Oceanography Committee **ICES CM 2001/C:06**

REPORT OF THE

WORKING GROUP ON OCEANIC HYDROGRAPHY

Reykjavik, Iceland
19-21 March 2001

International Council for the Exploration of the Sea

Conseil International pour l’Exploration de la Mer

Palægade 2–4 DK–1261 Copenhagen K Denmark

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1 SUMMARY OF WGOH 2000

1) The 2000 ICES Annual Ocean Climate Status Summary (IAOCSS) was prepared from regional climate reports. This is available at http://www.ices.dk/status/clim0001/
2) In summary, the North Atlantic Oscillation (NAO) Index continued to recover to positive values up to and including winter 2000 (winter is defined by the year of the January), though with some indication of an eastward shift in the NAO dipole pattern. The result was that most parts of the area under review showed moderate or warm conditions in 2000. Though the climatic data set for winter 2001 is not yet complete, early indications are that the NAO index has undergone a sharp return to negative conditions.
3) The predictability of climate in relation to fish stock assessment was discussed. The IAOCSS was highlighted as a product which may be of use by ICES stock assessment Working Groups in terms of setting the environmental context describing the habitats within which the stocks under assessment live. Better ways of including environmental information in the stock assessment procedure need to be found.
4) The "earlier warm period" of the 20th century (1925 to 1960) was examined in some detail. It offers a comparison to the present period of warming (1970s onwards), which is increasingly viewed by the Intergovernmental Panel on Climate Change (IPCC) as anthropogenic in origin. The Annex describing the results of this study forms a useful reference document.
5) A study to identify new sources of data and climatologies which may be of use to enhance the IAOCSS continues, and will be concluded in 2002.
6) In addition a new product from the ICES Oceanographic Data Centre was presented which may add an "operational" component to the IAOCSS through interactive data selection and display via the Internet. An Annex presents this proposal in detail, and Working Group members will work inter-sessionally in order to assess the potential of this development.
7) Progress within the SGGOOS was discussed. Three developments in particular were singled out; 1) The preparation of a "flyer" in order to explain the philosophy behind the Global Ocean Observing System (GOOS) to ICES Delegates and experts previously unfamiliar with this programme, 2) The proposed joint IOC / ICES / EuroGOOS Workshop to be held in Bergen in September 2001 in order to prepare plans for a North Sea regional GOOS with emphasis on Living Marine Resources, and 3) statements by SGGOOS wishing to see the IAOCSS enhanced in order that it may become an ICES contribution to GOOS.
8) Progress towards the ICES Symposium on Hydrobiological Variability in the ICES Area, 1990-1999 (The Second ICES Decadal Symposium: 8–10 August 2001, Edinburgh, Scotland, UK) were discussed. This meeting should prove an extremely valuable summary of the past decade, and contribute to ICES dissemination of information on ocean climate and its impact on ecosystems.
9) Other items discussed were underway ADCP measurements, the review of the 2000 WGOH report, a potential publication from the WGOH on regional oceanography and climate variability, the use of the Internet for information exchange between Working Group members, and developments of the Arctic Sub-Arctic Ocean Flux Array (ASOF).
10) The Working Group will meet next year in Halifax, Canada 18-22 March, 2002.

Action Points

1) Membership: Write to G. Reverdin (France) and I. Ambar (Portugal) asking them to seek nomination to the Working Group [Turrell]
2) Inter Working Group communication: A short summary of the 2001 WGOH will be circulated to all other OCC Working Groups [Turrell]
3) Review of Report: When the review is available at the 2001 Statutory Meeting it will be circulated to all members. [Turrell]

2 OPENING

The WGOH met at the Hafrannsóknastofnunin (Marine Research Institute) in Reykjavik, Iceland between 19-21 March 2001. The Working Group was welcomed to the Institute by the Director, Dr Johann Sigur-Johnson, and by the Working Group's local member, Svend-Aage Malmberg. After a brief introduction to the Institute the business of the meeting began.

3 REVIEW OF MEMBERSHIP

In the review of membership, it was noted that some progress had been made to recruit new members, while some work is yet to be done. The Working Group welcomed P Holliday (UK) and K Borenäs (Sweden) as bringing welcome new input to the Working Group. Membership from France and Portugal was still missing, however, and the Chair was once more charged with correcting this.

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

This is a standard item, 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 presented here as Annexes, 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 W) 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 2000 emerged. The summary of national contributions is reproduced below.

The North Atlantic Oscillation (NAO) Index continued to recover to positive values up to and including winter 2000 (winter is defined by the year of the January), though with some indication of an eastward shift in the NAO dipole pattern. The result was that most parts of the area under review showed moderate or warm conditions in 2000. Though the climatic data set for winter 2001 is not yet complete, early indications are that the NAO index has undergone a sharp return to negative conditions.

Surface temperatures off West Greenland were relatively warm during the summer of 2000 due to mild atmospheric conditions. Stronger inflows of polar water were noted. Ocean conditions in the Northwest Atlantic cooled slightly during 2000 relative to 1999 values, but were near or above normal in most areas. Sea-ice extent also increased slightly over the light ice conditions of 1999. An increased southward transport of polar waters was noted on the Labrador shelf. The surface waters of the Labrador Sea were observed to be slightly cooler, fresher and denser in the summer of 2000 compared to 1999. More convection and overturning took place in the Labrador Sea during the 2000 winter than in recent years, but not as intense as during the early 1990s. In Icelandic waters, 2000 revealed in general relatively high temperatures and salinities as in the last 2-3 years, following the very cold years of 1995 and 1996, although temperatures were also cooler than 1999 in this area. The annual mean air temperature over the southern Bay of Biscay during 2000 remained at nearly the same value as during the two preceding years. Surface waters were slightly cooler and fresher than in previous years. Early 2000 saw a peak in the temperature of surface waters in the Rockall Trough, caused by an influx of unusually warm water into the region. By the spring of 2000 the temperature had dropped somewhat, though remained above the long-term mean. 2000 was the 6th warmest year since 1971 in the North Sea, in terms of annual mean sea surface temperature. All months were warmer than average, except for June and July. There was evidence of a large input of freshwater from the Baltic Sea. Since 1996, temperatures are increasing in the southern and central Norwegian Sea. In 2000 the warming continued at the southern section while a cooling occurred at the central section. In the northern Norwegian Sea the temperature since 1996 has been close to the long-term average. The temperature in the Barents Sea decreased from 1°C above average during early winter to 0.2°C in the autumn. In the eastern Barents Sea stayed high during the whole year. A larger than normal inflow of Atlantic water results in warmer and more saline conditions in the eastern Greenland Sea.

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

The draft IAOCSS (Annex W) was discussed by the Working Group, and its contents agreed. As in 2000, the web version contains 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. Ms P Holliday (UK) must be thanked for preparing much of the 2000 IAOCSS.

6 EXAMINE THE POTENTIAL PREDICTABILITY OF OCEAN CLIMATE (TOR C)

Malmberg (Iceland) presented a review of this topic, with particular reference to the motivation behind this ToR, namely that environmental observations have, up until now, generally been used in an indirect and limited way in fish 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

Malmberg paid some attention to the biological responses which are notoriously non-linear. It has so far proved difficult to link cycles in the physical environment with cycles in biological events with quantitative rather than qualitative results, of which there are many examples in the literature. Furthermore, it was stated that fluctuations in the physical environment are the most important natural source of ecosystem variability. Some links between current physical conditions and their variability and those of biological conditions were shown, mainly from Icelandic waters with herring, capelin and cod (O-group, recruitment, migration, abundance, catch etc.) used as examples.

Malmberg then put forward the question "how far are we away from being able to predict climate including oceanic climate?". New visions on the use of oceanic physical conditions for prediction may be around the corner (e.g. GOOS, CLIVAR etc.). Presently environmental information is occasionally used in a qualitative way, in order to set some stock assessments into context. In some ways, through the monitoring and understanding of the physical marine environment, the potential and possible range of variability induced by climate variability can also be indicated along with stock assessments. If physical variability in the past can be linked to variations in biological conditions, then present physical conditions may be used to assess the present status for life in the sea, with some ability to suggest how growth and stock size might be influenced in the future, by present conditions. From that point of view current physical conditions have a predictive value for fish stock assessment which should not be neglected.

In Malmberg’s opinion, the future development in the use of climate prediction in relation to fish stock assessment depended on some key developments: 1) The better understanding of the potential of climatic variations and their links to ecological conditions, 2) Where suitable in systems dominated by advective processes, to look for upstream physical conditions, nearby and remote, with new technologies such as pattern recognition giving prospects for downstream hydro-biological conditions predictions in time and space. Malmberg reminded the Working Group that one of the aims of GOOS, "is to detect and forecast the effects off climate change variability".

A wide ranging discussion followed. Loeng (Norway) described a future programme commencing in Norway looking at climate variability and fish stocks. The Working Group was reminded of the work of the ICES/IOC Steering Group on GOOS (SGGOOS), particularly with respect to the planned workshop in Bergen in September 2001, where operational oceanography will be discussed which will generate new methods of placing environmental information and products into the stock assessment process. ICES is very well placed to play a lead role in these developments, and has the necessary wide range of expert Working Groups which can address the issues of how to incorporate environmental data into the stock assessment process. How information and dialogue may be exchanged between the relevant ICES Working Groups requires consideration by parent Committees. The IAOCSS is potentially one way in which information on climate variability may be passed into ICES stock assessment Working Groups.

7 RE-ANALYSE THE 1920-1950 WARM PERIOD IN THE NORTH ATLANTIC (TOR D)

The observed hemispheric warming of the past Century took place in two distinct episodes, from 1925 to 1960 and from the late 1970s to the present. The later event is increasingly viewed by the Intergovernmental Panel on Climate Change (IPCC) as anthropogenic, and coincided in the Atlantic sector with a record amplification of the NAO which itself may be a partial response to greenhouse gas forcing. Though the earlier warming episode was more prolonged, its causes remain less well known. In view of the influence of that earlier episode of warming on the global temperature trend and its association with high northern latitudes, the Arctic Ocean Science Board has recently begun its re-analysis.

Annex E presents a summary of the re-analysis, and this was presented to the Working Group by Dr Dickson (UK). The Working Group considered that this Annex represents a valuable description of the earlier warm period in the 20th century, and thus forms a useful reference document.

8 REVIEW NEW CLIMATOLOGIES FOR INCLUSION IN THE IAOCSS (TOR E)

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. This is an ongoing review study by members of the Working Group, and hence only a brief presentation was made summarising progress. In the 2002 WGOH, this review will be concluded, and a report presented to the Working Group.

9 EVALUATE ICES OCEANOGRAPHIC DATA CENTRE PRODUCTS (TOR F)

Dooley (ICES Oceanographer) presented a comprehensive document (Annex F) summarising a new data product made available by the ICES Oceanographic Data Centre which may enhance the “operational” nature of the IAOCSS. The Working Group has now developed and maintained the IAOCSS for three years. Its content and format provide a valuable contribution to the availability of information on the current state of the marine environment of the ICES fisheries areas in particular. It is built up from individual contributions based mainly on analyses from the ICES "Standard Stations" and "Standard Sections" and is backed up by expert analyses and interpretation by oceanographers who have expert knowledge of the fundamental aspects of the oceanography and climatology of these sections and stations. However, the purpose of this agenda item was to propose and debate the possibility of extending the basic IAOCSS product to include an operational element. The specific proposal is to make the preparation and availability of any time series on demand using a continuously updated and refreshed oceanographic database as the underlying source. The challenge is to do this in a way that reflects the main features of all the variability captured in the IAOCSS, yet can be generated in a simple and logical way by marine scientists who are not necessarily expert oceanographers and by other interested groups.

Annex F fully discusses this proposal, and highlights potential problems. These will be further analysed by Working Group members inter-sessionally, and results presented at the 2002 WGOH.

10 REVIEW PROGRESS DURING 2000 / 2001 OF THE ICES SGGOOS (TOR G)

Progress within the SGGOOS was discussed by the Working Group. Three developments in particular were singled out:

1) The preparation of a "flyer" in order to explain the philosophy behind the Global Ocean Observing System (GOOS) to ICES Delegates and experts previously unfamiliar with this programme. The text of the flyer was posted on the WGOH ftp site prior to the meeting, and members were asked to review it. Comments received were passed to members of the SGGOOS. The leaflet should be available for the 2nd ICES Decadal Symposium.

2) The proposed joint IOC / ICES / EuroGOOS Workshop to be held in Bergen in September 2001 in order to prepare plans for a North Sea regional GOOS with emphasis on Living Marine Resources. A draft programme and letter of invitation were posted on the WGOH ftp site prior to the meeting. The Workshop was discussed at length, and members encouraged to attend.

3) Statements by SGGOOS wishing the IAOCSS to become an ICES contribution to GOOS: These were extracted from the SGGOOS report and circulated to Working Group members prior to the meeting. The developments under agenda items 8 (ToR E) and 9 (ToR F) will move towards fulfilling the recommendations of SGGOOS.

11 DISCUSS UNDERWAY ADCP MEASUREMENTS (TOR H)

An update on vessel-mounted ADCP data collections on the Newfoundland Shelf was presented. It was noted that ADCPs have been used to collect vertical profiles of currents on the Newfoundland Shelf since the very early 1990s. Currently there are three ships with the Canadian Department of Fisheries and Oceans routinely collecting ADCP data in the Newfoundland region as part of fish assessment and oceanographic research surveys. In 1998 two offshore tugs supplying the Hibernia Oil Platform on the Grand Banks of Newfoundland were fitted with vessel mounted broadband ADCPs. These vessels are currently completing about 1-3 transects of the inshore branch of the Labrador Current per week. Efforts are continuing to process and archive the large amount of data collected using the Common Oceanographic Data Access System (CODAS) developed at the University of Hawaii. A preliminary analysis of the data processed to date clearly shows the detailed features of the circulation patterns and volume transport of the Labrador Current on the Newfoundland Shelf. This data set should eventually provide valuable information on the temporal and spatial structure of the circulation in the region.

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

Dickson (UK) presented a review of progress towards the ICES Symposium on Hydrobiological Variability in the ICES Area, 1990-1999 (The Second ICES Decadal Symposium: 8–10 August 2001, Edinburgh, Scotland, UK) He started by thanking all those who have helped progress.

Programme: A considerable proactive effort by the subject area leaders of the Scientific Steering Group (SSG) in the autumn paid dividends, so that by the deadline of 31 January 2001, a well balanced selection of 140 expressions of interest had been received in the Symposium Office in Hamburg. From these, the Co-convenors were able to select a list of 40 talks and 75 posters for presentation which seem balanced in terms of their geographical coverage and disciplinary content. A further 13 submissions were rejected solely on the grounds that they were thought insufficiently relevant to the main Symposium aim of describing the status of ICES waters in the 1990s. This draft selection was then circulated to the SSG for approval and comments, and since comments received were favourable, the outcome of the selection was notified to contributors before rather than after the ICES WGOH 2001 meeting, gaining time before the deadline for firming numbers for housing and events.

Timetable: As talks are to be held in sequence rather than parallel, the large number of submissions made it important to achieve an appropriately prominent role for poster presentations. The issue of how to give proper prominence to posters in Edinburgh was the main motivation for a third site visit which took place on 15 March, immediately before the WGOH 2001 meeting. As a result of this, a method of keeping all 80 posters in place throughout the three days of the meeting was agreed upon, without the need for any changeover. Two formal Poster Sessions of an hour each will be scheduled during the main part of the day on days one and two, resulting in some slight loss of talks.

Allowing two time-slots for the keynote lecture by Prof. P Jones, there will be time for a total of 42 talks in the three days, and a total of 41 such time-slots have been allocated. The breakdown of talks is (2nd Decadal / 1st Decadal); 9/9 plankton talks, 11/12 fish talks, 13/15 environment talks and 7/12 regional talks. With the collaboration and approval of Dr Malkki it was decided to organise a regional multidisciplinary session rather than Baltic for theme four.

Numbers: Between the WGOH meeting and 1 April, there is a critical period for the assessment of numbers for both Symposia. For some events firm numbers are not required until the summer, but with the Edinburgh Festival underway in August, the demand for accommodation and for tickets to events like the Tattoo is such firm numbers are needed by the 1st week in April.. For accommodation and events such as the Tattoo, a block booking has been made using an estimate of potential numbers. Hence an Intentions Form has been circulated to all participants by IFMH and by SAHFOS, and this is a vital document for participants to return, since it is the only means of converting estimates to numbers by the due date of 1 April. This point has obviously been heeded as the Hamburg office confirms though that the response has been rapid since the form was distributed.

Registration: A unified Registration Form for both Symposia has been designed and will shortly be placed on the ICES website. The deadline for submission and payment is the 15 June, which gives some time to adjust numbers if participants' are forced to change their plans.

Budget and Sponsors: Thanks again to a considerable proactive effort, a broad mix of sponsorship has been secured, including 5 contributions from industry, 8 from equipment suppliers/manufacturers, and 6 from science agencies. This has given an income margin needed to cover certain costs and to make certain strategic decisions (e.g. the cost of the Dinner kept to £25 per head, no registration Fees for honourees, cover for bank charges, etc.). The sponsors will be identified at the foot of the registration form. Equipment manufacturers have asked for space to display equipment as well as posters. Participants will note that after exploring a number of avenues for payment, it proved impractical to ask the IFMH Office to collect and distribute revenue as originally planned. The costs of money exchange and transfer were too high. Instead, CEFAS will act in this capacity

Next steps: The next important steps are a) by 1 April, to estimate "firm" numbers, notify the CPR SSG of "their" total, and adjust the accommodation and events tickets accordingly, b) by 15 June to register with payment to CEFAS (three methods) and c) for the Chair of the Editorial Board (Turrell - UK) to circulate the instructions to authors for the pre-conference Abstract Volume and for the post-conference Transactions Volume. It is intended to include both talks and posters in that volume.

13 PREPARE EDUCATIONAL / INFORMATION MATERIAL FOR THE ICES WEB SITE (TOR J)

Discussions under this agenda item developed along different lines. While it was considered that educational material was a valid object for the WGOH and ICES, considering the new Strategic Plan in particular, it was noted that large web based learning resources in the field of oceanography that were appearing elsewhere, particularly from the larger US educational establishments. The WGOH expertise lies in the field of regional oceanography and climate variability. The product of the ICES WGZE was then considered; the ICES Zooplankton Methodology Manual. This was thought to be an excellent product from an ICES WG, and the WG was asked to consider whether a similar volume might be prepared on regional oceanography and climate change by members of the WG. This discussion will continue inter-sessionally, and progress reviewed at the 2002 meeting.

14 ANY OTHER BUSINESS

The review of the 2000 WGOH Report (Annex D), presented to the Oceanography Committee during the 88th Statutory Meeting, was considered by the Working Group. Members found this to be very useful, and encouraged the Oceanography Committee to continue this process.

The method of distributing documents within the Working Group inter-sessionally was discussed. The use of the ftp site provided by ICES, along with distributed email seems to be, at the moment, the most practical way of doing business.

Dickson (UK) presented developing plans towards an Arctic-SubArctic Ocean Flux Array (ASOF). In May 1999, the AOSB announced plans to study the two-way oceanic exchanges that link the Arctic Ocean with subarctic seas The rationale is bound up with the fact that most projections of greenhouse gas induced climate change anticipate a weakening of the thermohaline circulation (THC) in the North Atlantic in response to increased freshening and warming in the subpolar seas. Since the overflow and descent of cold, dense waters across the Greenland-Scotland Ridge is a principal means by which the deep ocean is ventilated and renewed, the suggestion is that a reduction in upper-ocean density at high northern latitudes will weaken the THC. Further details are presented in Annex G.

15 DATE AND PLACE OF NEXT MEETING

Dr Hendry (Canada) kindly extended to the Working Group an invitation to Halifax in 2002. The Working Group will meet there during 18-21 March 2002.

16 RECOMMENDATIONS

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

North Atlantic Processes co-conveners for 2002 Loeng (Norway) and Turrell (UK)

<u>B</u> The WGOH (Chair Dr W. R. Turrell) should meet at BIO, Halifax, Canada 18-21 March 2002 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) Conclude the review of North Atlantic climatologies and their availability and usage, and additional data sources for the ICES Annual Ocean Climate Status Summary;
4) Review an evaluation of the interactive data summary product produced by the ICES Service Hydrographique in order to enhance the ICES Annual Ocean Climate Status Summary;
5) Review progress on the publication of the proceedings of the ICES Symposium on Hydrobiological Variability in the ICES Area, 1990-1999;
6) Review progress towards producing educational publications from the WGOH.

Justifications

<u>A</u> 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

<u>B</u> 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 2001.
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. For the past two years the WGOH has considered other data sources and climatologies that are of potential use for the Working Group, and in particular the IAOCSS. A document will be produced as an Annex summarising this work, and drawing conclusions from it with respect to developing the IAOCSS.
4. The ICES Oceanographic Data centre has prepared an interactive method of accessing and displaying data it holds. The WGOH will review this product, and assess it by conducting case studies inter-sessionally. These will be reviewed by the Working Group, and an assessment made of the value of this product.

5. The WGOH will review progress by the Scientific Steering Group and Editorial Panel on the publication of the proceedings of the ICES Symposium on Hydrobiological Variability in the ICES Area, 1990-1999, in order to identify any potential problems, help rectify them and provide advice intended for the third Decadal Symposium.
6. Following the production of the ICES Zooplankton Methodology Manual, the WGOH wishes to consider what publishable products it may generate in the future in order to enhance ICES dissemination of information to relevant stakeholders and the public.

a) The Working Group on Oceanic Hydrography recommends that

The 2001 / 2002 ICES Annual Ocean Climate Status Summary, edited by Dr W. Turrell and Ms P. Holliday (UK) as reviewed and approved by the Chair of the Oceanography Committee will be published in the *ICES Co-operative Research Report* series. The estimated number of pages is 35.

Priority:	This draft resolution enhances the development of the IAOCSS, and makes it an official and citable ICES product.
Scientific Justification:	Presently the IAOCSS is an Annex to the report of the WGOH, 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 35 page CRR
Participants:	
Secretariat Facilities:	Help with document preparation / publication
Financial:	
Linkages To Advisory Committees:	
Linkages To other Committees or Groups:	Publications Committee
Linkages to other Organisations	N/A

b) The Working Group on Oceanic Hydrography recommends that

2COH The **Working Group on Oceanic Hydrography** (Chair: W. Turrell, UK) will meet in Halifax, Canada from 18-21 March 2002 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) conclude the review of North Atlantic climatologies and their availability and usage, and additional data sources for the ICES Annual Ocean Climate Summary;

d) review an evaluation of the interactive data summary product produced by the ICES Secretariat in order to enhance the ICES Annual Ocean Climate Status Summary;

e) review progress on the publication of the proceedings of the ICES Symposium on Hydrobiological Variability in the ICES Area, 1990-1999;

f) review progress towards producing educational publications.

Supporting Information

Priority:	The activities of this group are fundamental to the terms of reference of the oceanography committee
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) For the past two years the WGOH has considered other data sources and climatologies that are of potential use for the Working Group, and in particular the IAOCSS. A document will be produced as an Annex summarising this work, and drawing conclusions from it with respect to developing the IAOCSS. d) The ICES Oceanographic Database has prepared an interactive method of accessing and displaying data it holds. The WGOH will review this product, and assess it by conducting case studies inter-sessionally. These will be reviewed by the Working Group, and an assessment made of the value of this product. e) The WGOH will review progress by the Scientific Steering Group and editorial Panel on the publication of the proceedings of the ICES Symposium on Hydrobiological Variability in the ICES Area, 1990-1999, in order to identify any potential problems, help rectify them and provide advice intended for the third Decadal Symposium. f) Following the production of the ICES Zooplankton Methodology Manual, the WGOH wishes to consider what publishable products it may generate in the future in order to enhance ICES dissemination of information to relevant stakeholders and the public.
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.); 5c (Co-ordinate international, monitoring and data management programmes which underpin ongoing ICES core science.) 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.); 5c (Co-ordinate international, monitoring and data management programmes which underpin ongoing ICES core science.) 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.); 5c (Co-ordinate international, monitoring and data management programmes which underpin ongoing ICES core science.) 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.)
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 (Bacon, UK). Agenda item discussion (1-2 hours Working

	GroupOH meeting) d) 5 days ICES Oceanographer Total = 4 days meeting time
Participants:	a) All members b) Holliday (UK) lead. All members. c) Bacon (UK) lead. All members. d) Dooley (ICES), Rossby (USA), Turrell (UK) e) Dickson (UK) f) Turrell (UK) lead. All members The Working Group would appreciate more active involvement of France and Portugal. Suggested names include Reverdin and Ambar
Secretariat Facilities:	None
Financial:	None apart from b) Publication / reproduction costs
Linkages to Advisory Committees:	b) ICES Annual Ocean Climate Status Summary available to ACFM and ACME c) Improve IAOCSS; ACME
Linkages to Other Committees or Groups	b) Publications Committee; Consultative Committee; SGGOOS c) SGGOOS
Linkages to Other Organisations:	b) IOC, JCOMM c) IOC, JCOMM

ANNEX A - AGENDA AND TERMS OF REFERENCE FOR 2001 WGOH MEETING

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

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

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

i) examine the potential predictability of ocean climate;

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

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

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

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

n) discuss underway ADCP measurements;

o) review progress towards the 2nd ICES Decadal Hydrobiological Variability Symposium;

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

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

Justifications

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.

