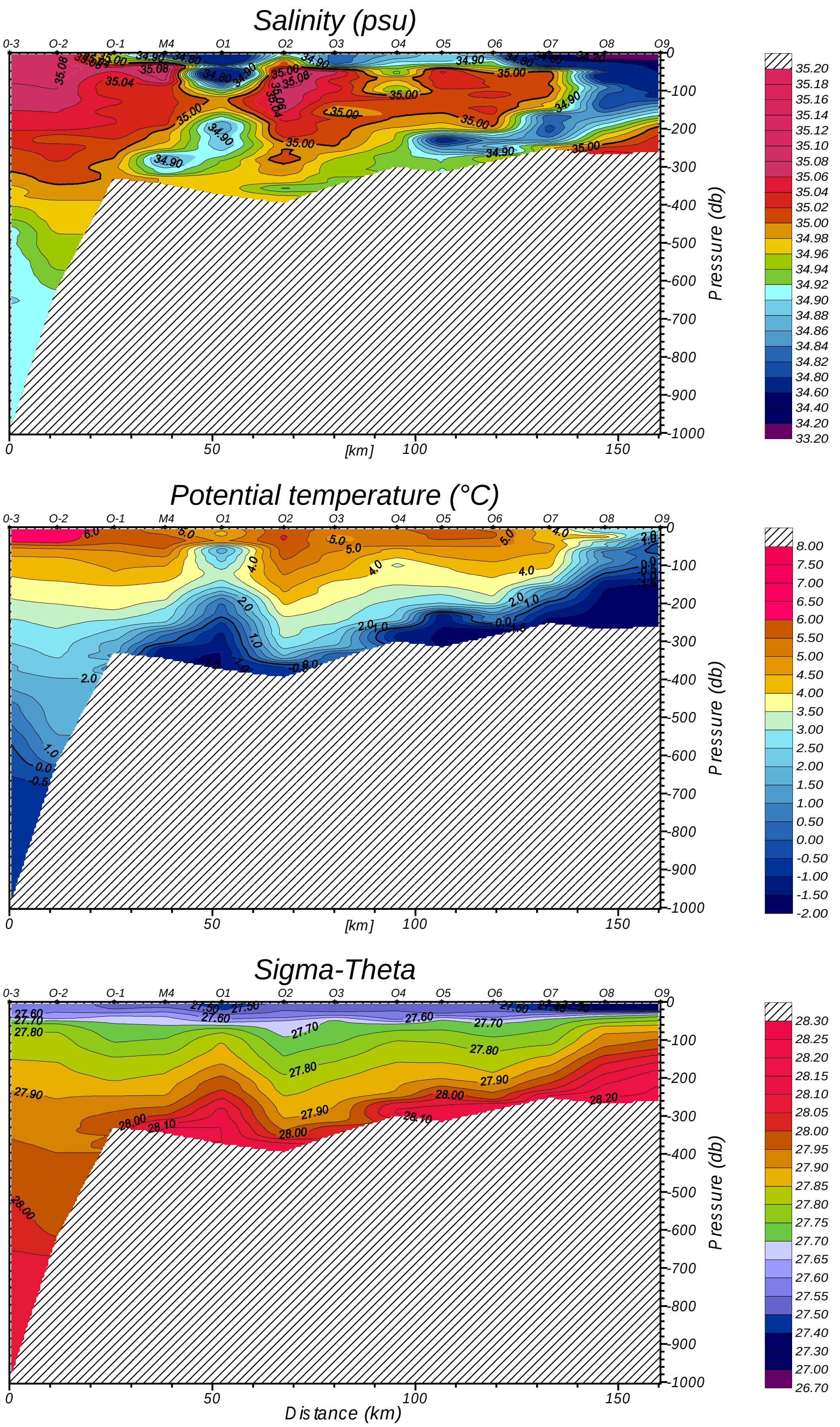


Fig.5 Salinity, temperature and density at the transect along the Storfjordrenna axis

ANNEX Q – AREAS 10 AND 11 (NORWEGIAN AND BARENTS SEAS) RUSSIAN REPORT

Russian Standard Sections in the Barents and Norwegian Seas

V. Ozhigin, PINRO, Murmansk, Russia

The Barents Sea

The main Russian standard sections in the Barents Sea are shown in Figure 1.The most regularly occupied one is the Kola Section (along 33°30′E longitude). In 1999 it was occupied 11 times.

The oceanographic conditions in the Barents Sea in 1999 were closely linked with the large-scale atmospheric circulation. The latter caused transport of warm air masses over the western Barents Sea and prevalence of cold air masses over the eastern part.

Air temperature data show significant difference between western and eastern parts of the Barents Sea. Air temperature over the western Barents Sea was variable in 1999 with high positive anomalies in winter and early spring, temperature decrease to the long-term average level in summer and a new increase in autumn. Cold air temperatures prevailed over the eastern Barents Sea in 1999. During the year air temperature increased from about 5 °C below the long-term average in January to about 3 °C above the normal in December.

Spatial contrasts in atmospheric circulation and air temperatures caused less than normal ice coverage in the northwestern Barents Sea and severe ice conditions in the eastern Barents Sea. In general, ice coverage in the whole area in 1999 was wider than normal but less than in 1998.

Spatial contrasts in air-sea interaction processes reflected also in the sea surface temperature (SST) anomalies distribution over the Barents Sea. SST was considerably higher than the long-term mean in the area west off the Bear Island and Spitsbergen in 1999. Measurements made in deeper layers show that the warming affected the whole water column over the shelf areas. Yearly mean SST in the southwestern Barents Sea was close to the normal but there was temperature increase in winter, decrease in spring and rapid increase during the second half of the year. In the southeastern sea, yearly mean SST was lower than the long-term average. There also was a considerable and rapid temperature increase in this area in the second half of the year.

Seasonal change of temperature in the Kola section in 1999 (Figure 2) was similar to seasonal variation of SST in the southwestern Barents Sea. The temperature varied during the year. There was a rapid temperature increase in the beginning of 1999. In March and April temperature was 0.5-0.6 °C above the normal. In late spring and summer temperature decreased considerably, to the level close to the long-term mean in August. At the end of 1999 there was a new rapid temperature increase, which continued at the beginning of the year 2000. From December to February temperature was 0.9-1.1 °C above the long-term average. In March the temperature decreased to 0.7 °C above the normal. Figure 3 shows that 1999 was a warm year. It is expected that the year 2000 will be a moderately warm year.

The Norwegian Sea

The standard sections occupied by PINRO research vessels in the Norwegian Sea are shown in Figure 4. These sections have been occupied in June of every year since 1959. In 1999 observations were made along the Sections 2c, 5c, 6c and 7c.

Southerly winds prevailed over the most Norwegian Sea and caused increased inflow of warm Atlantic Water from the Northeast Atlantic in 1999. Air temperature over the sea was close or slightly above the long-term average during the year.

Data from the summer survey in the southern and central Norwegian Sea show higher than in 1998 transport of Atlantic Water with the Norwegian Current, especially into the eastern Norwegian Sea. The temperature in the 0-200 m layer of the Eastern Branch of the Norwegian Current increased considerably in 1999 (Figure 5a). In the Section 6c it was 0.5 °C above the long-term mean and in the Section 7c it was even higher (1.2 °C above the normal). The temperature in the central Norwegian Sea remained lower than the long-term average but slightly higher than in 1998 (Figure 5b). In the Section 6c it was 0.4 °C below the long-term mean and in the area to the north (Section 7c) it was close to the normal.

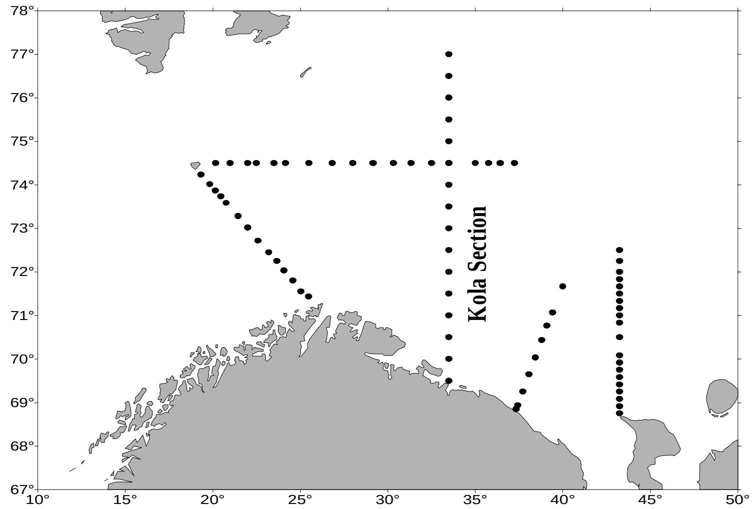


Figure 1. Main Russian standard sections in the Barents Sea

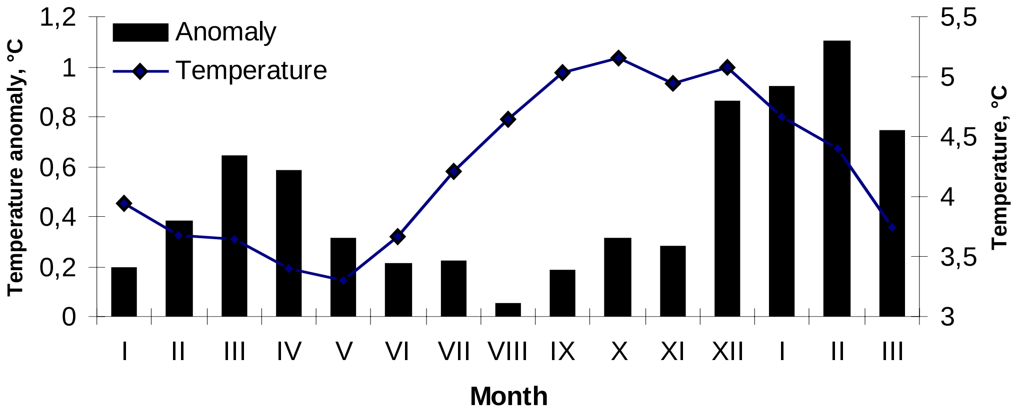


Figure 2. Monthly mean temperature and its anomalies in the 0-200 m layer in the Kola Section in 1999 and in the beginning of the year 2000

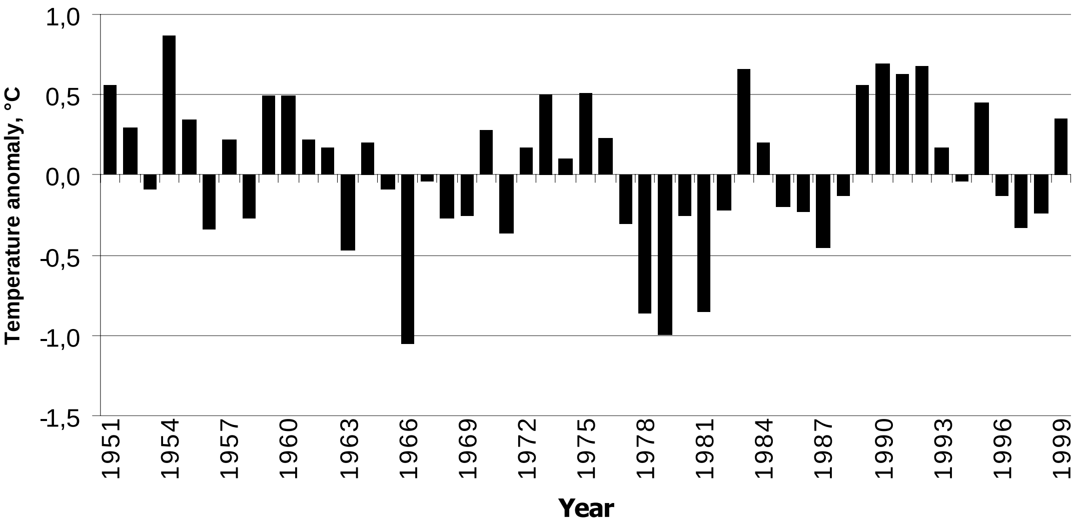


Figure 3. Yearly mean temperature anomalies in the 0-200 m layer in the Kola Section in 1951-1999