ANNEX B: LIST OF PARTICIPANTS

Lp.	Name	Institution	Country	E-mail
1.	Bacon, Sheldon	SOC	UK	s.bacon@soc.soton.ac.uk
2.	Borenäs, Karin	SMHI	Sweden	karin.borenas@smhi.se
3.	Breim, Johannes	MRI	Iceland	j.breim@hafro.is
4.	Colbourne, Eugene	DFO	Canada	colbourn@dfo-mpo.gc.ca
5.	Danielson, Magnus	MRI	Iceland	m.danielson@hafro.is
6.	Dickson, Bob	CEFAS	UK	r.r.dickson@cefas.co.uk
7.	Hendry, Ross	DFO	Canada	hendryr@dfo-mpo.gc.ca
8.	Holliday, Penny	SOC	UK	p.holliday@soc.soton.ac.uk
9.	Jónsson, Steingrímur	UNAK	Iceland	steing@unak.is
10.	Lavin, Alicia	IEO	Spain	alicia.lavin@st.ieo.es
11.	Loeng, Harald	IMR	Norway	harald.loeng@imr.no
12.	Malkki, Pentti	FIMR	Finland	malkki@fimr.fi
13.	Malmberg, Svend-Aage	MRI	Island	svam@hafro.is
14.	Ozhigin, Vladimir	PINRO	Russia	ozhigin@pinro.murmansk.ru
15.	Piechura, Jan	IO PAS	Poland	piechura@iopan.gda.pl.
16.	Rossby, Tom	GSO/URI	USA	trossby@gso.uri.edu
17.	Turrell, Bill	MLA	UK	turrellb@marlab.ac.uk
18.	Valdimarsson, Héðinn	MRI	Iceland	hv@hafro.is

ANNEX C: LIST OF MEMBERS

Dr H. van Aken
Netherlands Institute for
Sea Research
P.O. Box 59
NL-1790 AB Den Burg, Texel
Netherlands
aken@nioz.nl
TEL: +31(0)222 369416
FAX: +31(0)222 319674

Dr Sheldon Bacon
Southampton Oceanography
Centre
Waterfront Campus
European Way
Southampton SO14 3ZH
United Kingdom
sheldon.bacon@soc.soton.ac.uk

Dr G. Becker
Bundesamt f. Seeschiffahrt
und Hydrographie
Bernhard-Nocht-Str. 78
D-20359 Hamburg
Germany
gerd.becker@m2.hamburg.bsh.d400.de

Dr A.J. van Bennekom
Netherlands Institute for
Sea Research
P.O. Box 59
NL-1790 AB Den Burg, Texel
Netherlands
bennekom@nioz.nl

Dr J. Blindheim
Institute of Marine Research
P.O. Box 1870 Nordnes
N-5817 Bergen
Norway
Johan.Blindheim@imr.no
TEL: +47 55 238500
FAX: +47 55 238531

Dr K. Borenäs
SMHI
Nya Varvet 31
426 71 Västra Frölunda
Sweden
karin.borenas@smhi.se

Ms H. Cavaco
IPIMAR
Avenida de Brasilia
P-1400 Lisbon
Portugal
hcavaco@ipimar.pt

Mr E. Colbourne
Dept. of Fisheries & Oceans
P.O. Box 5667
St John's, Nfld A1C 5X1
Canada
colbourn@dfo-mpo-gc.ca
TEL: 709-772-6106
FAX: 709-772-5315

Dr C. Afonso Dias
IPIMAR
Avenida de Brasilia
P-1400 Lisbon
Portugal
cadias@ipimar.pt

Dr R.R. Dickson, FRSE
CEFAS
Lowestoft Laboratory
Lowestoft
Suffolk NR33 0HT
United Kingdom
r.r.dickson@cefas.co.uk
TEL: +44 1502 562244
FAX: +44 1502 513865

Prof. J. Elken
Estonian Marine Institute
Paldiski Rd. 1
106 37 Tallinn
Estonia
elken@phys.sea.ee

Dr E. Fahrbach
Alfred-Wegener-Institut für
Polar- und Meeresforschung
Columbus Center
D-27668 Bremerhaven
Germany
efahrbach@AWI-Bremerhaven.DE

Prof. A.F. Fiuza
University of Lisbon
Institute of Oceanography
Campo Grande
1700 Lisbon
Portugal
fiuza@fc.ul.pt

Mr N. Gooding
UK Hydrographic Office
Taunton
Somerset TA1 2DN
United Kingdom
ngooding@ocean.hydro.gov.uk

Mr E. Hagen
Institut für Ostseeforschung
Seestrasse 15
D-18119 Warnemünde
Germany
eberhard.hagen@io-warnemuende.de

Mr B. Hansen
Fiskirannsóknarstovan
P.O. Box 3051, Noatun
FO-110 Tórshavn
Faroe Islands
Denmark
bogihan@sleipnir.fo

Dr R.M Hendry
Dept. of Fisheries & Oceans
Bedford Institute of
Oceanography
P.O. Box 1006
Dartmouth, NS B2Y 4A2
Canada
hendryr@dfo-mpo.gc.ca

Dr N.K. Højerslev
Geofysisk Afdeling
Juliane Mariesvej 30
2100 Copenhagen O
Denmark
nkh@gfy.ku.dk

Ms Penny Holliday (WOCE IPO)
Southampton Oceanography
Centre
Waterfront Campus
European Way
Southampton SO14 3ZH
United Kingdom
P.Holliday@soc.soton.ac.uk

Dr K.P. Koltermann
Bundesamt f. Seeschiffahrt
und Hydrographie
Bernhard-Nocht-Str. 78
D-20359 Hamburg
Germany
Koltermann@m5.hamburg.bsh.d400.de

Dr A. Lavín
Instituto Español de Oceanografía
Laboratorio de Santander
Apdo 240
E-39080 Santander
Spain
alicia.lavin@st.ieo.es
TEL: 34 942 291060
FAX: 34 942 275072

Mr H. Loeng
Institute of Marine Research
P.O. Box 1870 Nordnes
N-5817 Bergen
Norway
harald.loeng@imr.no
TEL: +47 55 238466
FAX: +47 55 238531

Prof P. Lundberg
Fysisk Oceanografi
Stockholms Universitet
106 01 Stockholm
Sweden
peter@misu.su.se

Dr S.A. Malmberg
Marine Research Institute
P.O. Box 1390
Skúlagata 4
IS-l21 Reykjavík
Iceland
svam@hafro.is

Prof. J. Meincke
Institut für Meereskunde
der Universität Hamburg
Troplowitzstrasse 7
D-22529 Hamburg
Germany
meincke@ifm.uni-hamburg.de
TEL: +49 (0)40-42838-5985
FAX: +49 (0)40-42838-4644

Prof. J. Olafsson
Marine Research Institute
P.O. Box 1390
Skúlagata 4
IS-l21 Reykjavík
Iceland
jon@hafro.is

Mr S. Osterhus
University of Bergen
Geophysical Institute
Allegaten 70
N-5007 Bergen
Norway
svein@regn.gfi.uib.no

Dr V. Ozhigin
PINRO
6, Knipovitch Street
183763 Murmansk
Russia
ozhigin@pinro.murmansk.ru

Mme A. Pichon
EPSHOM
B.P. 426
29275 Brest Cédex
France
pichon@shom.fr

Dr J. Piechura
Institute of Oceanology
Polish Academy of Sciences
Powstancow Warszawy 55
81-712 Sopot
Poland
piechura@ocean.iopan.gda.pl
TEL: (+4858)5517281
FAX: (+4858)5512130

Prof. T. Rossby
Graduate School of
Oceanography
University of Rhode Island
Kingston R.I. 02881
USA
trossby@gso.uri.edu

Mr M. Stein
Bundesforschungsanstalt f.
Fischerei
Institut für Seefischerei
Palmaille 9
D-22767 Hamburg
Germany
Stein.ish@bfa-fisch.de
TEL: +49 403 890 5194
FAX: +49 403 890 5263

Dr W. Turrell
Fisheries Research Services
Marine Laboratory
P.O. Box 101
Victoria Road
Aberdeen AB11 9DB
United Kingdom
turrellb@marlab.ac.uk
TEL: +44 1224 876544
FAX: +44 1224 295511

Mr J.P. Vitorino
Instituto Hidrografico
Rua das Trinas 49
P-1296 Lisbon
Portugal

Mr W. Walcowzski
Institute of Oceanology
Polish Academy of Sciences
Powstancow Warszawy 55
81-712 Sopot
Poland
walczows@iopan.gda.pl
TEL: (+4858)5517281
FAX: (+4858)5512130

ANNEX D: REVIEW OF THE 2000 WGOH REPORT

REVIEW OF THE 2000 REPORT FROM THE WORKING GROUP ON OCEANIC HYDROGRAPHY

Reviewers: B. Hansen, H. Dahlin, J. Brown

The 2000 report of the OHWG is a comprehensive document, totalling 130 pages. Most of this consists of a series of annexes with information on the state of the ocean in various areas in 1999/2000. This includes “The Annual ICES Ocean Climate Status Summary” (AIOCSS), but also has more elaborate descriptions from the various WG participants. The AIOCSS and the more detailed information form a very useful source of information and the WG and its chairman are to be highly commended for the large amount of work they put into its compilation.

1. Were the Terms of Reference properly addressed and completed?

As a whole, the Terms of Reference (TOR) seem to have been adequately discussed and completed. The main focus of the meeting has been on the AIOCSS and the supporting information in the annexes, but a number of other tasks have been fulfilled. One task, not fulfilled, was the compilation of a list of oceanographic data sets in danger of being lost, but such a task would also seem somewhat over ambitious for a WG meeting. The group instead made specific recommendations on how to prevent loss of old data.

2. Is the report clear and understandable?

The length of the report and diversity of themes necessarily requires the reader to put some effort into assimilating it, but the discussion on the various TOR and scientific topics is well structured and clearly put. A few misprints (e.g. Iceland Sea instead of Iceland Basin) are a bit confusing.

3. Is the science quality adequate?

Most of the report concerns scientific, rather than administrative, topics and their treatment appears to have been as comprehensive as can expected from a meeting of this kind. The main task of the group, to compile the AIOCSS and its supporting regional contributions, can never be fulfilled better than the observational system allows. Within its limitations, this and the other tasks were treated adequately.

4. Are the conclusions well supported and acceptable?

Within the limitations noted above, the scientific conclusions seem acceptable. Other conclusions and recommendations are adequately supported.

5. Linkages to other topics, or work elsewhere in ICES?

The WG discussed a number of topics which involve other groups in ICES (e.g. GOOS, data management, radioactivity). A new initiative to have a meeting of all the Oceanography WG chairs was well received by the WG, as was a suggestion to circulate executive summaries of WG reports to other WG’s.

6. Is the work suitable for an ICES publication?

The AIOCSS started out as annex to the WG report. Since then it has been printed separately for the Annual Science Meeting and put on the web. This has increased its distribution, but it is not easily cited. Now, the WG recommends its regular publication as a Co-operative Research Report which would give it a more citable status. The supporting information for this recommendation, unfortunately, seems partly to be mixed with the previous recommendation in the report.

7. How should the work be continued?

The OHWG has functioned in its present form for many years although the increased focus on the production of the AIOCSS is fairly recent. The general satisfaction of participants and users argues a continuation along these lines as recommended by the WG for its next meeting.

8. Was attendance and expertise adequate?

The WG itself identified lack of attendance, both nationally and in terms of regional expertise and made recommendations for specific persons to be approached for attendance at future meetings.

ANNEX E: THE EARLIER WARM PERIOD IN THE NORTHERN NORTH ATLANTIC, 1925-60.

By

Bob Dickson

Centre for Environment, Fisheries and Aquaculture Science, Lowestoft, Suffolk NR 33 OHT, UK

1. Background

The observed hemispheric warming of the past Century took place in two distinct episodes, from 1925 to 1960 and from the late 1970s to the present (Figure 1; Dr Phil Jones, UEA-CRU, pers comm.). The later event is increasingly viewed by the IPCC (1996) as anthropogenic, and coincided in the Atlantic sector with a record amplification of the NAO which itself may be a partial response to greenhouse gas forcing (Gillett et al, in press). Though the earlier warming episode was more prolonged, its causes remain less well known. In view of the influence of that earlier episode of warming on the global temperature trend and its association with high northern latitudes (see below), the Arctic Ocean Science Board has recently begun its re-analysis.

2. The global distribution of warming

Figures 2 and 3 describe the global extent of the warming during each of the two main episodes as a function of latitude and longitude. In Figure 2, from Delworth and Knutson (2000), the warmth in the middle decades of the Century is seen to be largely confined to latitudes north of 40N whereas the recent warming has an almost global span. And by contrasting the global distribution of surface temperature anomaly in 1930-60 with that in 1961-90, Figure 3 confirms that the earlier warm episode was largely a feature of the N. Atlantic sector. Combining the evidence of Figs 2 and 3, the earlier warming is seen to be focused on the Atlantic northern gyre.

3. Comparing the recent and earlier warmings in the high latitude ocean

During the recent NAO-positive episode, a strengthened southerly airflow over the eastern Norwegian Sea with a lower air-sea temperature contrast is held responsible for driving a warmer (Dickson et al 2000), probably stronger (Haugan, VEINS results, pers comm) and probably narrower (Blindheim et al 2000) flow of Atlantic water northwards to the Barents Sea and Arctic Ocean. In keeping with the well-established correlation between winter NAO Index and SST anomaly, the warmth spread as a narrow band along the eastern boundary, with cold conditions (in general) elsewhere in the northern gyre.

During the earlier episode, a warm salty wave seems to have pervaded the entire sub-polar gyre. This was the period in which a precipitous warming of more than 2°C in the 5-year mean affected the West Greenland Banks (Smed 1965; Buch and Hansen, 1988), when mean temperatures reached their long term maximum at both Faroes (Hansen and Meincke, 1984) and along the Kola Section of the Barents Sea (Loeng, 1991), when the salinity of North Atlantic Water passing through the Faroe-Shetland Channel reached a century-long high (Dooley et al 1984) and when salinities were so high off Cape Farewell that they were thrown out as erroneous (Harvey, 1962). Most of these time-series are illustrated in Figure 4, from Dickson and Brander, (1993).

The different character of the two episodes of warming is most clearly evident in the Barents Sea. When we compare the Century-long temperature series along the Kola Meridian (33° 30'E) with Adlandsvik's Barents Sea Index (an inflow index based on the Bear Island – Fugloy pressure gradient) we find that the two series are closely correlated from the 1960s to the present, but uncorrelated before that. This suggests that the local pressure gradient helped determine the flux of warmth to the Barents Sea during the years of NAO dominance, but that in earlier decades, the temperature of the water spreading around the northern gyre to the Barents Sea was "pre-set", (remotely determined).

4. Forcing.

It seems plain that the warming which has been observed along the eastern boundary of the Atlantic to the Barents Sea in recent decades has its origin in the long-term amplification of the NAO to its extreme NAO-positive state (generally) in the 1990s (see Dickson et al 2000, their Figure 10). It is also clear that NAO forcing was relatively weak during the middle decades of the Century. EOF analysis of the Atlantic winter pressure field by Hurrell (2000, pers comm) shows that the percentage of slp variance explained by EOF 1 (the NAO dipole pattern) dropped to 38% in 1935-65 compared with 44% during the Century as a whole (1899-1999) and 52% during the recent period of NAO dominance (1966-99).

However, Hurrell's analysis does not identify a corresponding strengthening in any other recurrent mode of the Atlantic winter pressure field, i.e. there is no convincing correspondence between Atlantic hydrography and the time-dependence of the first three slp eigenfunction patterns over the present Century.

The index of atmospheric behaviour that appears to correspond most closely to the changing hydrography of the northern gyre is the so-called "u-index" of Kushnir (1994), which measures the relative strengths of the mean zonal wind at 30-40N compared with that at 50-60N over the central part (20-40W) of the open north Atlantic (see Figure 5 for a schematic). The u-index thus captures the changing sense (cyclonic or anticyclonic) of the airflow in Atlantic midlatitudes. Changes in the u-index have closely paralleled those of West Greenland SST (or indeed Faroes or Barents Sea temperature) over most of this Century (Figure 5), and since the strengthened cyclonic airflow of a positive u-index will provide southerlies at the entrance to the Nordic seas and an increased easterly airflow over the west-going Irminger Current to West Greenland, the association may be causal. A comparison of model output with the observed characteristics (rate and onset) of the mid-Century warming at W. Greenland, Faroes and Kola would be needed to establish this point.

5. Ecosystem effects at Greenland

During the so-called "warming in the north", the northward dislocations of biogeographical boundaries for a wide range of species from plankton to commercial fish, terrestrial mammals and birds were at their most extreme in the present century. The astonishing nature of these radical events is clear from the classic accounts by Ad. S. Jensen (1939), A. Vedel Taning (1943, 1949), B. Saemundsson (1934), P. M. Hansen et al (1935), A. Fridriksson (1949), N.M. Knipowitsch (1931), A.C. Stephen (1938) and many others, summarised in a comprehensive bibliography by Arthur Lee (1949) and reviewed in an ICES Special Scientific Meeting on "Climatic Changes in the Arctic in Relation to Plants and Animals" in 1948.

As the circulation and hydrography of the subpolar gyre underwent its slow evolution during the middle decades of this Century, the rise and spread of the West Greenland cod fishery was one spectacular result (Figures 6 and 7). We attribute this change to an increased transport of warmth and cod larvae from waters off southwest Iceland as the Irminger Current strengthened (see above; Dickson and Brander; 1993; Schopka, 1993, 1994). While it is possible that the first cod colonizing the West Greenland Banks established a self-sustaining stock there, purely through the amelioration of the marine climate, the parallelism between cod and haddock catches along the western banks (Figure 6; see Hovgård and Messtorff, 1987) seems to confirm that recruitment to the West Greenland cod stock was fed to a significant extent by a time-varying larval drift from Iceland. Unlike cod, haddock do not spawn successfully at West Greenland, so if adult haddock are caught there they must have drifted there as larvae; the closest known spawning site for haddock lies upstream near the cod spawning grounds off southwest Iceland.

However that may be, the result was an explosive development of the West Greenland cod fishery which, from a negligible tonnage in the early 1920s, rose to over 300 000 t yr^{-1} in the 1950s and 1960s, and to a maximum of >450 000 t yr^{-1} before abruptly declining once again between the late 1960s and the present, as cooler conditions returned (Buch and Hansen, 1988; Dickson and Brander, 1993). As the West Greenland cod stock built, so it expanded steadily northwards, reaching Upernavik by the late 30s (Figure 7). Such "cod periods" have been documented in the past at West Greenland, in the 1820s and 1840s (Hansen, 1949) and perhaps much earlier (Fabricius, 1780), but this change represented a return of cod to West Greenland after an absence of at least 50-70 yr (Buch and Hansen, 1988; Dickson *et al,* 1994).

As the NAO-minimum of the mid-60s brought polar conditions and a record sea-ice extent to North Icelandic waters (Malmberg 1969), and as the u-index underwent its sharp reversal (Figure 5), so the cod fishery at West Greenland and the warmth which sustained it both came to an abrupt end. By 1992, Jakobsson was able to report in his keynote review of *"Recent Variability in Fisheries of the North Atlantic"* that the Greenland fishery had not been self-sustaining for 35 years, and that despite occasional years (e.g. 1984) with a heavier drift of larvae from Iceland, it was unavailing. "By 1990, the cod had disappeared from Greenlandic waters."

6. Ecosystem effects off Iqaliut

For waters off Iqaluit, the issue is whether at the peak of the West Greenland cod stock, there was ever any significant exchange of larval and adult cod between West Greenland and the Labrador coast of Canada. The question is not whether it is possible----tagging returns show clearly enough that adult cod occasionally migrate in either direction (e.g. Templeman 1974, 1981)----but whether these exchanges were ever significant to the cod stocks on either coast. Dickson and Brander (1993) conclude that the evidence is fragmentary and inconclusive but cannot entirely be dismissed. During the absolute maximum of the W. Greenland cod stock, they find sequences of years when a proportion of W. Greenland larvae were observed to spread west into the Davis Strait, when the mean vertebral counts of cod off Iqaluit dipped towards the low values characteristic of W. Greenland fish, and when juvenile *Sebastes mentella* from much the same spawning grounds off SW Greenland were observed to arrive off Baffin Island and the northern Labrador Shelf (Templeman 1961). The key point, however, is that the chain of circumstances required to promote effective exchange between the cod stocks of W. Greenland and Labrador is sufficiently tenuous that successful intermixture must be a rare event.

7. Ecosystem effects elsewhere

Radical changes in the Atlantic ecosystem were not confined to W. Greenland and the Davis Strait in these middle decades of the Century. The "Russell Cycle" brought a more-southerly community to the ecosystem of the Western Channel at about the same time and perhaps for related reasons (eg Cushing 1982). In the Nordic Seas, the spawning stock biomass of the Norwegian spring-spawning herring rose to a maximum in mid-Century as the wave of warmth passed through the Northern Gyre, and the range of its feeding-spawning-overwintering movements expanded to the west and north following the retreat of the Ocean Polar Front (since reversed; see Vilhjalmsson 1997). In the Barents Sea the wave of warmth brought a sustained increase in the yield, weight, liver-weight, roe weight and recruitment of *skrei* from their pre-existing minima associated with the extreme cold in the early years of the Century (Helland-Hansen and Nansen, 1909; Anon, 1996).

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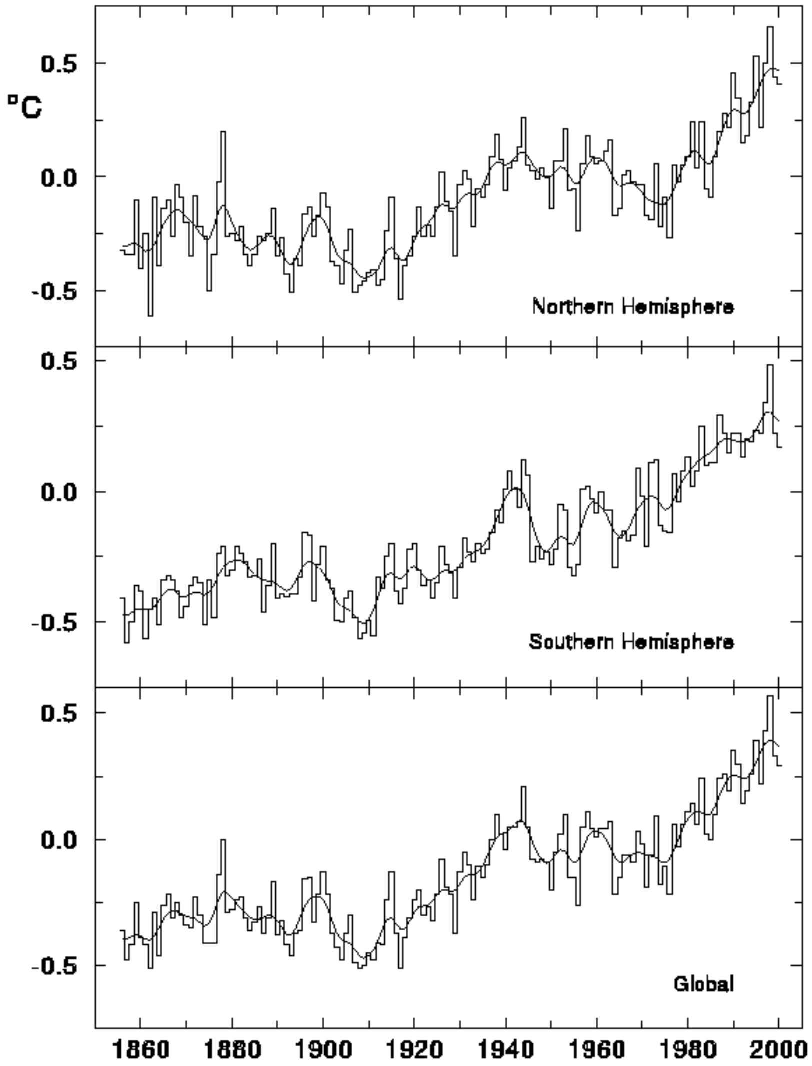


Figure 1. Hemispheric and global temperature averages on an annual timescale relative to 1961-90, kindly provided by Dr Phil Jones, Climate Research Unit, University of East Anglia.

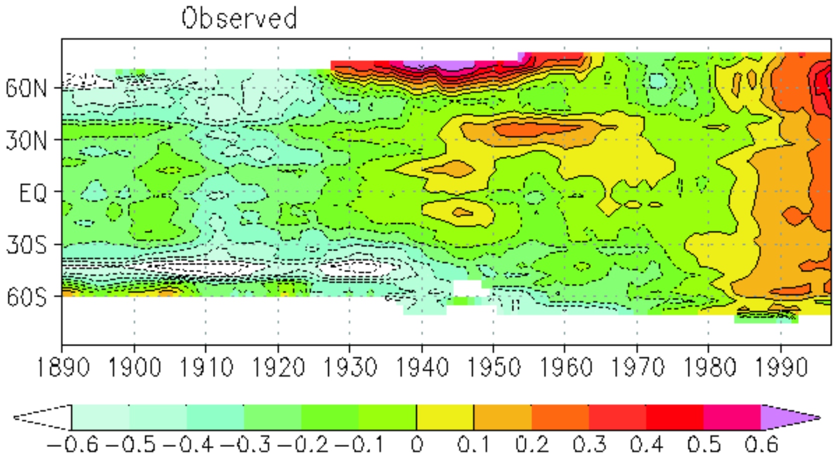


Figure 2. Observed distribution of zonal surface temperature anomalies (°C; 10 year lowpass filtered) as a function of time and latitude, from Delworth and Knutson, 2000.

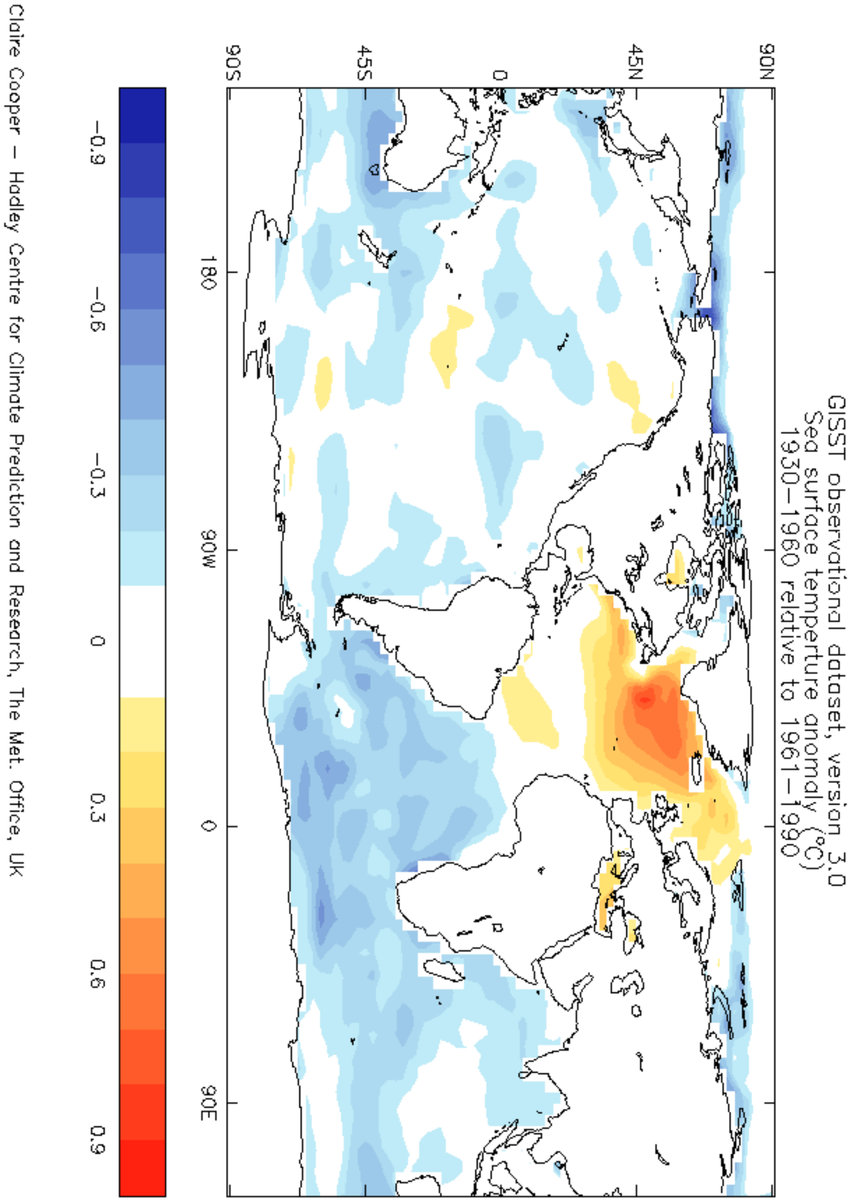


Figure 3. Global distribution of sea surface temperature anomalies (°C), 1930-60 relative to 1961-1990. (GISST observational dataset version 3.0).

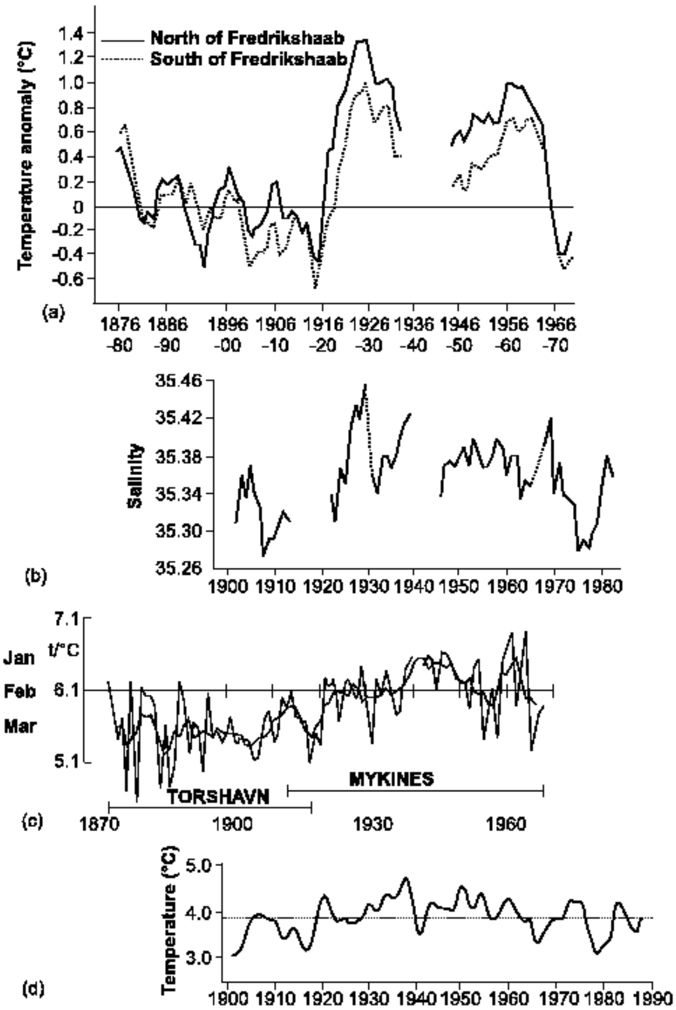


Figure 4. Records of the warm salty wave that passed through the subpolar gyre of the North Atlantic in the middle decades of the 20th Century (a) Surface temperature anomalies for West Greenland, 1876-1974 (Smed's data, from Buch and Hansen, 1988), (b) the salinity of the North Atlantic Water in the Faroe- Shetland Channel, 1902-82 (from Dooley et al 1984), (c) winter surface temperature at Faroes, 1875-1969 (from Hansen and Meincke, 1984), (d) 3-year running averages of yearly temperature along the Kola Section of the Barents Sea, 1900-90 (from Loeng 1991) plotted to a common time-base. From Dickson and Brander, 1993.

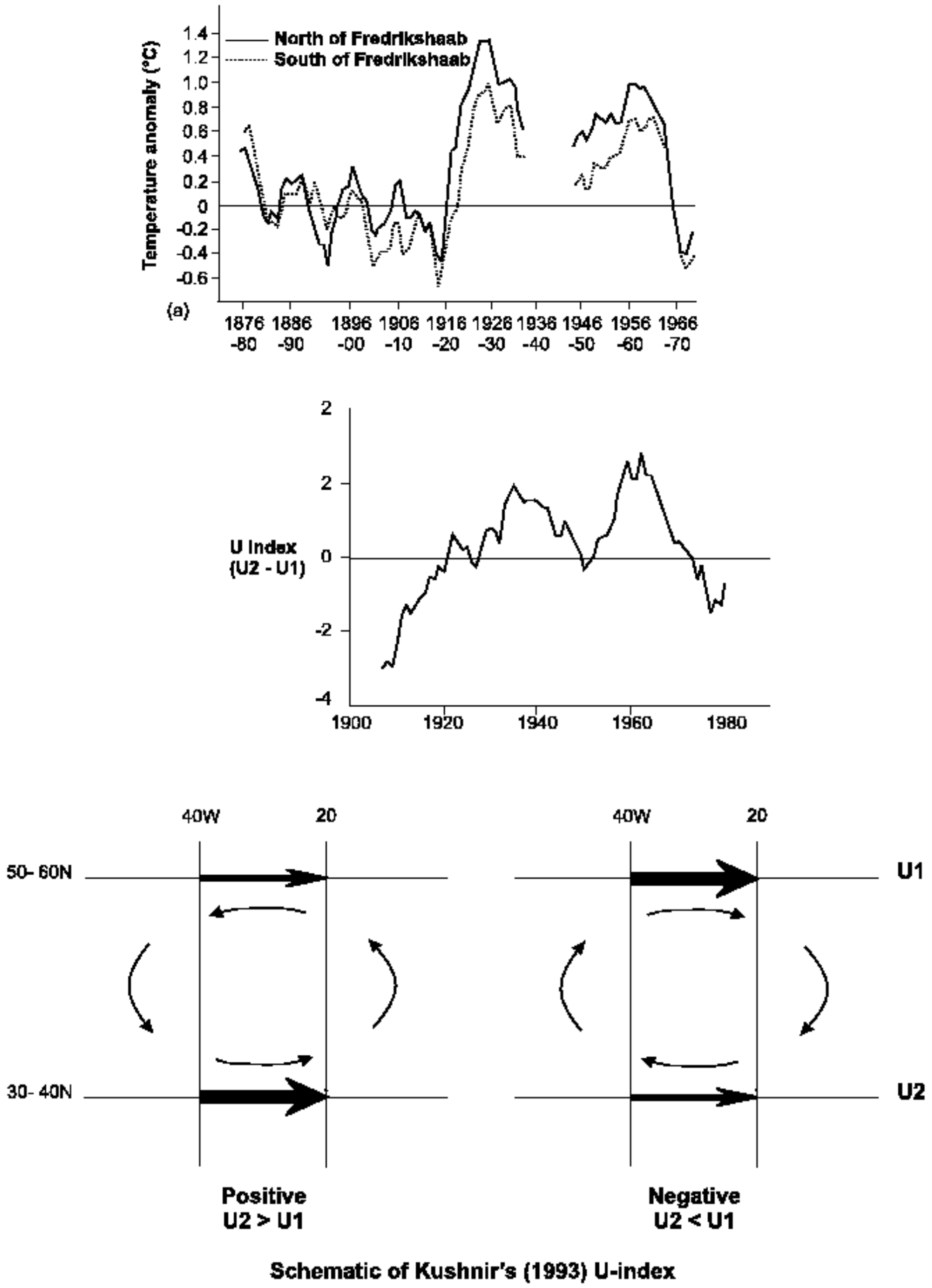
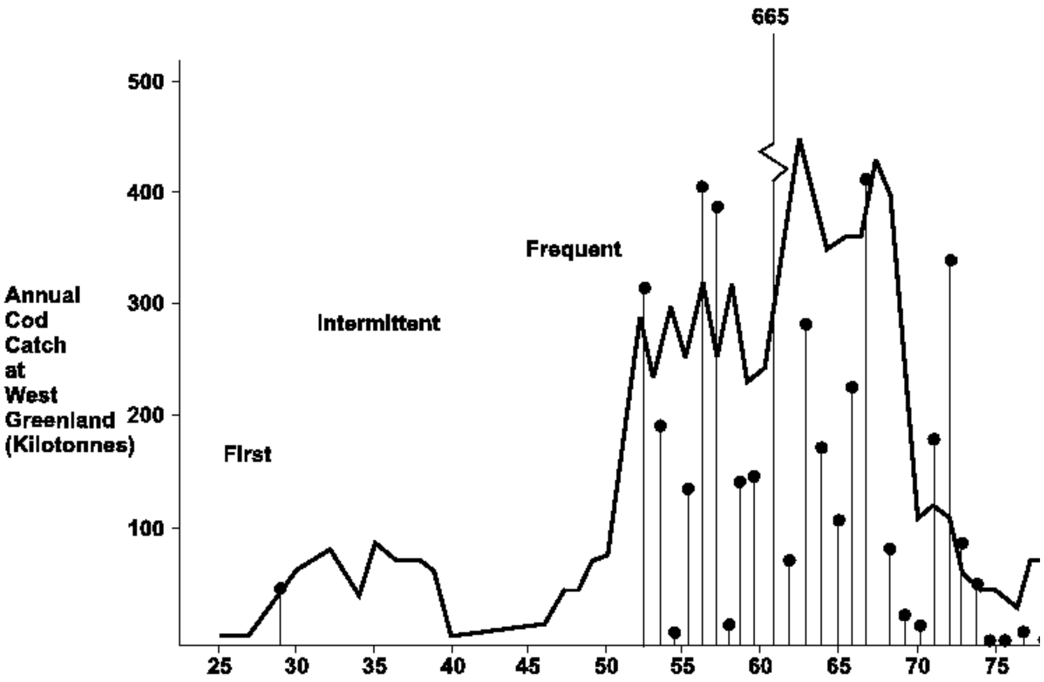


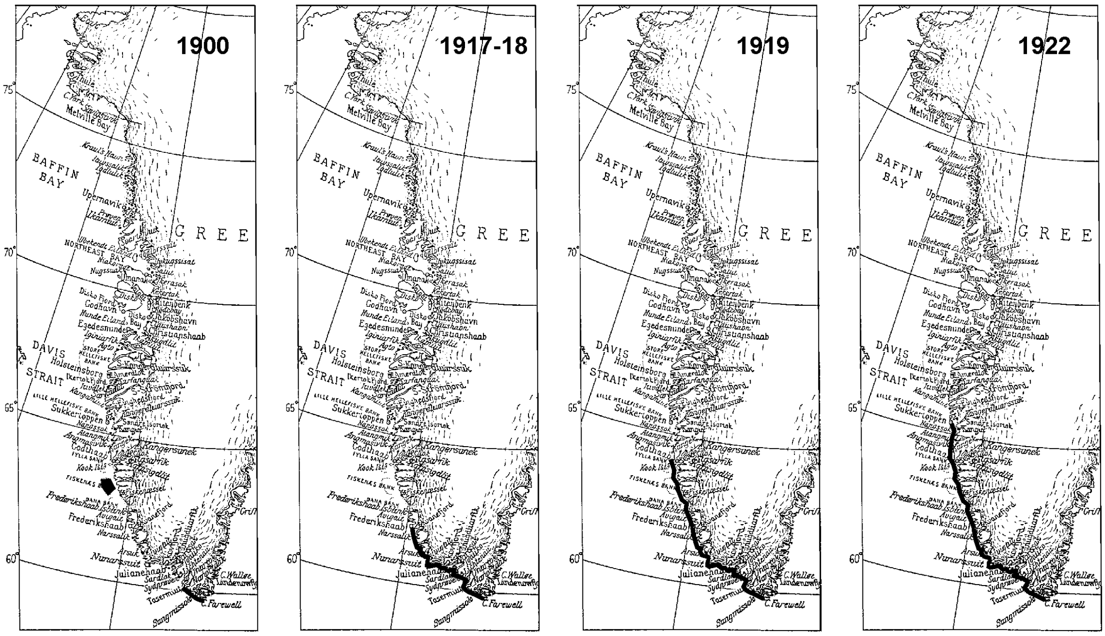
Figure 5. Variation of Kushnir's (1993) U-index over the present century compared with the change in SST anomaly on the West Greenland Banks, 1876-1974 (Smed 1965). The sense of the Atlantic airflow for positive and negative values of the index is schematically described in the lower panels. For further explanation see text.

Figure 6. Annual international catch of cod and haddock at West Greenland since 1925. (Cod data, left hand scale, from Buch and Hansen, 1988; haddock, right hand scale, from Hovgaard and Messtorff, 1987). Annotations refer to haddock catch.



Catches of cod and haddock off West Greenland, 1925 - 1985
(From Buch and Hansen, 1988. From Hovgaard and Messtorff, 1987)

Spread and Retraction of Cod at West Greenland

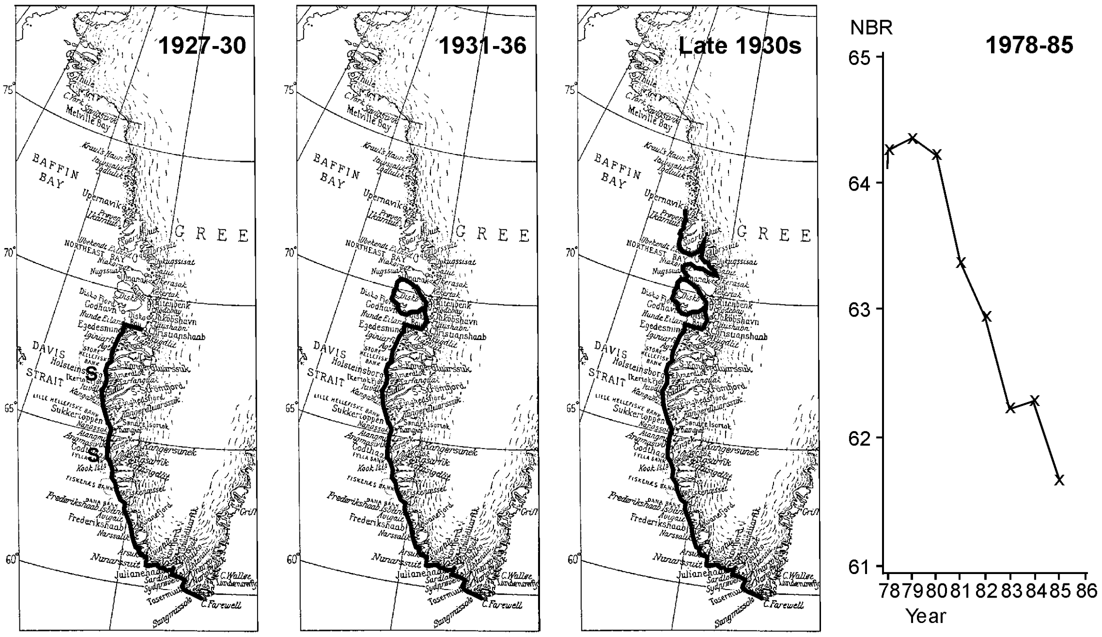


Cape Farwell & Fiskenes Bank

To Frederikshaab

To Godhaab

To Sukkertoppen



To Christianshaab
First evidence of spawning
DANA 1925

To Umanak

To Upernavik

Figure 7. Spread and retraction of cod at West Greenland in response to the amelioration and deterioration of the marine climate, 1900-85.

ANNEX F: EVALUATION OF ICES OCEANOGRAPHIC DATA CENTRE PRODUCTS

AN EVALUATION OF THE RELEVANCE OF CLIMATOLOGICAL AND TIME SERIES PRODUCTS PREPARED BY THE ICES OCEANOGRAPHIC DATA CENTRE AS POTENTIAL INPUT TO THE ICES ANNUAL OCEAN CLIMATE STATUS SUMMARY

By

H Dooley, ICES Oceanographer

Background

The Working Group has now developed and maintained the IAOCSS for three years. Its content and format provide a valuable contribution to the availability of information on the current state of the marine environment of the ICES fisheries areas in particular. It is built up from individual contributions based mainly on analyses from the ICES "Standard Stations" and "Standard Sections" and is backed up by expert analyses and interpretation by oceanographers who have expert knowledge of the fundamental aspects of the oceanography and climatology of these sections and stations.

The purpose of this agenda item is to propose and debate the possibility of extending the basic IAOCSS product to include an operational element. The specific proposal is make the preparation and availability of any time series on demand using a continuously updated and refreshed oceanographic database as the underlying source. The challenge is to do this in a way that reflects the main features of all the variability captured in the IAOCSS, yet can be generated in a simple and logical way by marine scientists who are not necessarily expert oceanographers and by other interested groups.

The proposal assumes it is the ICES Service Hydrographique that is the maintainer and provider of this product. This does not mean that this should be the expected final conclusion as other organisations may be in a better position to provide a more robust, statistically valid and relevant product. For example the "World Ocean Database" CD-ROM series produced by the Ocean Climate Laboratory (OCL) of the World Data Centre "A" already includes products which may be of use in this context.

Introduction to Proposal

The proposal described here uses information and material brought together and developed for the VEINS (Variability of Exchanges in the Nordic Seas) Project. The ICES Service Hydrographique managed the datasets produced as part of this Project and is responsible for the production of the project CD-ROM which is due to be published at any time. Many of the Working Group members took a very active role in this project. During its three year life span, the Project produced an amazing amount of data, including some 3,906 CTD and water bottle (nutrient, freons,, carbons, O-18) stations and 546 current (ADCP and RCM) time series. All these data, and related metadata and products will be included on the CD-ROM.

Trial Dataset

All the publically available historical data of the Nordic Seas north of 58°N that is in the Service Hydrographiques archives are being included on the VEINS CD-ROM, as noted in the Technical Annex for that Project. This data set is perhaps the most comprehensive one that is currently available for this area (see Figure F.1) but important gaps remain. These include some of the data published recently as part of an ACSYS funded data CD-ROM compilation (BARKOD) and the Service Hydrographique is currently identifying gaps in its own database in relation to the contents of this CD-ROM. Some of these data have never been previously in the public-domain, for example the data sets of the Norwegian Polar Institute in Tromso. However many important gaps will remain, for example the BARKOD project only addressed temperature and salinity data in its relatively small geographic area of interest and rejected all other data types (e.g., oxygen and nutrients). Importantly, the BARKOD CD-ROM did not include the data sets of the Knipovitch Institute (PINRO) in Murmansk, the location of the Working Group meeting on 1998. In spite of the contacts established at that time, and the resulting provision of Norwegian and Barents Sea data sets held by the Service Hydrographique to PINRO, it has still not been possible to acquire any part of the huge data sets that were demonstrated to the Working Group at that time. It is anticipated that acquisition of the PINRO datasets would double the size of the currently available dataset for this area.

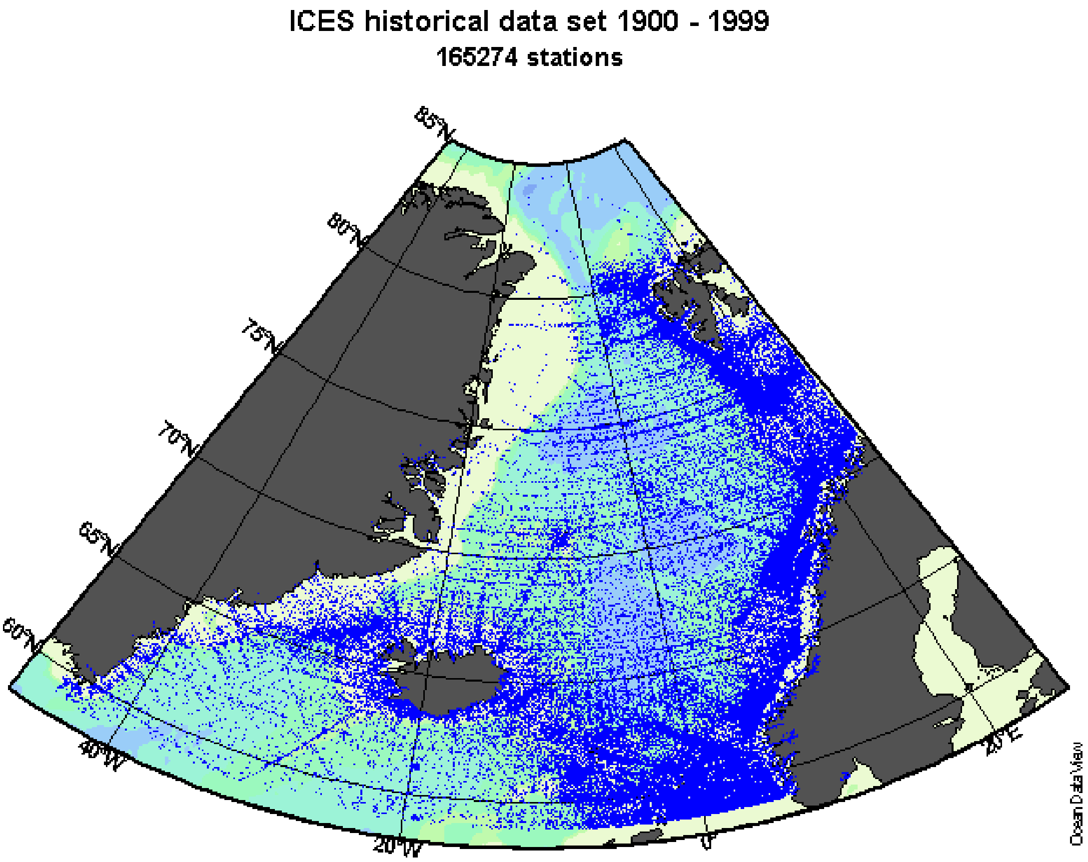


Figure F.1 Station distribution of the historical Hydro-chemistry/CTD data set published on the VEINS CD-ROM.

Gaps in data sets such as the ones described above will be a major stumbling block in producing any type of "operational" time series product if the basic data does not compare with the data on which the "expert" time series has been created. This restraint is perhaps the major consideration in producing a suitable product.

Data Preparation

The basis of the proposed time series product that is included in the VEINS CD-ROM is the compilation of a gridded data set (in this case 1x2 degree). Initially, the basic data are vertically interpolated to pre-determined (pressure) surfaces (in this case the IAPSO standard pressures). From there a statistical analysis for each month is made, producing data sets such as the extract shown below in Table F.1. Statistics include quantities such as mean and standard deviations for each grid and month, but the software can produce other quantities, such as median and percentiles, if desired. No spatial interpolation is performed in this analysis which may be considered a shortcoming. But earlier tests employing objective analysis did not yield any additional useful information. A conclusion was that gridded statistics are best improved by going the extra mile to acquire all available data.

							Standard		
lat	lon	year	mth	depth	n	mean	deviation	min	max
64.5	-28	1903	6	0	2	35.14	0	35.14	35.14
64.5	-28	1929	8	0	1	35.1	0	35.1	35.1
64.5	-28	1931	7	0	1	35.16	0	35.16	35.16
64.5	-28	1932	7	0	1	35.08	0	35.08	35.08

lat	lon	year	mth	depth	n	mean	Standard deviation	min	max
64.5	-28	1933	3	0	1	35.13	0	35.13	35.13
64.5	-28	1933	7	0	1	35.12	0	35.12	35.12
64.5	-28	1938	6	0	3	35.1867	0.0047	35.18	35.19
64.5	-28	1953	6	0	1	35	0	35	35
64.5	-28	1954	5	0	4	35.145	0.0328	35.09	35.17
64.5	-28	1903	6	100	2	35.1502	0.0098	35.1404	35.16
64.5	-28	1929	8	100	1	35.1398	0	35.1398	35.1398
64.5	-28	1931	7	100	1	35.1404	0	35.1404	35.1404
64.5	-28	1932	7	100	1	35.1386	0	35.1386	35.1386
64.5	-28	1933	3	100	1	35.1509	0	35.1509	35.1509
64.5	-28	1938	6	100	3	35.1934	0.0093	35.1803	35.2003
64.5	-28	1951	7	100	1	35.1296	0	35.1296	35.1296
64.5	-28	1953	6	100	1	35.0997	0	35.0997	35.0997
64.5	-28	1903	6	500	2	35.0805	0.0195	35.0611	35.1
64.5	-28	1929	8	500	1	35.1268	0	35.1268	35.1268
64.5	-28	1933	3	500	1	35.1332	0	35.1332	35.1332
64.5	-28	1938	6	500	2	35.121	0.0397	35.0813	35.1607
64.5	-28	1903	6	1000	1	35.0153	0	35.0153	35.0153
64.5	-28	1929	8	1000	1	35.0066	0	35.0066	35.0066
64.5	-28	1903	6	1500	1	35.003	0	35.003	35.003

Table F.1 Extract of gridded monthly statistics of salinity which form the basis of the proposed product

Time Series Presentation

For the purpose of the VEINS CD-ROM, many of the gridded statistical data sets described in the previous section were first prepared on fixed pressure surfaces, viz 0, 100, 500 and 100dbars and also the bottom, and plotted as time series in as standard a way as possible. These plots are then made accessible via a clickable chart laid out in a grid. Fig F.2 shows the grid prepared for the area centred on the Faroe-Shetland Channel and Fig F.3 shows the time series brought up by clicking on one of these grids. The statistical data sets on which these time series are produced are also available for download from the CD-ROM by clicking on the time series chart. This will allow the user to produce different plots based on these data as desired.

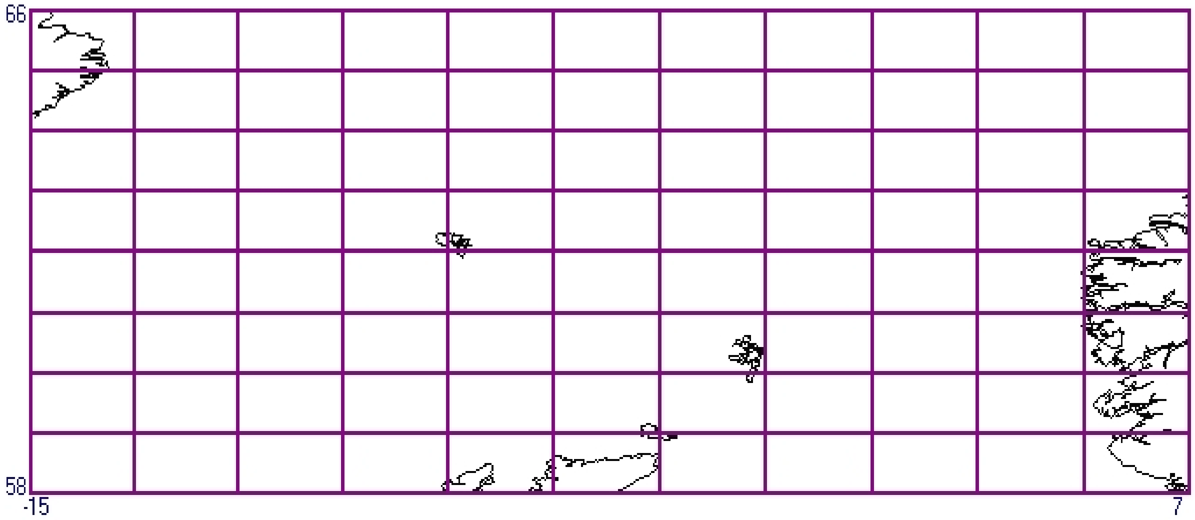


Figure F.2 – Chart showing grid distribution in the ICES-Scotland-Norway region

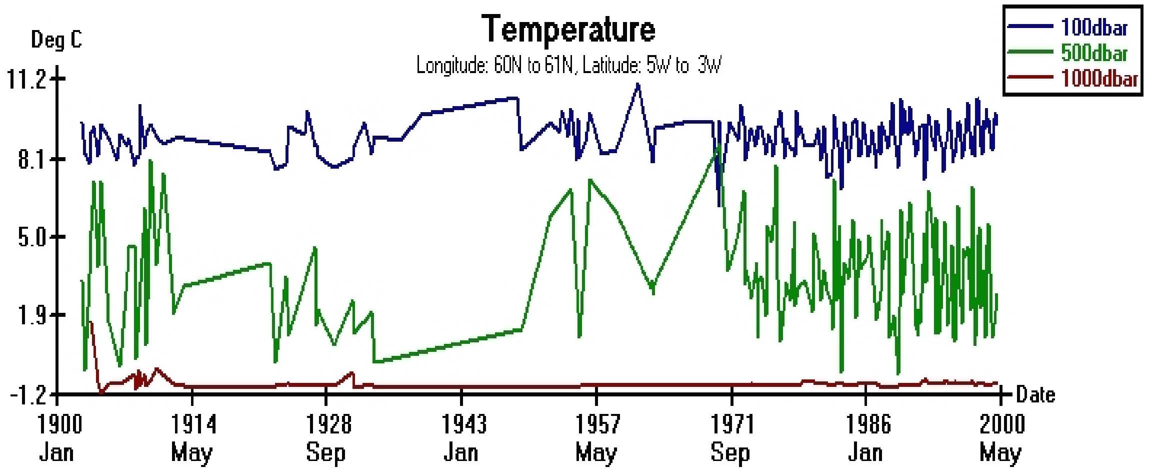


Figure F.3 – Monthly time series of temperature and salinity obtained by clicking on one of the grid cells in Figure F.2.

The Way Ahead

The “operational” products described above have been developed for use on a CD-ROM which requires that all time series are produced in advance, in a fixed way. Therefore the user cannot choose any time series on demand. The demonstration (VEINS) product has been limited to include only temperature and salinity time series. For any future product, this may need to be expanded to include all available parameters, which presently span more than 50 data types for the NORDIC seas alone. It is clear, therefore that the preparation of all possible time series and products in advance is quite impractical. However before addressing possible answers to this question the Working Group will need to satisfy itself that this product has the potential to be practical and useful adjunct to the IAOCSS. In particular it will need to satisfy itself that the information generated by this process satisfactorily compares with the products prepared for the IAOCSS. Having then incorporated any improvements to overcome any identified inconsistencies and shortcomings, consideration must then be given on ways to “operationalise” this product. A likely candidate for this would be to allow users to make selections from a web-based interface, and generate time series based on his selections, “on the fly”.

Discussion

The Group noted the potential value of a product of this nature, not least because it should promote the ICES oceanographic database to the wider oceanographic community, such as CLIVAR and WOCE. It recognised however the importance that a product of this nature should not conflict with time series prepared for the IAOCSS. These latter time series are prepared in a more rigorous way taking into account specific local conditions. It was noted that great care must be taken in making such data products available to other scientists, in particular to those who do not have an understanding of oceanography and oceanographic time series. It was also noted that data products such as this could prove valuable in providing statistics of the potential energy anomaly ( ) which could allow for an assessment of the variability of deep basin transport processes. Ultimately, however, the Working Group would have to satisfy itself that it was appropriate for ICES to release products of this nature. Hence an essential next step is to conduct a more rigorous intercomparison of this product with the IAOCSS products. T Rossby agreed to work with H Dooley in order to undertake this specific task. Fig F.4 gives an example of the comparisons that may be possible. In this case the Area 7 Northwest European Shelf Edge salinity time series produced in the IAOCSS is compared with the corresponding one generated from the set of monthly mean gridded salinity values at 100dbars.

The Group considered various ways of developing such a product further, and noted the various web sites under the auspices of the IPCC and others which would provide additional possibilities for generating products on the “fly”. Computer and skill limitations at the Secretariat may restrict the adoption of some of these possibilities. H Dooley was encouraged to provide a demonstration of the potential of this product for the Edinburgh (Decadal 2) Symposium in August 2001.

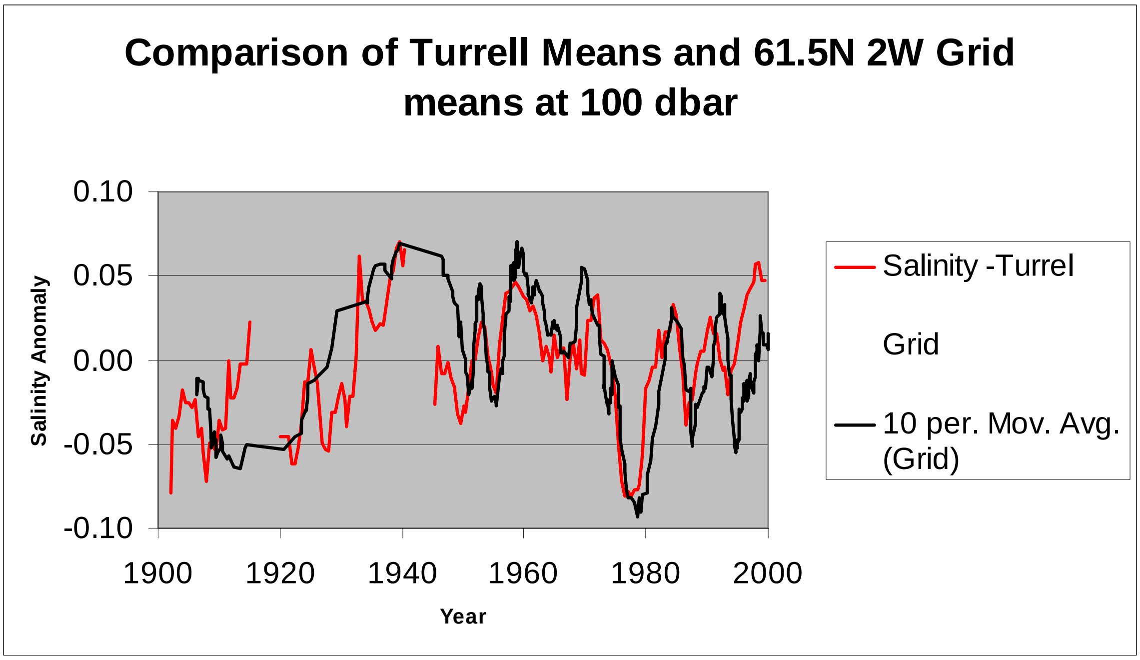


Fig F.4 Example of a comparison of time series of Faroe-Shetland Channel salinity anomaly (Turrell Means), and one produced from the proposed data product.

ANNEX G: DEVELOPING PLANS FOR AN ARCTIC-SUBARCTIC OCEAN FLUX ARRAY (ASOF)

Developing plans for an Arctic-SubArctic Ocean Flux Array (ASOF).