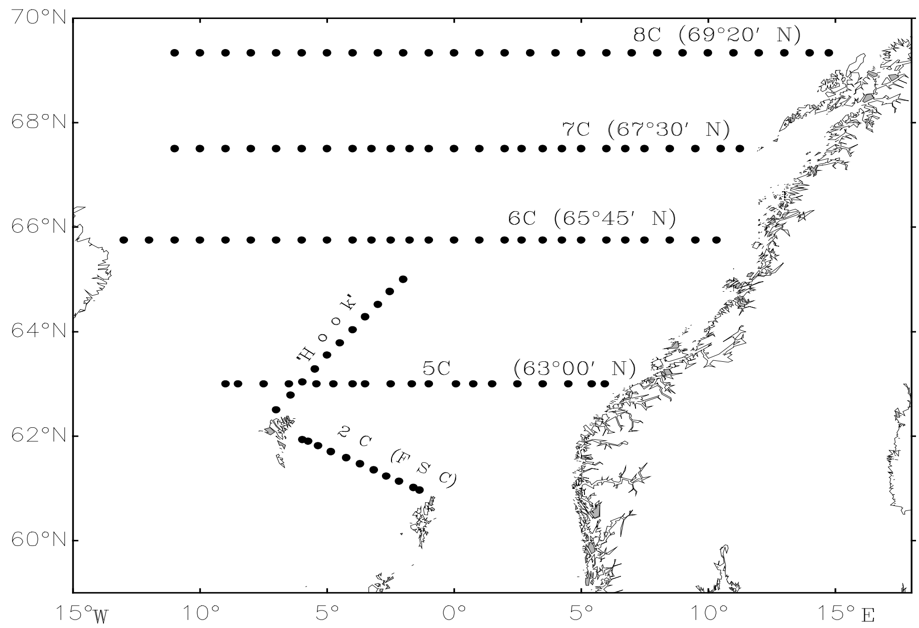


Figure 4. Russian standard sections in the Norwegian Sea

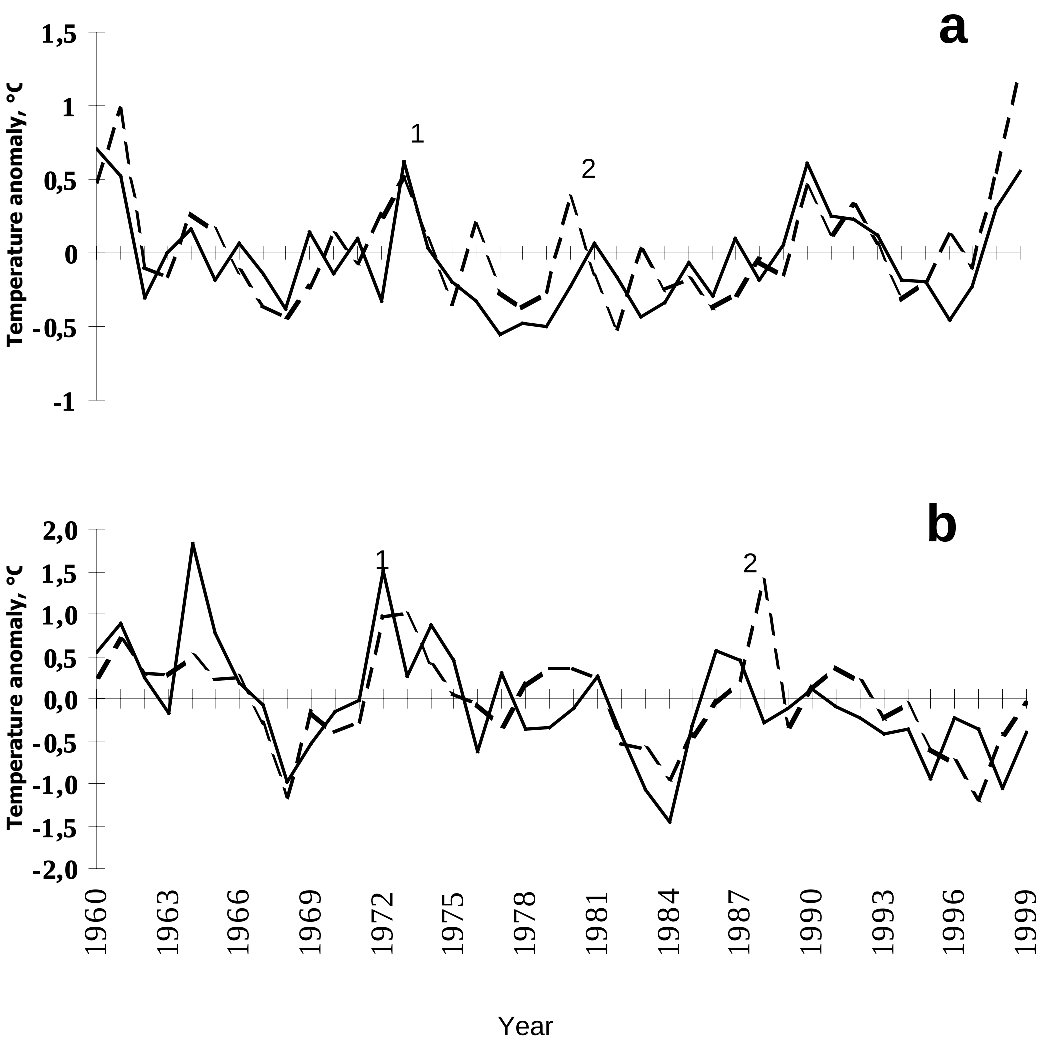


Figure 5. Temperature anomalies of Atlantic Waters of the Norwegian Current's East Branch (a) and the mixed waters in the central Norwegian Sea (b) in the 0-200 m layer in the Sections 6c (1) and 7c (2) in June 1960-1999

ANNEX R – AREA 12 (GREENLAND SEA) GERMAN REPORT

Hydrographic conditions in the Greenland Sea and Fram Strait

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The hydrographic conditions in the Greenland Sea are monitored by AWI on a section along 75° N and in the framework of the European Union MAST III Programme VEINS (Variability of Exchanges in the Northern Seas) in Fram Strait (Figure 1). The temperature and salinity transects obtained in 1998 are displayed in Figs. 2 and 3.

The variations of the properties of the Atlantic Water (AW) and the Return Atlantic Water (RAW) observed on the CTD-transects at 75°N are displayed in Tab. 1 and Figure 4. The properties of the Atlantic Water are given as temperature averages over a depth range from 50 to 150 m of the stations between 10° and 13° E (inclusive). The Return Atlantic Water is characterised by the temperature and the salinity maxima below 50 m averaged over three stations west of 11.5° W. The number of stations used to calculate the averages are indicated in Tab. 1 for each item (i.e. for T-AW, S-AW, T-RAW, and S-RAW). Stations in the AW have a spacing of 10 nautical miles, those used for RAW a spacing of less than 5 nautical miles. The salinities for 1989 and 1990 are of reduced accuracy because of instrumental problems (Salzgitter CTD working erroneously). All other data from SBE 911+.

Table 1: Temperature and salinity for AW and RAW from CTD-transects at 75°N, sampled by AWI (G. Budeus).

Year	Month	T-AW	S-AW	T-RAW	S-RAW	#stations
1989	06	4.24	(35.07)	2.08	(34.94)	5/(5)/3/(3)
1990	08	5.12	(35.10)	2.50	(34.97)	5/(5)/3/(3)
1994	07	4.54	35.07	2.57	34.99	5/5/3/3
1995	10	4.87	35.04	3.48	35.01	5/5/3/3
1996	09	4.67	35.06	-	-	3/3/-/-
1997	09	4.17	35.04	2.64	34.96	5/5/3/3
1998	09	4.27	35.04	2.21	34.95	5/5/3/3
1999	07	4.55	35.07	1.94	34.95	5/2/3/3

The variations of the water mass properties in Fram Strait are displayed in Figure 5. Mean temperatures and salinities are give for two depth levels (5 to 30 m and 50 to 500 m). Horizontally three areas are distinguished. The West Spitsbergen Current (WSC), between the shelf edge and 5° E, the Return Atlantic Current (RAC) between 3°W and 5°E and the East Greenland Current (EGC) between 3°W and the Greenland shelf edge. The data from 1988 are taken in June, the other surveys occurred in August/September.

To obtain transport estimates through Fram Strait by direct measurements, 14 current meter moorings were deployed in Fram Strait from September 1997 to September 1999 with a replacement in September 1998. The measurements were carried out in the framework of VEINS and are planned to continue under OPEC (Ocean Processes and European Climate). The moored instruments cover the water column from 10 m above the seabed to approximately 60 m below the surface. Three moorings in the East Greenland Current were equipped with upward looking Doppler Current Meters reaching to the sea surface. In the horizontal the measurements extend from 6∞51íW - the eastern Greenland shelf break - to 8∞40íE - the western coast of Spitsbergen - on a line along 78∞50íN on the eastern part and along 79°N on the western part of the transect. The flow field through the strait was compiled by interpolation based on the records of 41 current meters for the first year and 45 for the second year.

The velocity field averaged over two years from September 1997 to September 1999 reflects the well known current system in Fram Strait. The northward flowing West Spitsbergen Current reaches a maximum speed in the core over the upper continental slope of 24 cm/s. The core of the southward flowing East Greenland Current reaches 9 cm/s. The volume transports obtained from the mean currents and the area occupied by the two current systems result as 8 Sv to the north and 9 Sv to the south with a net transport through the strait of 1 Sv to the south. However, the time variability of the area occupied by each of the two current systems on the vertical transect causes their transports to be nonlinear quantities. The effect of the nonlinearity on the derived mean properties is still under investigation. Averages over a time series of monthly mean transports (Figure 6) result in 10.8 Sv to the north and 11.2 Sv to the south.

For more details see G. Krause (Ed), 1999: The Expedition ARKTIS XV/1 of RV "Polarstern" in 1999, Berichte zur Polarforschung, 339, 28pp and U. Schauer (Ed), 2000: The Expedition ARKTIS XV/3 of RV "Polarstern" in 1999, Berichte zur Polarforschung, 350, 63pp.

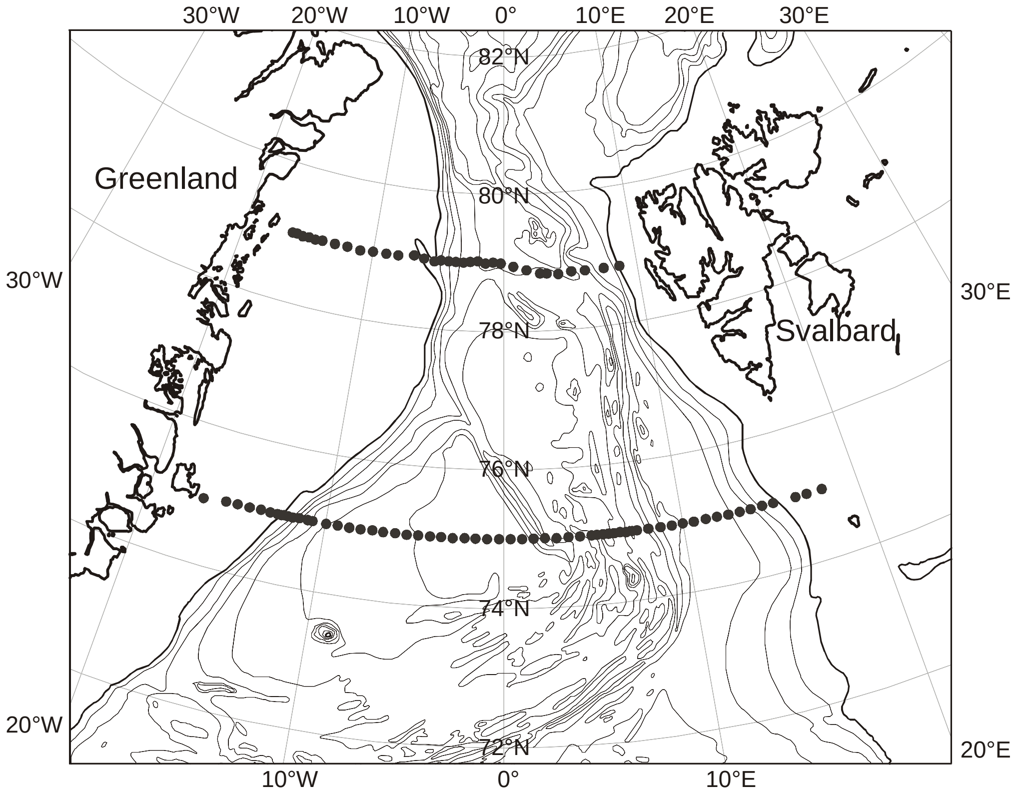

Fig. 1

Map with the positions of the CTD profiles carried out at 75° N in the Greenland Sea and in Fram Strait.