By

Bob Dickson, CEFAS, Lowestoft, UK

Background

In May 1999, the AOSB announced plans to study the two-way oceanic exchanges that link the Arctic Ocean with subarctic seas1. The rationale is bound up with the fact that most projections of greenhouse gas induced climate change anticipate a weakening of the thermohaline circulation (THC) in the North Atlantic in response to increased freshening and warming in the subpolar seas2-4. Since the overflow and descent of cold, dense waters across the Greenland-Scotland Ridge is a principal means by which the deep ocean is ventilated and renewed, the suggestion is that a reduction in upper-ocean density at high northern latitudes will weaken the THC.

Unfortunately, our models do not yet deal adequately with many of the mechanisms believed to control the THC, and our observations cannot yet supply many of the numbers they need. For example our present observations of this large scale overturning circulation (in the North Atlantic or anywhere else) are insufficient to detect whether or not it is changing; we have no measurements of the freshwater flux between the Arctic Ocean and Atlantic by either of its two main pathways; we have new measurements (from the EC VEINS project) of the heat and salt flux to the Arctic Ocean but not yet of its variability on any scale; we have a growing knowledge of the long-term variability of dense overflows which “drive” the THC but only embryonic ideas as to their causes, etc. Understandably then, we would take the view that these key mechanisms and processes are too crudely represented in the present generation of climate models.

Palaeoclimate records, however, show that massive and abrupt climate change has occurred in the Northern Hemisphere, especially during and just after the last Ice Age5-8, with THC change as the most plausible driver, and both palaeo-climate records and models suggest that the changes in the strength of the THC may occur rapidly, in a few decades. Further, in our admittedly-short modern records of ocean variability, we have growing evidence that hydrographic changes of decadal scale in the Arctic and subarctic seas are able to feed south across the deep northern overflows to cause hydrographic changes in the deep and abyssal layers of the Labrador Sea. These variations are large and long-sustained---eg the freshening of both dense overflows by between 0.01 and 0.02 per decade for the past 3.5 decades---though we don’t yet know enough about process to determine their climatic significance.

The high northern latitudes and the ocean fluxes that connect them to adjacent seas are plainly not the only constituent parts of this problem. The THC is driven globally by upwelling, downwelling and a strong component of upper-ocean wind-forcing, and fluctuations in any one of these components might affect the strength of the THC [see, for example, Toggweiler and Samuels9 for the role of the Southern Ocean windfield, or Latif et al10 for the role of the tropics in re-stabilising the THC under greenhouse warming conditions; see also ref 11]. Nonetheless buoyancy loss in the northern high latitudes and the factors that control it are still of a fundamental importance, are areas of continuing ignorance and are becoming tractable by modern observing systems. These thermohaline controls and linkages, then, form the research focus of ASOF.

The Evolution of ASOF

In the past year we have made three steps towards constructing a science plan for ASOF. On 6 April 2000 in Cambridge UK, as a joint initiative of the Arctic Ocean Science Board and the International Arctic Science Committee, a discussion meeting on the Sustained Monitoring of Arctic Fluxes was held during Arctic Science Summit Week, with three main objectives. First, to discuss the palaeo- and modelling evidence that THC slowdown or shutdown has happened in the past and is likely to recur in the future. Second, to begin to define the system of critical measurements that will be needed to understand the role of the high-latitude oceans in decadal to centennial climate variability. And third, to discuss ways of achieving the coordinated long-term stamina in our funding that we will need if we are to implement such a system across all the main gateways to/from the Arctic Ocean over a period of a decade or more.

The scientific planning of ASOF was later advanced by means of a second discussion meeting and workshop, held at the Norsk Polarinstitutt, Tromso on 21-24 September 2000, in conjunction with the H. U. Sverdrup Symposium. Whereas the original meeting had focused on the fundamental questions “Has THC shutdown happened before?” and “Are we right to assume it can recur?” the Tromso workshop had the aim of providing a more complete description of the required observing system, with preliminary costs, and with some results in support (where these exist).

The design of an ASOF array was further refined at a National Academy of Sciences Workshop on Abrupt Climate Change: Science and Public Policy, held at Lamont Doherty Earth Observatory, Palisades NY, on October 30-31 2000. Throughout this evolution, discussion has been guided by a sequence of so-called “Strawmen” circulated in advance and intended to provide a concise, modern and expert view of the issues discussed. The third and last of these Strawmen, describing the present state and rationale for ASOF can be found on the SEARCH and NPI websites [http://www.psc.apl.washington.edu/search/ASOF and http://www.npolar.no/asof].

Present State of ASOF Planning

Since then, with the active encouragement of the NSF, NOAA, NPI, and the University of Washington’s SEARCH* Program (in many ways the parent body of ASOF), plans have advanced to the point of designing a prototype array (Figure 1) and establishing an ISSG to carry the concept through to implementation. The basic aims have not changed. The intention is still to establish a coordinated, circum-Arctic system of ocean flux measurements with decadal ‘stamina’ to cover all of the gateways that connect the Arctic Ocean with subarctic seas. These space-time requirements are easily justified. Studies by the Seattle Group that motivated the SEARCH program provide clear evidence that recent changes in the marine climate of the Arctic Ocean are decadal and pan-arctic in scale and ---at least in part---- reflect a changing balance between Atlantic and Pacific influences. And coupled with the fact that the most advanced models now suggest that ocean fluxes through different Arctic gateways may be linked in their time-dependence12, it makes sense to make these measurements at the same time [*Study of Environmental Arctic Change].

We cannot entirely restrict our attention to “Arctic gateways” however. In a program concerned with the slowdown or shutdown of the THC, some part of our observing system must be directed at measuring the rate of the meridional overturning circulation of the North Atlantic south of the Greenland-Scotland Ridge. Thus the proposed ASOF observing system extends south to 25ºN (see Figure 1). It would be myopic also to ignore the Labrador Sea as the site through which all the deep and bottom waters that “drive” the THC must pass, and we devote a considerable observing effort to that site. At least initially, the appropriate emphasis in making our long observational series is seen to lie in “keeping pace with” change rather than its prediction, while generating the data sets and time-series needed to develop the predictive skill of climate models.

The ASOF ISSG will aim to get most of this array into the ocean by the end of 2003 and four factors suggest this is possible. First, certain of the key measurements are already underway. The transport through the Bering Strait has been estimated for decades13 and measured since 1990 14,15; the core of the Denmark Strait overflow has been measured with gaps since 1986. Second, in its initial form, the ASOF ISSG is strong in the practical business of maintaining arrays of equipment in these challenging waters. Third, almost all of the techniques needed to make the necessary measurements now seem available or are in prospect. The development at Bedford Institute of Oceanography of the Watson compass for measuring flow directions close to the north magnetic pole, the emergence of a range of cheap profiling CTD systems capable of sub-ice hydrography, the successful trials of sea-glider systems in the past summer giving the prospect of enriching our sparse moored arrays at realistic cost mean that this is possibly the first time that much of ASOF might be achieved. And fourth, several recent initiatives give hope of achieving the coordination and stamina of funding that will be vital to implementing a program with the scope and duration that is needed here. One such is the recent bi-lateral UK-Norway Initiative on Abrupt Climate Change proposed to address this issue by the two Prime Ministers in 1998 which has been developed subsequently into a thematic programme by the UK Natural Environment Research Council and into the NOClim programme by the Norwegian Research Council [http://www.nerc.ac.uk/funding/thematics/thc/ABRUPTFINAL.htm]. The ease of achieving the required intercontinental spread of funding for ASOF could be greatly helped when an implementing arrangement for NSF-EC co-operation on a range of scientific research topics comes into force. The list of topics, including ASOF, has been agreed and we are told that signing is likely in the next few months.

Next Steps

We now know the structure of the ASOF-ISSG. Though its membership covers the full geographical spread of the array, we intend to organise the SSG under two Deputy Chairs ---Jens Meincke of the University of Hamburg as DC (E) and Peter Rhines of the University of Washington as DC (W) ---to permit the western and eastern groups of the SSG to meet with greater flexibility and greater frequency than could the whole group. The ASOF Chair and two Deputy Chairs will meet in Iqaluit during Arctic Science Summit Week in April 2001 to plan the mix of design studies and equipment trials and that will form the business of the full Group until implementation, to progress the ASOF Science Plan including links to national programmes, to report progress to ASSW participants on Project Day (Sunday 22 April), to debate means of international co-ordination in both science and funding, and to receive the collective advice of Arctic operators on unresolved issues. Once per year in the fall, it is planned that the full ISSG will meet, beginning in fall 2001 in Washington DC and continuing in (probably) Hamburg in fall 2002, probably as a Euroconference.

The initial discussion phase is all but ended. The work to implementation is beginning. Progress can be tracked on SEARCH and Norsk Polarinstitutt websites.

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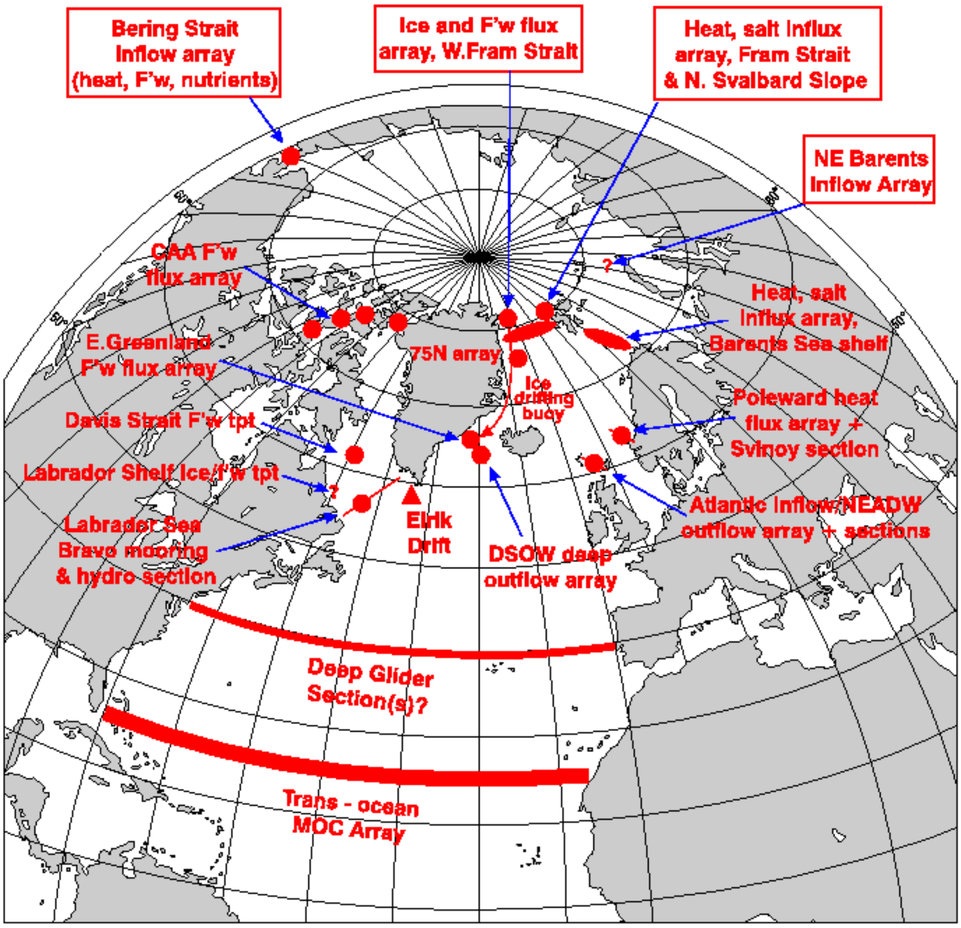

Figure 1. Configuration of prototype ASOF Array.

Figure 1. Distribution of the observing sites that make up the prototype ASOF Array. The justification for each is described in the Strawman-3 document on the websites of the U. Washington SEARCH Program and the Norsk Polarinstitutt, Tromso.

ANNEX H: THE NAO IN WINTER 2001

Early indications of a sharp return to NAO-Negative conditions.

R R Dickson, S Dye (CEFAS, Lowestoft) and J Meincke (IFM Hamburg)

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. The conventional index of NAO activity is the mean pressure difference between the two main cells but various station pairs have been used in its calculation, notably the Lisbon-Stykkisholmur winter (DJFM) index of Hurrell (1995; 1996) and the Iceland-Gibraltar Index of Jones et al (1997).

The characteristics of the NAO and many aspects of the ocean's response were described in the equivalent context-setting sections of recent WGOH reports (Dickson and Meincke, 1999, 2000). 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 large decrease in winter 1995-96* and both the 1999 and 2000 WGOH reports have described the recovery to more positive values since then. (*hereafter the winter is defined by the year of the January).

In this brief note, we point out two significant features of the NAO in the winter just ended. First, though the March slp values are not yet available, the evidence is that the "recovering" NAO Index will be found to have undergone a further rapid reversal to negative values; second, that in this particular winter, it makes more difference than usual which station pair we use to define the Index.

The NAO in winter 2001

Figure 1 describes the Atlantic distribution of slp anomaly in (a) December 2000, (b) January 2001 and (c) February 2001 respectively, with panel (d) showing the December to February composite (NCEP/NCAR Reanalysis data from the NOAA-CIRES Climate Diagnostics Center: www.cdc.noaa.gov/Composites). In every month but especially in December and February, the NAO dipole pattern is configured in such a way that the more northerly (southerly) cell exhibits a positive (negative) slp anomaly, so that the composite is strongly NAO-negative. With centres over Iceland-Greenland and Azores-Biscay, it is difficult to detect any marked difference from the classical EOF-1 slp anomaly distribution (shown as Fig 1a in the WGOH Report 2000, p 23).

On the UEA-CRU website (www.cru.uea.ac.uk) monthly values of the Jones Gibraltar-Iceland index are listed for December 2000 and January 2001 only, as –1.41 and + 0.02 respectively, but inspection of the individual monthly maps confirms that because of the locations of Lisbon and Gibraltar in relation to the southern pressure-anomaly centre, the Gibraltar-Iceland pressure pair is likely to record a smaller pressure difference than Lisbon-Iceland.

Response

The return to strongly NAO-negative conditions, however briefly it lasts, is likely to have an important bearing on the ocean and ecosystem response. This stems from the dominant role of the winter NAO in driving both, and in particular its control of all three of the factors that alter the ocean's circulation (windspeed & direction, evaporation minus precipitation and the fluxes of sensible and latent heat). The responsiveness of the ocean is now known to be sufficiently rapid to reflect even short-term annual changes in the NAO. In their review of the large-amplitude but short-lived drop in the Index in 1996, Dickson and Meincke (1999) showed that a clear response was evident in a wide range of parameters, including 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 sea temperatures and cod recruitment of the southern North Sea.

Though the NAO pattern for the full winter is not yet available and though the ocean's response has still to be worked through, this **interim** report is compiled both as a pointer to the sorts of environmental changes that are likely to appear in our observations and to restate a general caveat regarding the reliability of simple 2-point indices of NAO behaviour. Namely, that although a simple pressure difference may offer a useful 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 that will determine the Ocean's response. And it is that specific local configuration of the NAO that will determine whether the observed ocean/ecosystem response conforms with our past experience in a given sea-area. The correlation between the NAO Index and both windstrength and SST, based on 50 years of observations are perhaps the best established indicators of the sort of change we can expect if forcing and response follow past experience, and are added here as Figure 2.

A first glance at the SST anomalies along the Felixstowe-Rotterdam route (Fig 3) is not very informative. The slight recent cooling is not yet enough to be certain we are registering anything other than noise. NAO variability is sufficiently important as a source of marine environmental change however to suggest that we maintain a close watch on this and other indicator data sets over the next few months.

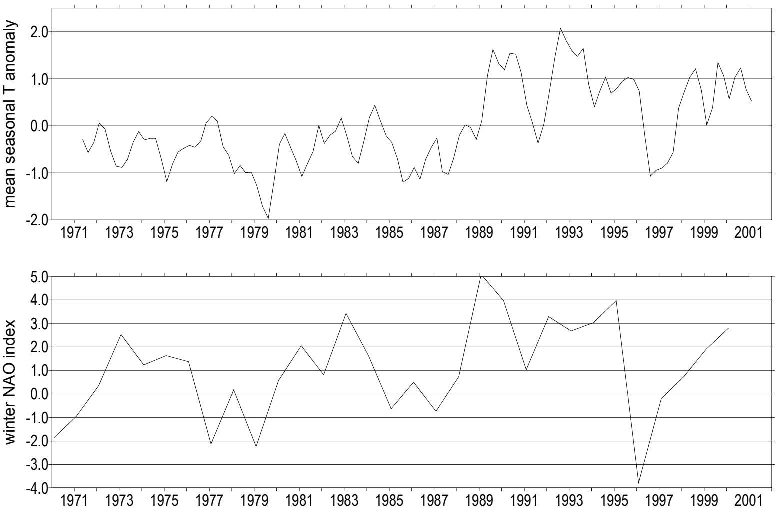

Figure 3. Comparison between the NAO Index (lower panel) and the time-dependence of seasonal SST anomalies averaged for the Felixstowe-Rotterdam route across the Southern Bight of the North Sea (upper panel; normal period 1970-99). The NAO Index for the whole (djfm) of winter 2001 is not plotted (not yet available). The last point on the SST anomaly curve includes data from December 2000-February 2001, but shows no evidence yet of the amplitude of cooling that we might expect from NAO-negative conditions (*vide* Fig 2b)

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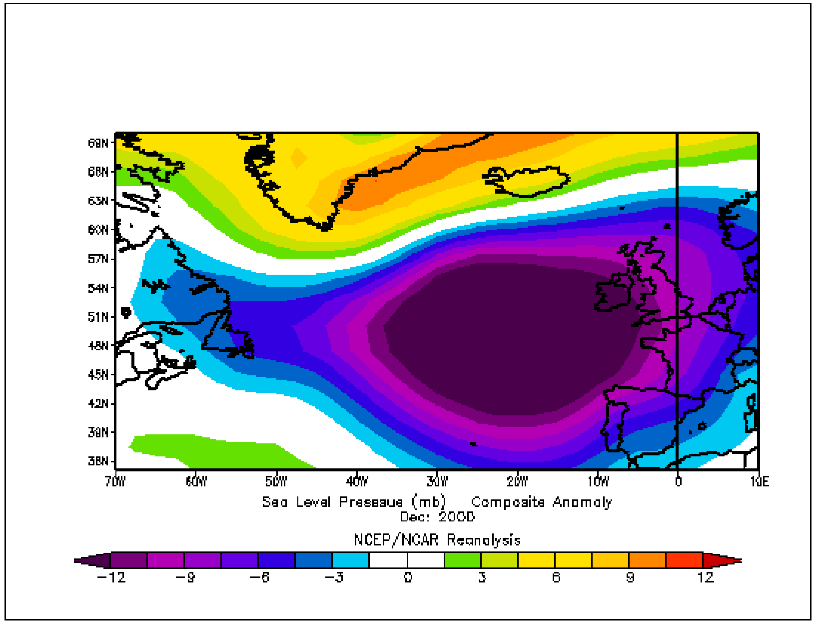
Figure Captions.

Figure 1. The Atlantic distribution of slp anomaly in (a) December 2000, (b) January 2001 and (c) February 2001 respectively, with panel (d) showing the December to February composite (NCEP/NCAR Reanalysis data from the NOAA-CIRES Climate Diagnostics Center: www.cdc.noaa.gov/Composites).

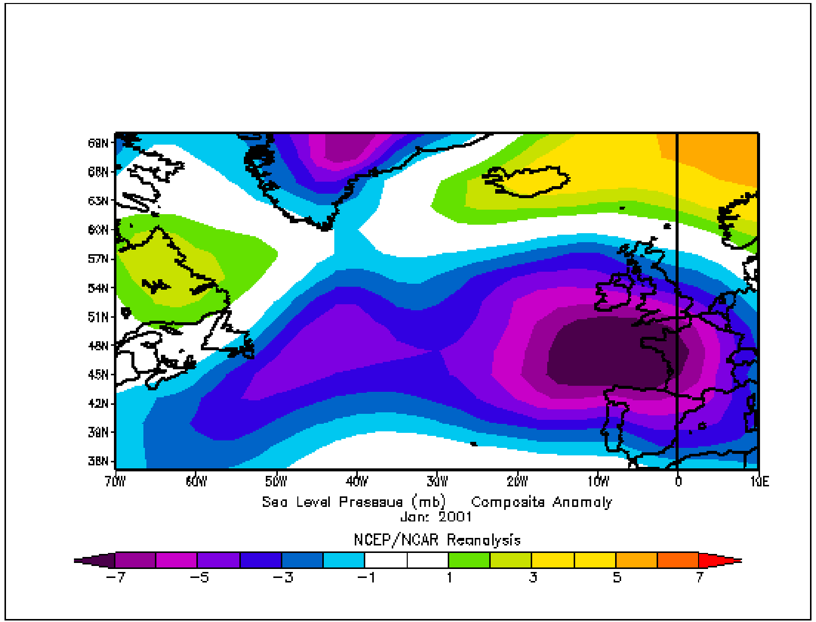
Figure 2. Spatial distribution of the Pearson correlation coefficient between the NAO Index and (a) local winter scalar windspeed (ms^{-1}) and (b) local sea surface temperature (°C) for the period 1950-95. Winter is taken as the months January to March. Kindly provided by Ben Planque, IFREMER, Nantes, pers comm.



Sea Level Pressure (mb) Composite Anomaly
Dec: 2000

NCEP/NCAR Reanalysis

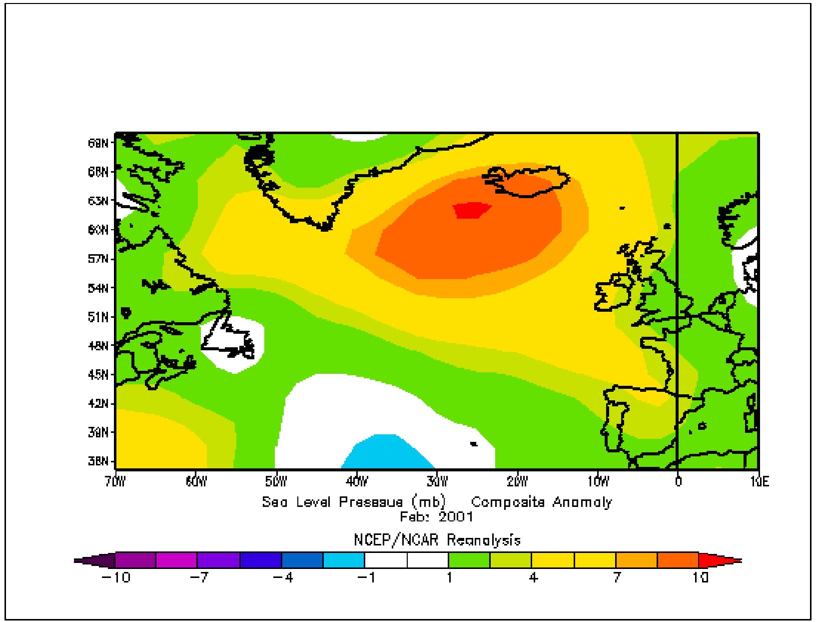
NOAA−CIRES/Climate Diagnostics Center



Sea Level Pressure (mb) Composite Anomaly
Jan: 2001

NCEP/NCAR Reanalysis

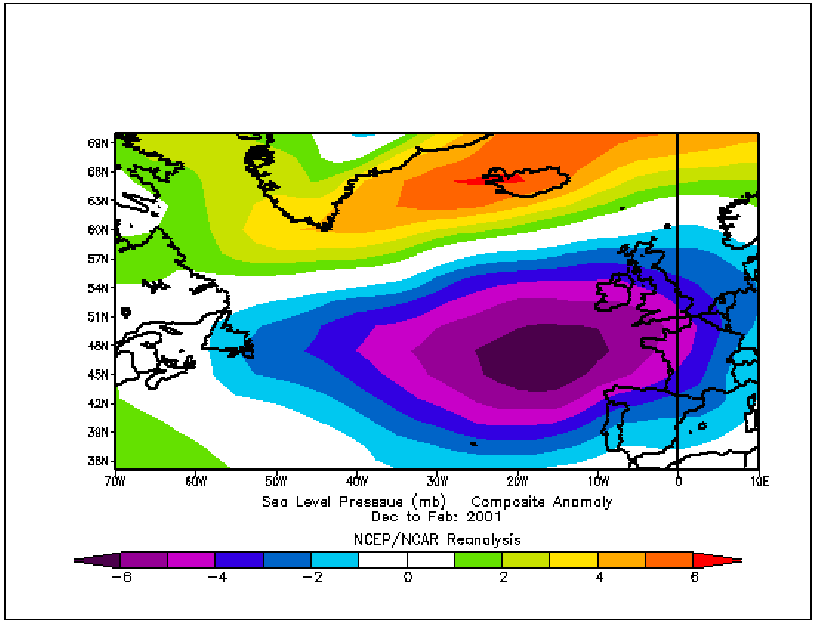
NOAA−CIRES/Climate Diagnostics Center



Sea Level Pressure (mb) Composite Anomaly
Feb: 2001

NCEP/NCAR Reanalysis

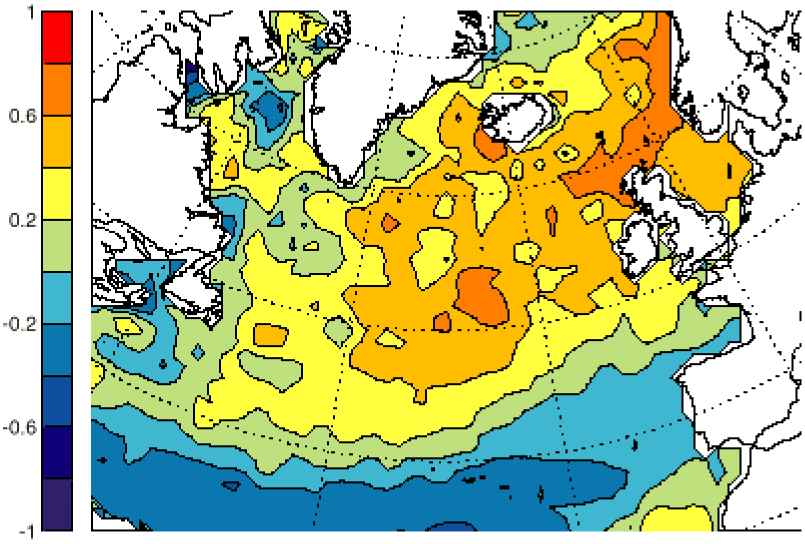
NOAA−CIRES/Climate Diagnostics Center



Sea Level Pressure (mb) Composite Anomaly
Dec to Feb: 2001

NCEP/NCAR Reanalysis

NOAA−CIRES/Climate Diagnostics Center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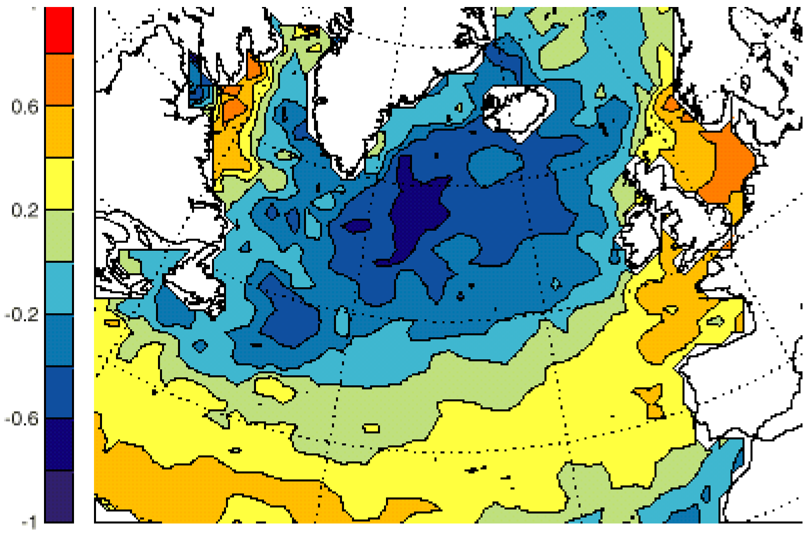
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ANNEX I: AREA 1 (WEST GREENLAND) DANISH REPORT

By

E Buch

Introduction

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. Following its long period of extreme positive values, the NAO index suddenly underwent a sharp decrease to a short-lived minimum in the winter of 1995-96. Since that temporary minimum, a steady recovery towards positive values of the winter NAO is observed, Fig. 1. However the recovery has so far been incomplete, a comparison of the Atlantic sea level pressure anomaly pattern for the early 1990s (1993-5) with those for winters 1999 and 2000 it is found that the recent NAO pattern is displaced slightly towards the east or northeast, ICES, 2000.

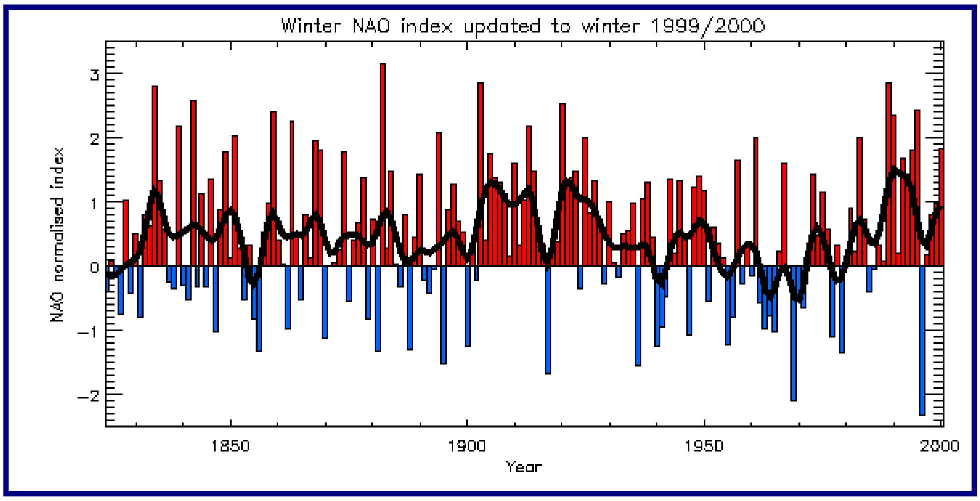


Fig. 1. *Timeseries of the winter NAO (December to March average). After Jones et al (1997) updated to the winter 1999/2000.*

This subtle change has little effect on the subtropical gyre of the Atlantic and along its eastern boundary to the Barents Sea where evidence of the widespread warming that normally is associated with the positive NAO is found. However in the Northwest Atlantic, this slight eastward retraction of the "normal" NAO pattern has made an important difference to the marine climate. Instead of a chill and strong northwesterly airflow promoting cooling there, as it did in the early 1980s and 1990s, any northwesterly airflow is now mainly confined to the east of Greenland, while the Labrador Sea is occupied by light or southerly anomaly-winds, ICES 2000.

West Greenland lies within the area which normally experiences cool conditions when the NAO index is positive. However, although the NAO index has been positive since 1996 and in the winter 1999/2000 recovered to the level of extreme positive values experienced in the early 1980'es and especially in the early 1990'es, conditions around Greenland remained warm. In 2000 the annual mean air temperature in Nuuk was –0.80°C, which is 1.03°C above normal, Fig. 2. This confirms the above mentioned anomalous NAO pattern over the area.

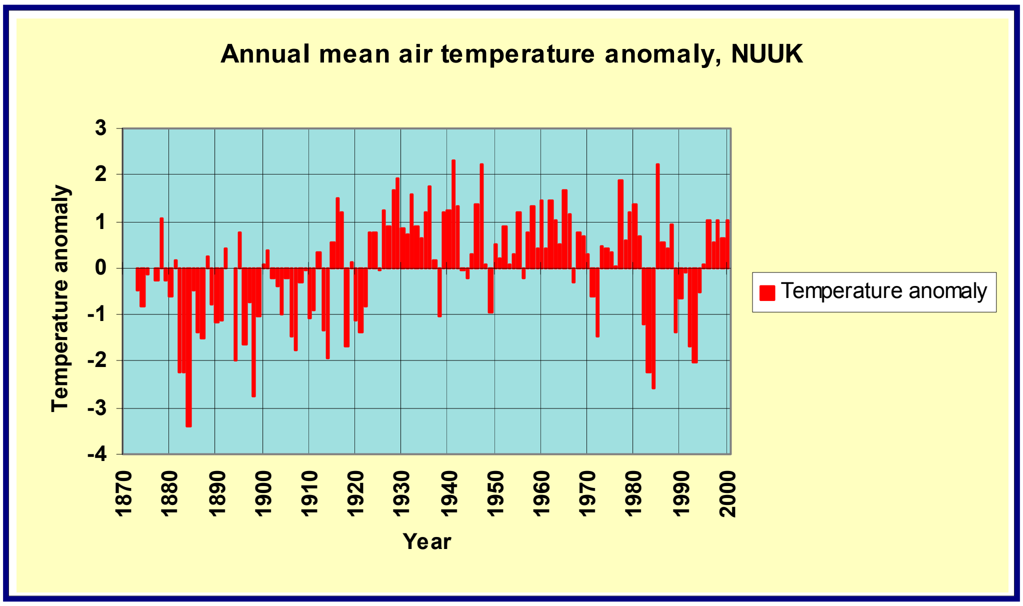


Fig. 2. *Anomaly in the annual mean air temperature observed at NUUK for the period 1873 to 2000.*
(The anomaly is taken relative to the mean temperature for the whole period).

Changes in the ocean climate in the waters off West Greenland generally follow those of the air temperatures. The relatively mild atmospheric conditions are reflected in the mean temperature on top of Fylla Bank in the middle of June, Fig. 3.

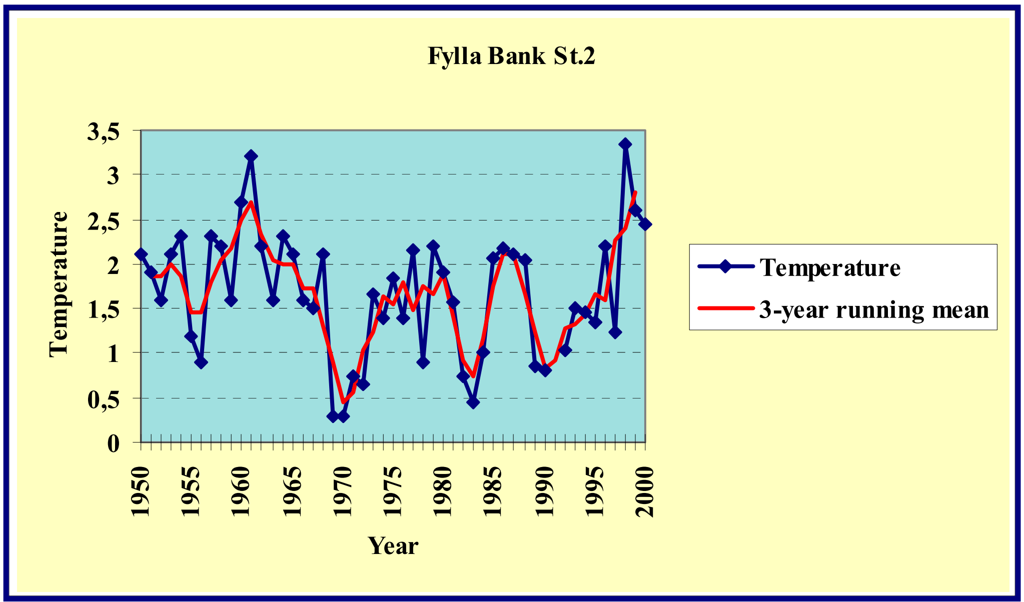


Fig. 3. *Timeseries of mean temperature (observations and 3 year running mean) on top of Fylla Bank (0 - 40 m) in the middle of June.*

The 2000 temperature value (T = 2.45°C) is the fifth highest temperature 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

Measurements

The 2000 cruise was carried out according to the agreement between the Greenland Institute of Natural Resources and Danish Meteorological Institute during the period June 29 - July 10, 2000 onboard the Danish naval ship **“TULUGAQ”.** Observations was performed on the following stations (see also Fig. 4):

- 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

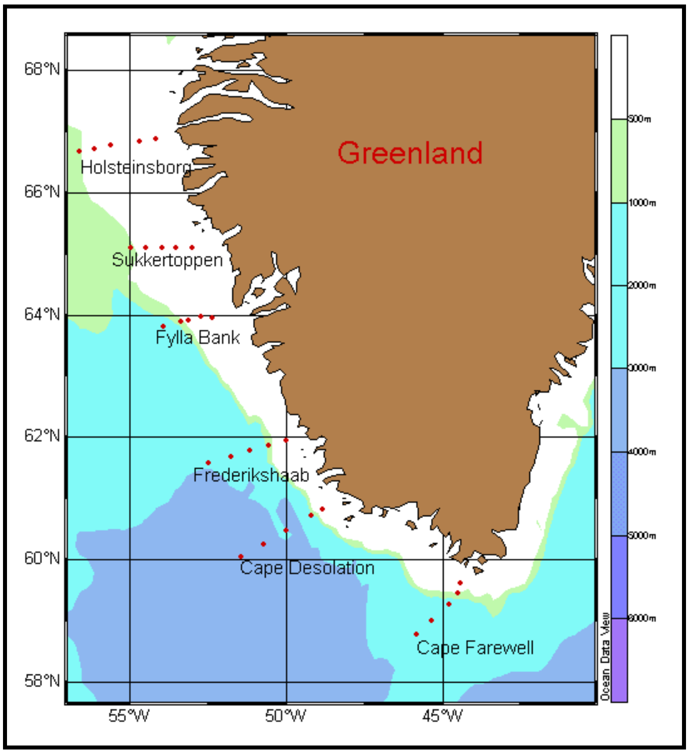


Fig. 4. *Position of the standard sections off West Greenland*

On each station the vertical distributions of temperature and salinity was measured from surface to bottom, except on stations with depths greater than 750 m, where 750 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. Close to Cape Farewell “Storis” was present, Fig. 5; but fortunately not in quantities preventing the measuring program being carried out.

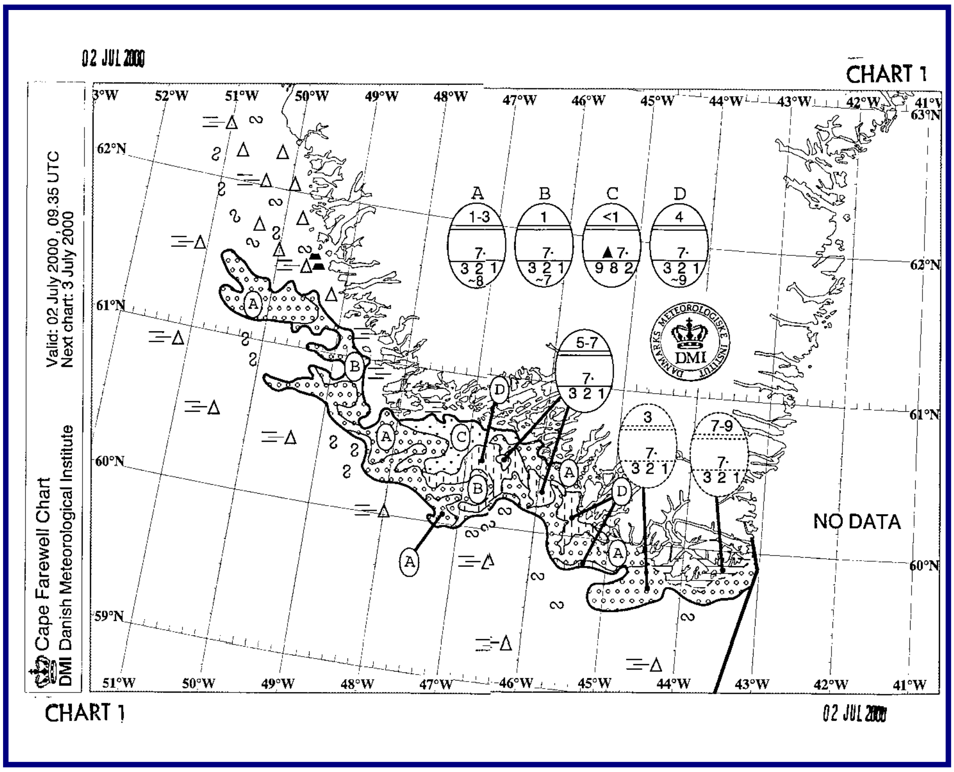


Fig. 5. *Distribution of sea ice in the Cape Farewell region July 2, 2000*

Data handling

Measurements of the vertical distribution of temperature and salinity were carried out using a SEABIRD SBE 9-01CTD. 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.

CTD data collected by the Greenland Institute of Natural Resources during two cruises with R/V Adolf Jensen and two cruises with R/V Paamiut using the same instrumentation have gone through the same calibration and quality check.

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.

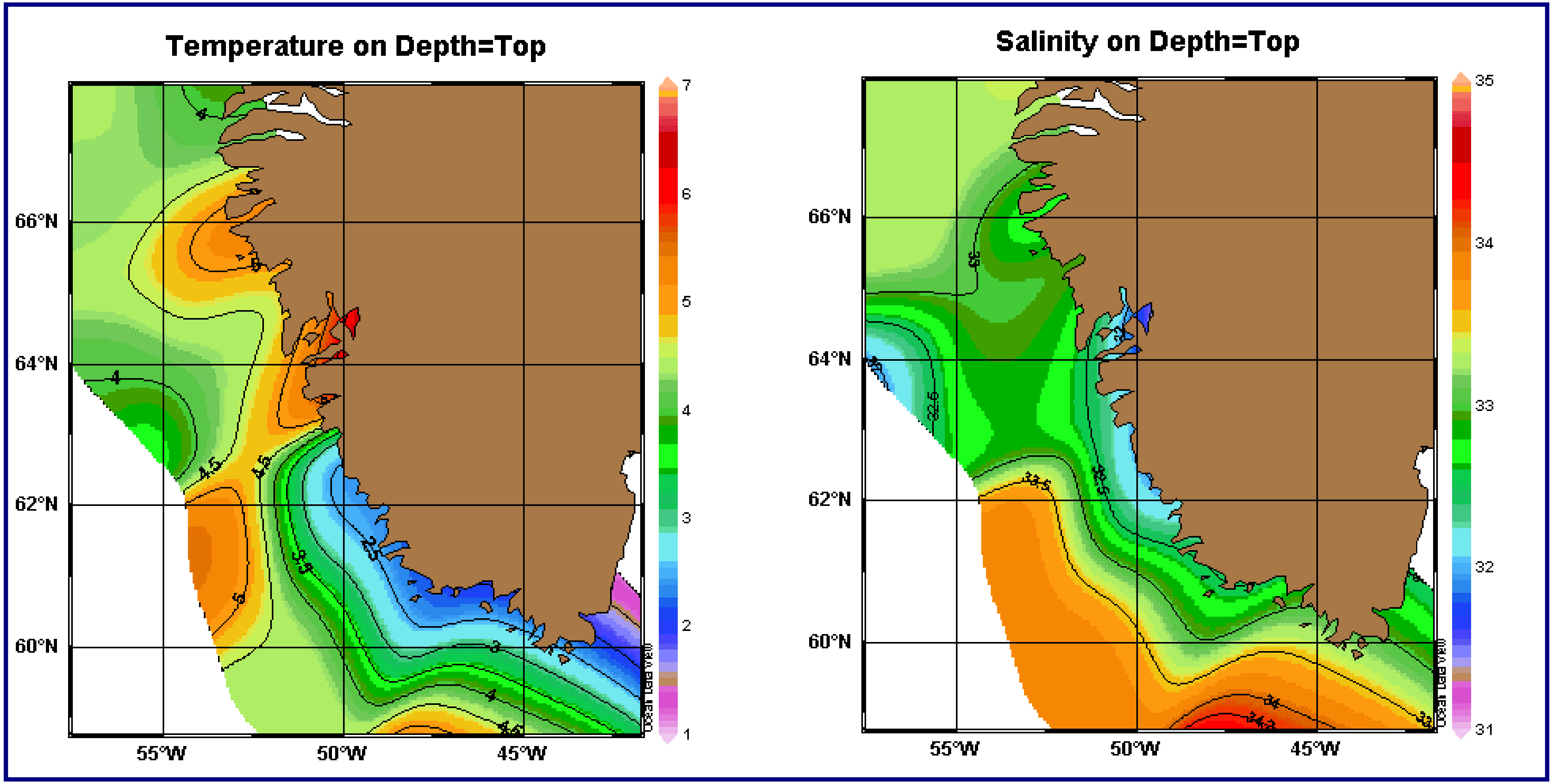


Fig. 6. *Surface temperature and salinity, July 2000*

Oceanographic conditions off West Greenland in 2000

The surface temperatures and salinity's observed during the 2000 cruise are shown in Figs. 6. The cold and low salinity conditions observed off Southwest Greenland reflect the inflow of Polar Water carried to the area by the East Greenland Current. Water of Atlantic origin (T> 3°C; S> 34.5 psu) is found at the surface only at the three outermost stations on the Cape Farewell Section.

The sea surface temperatures are generally higher in 2000 compared to 1999 in the entire area with temperatures well above 5°C in certain regions.

The 2000 mean salinity value (33.32 psu) on top of Fylla Bank (Fig. 7) was slightly lower than in 1999, and below the average value of 33.40 psu.

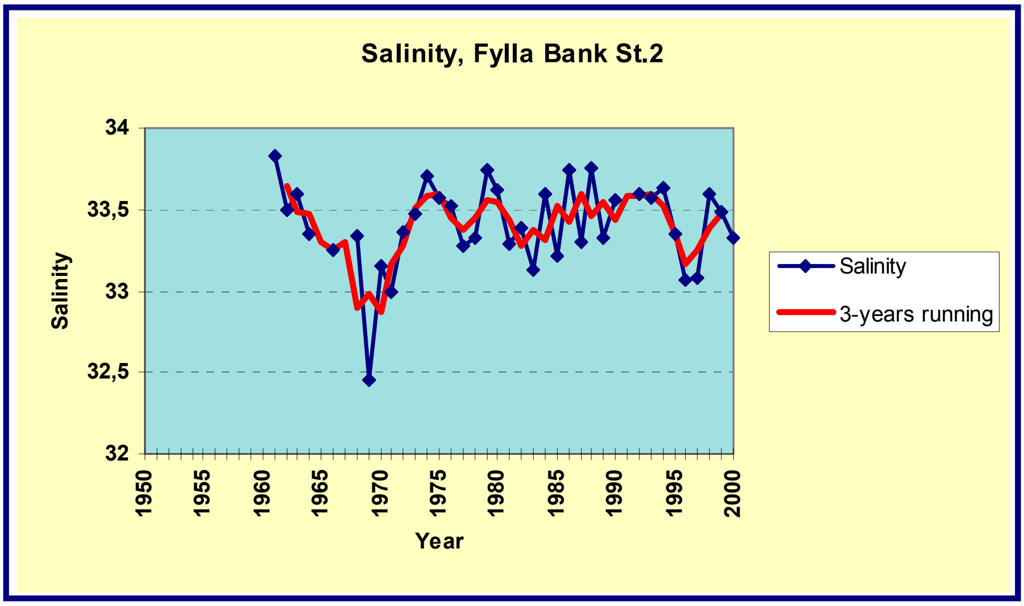
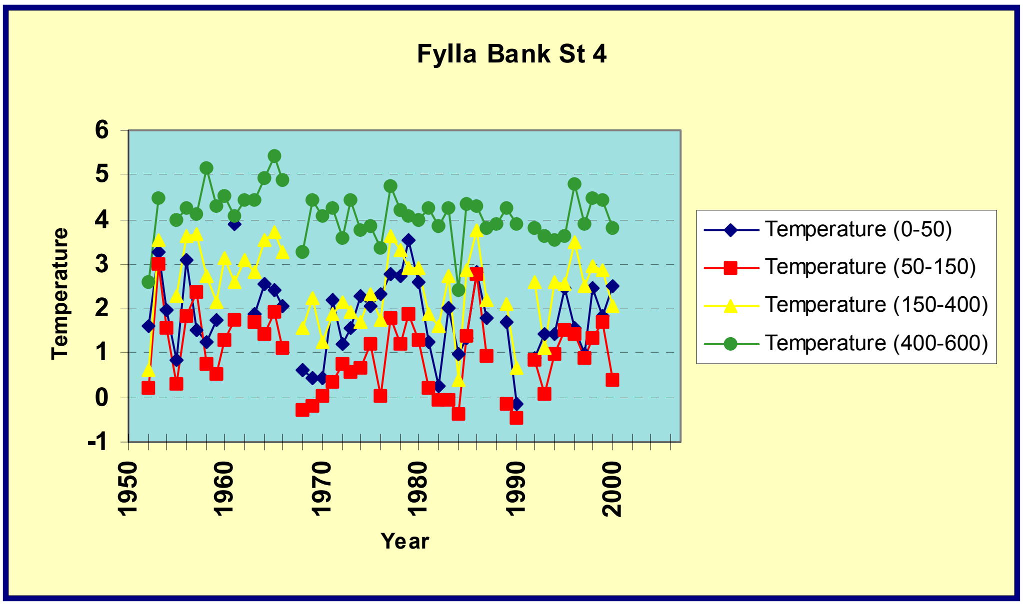


Fig. 7. *Time-serie of the mean salinity (observations and 3 year running mean) on top Fylla Bank (0-40m) in the middle of June*

Time series of the temperature and salinity conditions west of the Fylla Bank (Fylla Bank St. 4) at various depth intervals are presented in Fig. 8 a,b. The surface conditions as described above are also seen at this station. More interestingly it shall be noted that in 2000 a decrease in temperature as well as salinity compared to the previous years was observed at intermediate depth (the 50-150m and 150-400m intervals). These two depth intervals are the domain of the Polar Water along the Southwest Greenland fishing banks. The relatively low temperature and salinity values therefore indicate increased inflow of polar water in 2000, which also can be seen in the vertical section plots displayed in Figs. 10-17.

At great depth (400-600m) a relatively large decrease in temperature was observed in 2000 together with a slight decrease in salinity. This indicates that only Northwest Atlantic Mode Water was present at Fylla Bank in July 2000, which also can be seen in Fig. 14.

a)



b)

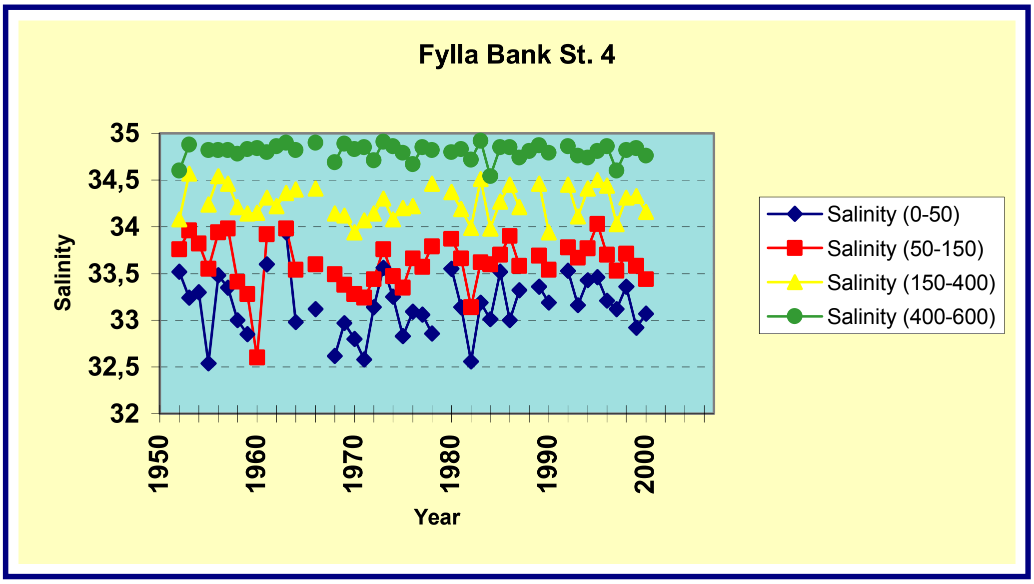


Fig. 8. *Time-serie of:*
a) mean temperature
b) mean salinity
in four depth intervals at Fylla Bank St.4, primo July

The vertical distribution of temperature, salinity and density as well as TS-relations at sections along the West Greenland coastline is given in Figs. 10 - 22. In addition to data from the six standard sections obtained during the TULUGAQ cruise in early July, data from Fylla Bank in May and medio July are also presented together with data from the Disko Bay and further north obtained during the R/V PAAMIUT cruise in August.

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 Frederikshaab and southward. From Fylla Bank and northward the core of Polar Water was observed just west of the banks a depth of 50 - 150 m.

The development in time of the temperature and salinity conditions at Fylla Bank can be se seen in Figs. 13-15. Medio May rather cold conditions are found in the upper 150- 200 m due to winter cooling. In July the surface temperatures has increased due to atmospheric heating; but the inflow of Polar Water dominates the 50-150m depth interval just west of the bank.

At Egedesminde and northwards a cold layer is found between approximately 25 and 150m with extreme low temperatures at around 100m. This cold water most likely is Polar Water transported to the West Greenland waters by a side branch of the southward flowing Baffin Current.

Temperature and salinity observations at greater depth showed that pure Irminger Water (T ~ 4.5°C, S > 34.95 psu) was not present in the area during the summer of 2000 – not even at the southernmost section at Cape Farewell. Modified Irminger Water (34.88 < S < 34.95) was, however, present in great quantities and was observed as far north as to the region between Little Hellefiske Bank and the Holsteinsborg section.

Northwest Atlantic Mode Water (3.5 < T < 4.5; 34.5 < S < 34.88) was observed at all sections from Cape Farewell to Nugssuaq.

Model simulations

The Danish Meteorological Institute has set-up a 3D-ocean model for the Greenland Waters using the linear harmonic model Fundy (Lynch and Werner, 1987; Greenberg et al, 1998). The main purpose of this model implementation is the production of ocean forcing fields to the institutes operational ice forecasting model (Kliem, 2000). The model is, however, well suited for calculations current fields, temperature and salinity fields as well as drift patterns of passive objects like plankton, fish eggs etc.

Based on the temperature and salinity observations from the TULUGAQ cruise in July 2000 the current field along the west coast of Greenland has been calculated, Fig. 9.

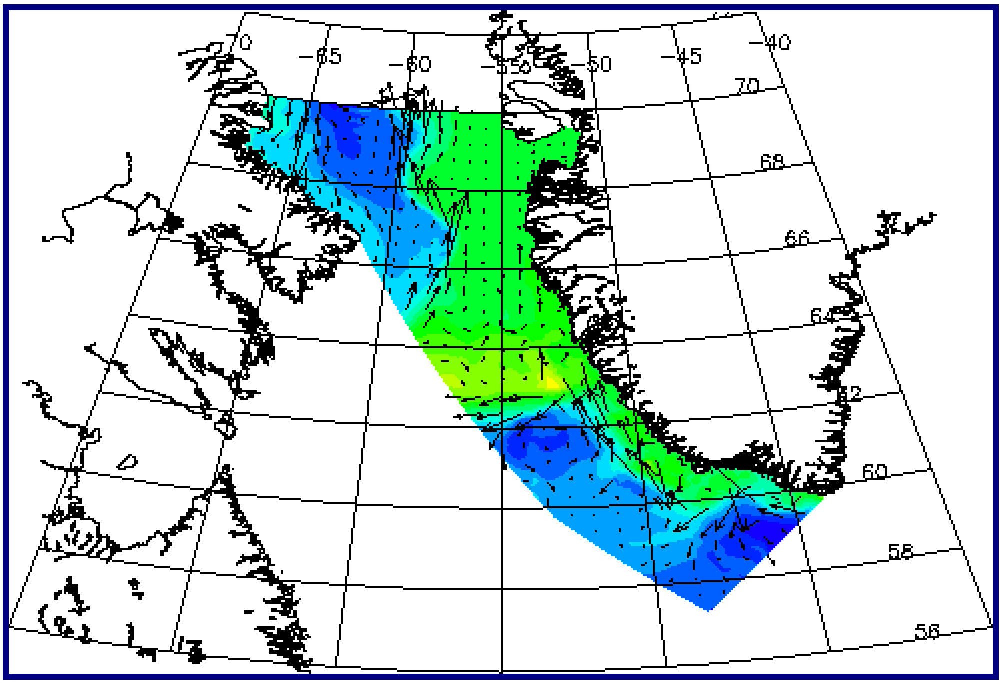


Fig. 9. *Surface currents along the west coast of Greenland, first week of July 2000. The colour coding represents the surface elevation.*

The model simulation reflects the main features of the ocean circulation in the West Greenland area. The northward flow along the coast with strong currents in the southern part, the deflection towards the west around 64–65°N. It is of special interest to note the large-scale eddy north 66°N transporting cold Polar Water from the Baffin Current towards West Greenland, since –as discussed above- this cold water was observed at the Egedesminde Section and further north in August 2000, Figs 18; 21-22.

Conclusions

The oceanographic conditions off West Greenland during the summer 2000 was characterised by:

- High surface temperatures due to mild atmospheric conditions.
- Relatively high inflow of Polar Water.