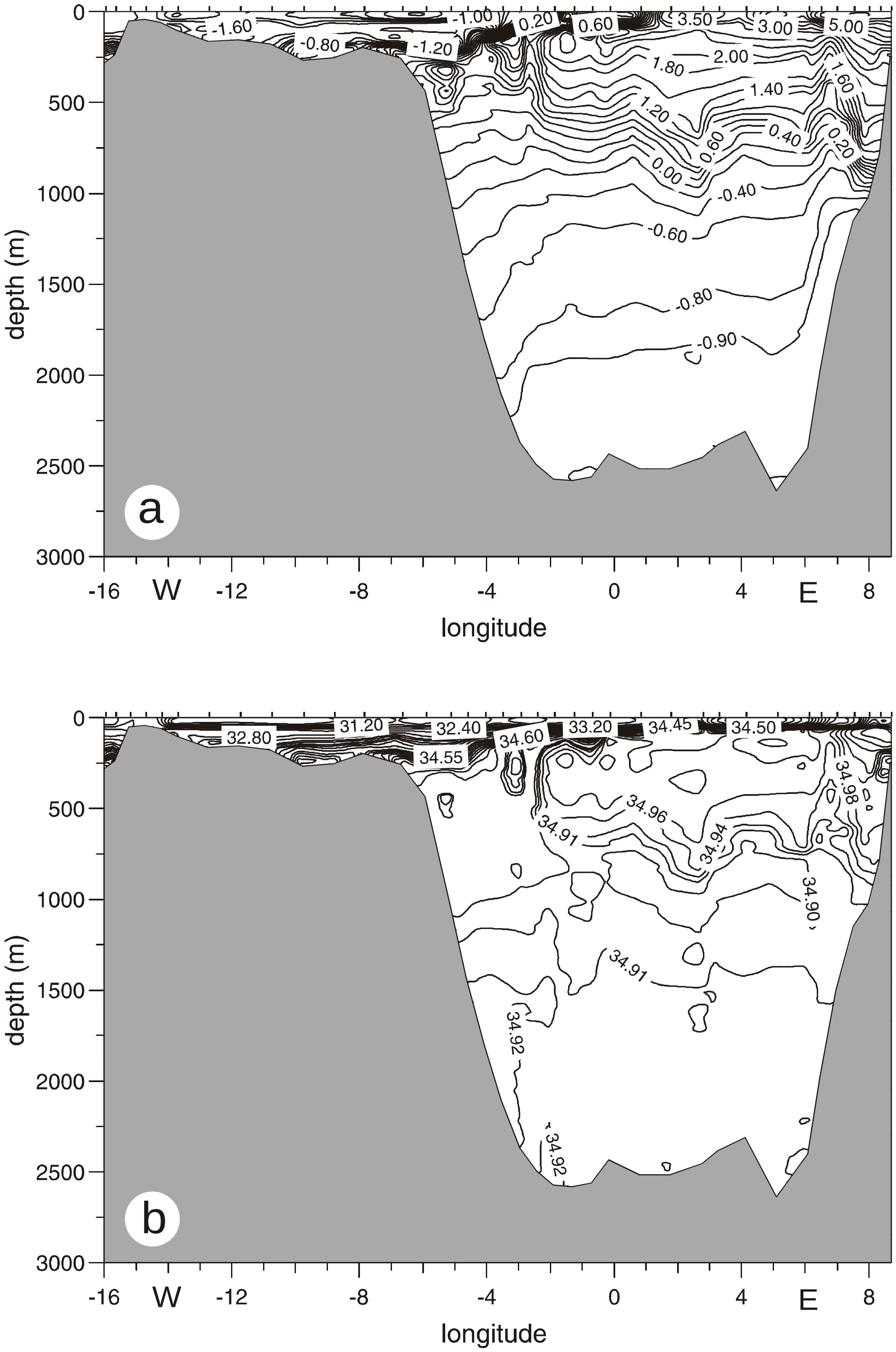

Fig. 2

Vertical transect of potential temperature (a) and salinity (b) across Fram Strait carried out in summer 1998.

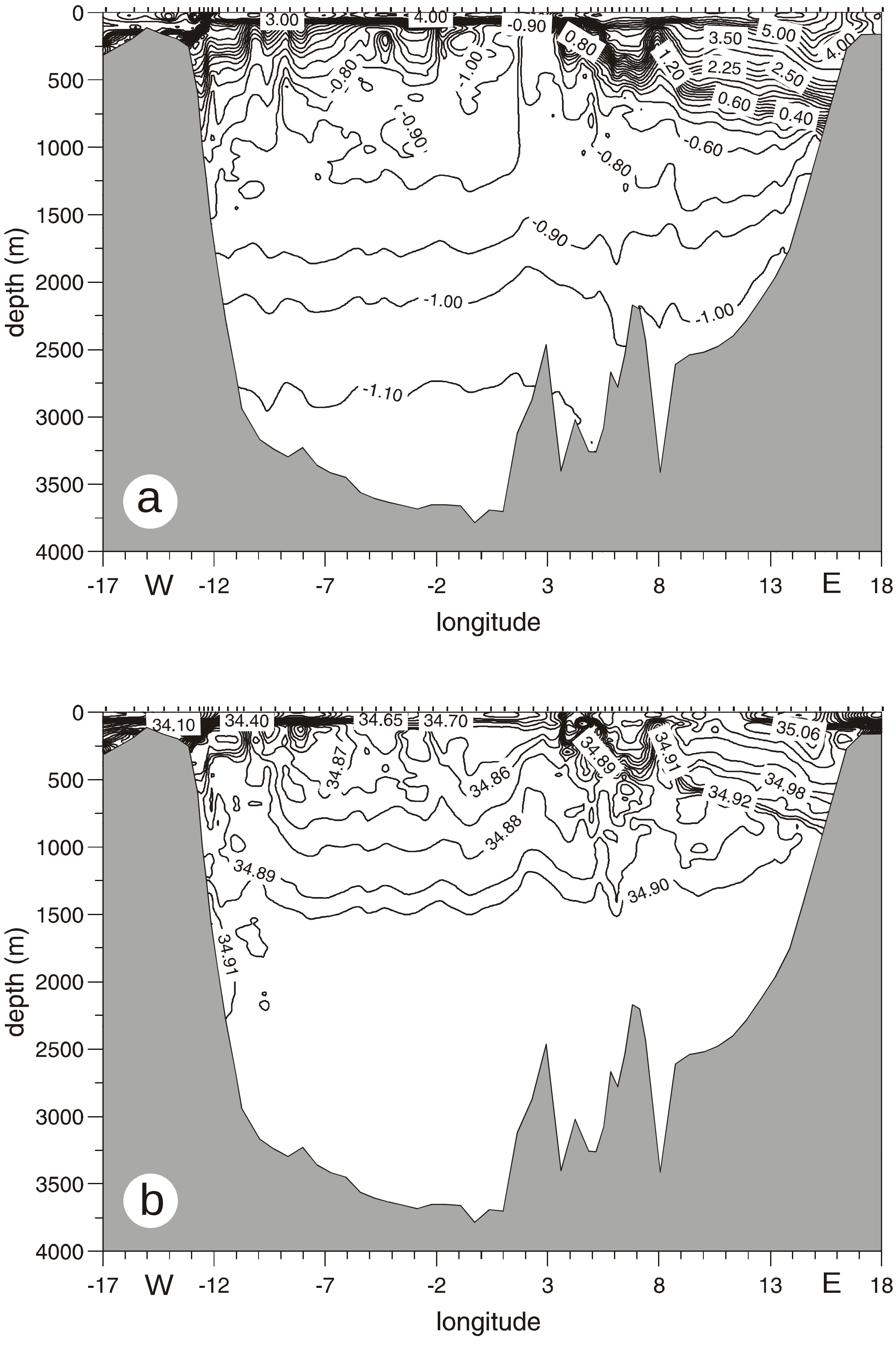

Fig. 3

Vertical transect of potential temperature (a) and salinity (b) at 75°N in the Greenland Sea carried out in summer 1998.

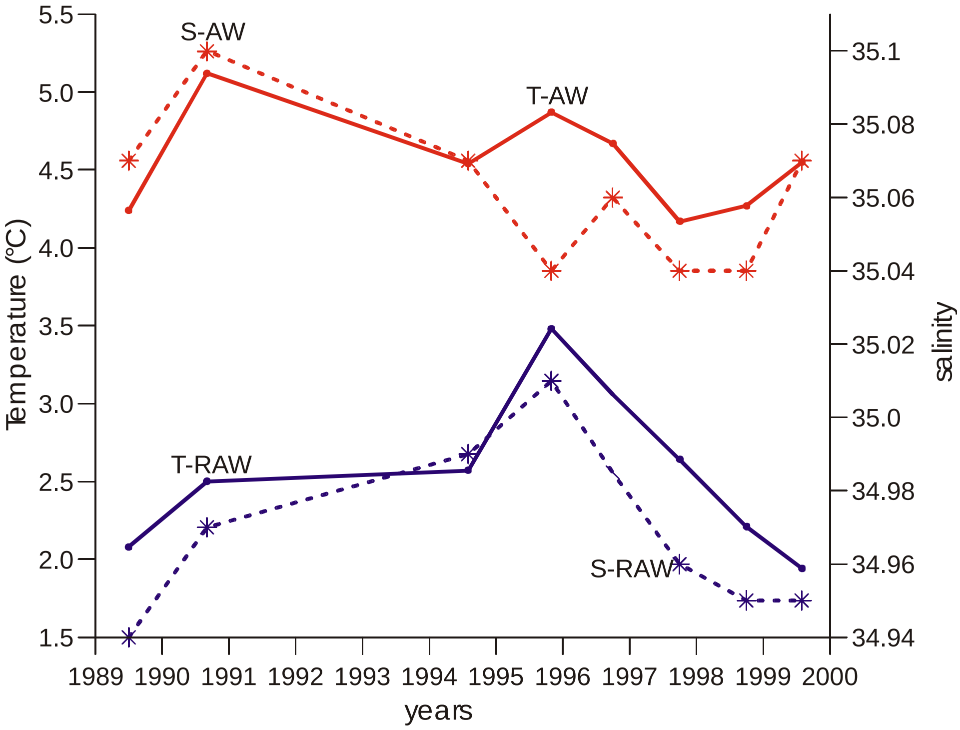

Fig. 4

The variations of the properties of the Atlantic Water (AW) and the Return Atlantic Water (RAW) observed on the CTD-transects at 75°N.

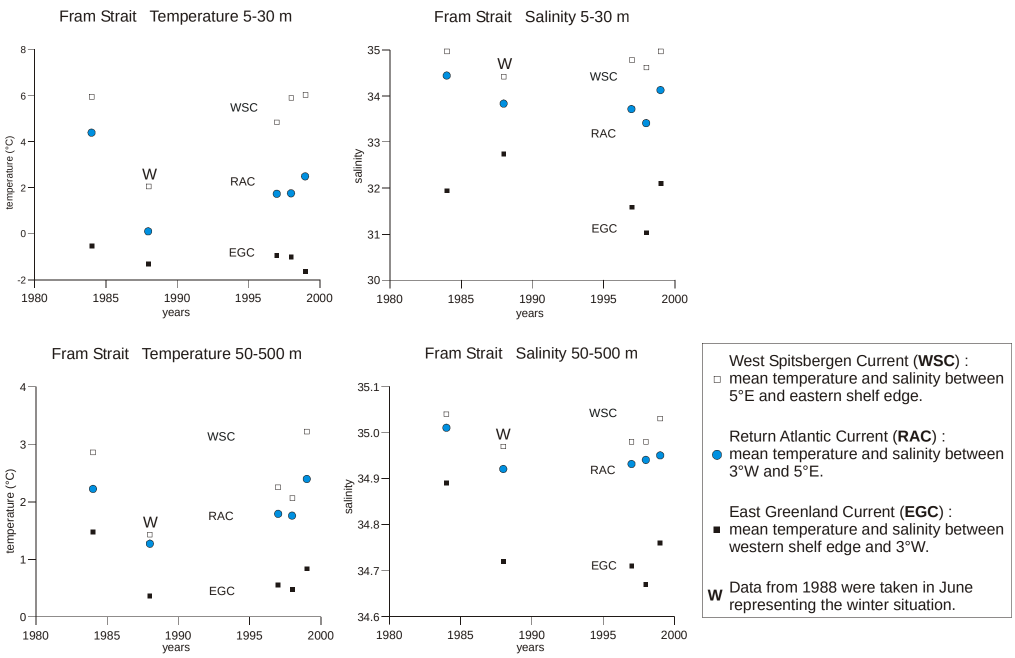

Fig. 5

The variations of the mean temperatures and salinities in Fram Strait in the West Spitsbergen Current (WSC), the Return Atlantic Current (RAC) and the Greenland Current (EGC) The data from 1988 are taken in June, the other surveys occurred in August/September.

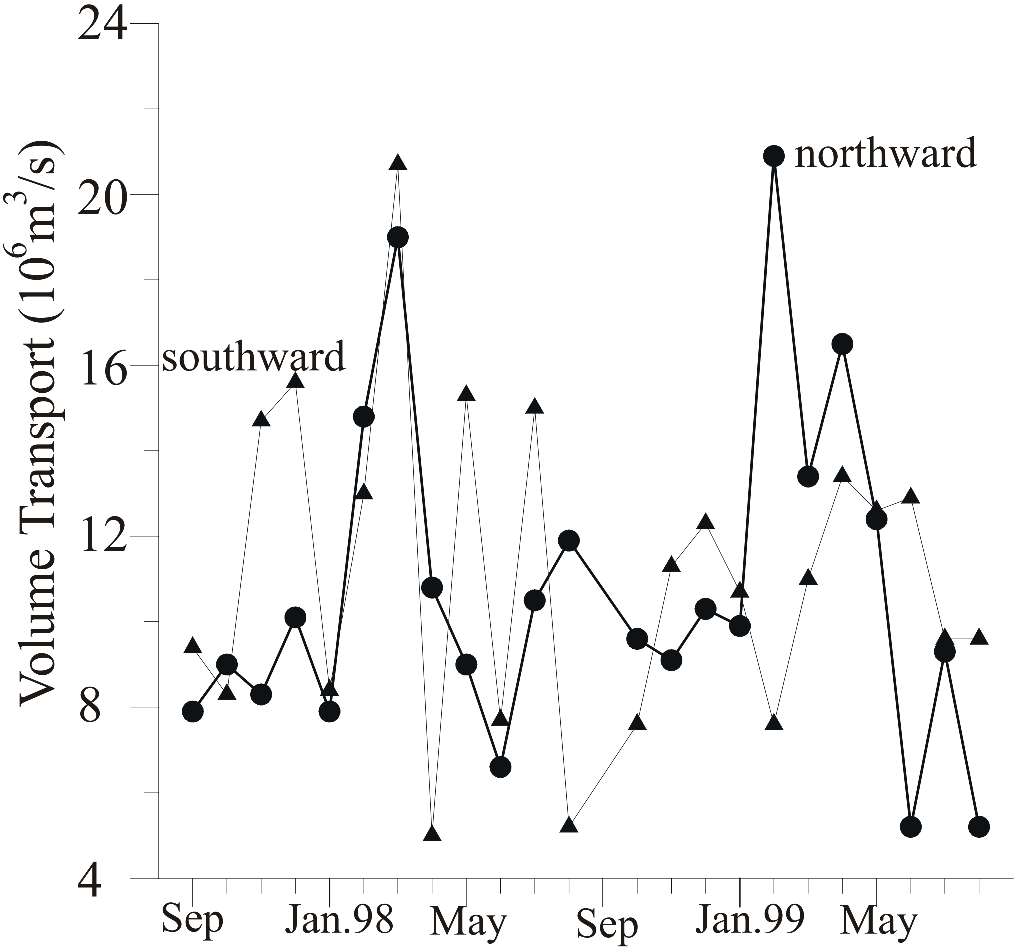

Fig. 6

Monthly mean volume transports through Fram Strait obtained from moored current meter measurements form September 1997 to September 1999.

The Annual

ICES

Ocean Climate Status Summary

1999/2000

Prepared by the

Working Group on Oceanic Hydrography

Editor: Bill Turrell

WWW.ices.dk/status/clim9900

The 1999/2000 ICES Annual Ocean Climate Status Summary

Summary

The North Atlantic marine climate is largely controlled by the so-called North Atlantic Oscillation or NAO, which is driven by the Azores High and the Iceland Low pressure cells. In a given year, the intensity of the NAO is simply described by the pressure difference between these two main cells and this NAO Index is normally measured between Lisbon (Portugal) and Stykkisholmur (Iceland). Over the past four decades, the NAO Index has shown a progressive increase from its most extreme and persistent negative state in the 1960s to its most extreme positive state during the late-1980s early-1990s, allowing us to build up a picture of the kinds of ocean response to expect under either phase of the NAO.

Following its long period of amplification, the NAO index suddenly underwent a sharp decrease to a short-lived minimum in the winter of 1995-96 with radical and recognisable changes in the North Atlantic (see section below). Since that temporary minimum, we have seen a steady recovery towards positive values of the NAO and the resumption of many of the ocean-climate features we have come to associate with that positive phase.

However, the recovery has so far been incomplete. Whereas warm, saline conditions have resumed along the eastern boundary of the North Atlantic to the Barents Sea as expected, conditions in the NW Atlantic are still abnormal for the positive state of the NAO. Instead of a cold and strong northwesterly airflow promoting intense cooling there in winter as it did in the early >90s, we now find that northwesterlies are mainly confined to the east of Greenland, so that the Labrador Sea is instead occupied by light or southerly anomaly-winds. It is within this overall context that the climatic status of individual sea-areas in 1999 should be viewed.

Main features are:

West Greenland air and sea temperatures were still very mild compared to average conditions.

In the Northwest Atlantic, air and sea temperatures were exceptionally warm, with a reduced occurrence of sea ice.

In the Labrador Sea, open-ocean convection was weak and shallow. Near surface waters were warmer and fresher than in 1998.

- In the Atlantic waters both south and north of Iceland temperatures and salinities were above average and among the highest observed for decades.
- In the Bay of Biscay air temperatures were warmer than average, and surface waters were the warmest observed in the period1992-1999.
- In the Rockall Trough (Northeast Atlantic) the temperatures were the highest recorded in the region since measurements began 25 years ago, and salinities remain considerably above average.
- Further north, Atlantic water at the northwest European shelf edge was also warm and saline.
- In the North Sea, 1999 was characterised by warmer than average surface temperatures throughout the year, particularly in September.
- In the Norwegian Sea, temperatures continued to be above the long-term average. Salinities continue to decline.
- Temperatures in the Barents Sea quickly rose at the start of 1999, starting in the west, and warm conditions generally prevailed throughout the area all year.
- In the Greenland Sea and Fram Strait the temperature and salinity of the northward flowing Atlantic water increased, whereas the southward return flow from the Arctic continued to cool and freshen.

Objective of the Third ICES Ocean Climate Summary

This, the third annual ICES Ocean Climate Summary, continues to develop further uses and dissemination of results from the ICES set of standard sections and stations - the ICES Ocean Observing System (I-OOS). The objective of this year's summary is to present a simplified version of national reports, in a non-technical manner, in order to set the oceanic climate context for the period 1999/2000. It is intended to be of use to managers of any aspect of the marine environment in the ICES area. In addition to the presentation of data, the ICES Working Group on Oceanic Hydrography has added some expert interpretation. The full set of national summaries may be found at http://www.ices.dk/status/, where each area is analysed in more detail.

The North Atlantic Oscillation (NAO) Index

Since the NAO is known to control or modify three of the main parameters which drive the circulation in the ocean area covered by this climate summary (i.e. wind speed, air/sea heat exchange and evaporation/precipitation) a knowledge of its past and present behaviour forms an essential context for the interpretation of observed ocean climate change in 1999.

When we consider the NAO index for the present decade, and the present decade in the context of this century (**Figure 1**), the 1960s were generally low-index years while the 1990s are high index years. There was a major exception to this pattern occurring between the winter preceding 1995 and the winter preceding 1996, when the index flipped from being one of its most positive values to its most negative value this century.

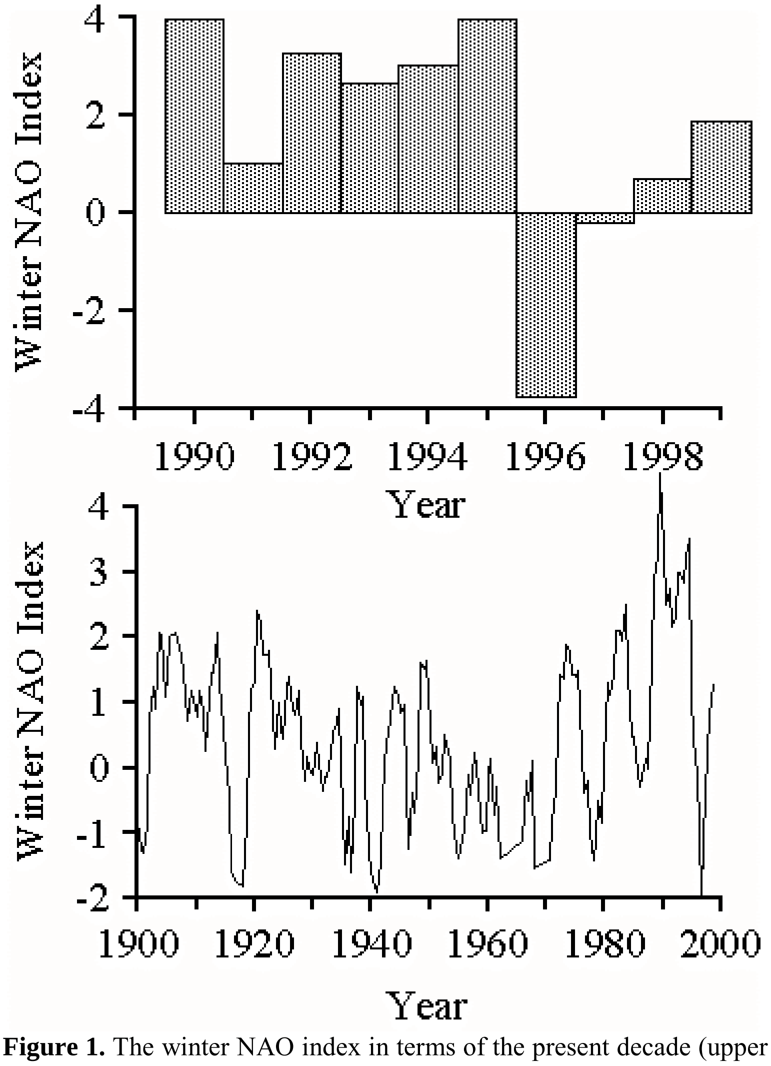

Figure 1. The winter NAO index in terms of the present decade (upper figure) and the present century (lower figure - a 2 year running mean has been applied).

The index is now rising from the extreme low, and the recovery continues during the winter preceding 1999. Thus 1999 has a positive NAO index. However, although the simple index continues to increase back to positive values, the actual pattern of the NAO over the ICES area did not recover to a "normal" distribution expected during high NAO years. The next section has more details.

In the remainder of the ocean climate summary the regional descriptions will proceed in an anti-clockwise manner around the North Atlantic, commencing in the waters west of Greenland. This follows the main circulation pattern of the North Atlantic (**Figure 2**).