- Pure Irminger Water was absent even in the Cape Farewell region

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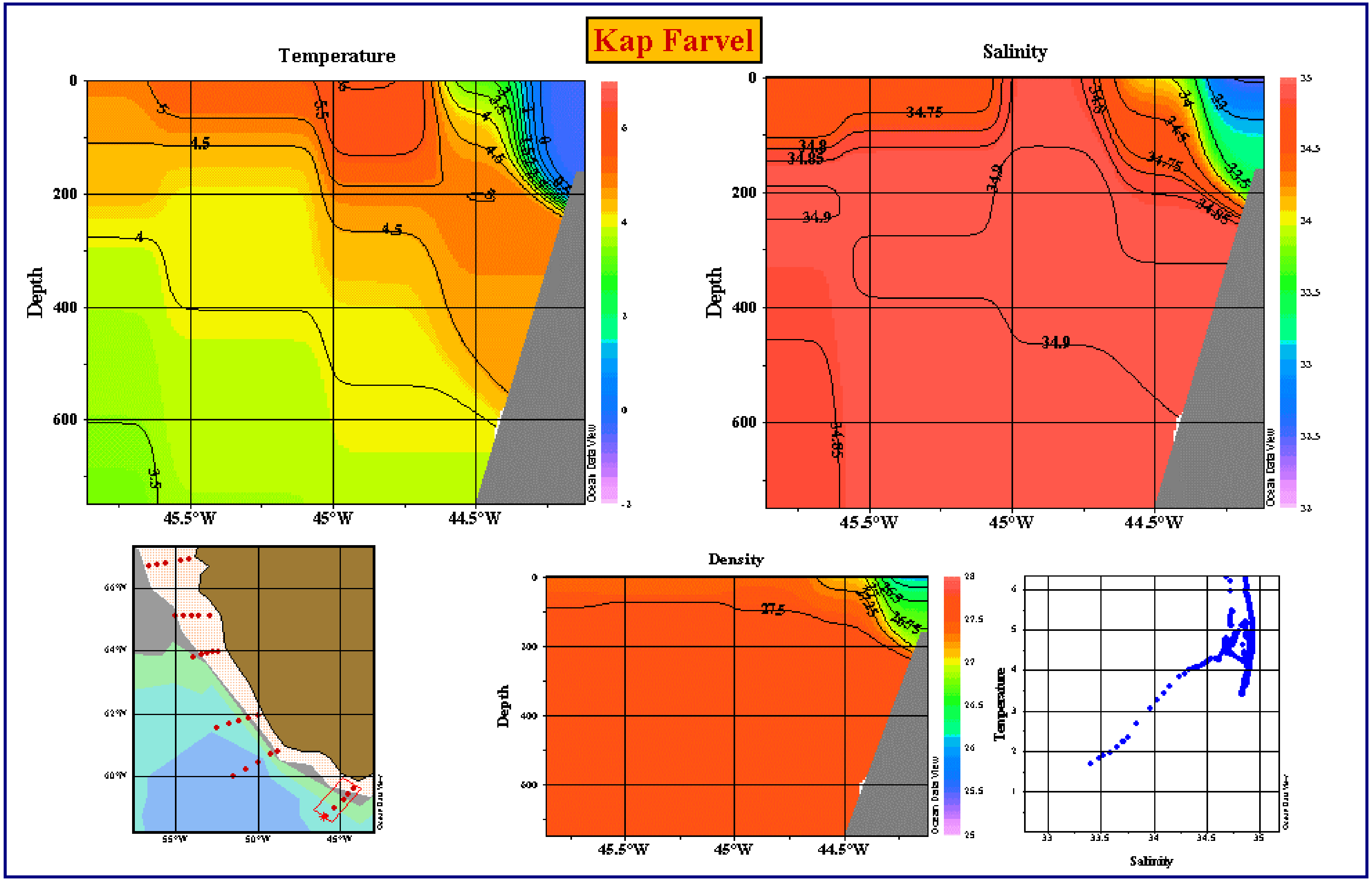

Fig. 10. *Vertical distribution of temperature, salinity and density at the Cape Farewell section, June 29, 2000*

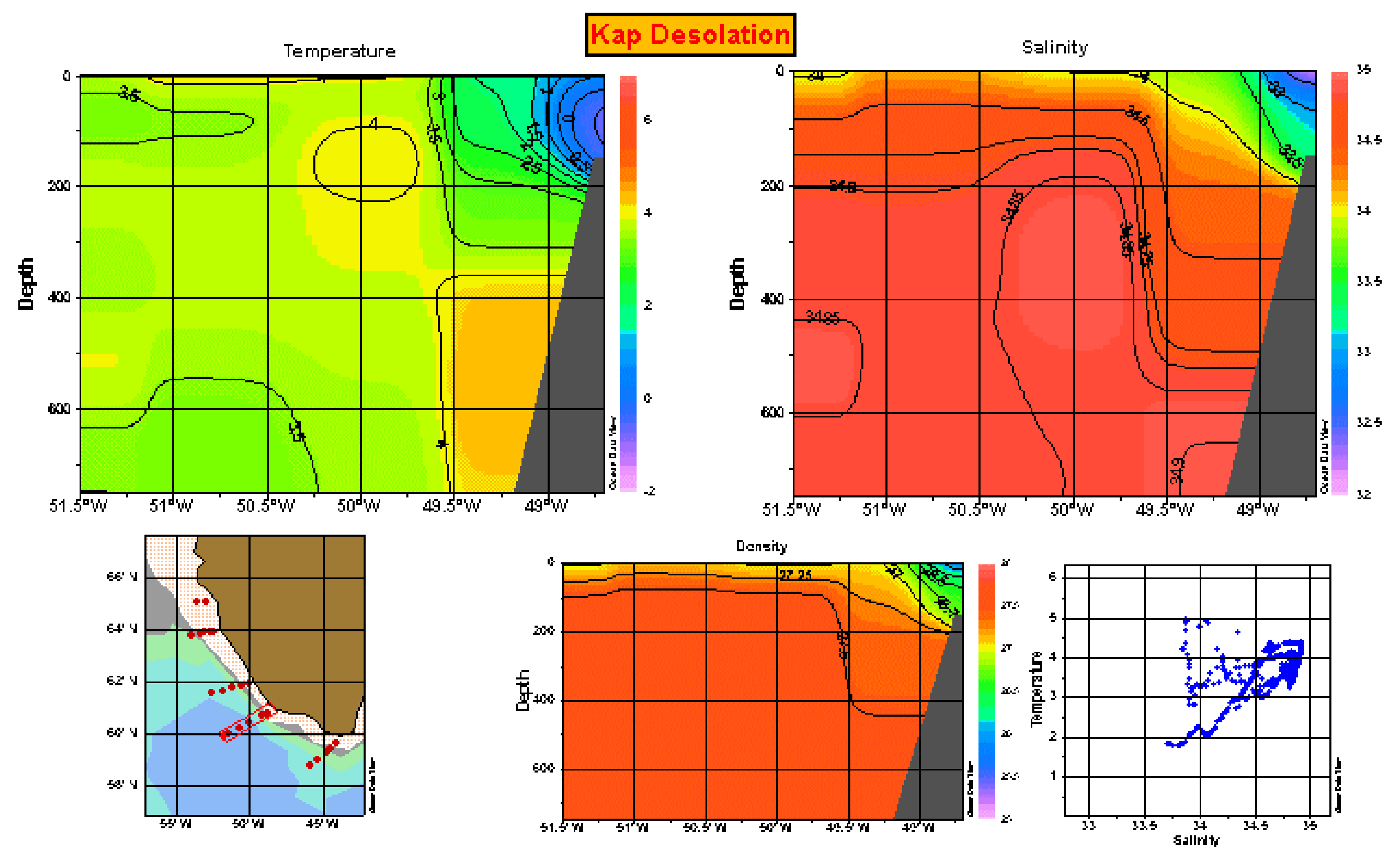

Fig. 11. *Vertical distribution of temperature, salinity and density at the Cape Desolation Section, July 1, 2000.*

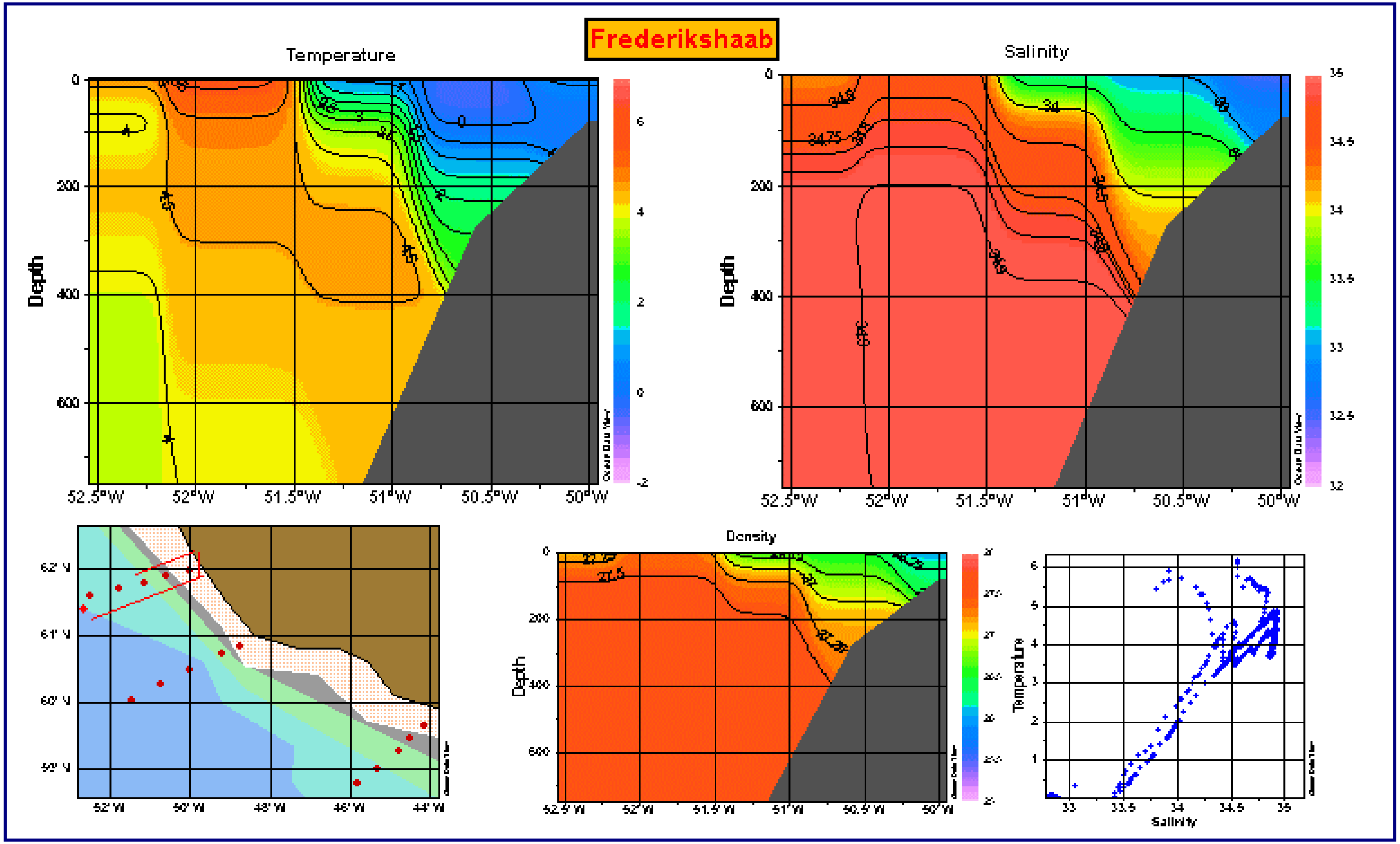

Fig. 12. *Vertical distribution of temperature, salinity and density at the Frederikshaab Section, July 4, 2000.*

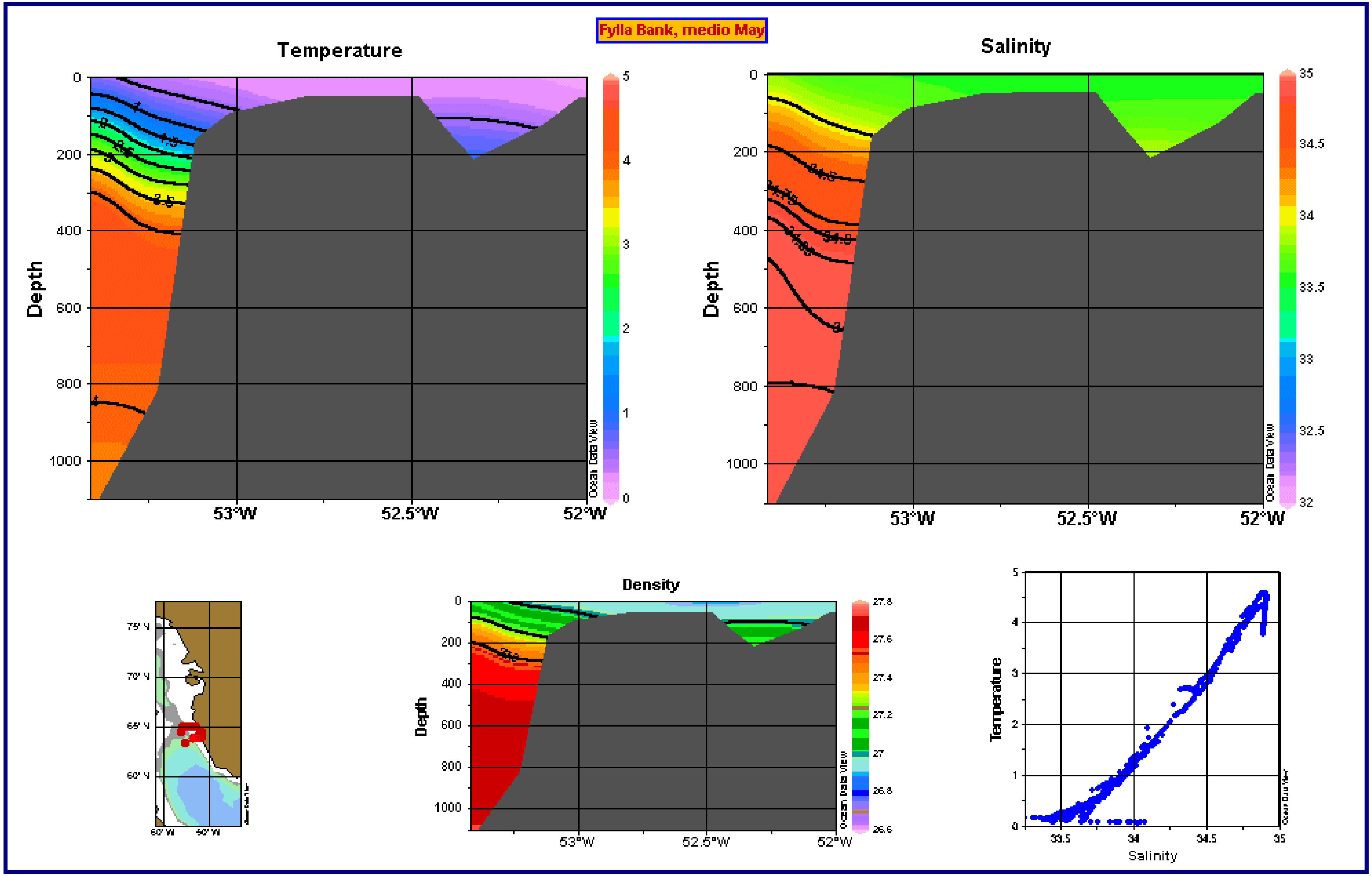

Fig. 13. *Vertical distribution of temperature, salinity and density at the Fylla Bank Section, May 12, 2000.*

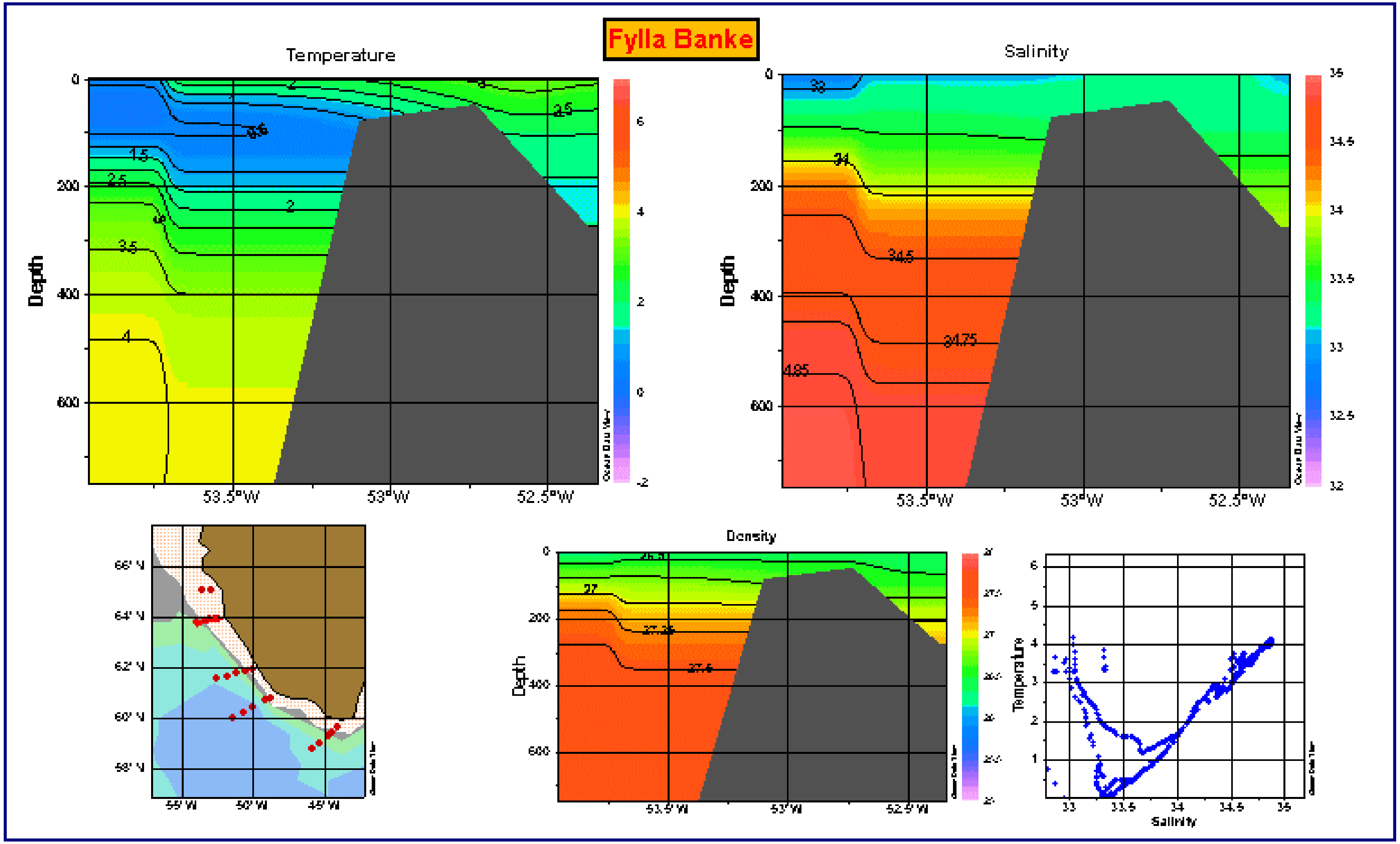

Fig. 14. *Vertical distribution of temperature, salinity and density at the Fylla Bank Section, July 9, 2000.*

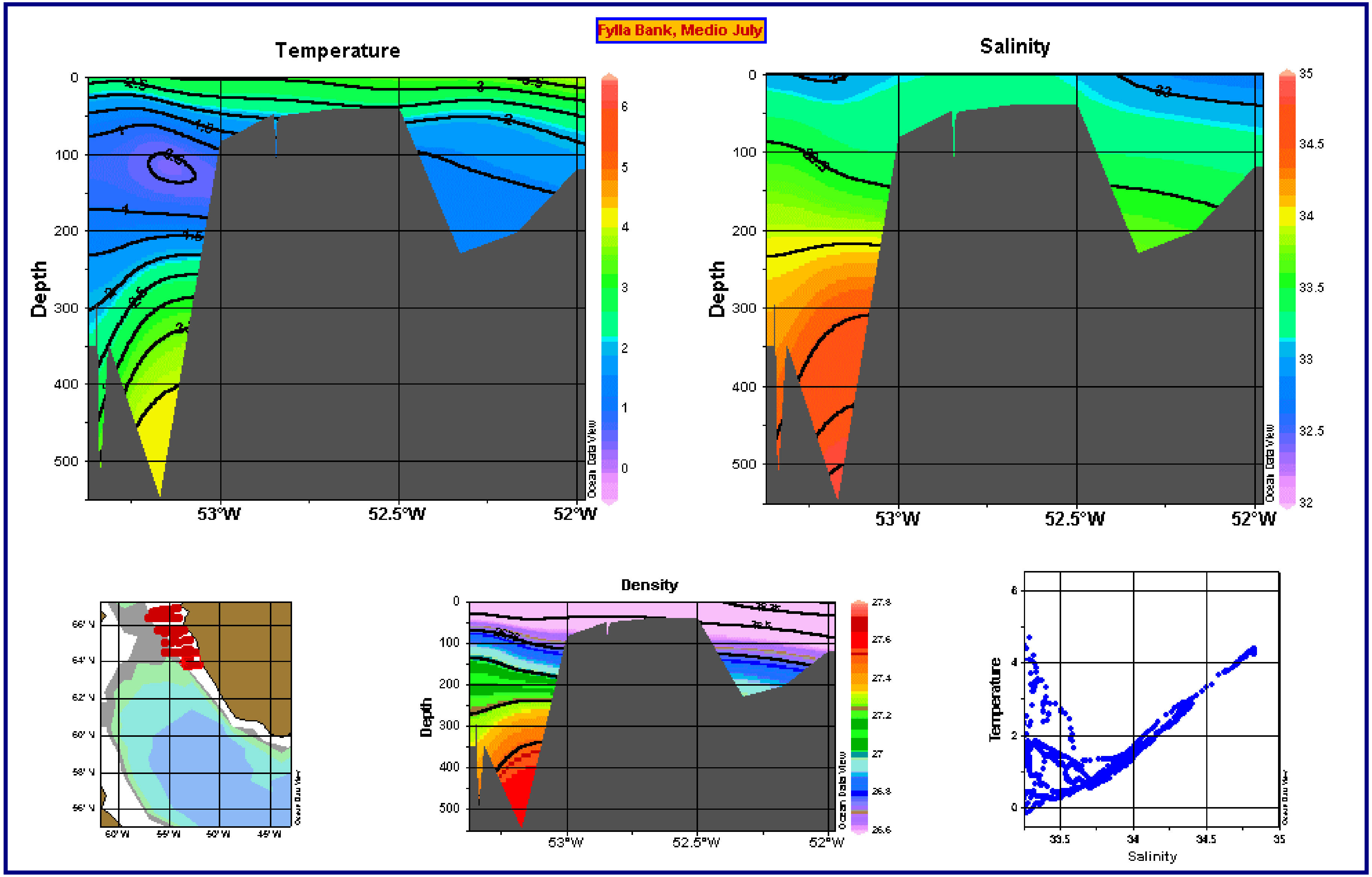

Fig. 15. *Vertical distribution of temperature, salinity and density at the Fylla Bank Section, July 15, 2000.*

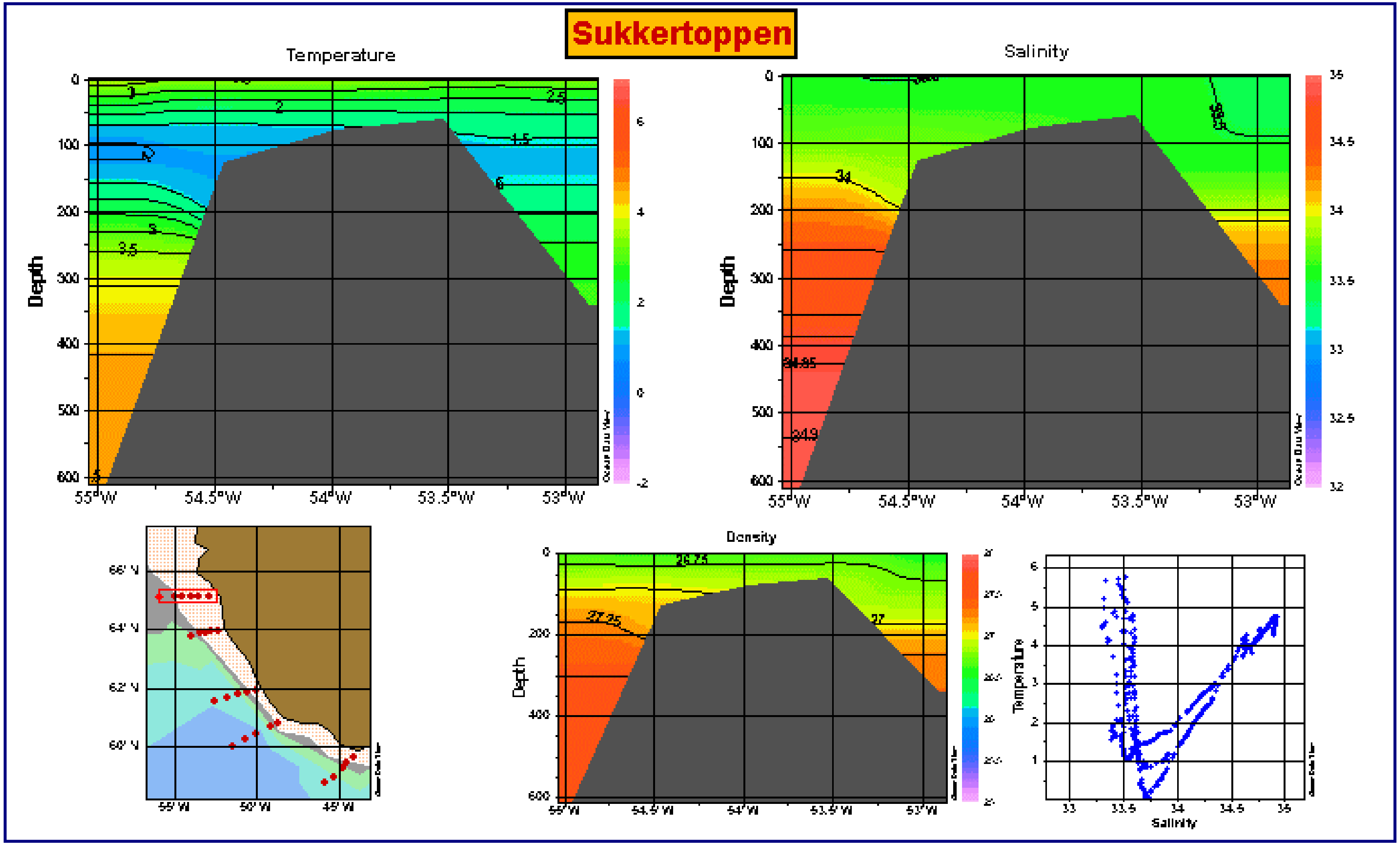

Fig. 16. *Vertical distribution of temperature, salinity and density at the Lille Hellefiske Bank Section, July 9, 2000.*

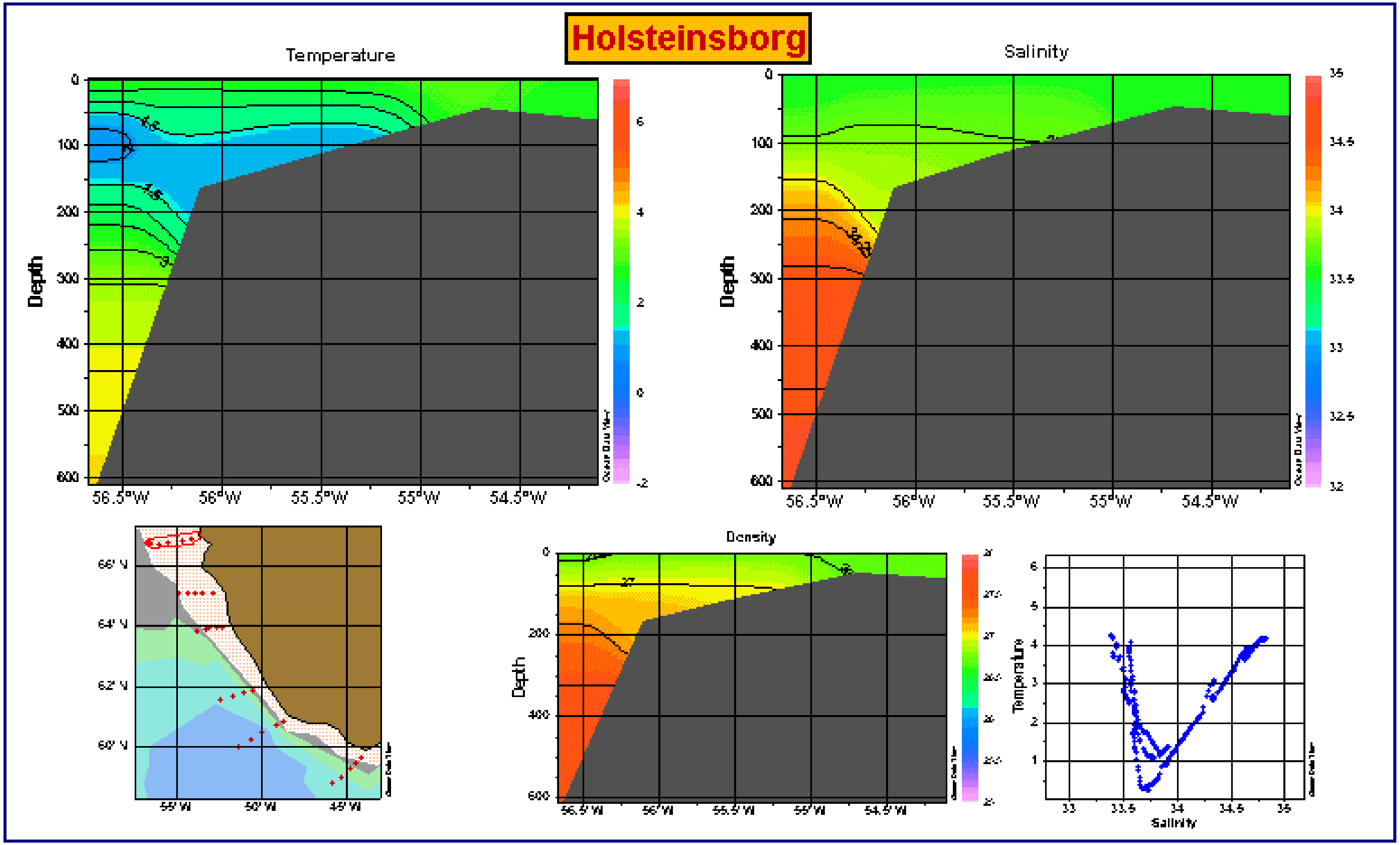

Fig. 17. *Vertical distribution of temperature, salinity and density at the Holsteinsborg Section, July 10, 2000*

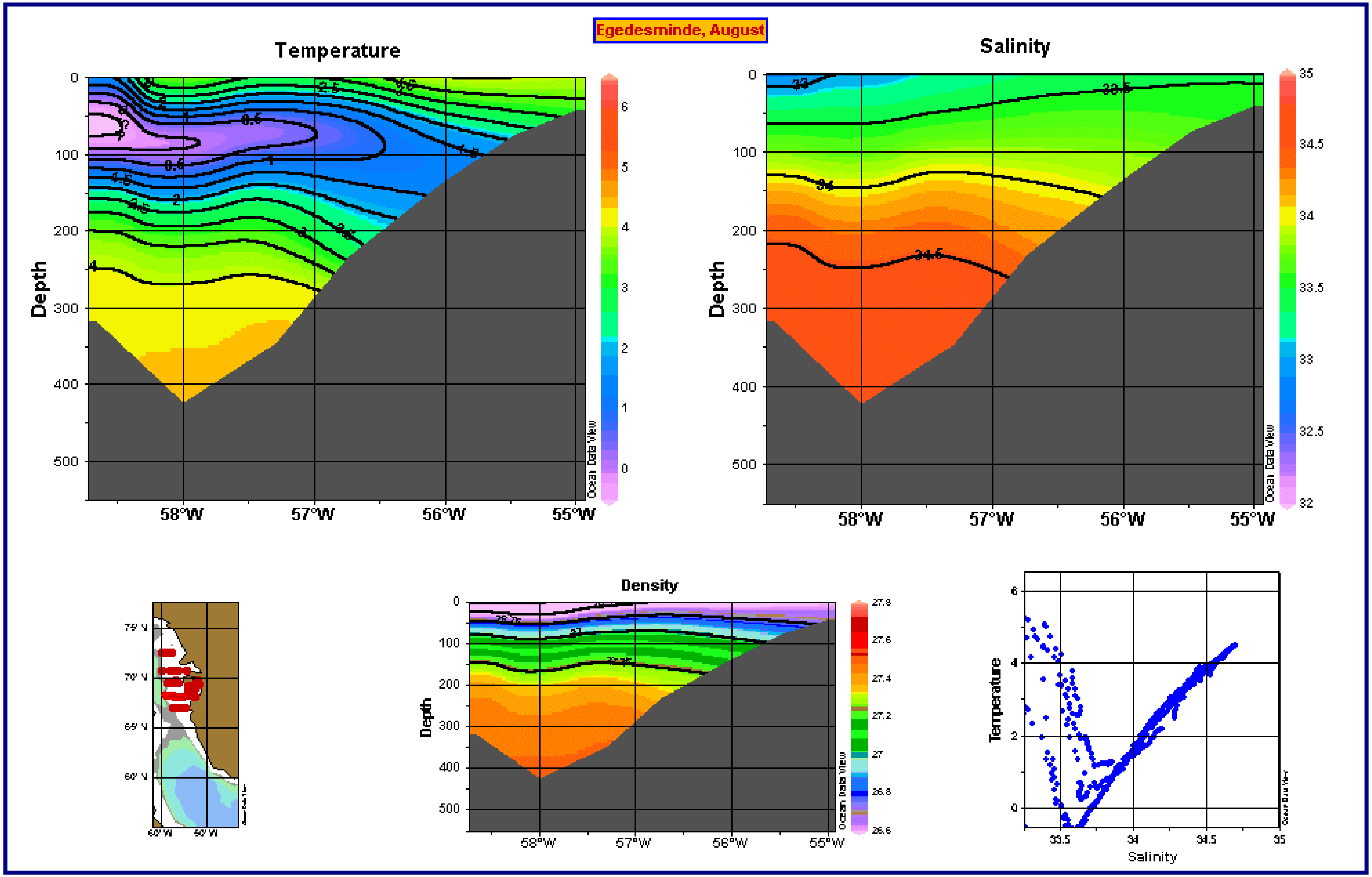

Fig. 18. *Vertical distribution of temperature, salinity and density at the Egedesminde Section, August 6, 2000*

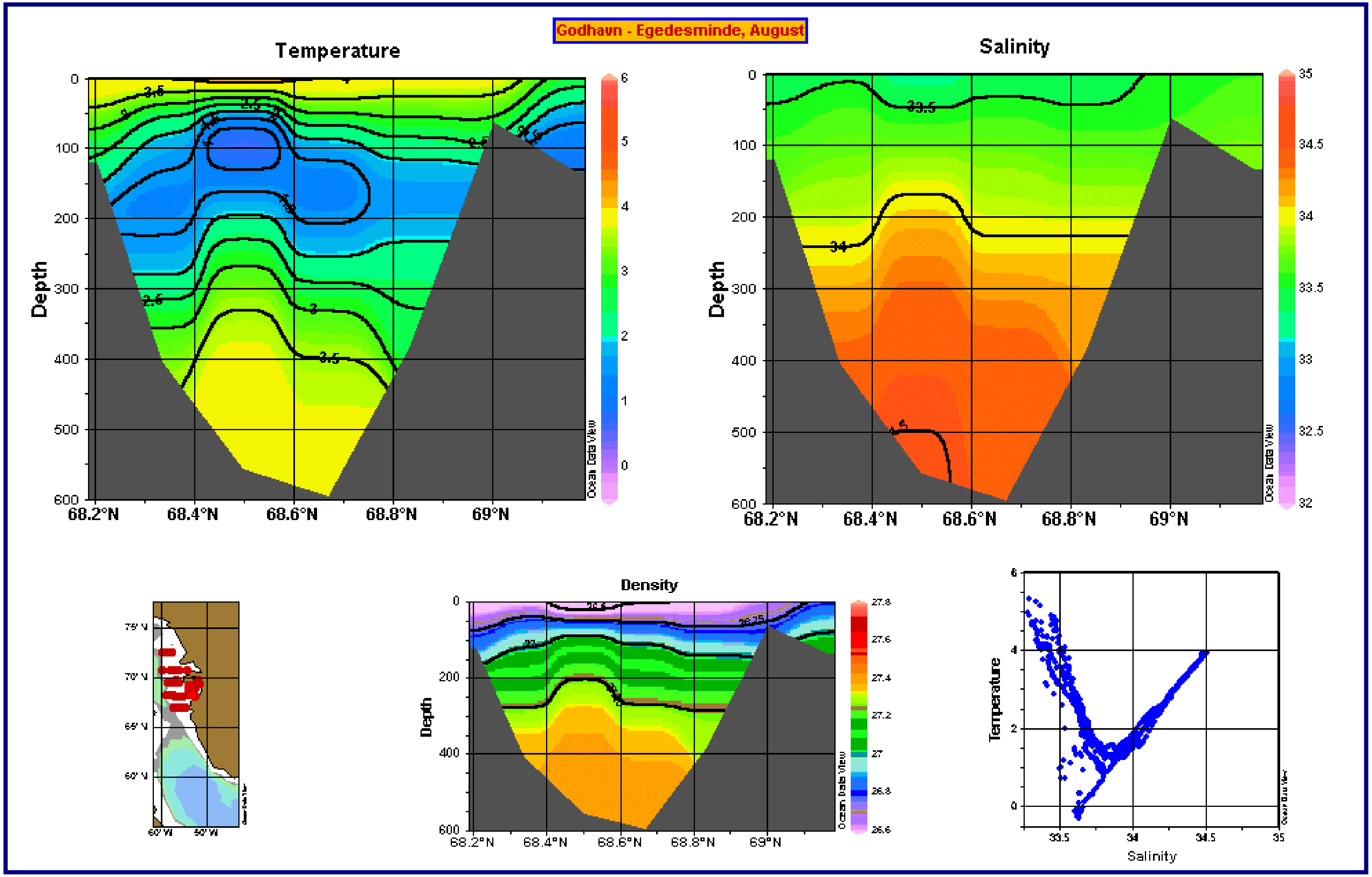

Fig. 19. *Vertical distribution of temperature, salinity and density at the Godhavn-Egedesminde Section, August 14, 2000*

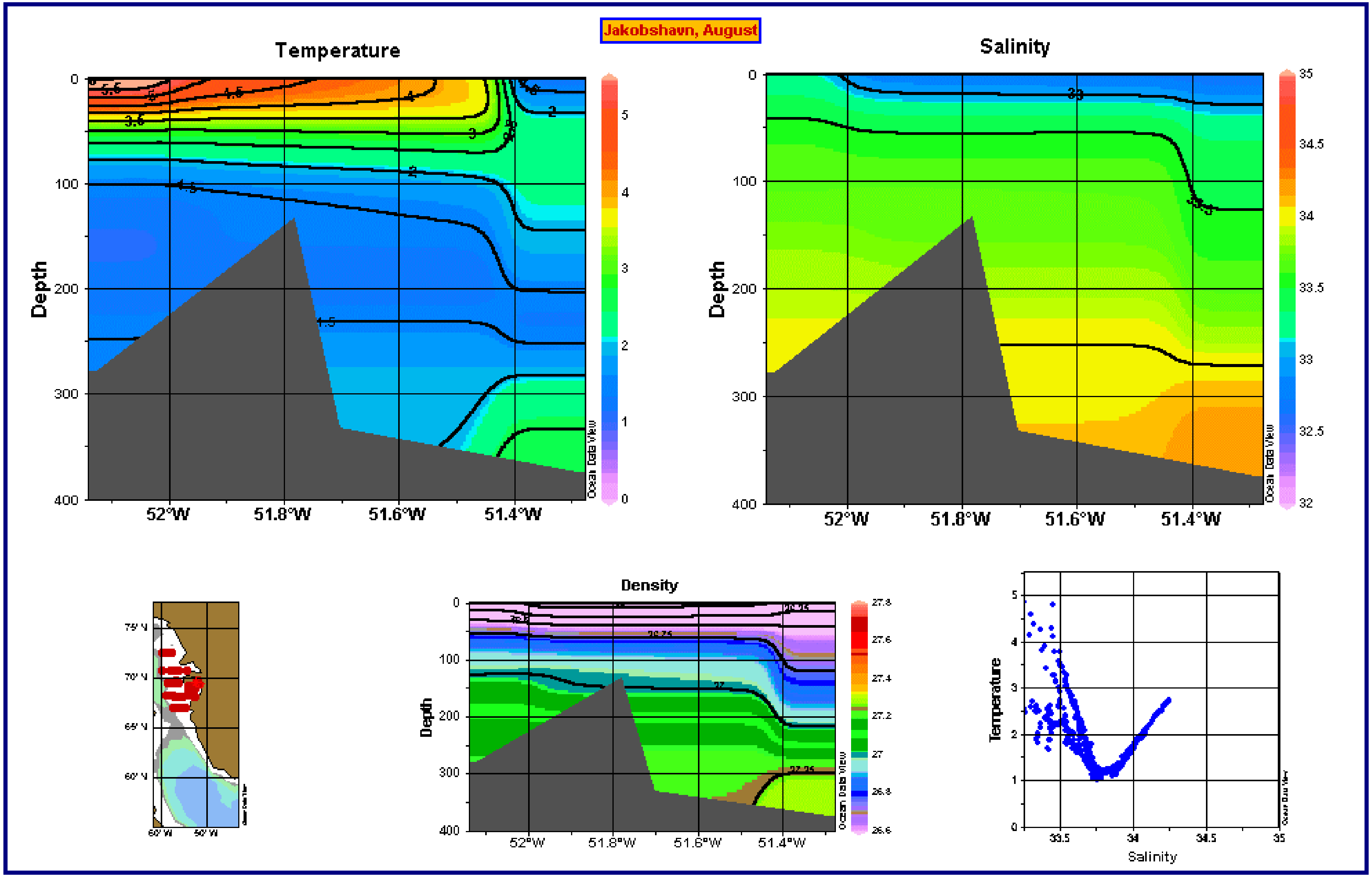

Fig. 20. *Vertical distribution of temperature, salinity and density at the Jakobshavn Section, August 24, 2000*

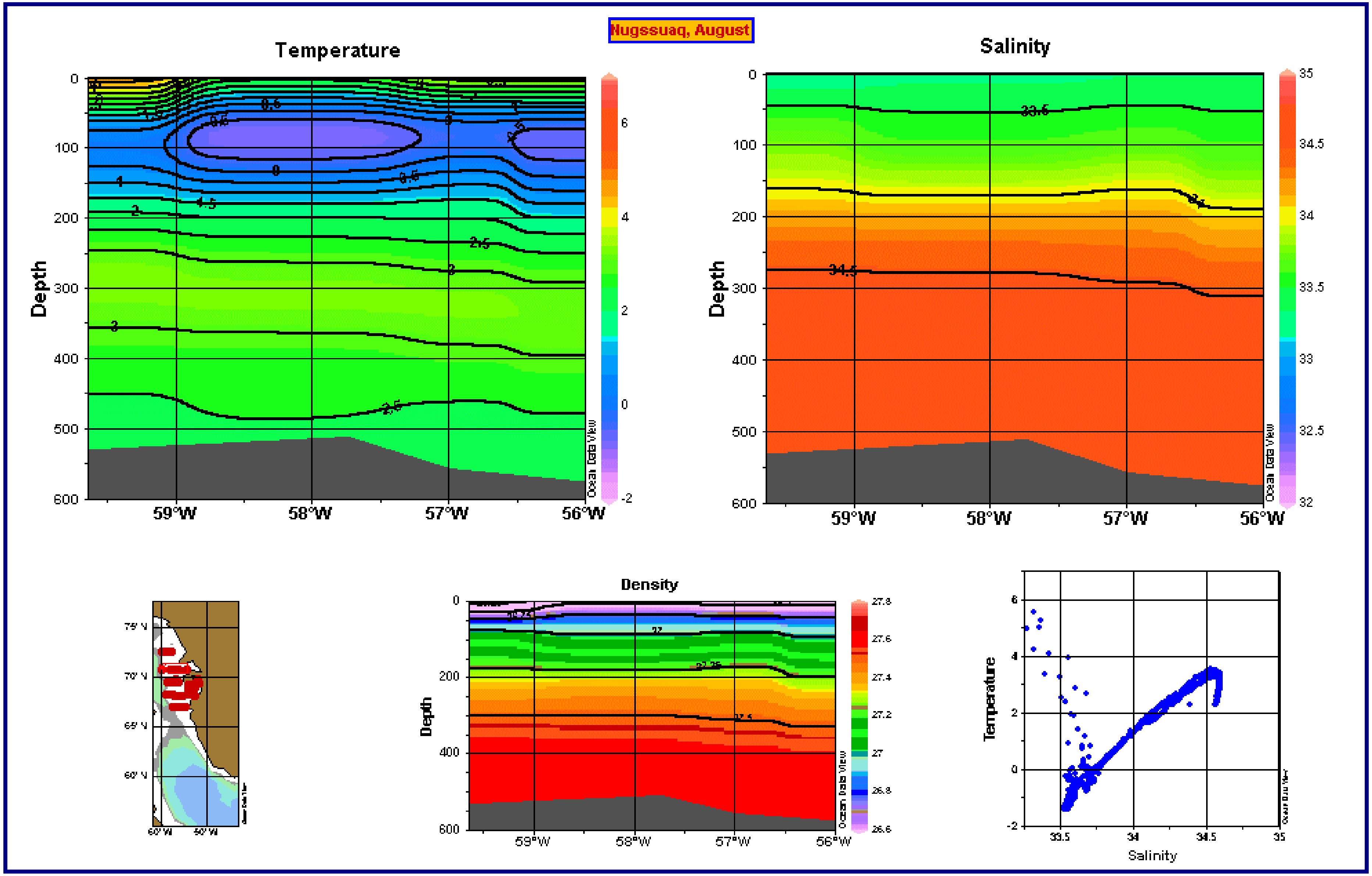

Fig. 21. *Vertical distribution of temperature, salinity and density at the Nugssuaq Section, August 20, 2000*

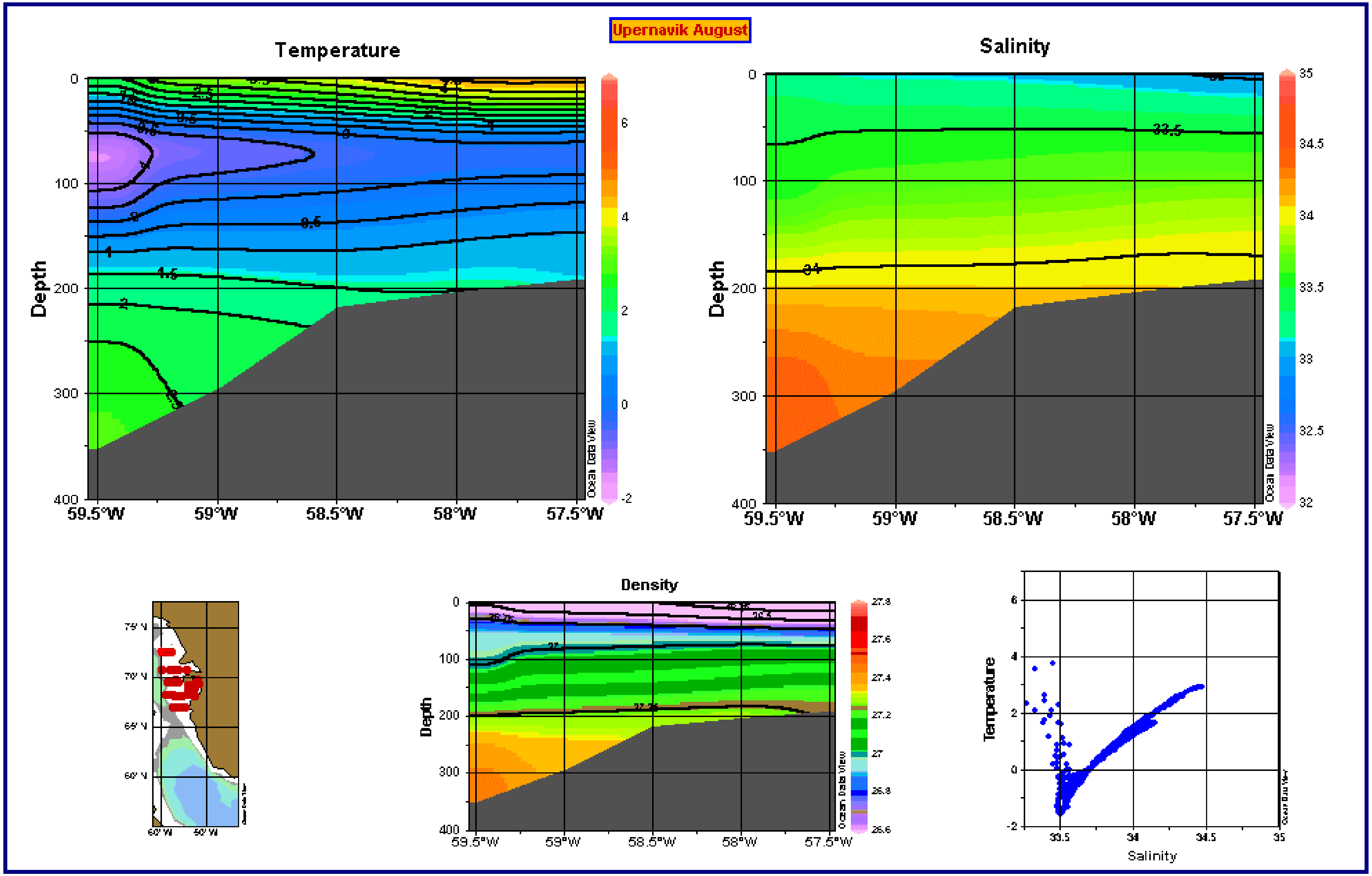

Fig. 22. *Vertical distribution of temperature, salinity and density at the Upernavik Section, August 19, 2000*

ANNEX J: AREA 1 (WEST GREENLAND) GERMAN REPORT

Report on Oceanographic results from cruise WH221
West Greenland (5 - 17 October 2000)

by
M. Stein
Institut für Seefischerei
Bundesforschungsanstalt für Fischerei
Palmaille 9, D-22767 Hamburg

Background

Investigations performed by FRV "Walther Herwig III" in October 2000 at NAFO Standard Oceanographic Sections Cape Desolation, Frederikshaab Bank, Fyllas Bank and Little Halibut Bank are part of the annual autumn groundfish survey to East and West Greenland waters performed by Germany since 1963 (fig. 1).

Material and Methods

CTD/Rosette observations were done at each fishing station and at international oceanographic standard stations and sections initiated during ICNAF*) times and followed by NAFO. The present report deals with 15 CTD/Rosette stations (fig. 2). Salinity readings of the CTD profiles were adjusted to water samples derived by Rosette water sampler. Data analysis and presentation was done using the most recent version of Ocean Data View (5.3). Theta/S sections of Frederikshaab Bank Section, Fyllas Bank Section and Lille Hellefiske Bank Section are displayed in figs. 3 to 6. Water mass analysis was done using the "patch" option in Ocean Data View for Irminger Water (4°C < Theta < 6°C, 34.95 < S < 35.1) for both the 1999 and the 2000 autumn observations (figs. 7 to 10). Time series of temperature anomaly at Fyllas Bank station 4 is given in fig. 11, and the time series of salinity calibration samples is given in the final plot (fig. 12).

Preliminary results

As in previous years, West Greenland waters were warmer than normal (rel. 1963-1990). The surface layer (0-200m) at Fyllas Bank station 4 revealed thermal conditions which were 1.55 K above the long-term mean (fig. 11). The major heat input to the water column is derived by advection, i.e. the warm Irminger Component of the West Greenland Current. During 1999 Irminger Water was observed as far north as Lille Hellefiske Bank (65° 06'N, c.f. figs. 2, 7, 8). The green spot in the Theta/S diagrams marks the water mass characteristics of Irminger Water (4°C < Theta < 6°C, 34.95 < S < 35.1; figs. 7, 8). The vertical extension of this warm water during the autumn 2000 observations is marked green in figs. 9 and 10. It should be noted that in contrast to 1999 during 2000 no Irminger Water was observed at the Hellefiske Bank Section. Northernmost extension of this water was seen at Fyllas Bank Section (fig. 10).

The deep layer at the Cape Desolation section indicates a slight increase in salinity at the 3000 dbar level (fig. 12) if compared to the 1999 observations (1999: 34.835; 2000: 34.862). Due to technical problems, there are unfortunately no calibration samples available for depths other than the 3000 dbar level.

Figures and captions

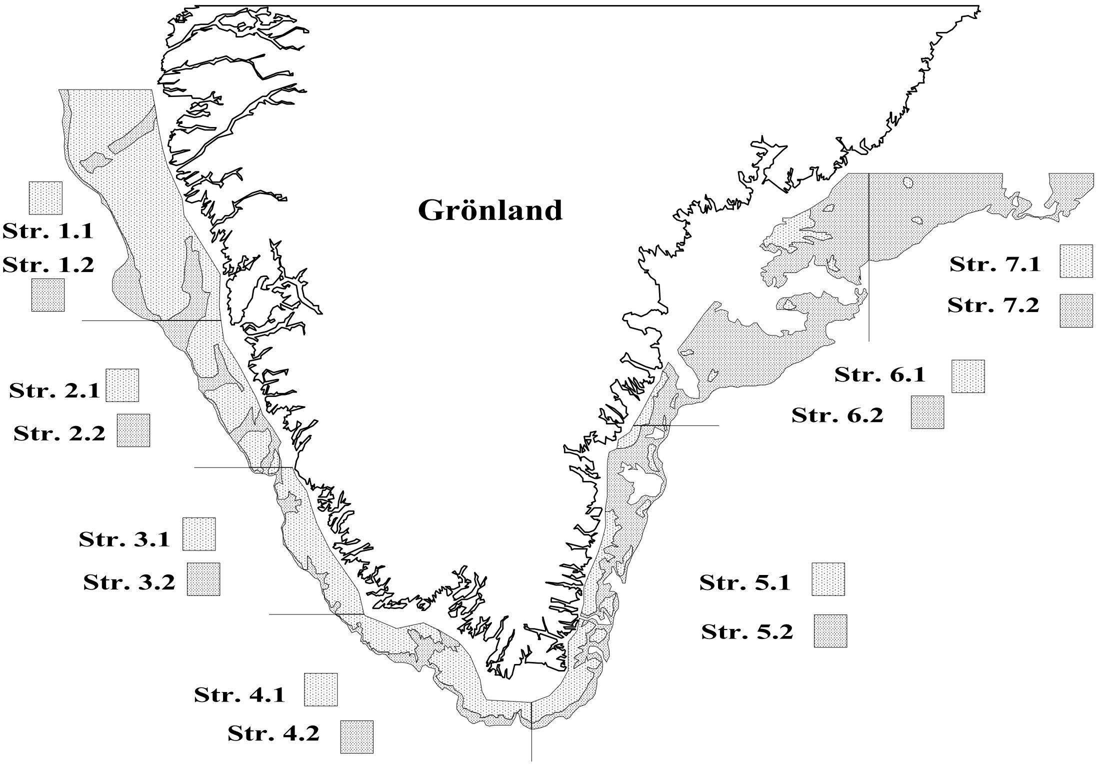

Fig. 1 Area of investigation during WH 221, and individual survey strata (15 September – 27 October 2000)

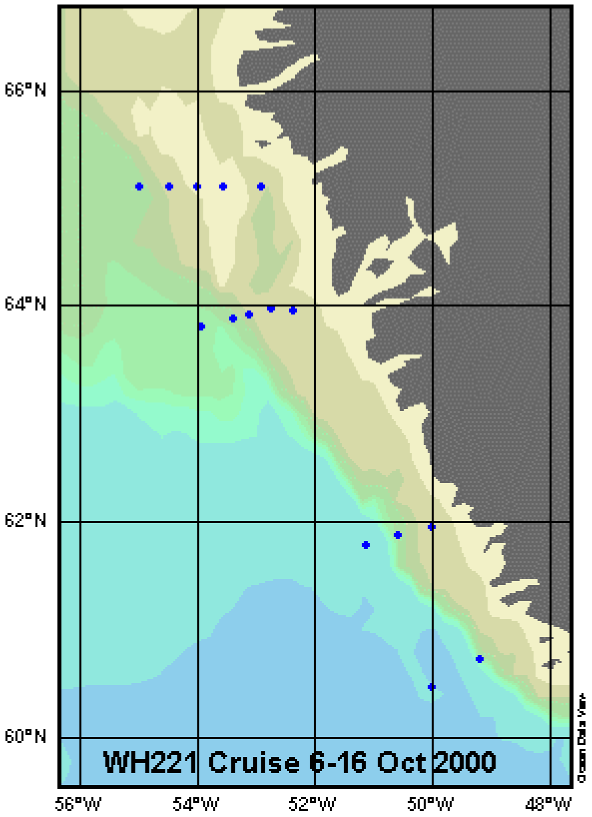

Fig. 2 Positions of sampled NAFO Standard Stations and Sections (6 – 16 October 2000)