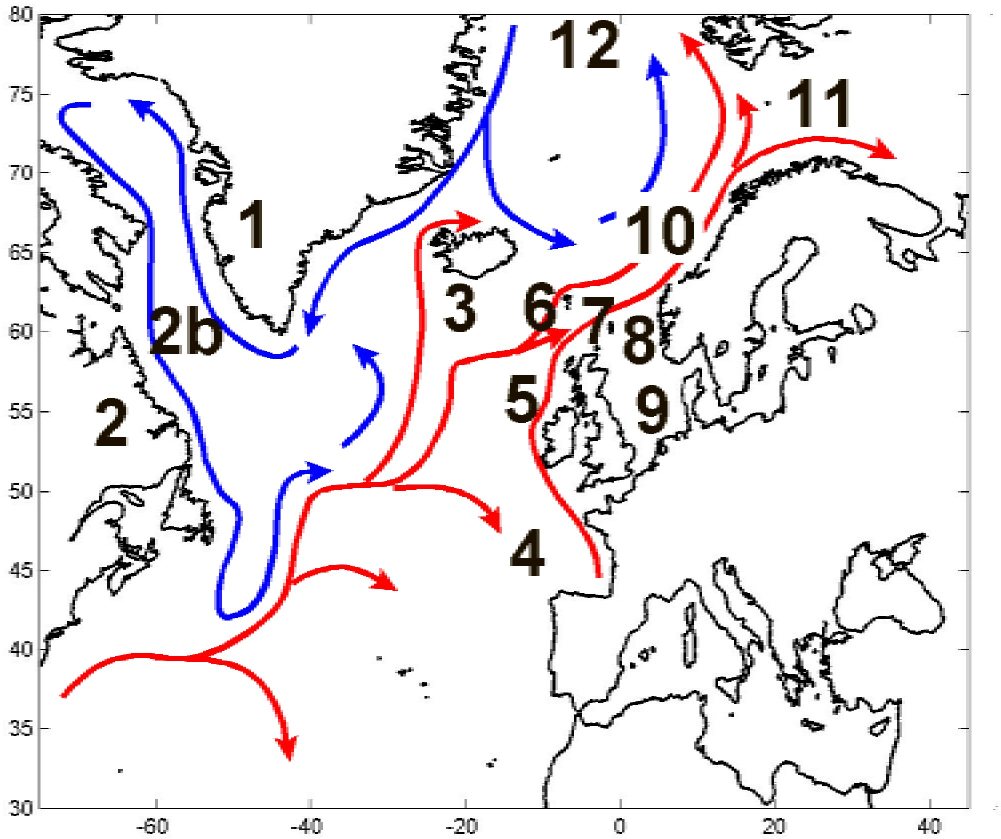

Figure 2. Schematic of the general circulation of the North Atlantic in relation to the numbered areas presented in the 1999/00 Annual ICES Ocean Climate Status Summary. The blue arrows indicate the cooler waters of the sub-polar gyre. The red arrows show the movement of the warmer waters in the sub-tropical gyre.

Box 1 - Continued Atypical Behaviour of the Winter NAO

In recent decades, the pattern and amplitude of the wintertime North Atlantic Oscillation (NAO) have been the main factors to consider in interpreting change in the marine environment across the North Atlantic and Nordic Seas. Over these past four decades, the NAO pattern has gradually altered from its most extreme and persistent negative phase in the 1960s to its most extreme positive phase during the late-1980s-early 1990s, allowing us to build up a picture of the kinds of ocean response to expect under either phase of the NAO.

Following its long period of amplification, the winter NAO index suddenly underwent a sharp decrease to a short-lived minimum in the winter of 1995-96 (Figure B) with radical and recognisable changes in Atlantic sea level, in the pole-ward transport of heat by ocean currents, in the pattern of the Atlantic gyre circulation, in the storm climate and precipitation regime over north-west Europe, in the efflux of ice from the Arctic, and on cod recruitment.

Since that temporary minimum, we have seen a steady recovery towards positive values of the winter NAO and the resumption of many of the ocean-climate features we have come to associate with that positive phase. However the recovery has so far been incomplete. Comparing the Atlantic sea level pressure anomaly pattern for the early 1990s (1993-5) with those for winters 1999 and 2000 (Figures A, B, C), we find that the recent NAO pattern is displaced slightly towards the east or north-east.

This subtle change has little effect on the subtropical gyre of the Atlantic or along its eastern boundary to the Barents Sea where we find evidence of the widespread warming we would normally associate with the positive NAO. However in the northwest Atlantic, this slight eastward retraction of the "normal" NAO pattern has made an important difference to the marine climate of the Labrador Sea and West Greenland Banks. Instead of a chill and strong northwesterly airflow promoting cooling there as it did in the early 90s (see Figure A), with intense and deep-reaching convection (to

>2300m) in the Labrador Sea, we now find that any north-westerly airflow is mainly confined to the east of Greenland (see Figures B & C) so that the Labrador Sea is instead occupied by light or southerly anomaly-winds.

Thus reports from the West Greenland Banks are of continued warmth rather than cooling, and convection in the Labrador Sea remains weak and shallow. The latter change is particularly dramatic. Intense and deep-reaching convection not only produces a deep homogeneous LSW water mass but drives a strong cyclonic circulation in the Labrador Sea. Now, with that stimulus removed, the centre of Labrador Sea is occupied by a vertical stack of disparate water masses, reflecting not only the past products of a weakening convection, but the lateral intrusion of other water masses from a variety of sources around the boundary.

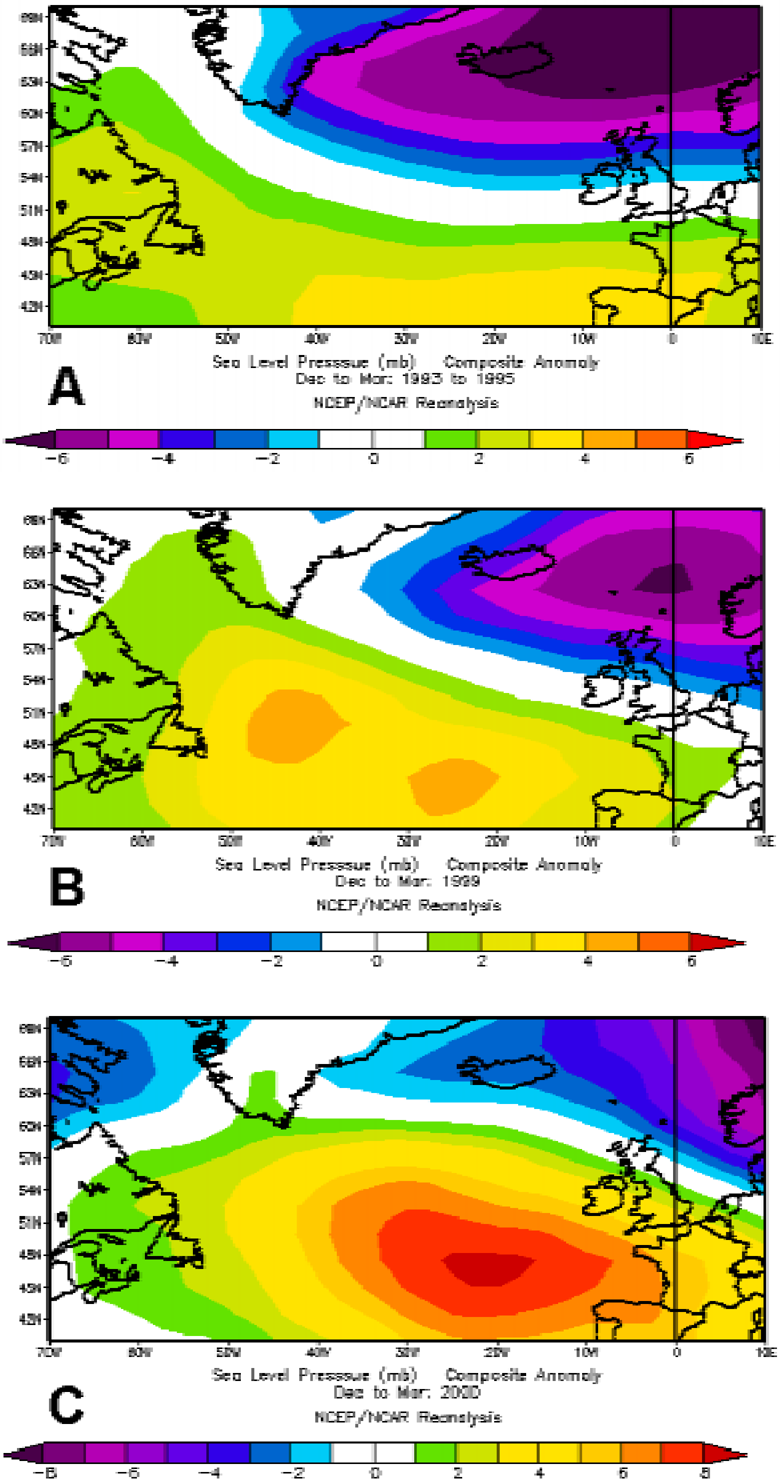

Figure A Winter (December - March) Sea Level Pressure (mbar) composite anomaly for 1993 – 1995. **B** 1999. **C** 2000.

Regional Descriptions

Area 1 - West Greenland

Greenland lies within the area which normally experiences cool conditions when the NAO index is positive. However, although the NAO in 1999 recovered to positive values, conditions around Greenland remained warm, confirming that during 1999 there was an anomalous NAO pattern over the area.

Air temperatures during the period 1989 to 1994 were particularly cold. The reversal of the NAO in 1996 brought relatively mild conditions to the area, and these have persisted into 1998 and 1999.

Changes in the ocean climate in the waters to the west of Greenland generally followed those of air temperature. The exceptionally high temperatures in 1998 cooled a little in 1999, but the year was still one of the five warmest years since 1950

Area 2 - North West Atlantic

Annual mean air temperatures throughout most of the northwest Atlantic warmed relative to 1998, setting record high values in the region from southern Labrador to Cape Cod (**Figure 3a**). The maximum air temperature anomalies and the largest increases relative to 1998 were in the Gulf of St. Lawrence, on the Scotian Shelf and over eastern Newfoundland, where values were up to 2°C above their long-term (1961-1990) means. Seasonally, air temperatures in most areas of the northwest Atlantic were above normal in 10 out of the 12 months of 1999.

Sea ice on the Labrador and Newfoundland Shelves generally appeared at the expected time but left early, resulting in a shorter duration of ice than normal. The ice coverage in these areas during 1999 was lower than average but similar to 1998 (**Figure 3b**). The number of icebergs reaching the Grand Banks in 1999 was only 22, well down from the 1384 icebergs observed in 1998. The small number of bergs in 1999 was consistent with reduced ice cover and warmer-than-normal air temperatures.

Off Newfoundland, the average ocean temperature (**Figure 3c**) ranged from a record low during 1991 (high NAO index in preceding winter), a near record high in 1996 (following the reversal in the preceding winter to the record low NAO index), and above the long-term (1961-1990) average in 1999, an increase over 1998. The average summer salinity, which was below normal during most of the early 1990s, returned to near normal values during 1997 and 1998 but fell to below normal values during 1999 (**Figure 3d**).

A robust index of the general oceanic environmental conditions off the eastern Canadian continental shelf is the extent of the cold intermediate layer (CIL) of sub-zero °C water (**Figure 3e**). This winter cooled water remains trapped between the seasonally heated upper layer and the warmer shelf-slope water throughout the summer and fall months. During the 1960s, when the NAO was well below normal and had the lowest value ever in this century, the volume of CIL water was at a minimum, and during the high NAO years of the early 1990s, the CIL volume reached record high values. During 1999 the CIL index off eastern Canada decreased over 1998 values, continuing the below normal trend established in 1995.

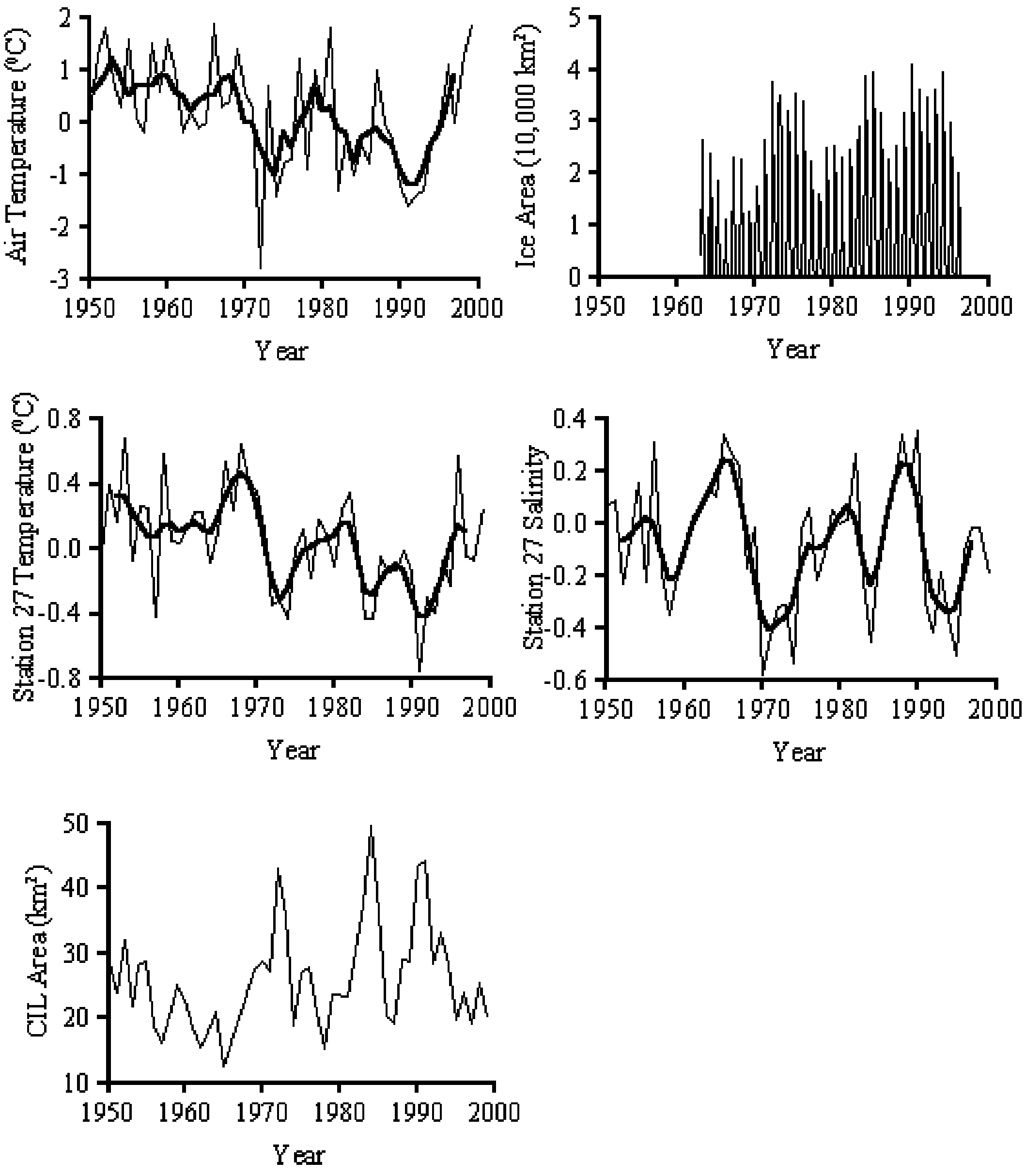

Figure 3. Area 2 - North West Atlantic. **a)** Annual air temperature anomalies (dashed line) and 5-year running means (solid line) at Cartwright on the Labrador Coast, **b)** monthly mean sea-ice area off Newfoundland and Labrador between 45°N - 55°N, **c)** the depth-averaged Station 27 annual temperature and **d)** salinity anomalies, and **e)** the time series of cold intermediate layer (CIL) off Bonavista, Newfoundland.

Area 2b - The Labrador Sea

The Labrador Sea is located between Greenland and the Labrador coast of eastern Canada. The counter-clockwise flow around the perimeter of the deep Labrador Sea, consisting of the northerly flowing West Greenland Current and the southerly flowing Labrador Current, forms the north-western loop of the sub-polar gyre. In wintertime cold north-westerly winds can cool the surface waters of the central western Labrador Sea to such an extent that they become more dense than the underlying water and sink, sometimes to depths as great as 2000m. The strength and depth of this winter convection varies from year to year depending on the weather experienced during the winter.

Relatively mild conditions in the Labrador Sea since the low-NAO index conditions of 1995 / 1996 have produced only shallow convection. This trend continued during the 1998 - 1999 winter, and there was little evidence of convection during the summer of 1999. The seasonally warmed upper layer of the Labrador Sea was warmer and fresher in mid-summer 1999 than at the same time in 1998. The low salinities might be related to earlier melting of sea ice on the Labrador coast in 1999 compared to 1998 or to a build up of freshwater in the surface layers due to the lack of vertical mixing in previous years. Conditions were also warm but more saline in the intermediate layer, and this could be a result of a continued supply of warm, saline Irminger Sea water during the past few years.

Area 3 - Icelandic Waters.

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

In general hydrographic conditions in Icelandic waters in 1999 revealed, as in 1998, favourable temperatures and salinities (**Figure 4a**). The salinity of the warm water from the south was high between 1920 and 1964, fell during the "ice years" of 1965-1970, and has since been increasing again. In 1999 it continued at its highest value (35.20) since the ice-years and this level has now been maintained since November 1997. The inflow during 1999 of warm and saline water from the south into North Icelandic waters was stronger than it has been for decades (**Figure 4b**). No trace was found of the low-saline surface layer above the warm inflow observed since 1996 in North Icelandic waters.

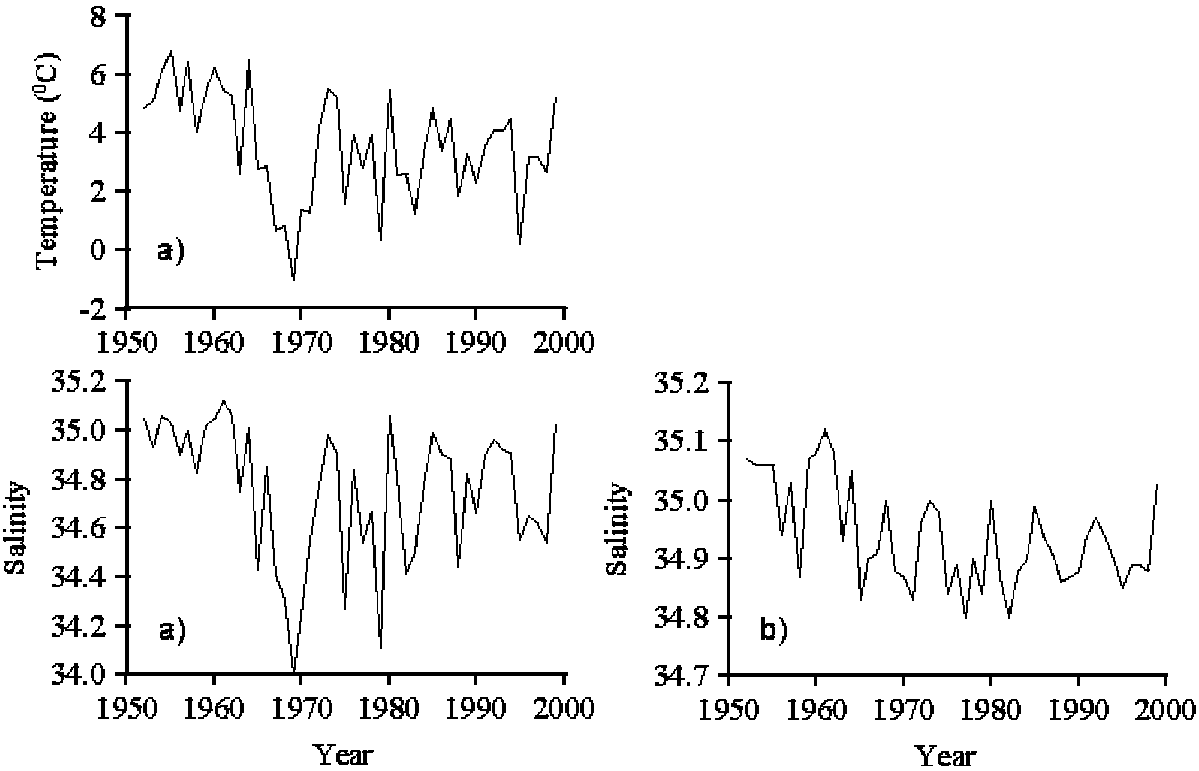

Figure 4. Area 3 - Icelandic waters. **a)** Temperature and salinity at 50 m in spring in North Icelandic Waters. **b)** The maximum salinity in the surface layers (upper 300m) north of Iceland showing the 1999 inflow of saline water from the south.

The mild conditions in Icelandic waters in 1999 continue the improving trend following the extremely cold conditions in 1995. Temperatures and salinity values in the cold East Icelandic Current were also relatively high in 1999 and improved further towards the end of the year (temperature above 0° C, salinity up to 34.8). Observations in February 2000 furthermore revealed ongoing favourable hydrographic conditions in Icelandic waters.

Area 4 - Bay of Biscay and Eastern Atlantic

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

The annual mean air temperature over the Bay of Biscay followed the ongoing heating trend (**Figure 5**). In Santander, 1999 had the same average value as for 1998 (14.8°C, 0.5°C over the 1961-1999 average).

1999 presents the widest amplitude in the seasonal cycle of seawater temperature at 10 m (8.9°C) with summer/early autumn temperatures more than a degree above the 1992-1999 mean (between August and October). At this depth, the 1999 annual mean was 16.1°C, the warmest year of the time series. The trend obtained from this series is 0.04°C/year. Sea surface salinity in the Bay of Biscay, which was increasing from a low salinity event in 1995, has stopped and during 1999 has begun to fall.

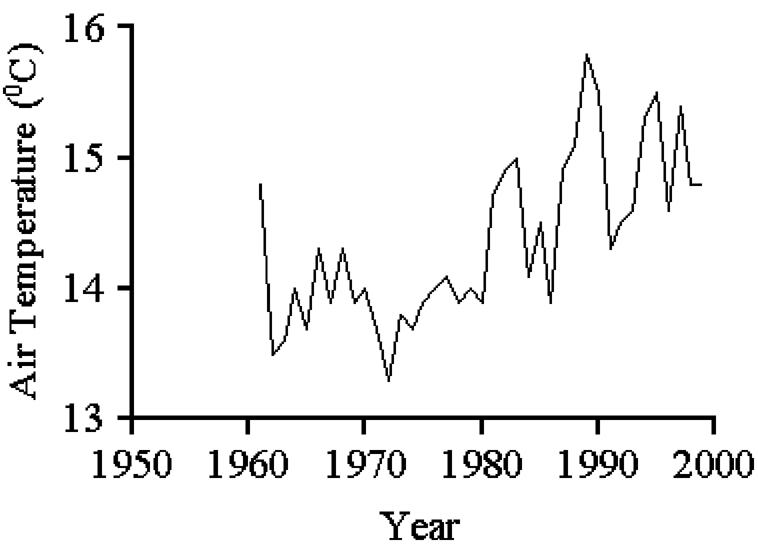

Figure 5. Area 4 - Bay of Biscay and Eastern Atlantic. Annual mean air temperatures at Santander, northern Spain.

Area 5 - Rockall Trough

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

In 1999 and early 2000 the surface waters of the Rockall Trough continued the trend of increasing temperatures seen since 1995 (**Figure 6**). A maximum of 0.5°C greater than the mean for the last 25 years was reached in February 2000, the highest temperatures recorded in the region since measurements began. The salinity appears to be reducing following a peak in 1998, though remain considerably above average conditions.

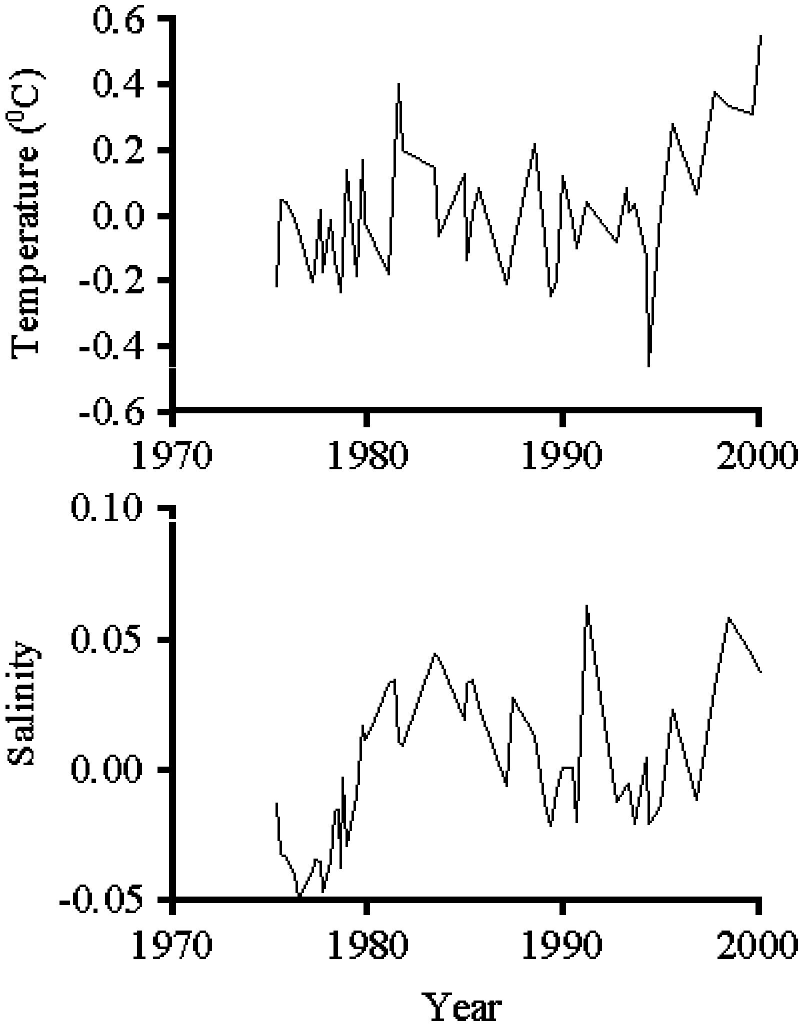

Figure 6. Area 5 - The Rockall Trough. The average salinity and temperature across the Rockall Trough at an approximate depth of 800m.

Area 6 - Faroe Bank Channel

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

In the mid-1990s the Atlantic water in the Faroe Bank Channel was relatively cold and fresh. Since then, temperature and salinity have increased (**Figure 7**). The first half of 1999 was fairly cold, but towards the end of the year the 100-300 m layer in the Faroe Bank Channel was again warm.

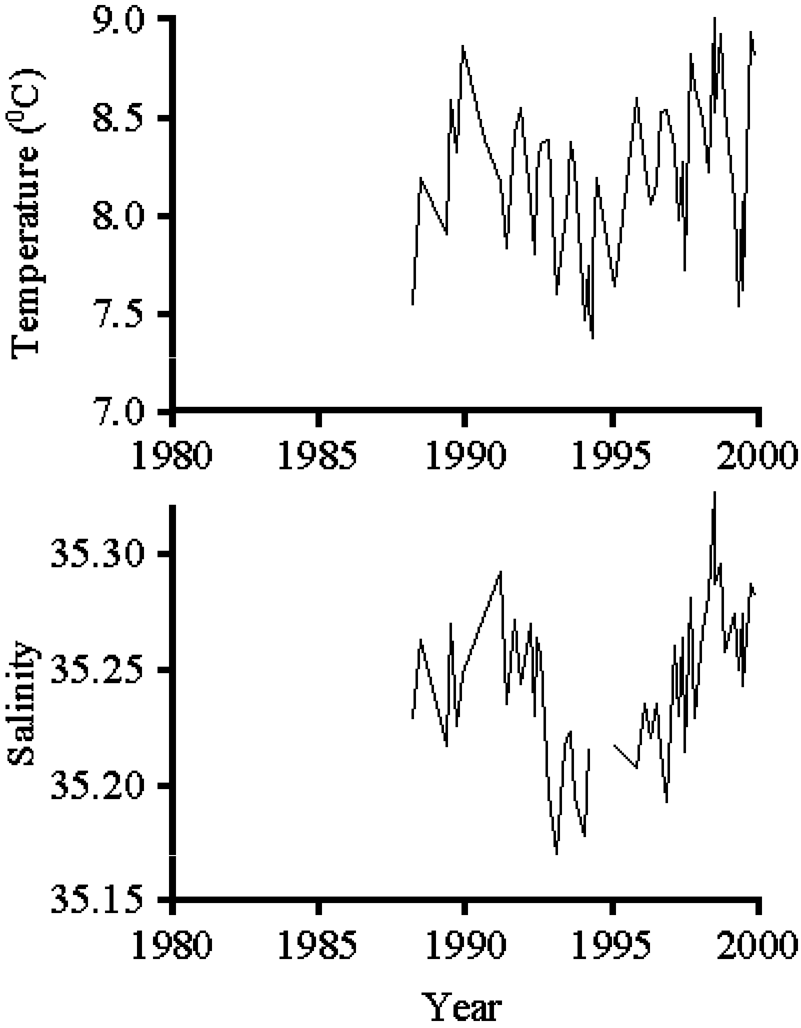

Figure 7. Area 6 - Faroe Bank Channel. Temperature and salinity in the surface Atlantic waters entering the Faroe Bank Channel.

Area 7 - Northwest European Shelf Edge

Atlantic water lying at the northwest European shelf edge has been warming since 1987 at a rate of 0.5 °C/decade. Particularly high temperatures (**Figure 8**) were observed in the spring of 1998 but, while temperatures remain well above the long-term average, they were cooler in 1999 compared to 1998. A similar trend was seen in salinity, with values in the Atlantic Water at the shelf edge remaining well above the long-term average, but below the 1998 high values. Warm, saline conditions are consistent with a positive NAO for this area.

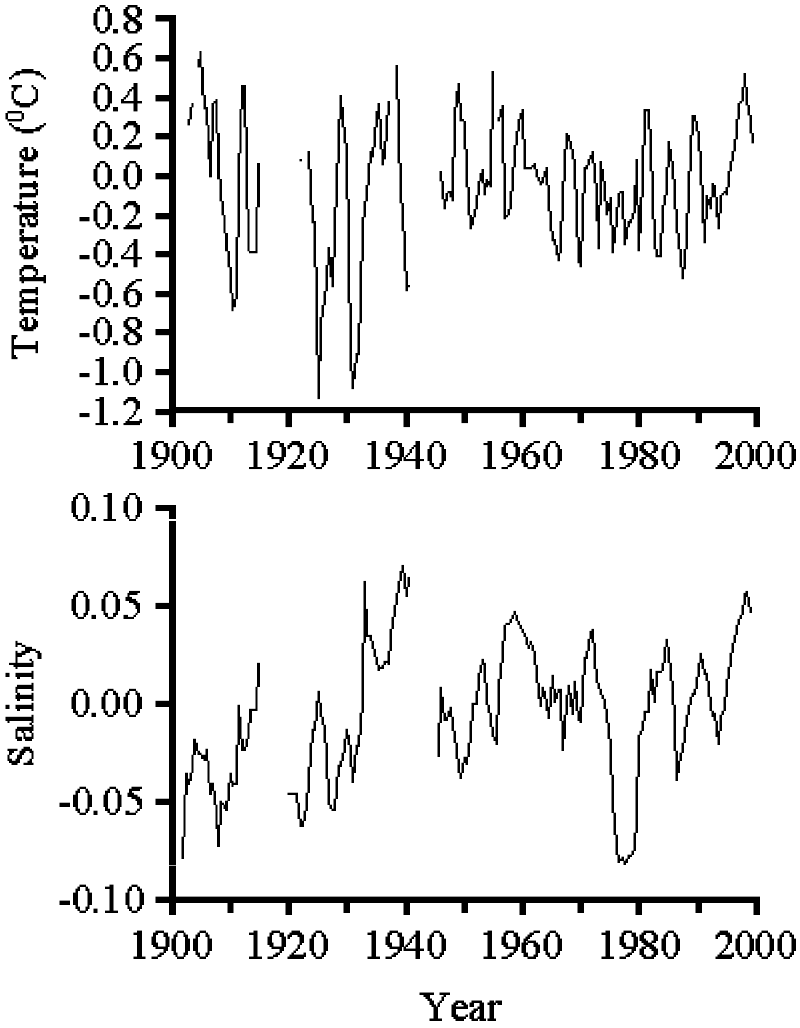

Figure 8. Area 7 - North west European shelf edge. Temperature and salinity anomalies in the surface Atlantic waters lying within the slope current north of Scotland.

Areas 8 and 9 - Northern and Southern North Sea

In the bottom waters of the northern North Sea temperatures were cooler than 1998, and returned to almost the long term average. Salinities however continued to increase (**Figure 9**) and are again approaching the high values seen in the early 1990s. Changes in the Skagerrak are a good indication of larger scale change in the North Sea. **Text Box** 2 introduces the Skagerrak to the ICES AOCSS for the first time.

In terms of sea surface temperature (SST), the annual average over the area was 10.7 °C, making 1999 the 2nd warmest year since 1971. Six of the seven warmest years during this 30-year period have occurred in the 1990s. While seasonal cooling usually begins in mid-August, relatively warm temperatures lingered through September, and this prolonged summer season is considered to be the most anomalous feature of the seasonal SST cycle in 1999 (**Figure 10**).

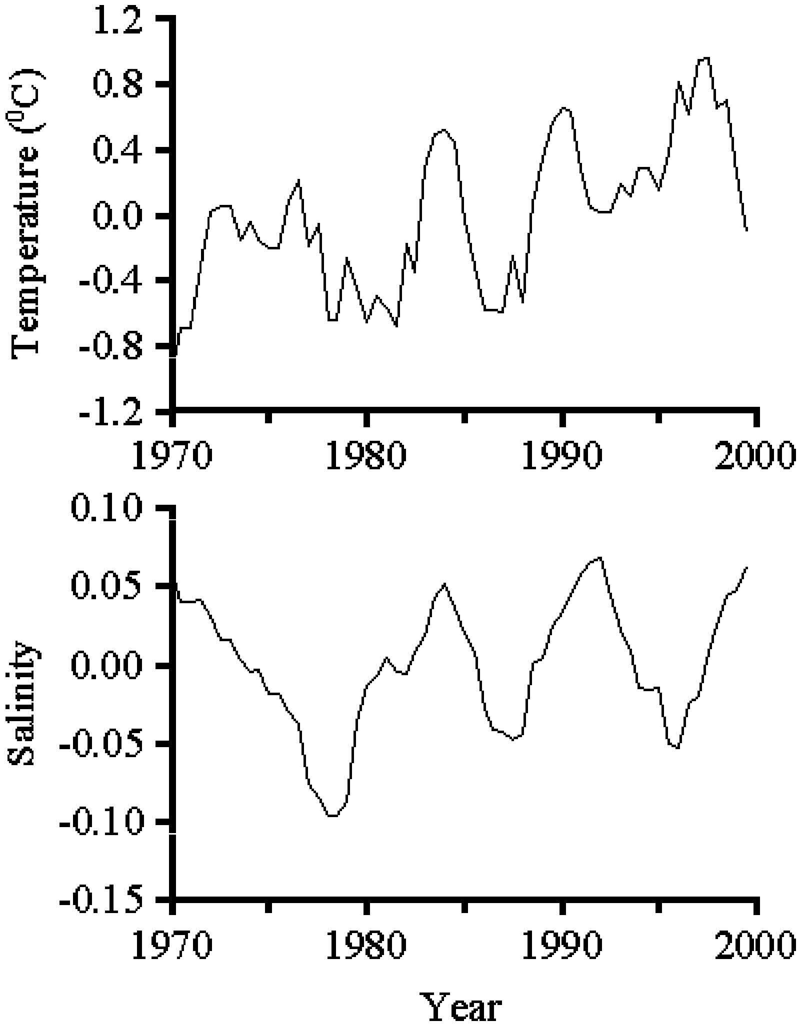

Figure 9. Area 8 - Northern North Sea. Temperature and salinity anomalies in the waters lying near the bottom in the central northern North Sea basin.

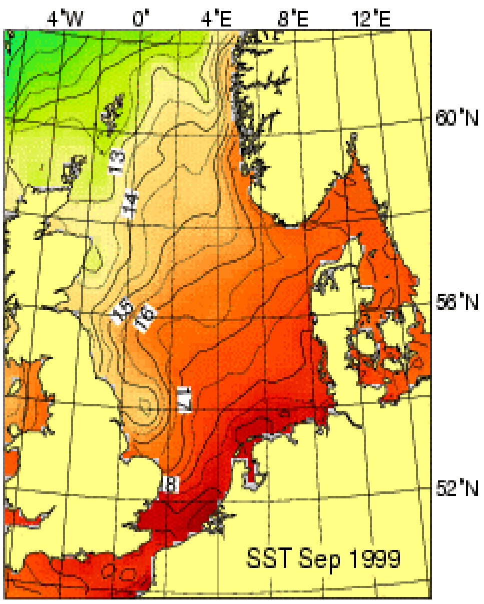

Figure 10. Areas 8 and 9 - Northern and Southern North Sea. Sea surface temperature anomalies in September 1999. Unusually persistent summer temperatures resulted in this month being much warmer than average with SST anomalies of 2 to 3☜C setting a new record in a 30 year long time series.

Text Box 2 – The Skagerrak

The deepest part of the North Sea is the Skagerrak where depths exceed 700m, between Denmark and Norway. Conditions in the deep waters are generally understood to reflect changes in the volume inflow of warm, salty, nutrient rich Atlantic water, and more specifically the variations in deep water properties of the North Sea arising from circulation changes and changes in the degree of heating and cooling.

Figure D includes time series of annual mean temperature, salinity and oxygen at 500m depth in the Skagerrak during the 20th Century. Prior to the 1950s the quality of the time series is limited by the paucity of data, but from the 1960s onwards the volume of data is large enough to assure representative mean values with low standard deviation.

The figure shows pronounced variability at decadal time scales. Notable is the significant upward trend in temperature since the 1950s, and especially so during the 1990s. In fact the highest average annual temperature occurred in 1999 when the average was almost 2 degrees higher than the 1950s average. The salinity time series shows no trend but clearly exhibits significant variability at decadal time scales. The oxygen time series peaks in 1955 when there was considerable renewal of the bottom waters by large Atlantic inflows to the area. Also clear in this time series is an almost 10% decline in oxygen values since 1980. Only 30% of this decline can be explained by the overall increasing temperatures in these waters in the past few decades. Thus this time series may provide evidence of the impact of increasing nutrient discharges on this part of the North Sea.

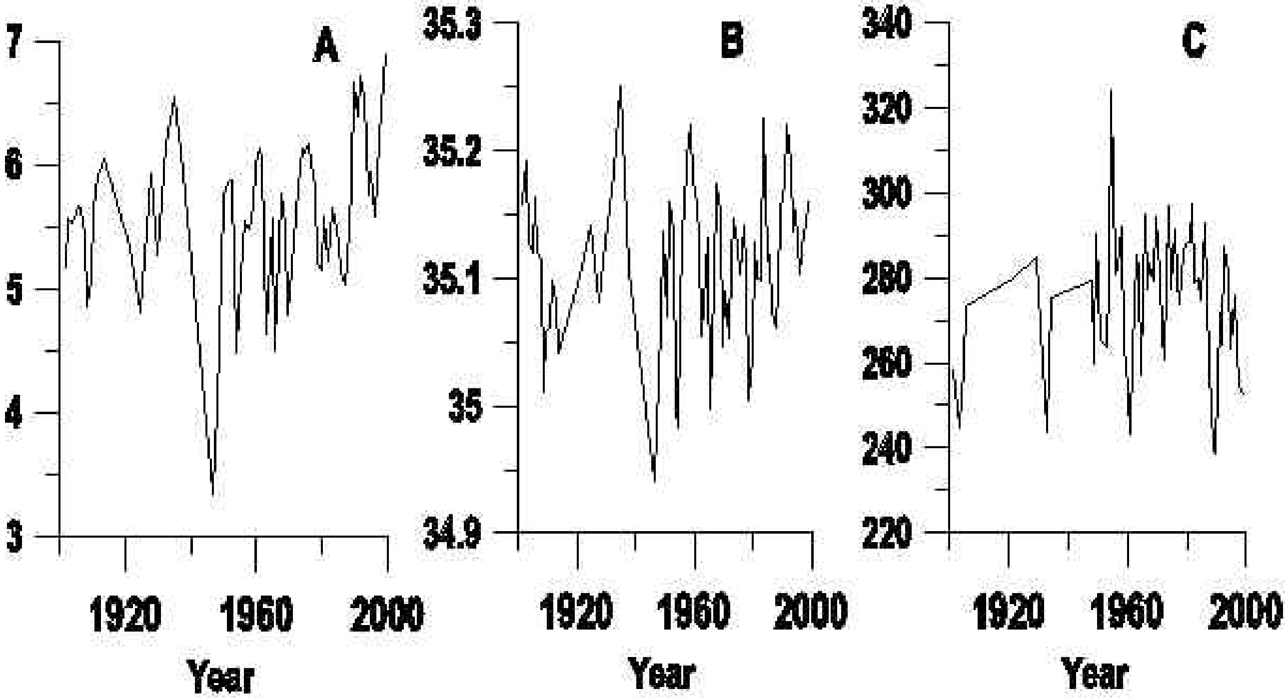

Figure D. Time series at 500m depth in the Skagerrak (eastern North Sea) for the period 1900 to the present: (A) is temperature (C), (B) is salinity and (C) is Oxygen (umol/l).

Area 10 - Norwegian Sea

In the southern Norwegian Sea temperatures decreased by more than 1°C from the extremely high temperatures in 1998, but were still 0.1°C higher than the long-term average (1978-1999). In the northern Norwegian Sea a gradual warming has taken place since 1996, and this continued in 1999 (**Figure 11**).

An overall feature of the conditions over the slope in the Norwegian Sea is a trend toward higher temperatures and lower salinities. The magnitude of this trend increases northwards. The rate of warming at the northern section (76°N, **Figure 11**) amounts to 1.03°C since 1978, compared to 0.12°C at the southern section (63°N). In contrast, the salinity trend is strongest in the south, with decreases of 0.08 since 1981 compared to 0.04 at 69°N. As well as the long-term trends, the shorter-term variability also shows a northward increasing correlation with the NAO.

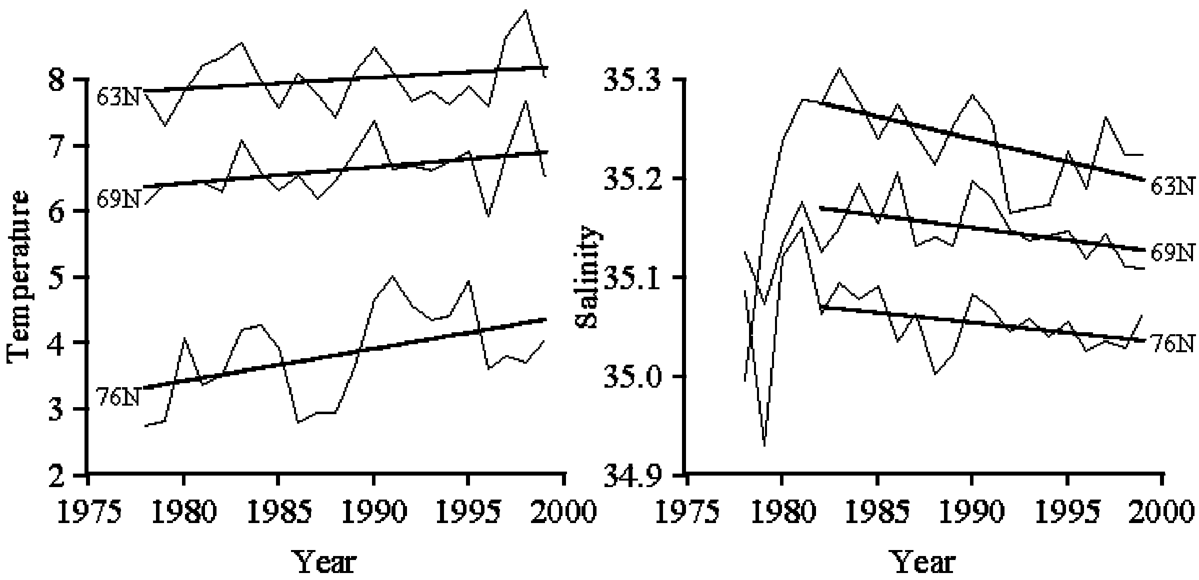

Figure 11. Area 10 - The Norwegian Sea. Average temperature and salinity above the slope at three sections, Svinøy (approx 63°N), Gimsøy (approx 69°N) and Sørkapp (approx 76°N), representing the southern central and northern Norwegian Sea.

Area 11 - Barents Sea

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

After a period with high temperatures in the first half of this decade, the temperatures in the Barents Sea dropped to values slightly below the long term average over the whole area in 1996 and 1997. From March 1998, the temperature in the western area increased to just above the average (**Figure 12**), while the temperature in the eastern areas stayed below the average during 1998 (**Figure 13**). From the beginning of 1999 there was a rapid temperature increase in the western Barents Sea (0.9°C above the average), which also spread to the eastern part of the Barents Sea. During spring and summer the temperature in the whole area was 0.3°C above the long-term mean. At the end of 1999 and beginning 2000 there was a new sudden temperature increase, which led to temperatures 1°C higher than average in the western and eastern Barents Sea.

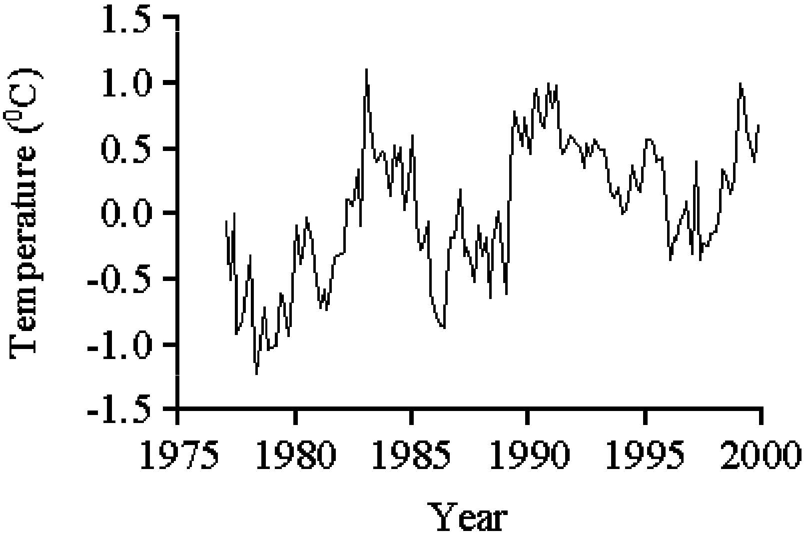

Figure 12. Area 11 - The Barents Sea (West). Temperature anomalies in the Norway - Bear Island section in March.

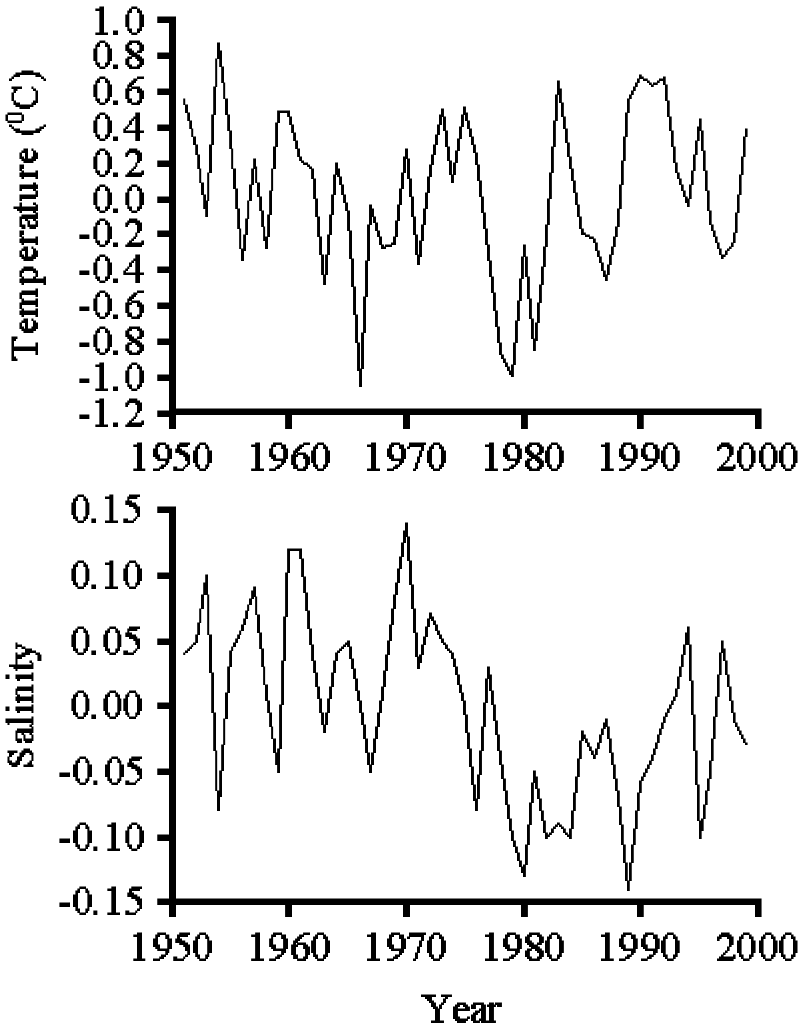

Figure 13. Area 11 - The Barents Sea (East). Temperature and salinity anomalies observed in the main currents through the Kola section.