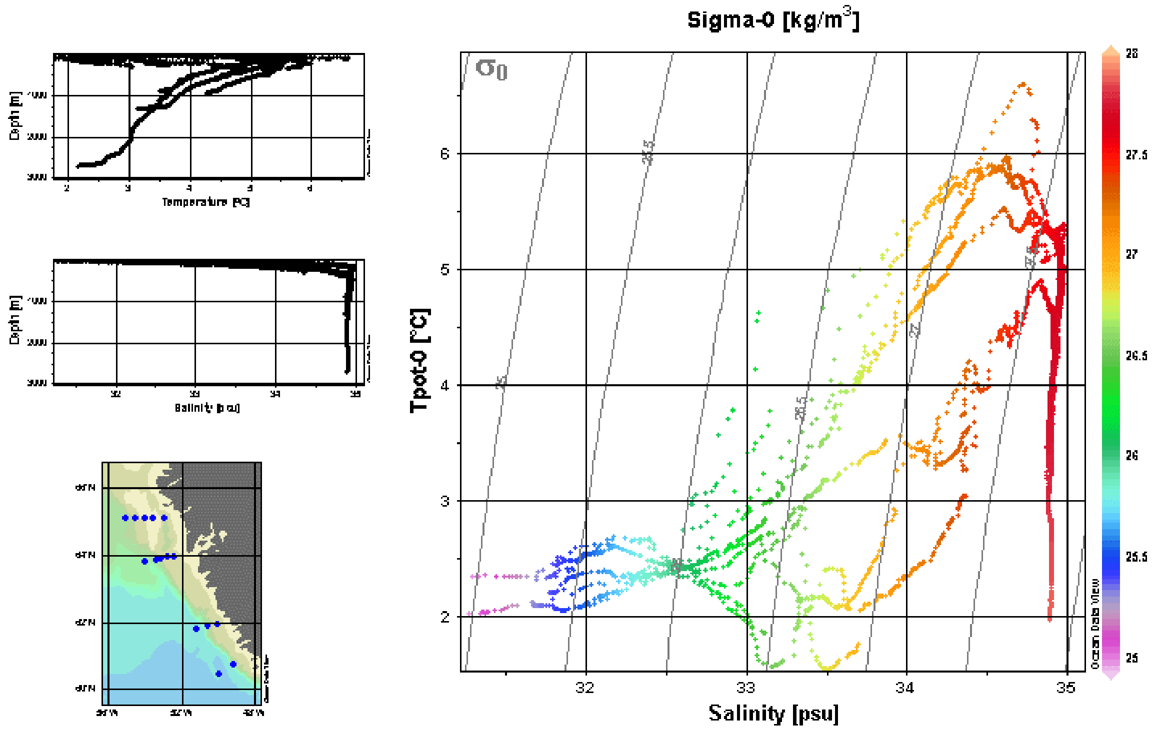

Fig. 3 Theta/S diagram of station profiles indicated in Fig. 1

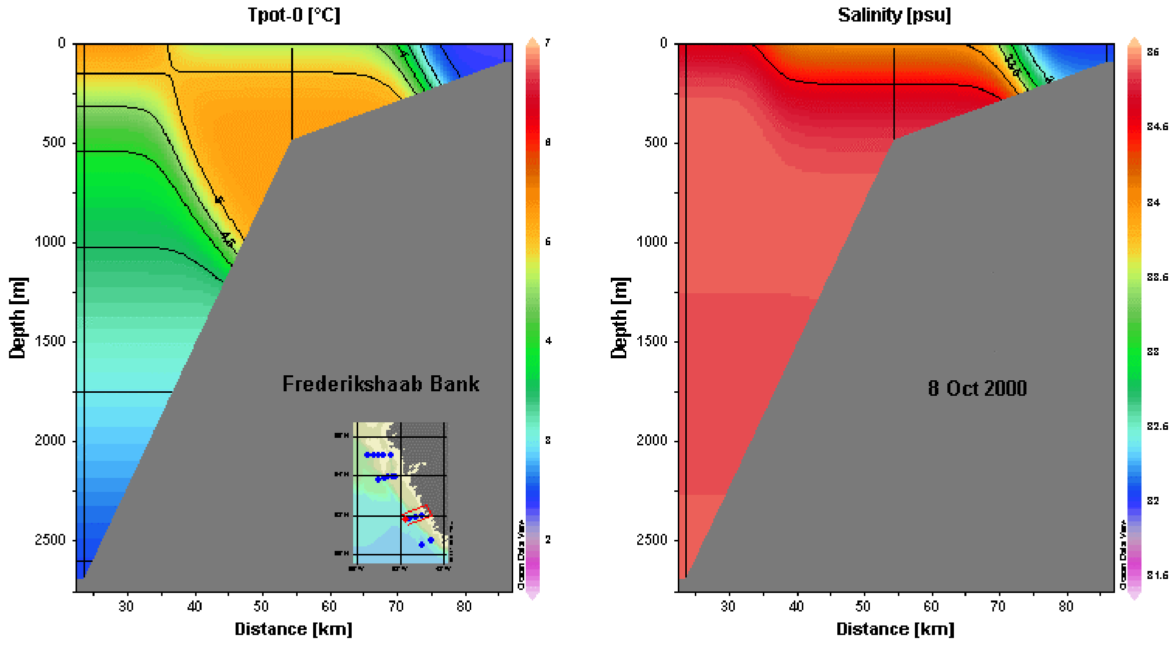

Fig. 4 Potential temperature and salinity along Frederikshaab Bank Section (8 October 2000)

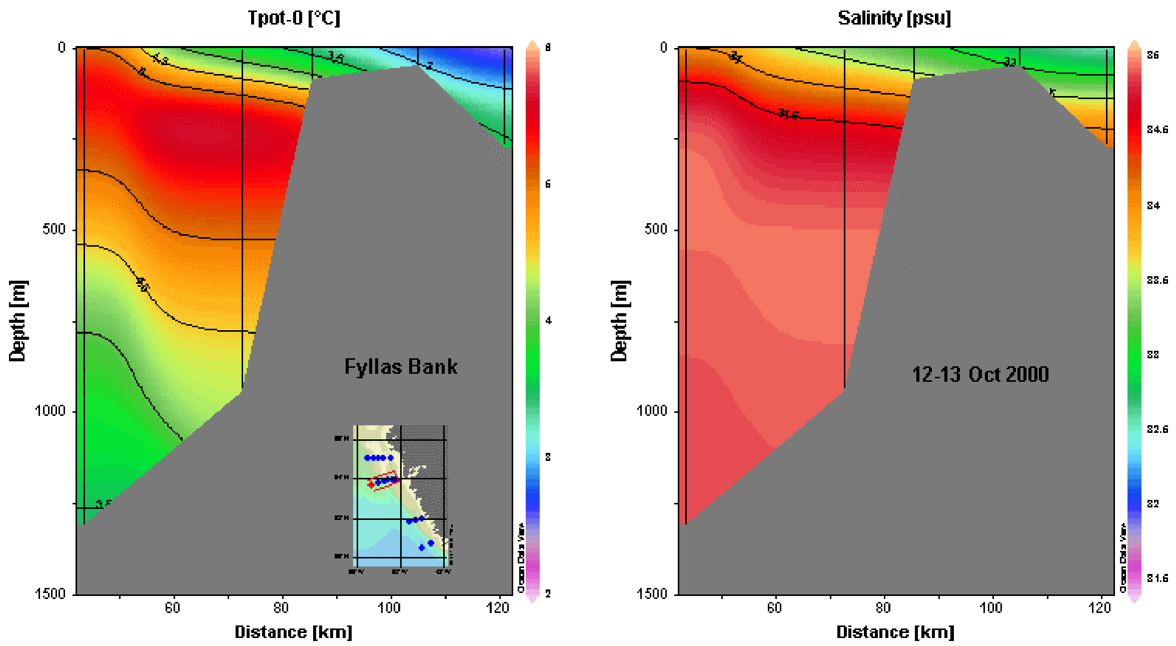

Fig. 5 Potential temperature and salinity along Fylla Bank Section (12 - 13 October 2000)

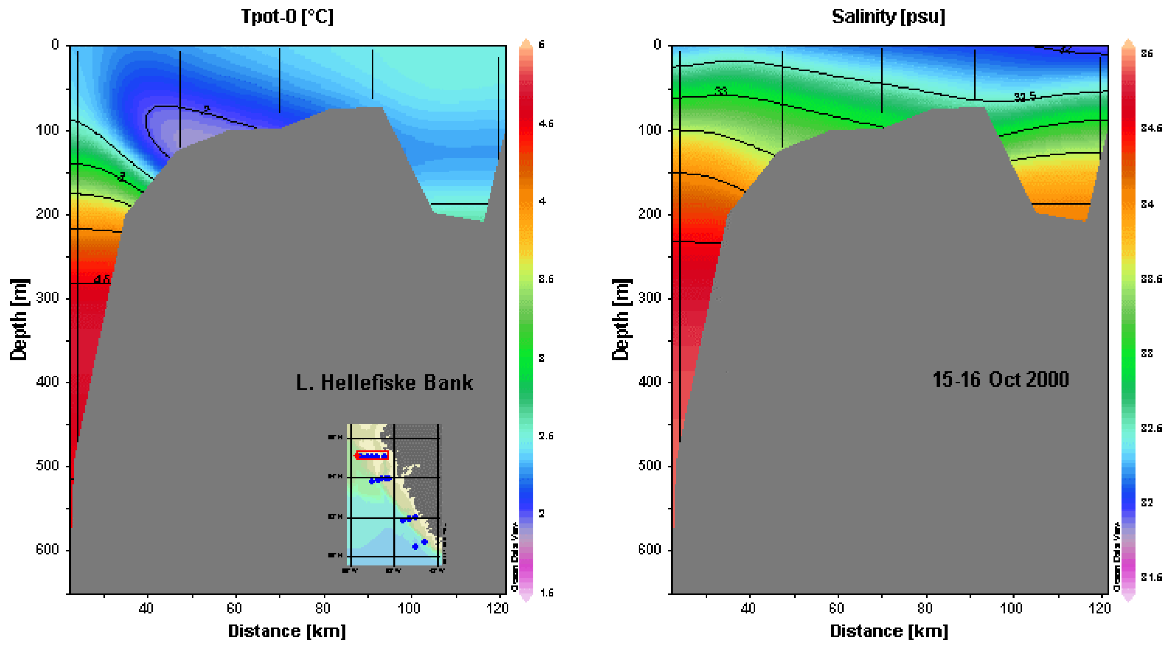

Fig. 6 Potential temperature and salinity along L. Hellefiske Bank Section (15 - 16 October 2000)

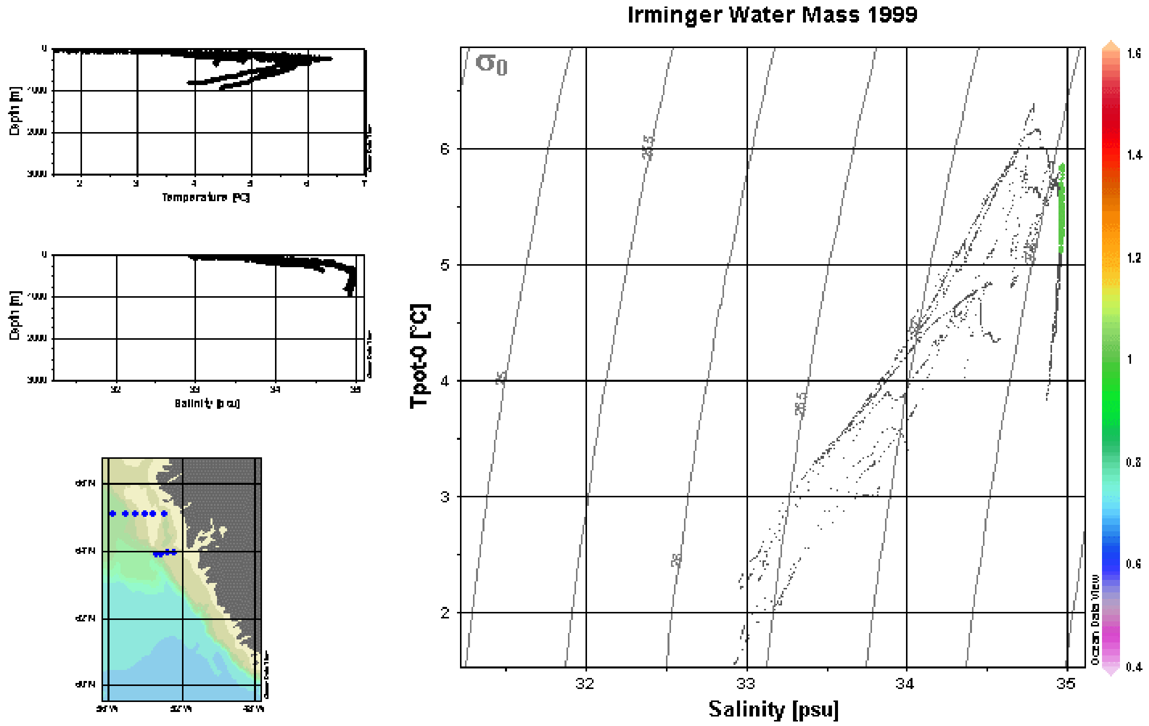

Fig. 7 Theta/S diagram with patch of Irminger Water mass (green area: 4°C < Theta < 6°C, 34.95 < S < 35.1) for 1999 autumn

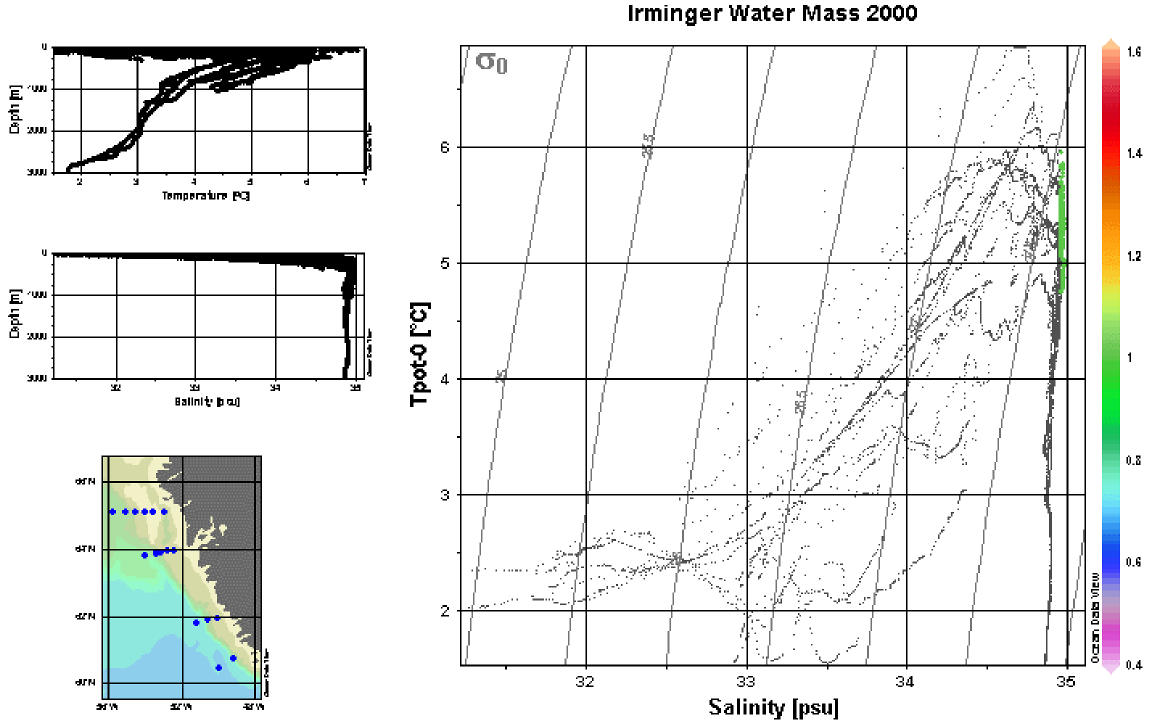

Fig. 8 Theta/S diagram with patch of Irminger Water mass (green area: 4°C < Theta < 6°C, 34.95 < S < 35.1) for 2000 autumn

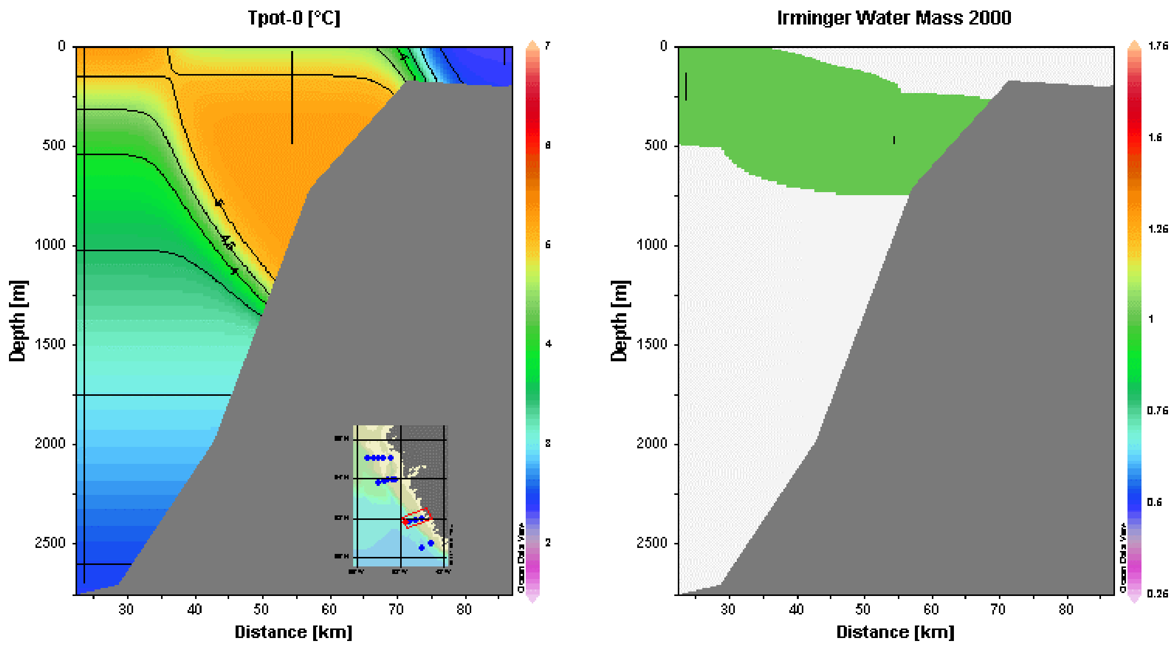

Fig. 9 Potential temperature and Irminger Water mass along Frederikshaab Bank Section (8 October 2000)

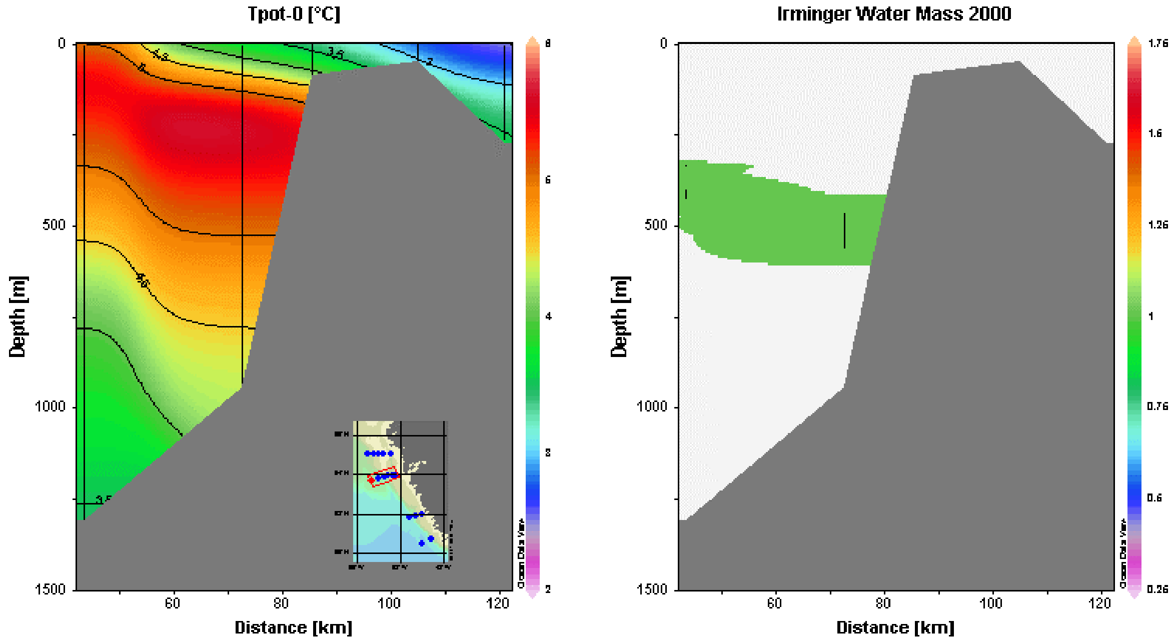

Fig. 10 Potential temperature and Irminger Water mass along Fyllas Bank Section (12 - 13 October 2000)

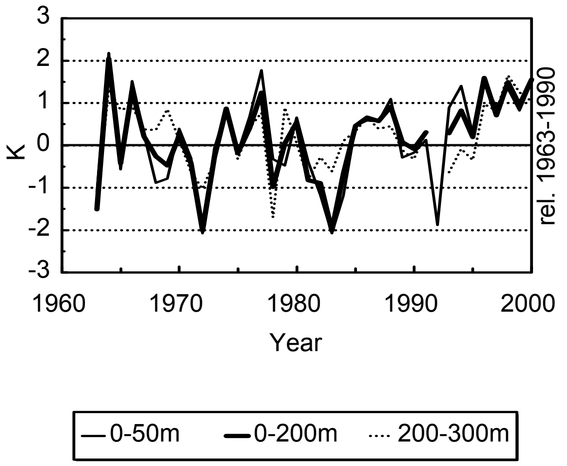

Fig. 11 Mean temperature anomalies of water layers at station 4 of the Fyllas Bank Section (0-50m: thin; 0-200m: bold; 200-300m: dashed)

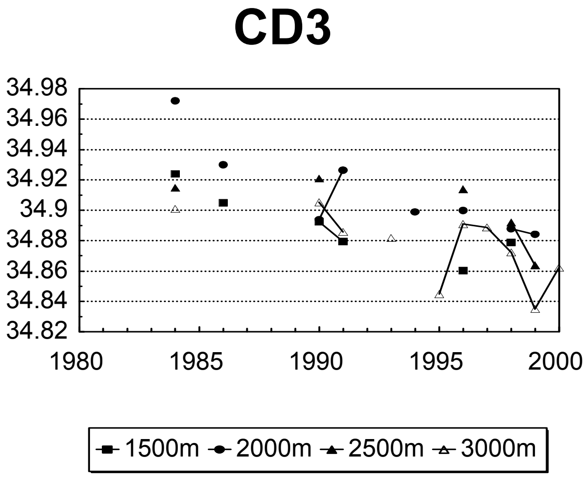

Fig. 12 Salinity of calibration samples at Cape Desolation Section station 3 (60°28'N, 50° 00'W)

*) ICNAF = International Commission for the Northwest Atlantic Fisheries

ANNEX K: AREA 2 (NORTHWEST ATLANTIC) CANADIAN REPORT

Environmental Conditions in the Northwest Atlantic during 2000 (ICES Area 2)

E. Colbourne

Department of Fisheries and Oceans
P. O. Box 5667
St. John's Newfoundland, Canada A1C 5X1

Introduction

Meteorological and oceanographic conditions during 2000 are presented referenced to a standardized 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 (Figs. 1 and 2). 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^o 32.8$^'$ N and longitude -52^o 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 3-4 times per month on average, with 59 occupations during 2000.

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. As part of an expanded Atlantic zonal monitoring program (AZMP) the Bonavista and Flemish Cap transects are now occupied during the spring and fall with the addition of the Southeast Grand Bank transect. In addition, during the summer of 2000 two transects on the mid-Labrador Shelf (crossing Makkovik and Nain Banks) were occupied. In this report the results from these transects for the summer of 2000 are presented.

Meteorological and sea-ice conditions

Monthly air temperature anomalies for 1999 and 2000 relative to their 1961-90 mean at eight sites in the northwest Atlantic from Godthaab in Greenland to Cape Hatteras on the eastern coast of the United States are shown in Fig. 3. The predominance of warmer-than-normal air temperatures over most of eastern Canadian waters during 2000 is clearly evident with anomalies of +3° to 4°C common. Monthly air temperatures were above normal in 8-10 out of 12 months of 2000 at most sites. The time series of the annual air temperature anomalies are shown in Fig. 3. The annual mean air temperature anomalies for 2000 were above normal in 6 out of the 8 sites examined, with annual anomalies reaching 1.4^{o}C at the Magdalen Islands and up to 1.2^{o}C at St. John's and Cartwright. Except for the northern regions where annual anomalies warmed slightly over the 1999 values, most sites experienced a decrease over the record setting 1999 values. 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 in most years creates strong northwest winds, cold air and sea temperatures and heavy ice in the Labrador Sea and Newfoundland Shelf regions. During both 1999 and 2000 the NAO anomaly was well above normal (+14 mb) and had increased significantly from the 1998 value which was +1.1 mb (Fig. 5). The 1999 and 2000 index returned to a level similar to that observed during the first half of the 1990s and was above the lower-than-average values 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 the past 2 years the colder-than-normal winter conditions usually associated with high NAO index did not extend into this region.

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^{o}N) show that the peak extent during 2000 increased slightly over 1999 but was still much lower than the heavy ice years of the early 1990s (Fig. 6). The average ice area during both the period of southward advancement (January to March) and northward retreat (April to June) rose slightly relative to 1999. However, during both periods the average ice area was below the long-term mean and was much less than the heavy ice years of the early 1990s (Fig. 6). In general, sea ice coverage was lighter-than-average and of shorter duration than normal during 2000 on the Newfoundland and Labrador Shelves.

Time Trends in Temperature and Salinity at Station 27

Depth versus time contour maps of the annual cycle in temperature and salinity and their associated anomalies for 2000 at Station 27 (Fig. 1) are displayed in Fig. 7. The monthly anomalies at the surface and bottom are displayed in Figs. 8 and 9 (top panels). The cold near isothermal water column during the winter months has temperatures ranging from 0^{o}C to –1^{o}C. These temperatures persisted throughout the year in the bottom layers. The surface layer temperatures were near constant at about 0^{o}C from January to early April, after which the surface warming commenced. By late April upper layer temperatures had warmed to 1^{o}C and to over 14^{o}C by August at the surface, after which the fall cooling commenced. These values ranged from 0.25^{o} to 0.5^{o}C above normal for the winter months over most of the water column, but decreased to below normal values below 10-m depth during late June and July. This cold anomaly penetrated deeper into the water column during late summer and fall months reaching the bottom by the end of the year. Temperatures in the upper water column remained above normal from August to December with anomalies exceeding 1°C. Bottom temperatures ranged from 0.25^{o} to 0.5^{o}C above normal from January to June and near normal during the remainder of the year. Surface salinities reached a maximum of >32 by May and decreased to a minimum of <31 by late August. These values ranged from 0.1-0.4 below normal during the winter months to slightly above normal during the summer in the upper water column and slightly below normal during the remainder of the year. Except for the positive near surface anomaly during the summer months salinities were generally below normal during most of 2000 on the inner Newfoundland Shelf.

The annual time series of the surface and bottom temperature and salinity anomalies show three colder and fresher-than-normal periods at near decadal time scales since the early 1970s (Figs. 8 and 9 bottom panels). At the surface, the negative temperature anomaly that reached a peak in the early 1990s began to moderate to about normal values by the summer of 1994 and have continued above normal up to 2000. Near bottom at 175-m, temperatures were generally below normal from 1983 to 1994, the longest continuous period on record. During 1994 and 1995 bottom temperatures begin to warm and by 1996 were above the long-term average. These warmer-than-normal values have continued up to 2000. Near surface salinity anomalies (Fig. 9) show the large fresher-than-normal anomaly that began in early 1991 had moderated to near normal conditions by early 1993 but returned to fresher than normal conditions by the summer of 1995. Salinities approached near normal values during 1996 but decreased to mostly below normal values from 1997 to 2000.

The vertically averaged (0-176 m) annual temperature anomaly (which is proportional to the water column heat content anomaly) time series (Fig. 10 top panel) 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 and 2000. The 0-50 m vertically averaged summer (July-September) salinity anomalies (Fig. 10 bottom panel) 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 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. From 1996 to 2000 salinities have ranged from near normal to below normal values. In general, during the past several decades cold ocean temperatures and fresher-than-normal salinities were associated with strong positive NAO index anomalies, colder-than-normal winter air temperatures, heavy ice conditions and larger than average summer cold-intermediate-layer (CIL) areas on the continental shelf (Drinkwater 1996, Colbourne et al. 1994).

Standard Sections

Flemish Cap (47° N)

The Flemish Cap transect was occupied 3 times during 2000, April, July and November. Near surface temperatures along this transect ranged from 1-2°C during the spring to 8-12°C during the summer (Fig. 11) and 6-8°C during the fall. Sub-zero °C temperatures generally persisted throughout the year from below 50-m depth to the bottom over most of the Grand Bank. The coldest water is normally found in the Avalon Channel and at the edge of the Grand Bank corresponding to the inshore and offshore branches of the Labrador Current. Over the Flemish Cap temperatures reach a maximum of about 12°C at the surface during July and remain at about 4-5°C at 80-m depth to the bottom throughout most of the year. During the summer temperatures were generally below normal in the upper water column, above normal at intermediate depths and about normal near bottom on the Grand Bank. Deep-water temperatures over the Flemish Pass and Cap were near normal during the summer of 2000. Except near the surface, summer salinities along this transect on the Grand Bank were generally fresher than normal during 2000.

Bonavista

The Bonavista transect was also occupied 3 times during 2000, May, July and November. The dominant feature along this transect is the cold intermediate layer of sub-zero °C shelf water (CIL) which develops during early spring. Temperatures along the Bonavista transect in the upper 20-m of the water column ranged from sub-zero °C during spring, reaching a maximum of 8-10°C during the summer (Fig. 12) and decreasing to 3-4°C during the fall. These values were generally below normal during the summer except in the offshore portion in the warmer slope water. Near bottom temperatures across the northeast Newfoundland Shelf were up to 0.5°C above normal during the summer of 2000. Bonavista transect salinities generally range from <33 near the surface in the inshore waters to >34 in the offshore region. Bottom salinities ranged from 32.5 in the inshore regions, to 34.75 at about 325-m depth near the shelf edge. Salinities were generally fresher-than-normal (up to 0.3) in the intermediate depths on the shelf during the summer and saltier-than-normal in the surface waters particularly in the offshore shelf-slope regions.

White Bay

The White Bay section, which crosses the deepest portions of the northeast Newfoundland Shelf, was occupied in July of 2000 (Fig. 13). The CIL is also quite evident along this transect with a large area of water with sub-zero °C temperatures extending from the coast and offshore to over 400 km. Temperatures along this transect were generally below normal during 2000 in the upper 50 m of the water column and over all depths at mid-shelf. Below 50-m depth temperatures were above normal near shore and in the offshore areas. Salinities generally ranged from <31.5 near the surface in White Bay to >33.75 in the offshore region. Bottom salinities ranged from 33 near shore to 34.75 at the edge of the shelf. These values were fresher than normal (up to 0.4) in areas corresponding to CIL waters and generally above normal near the surface and in the deeper waters of the outer shelf regions.

Seal Island

The Seal Island transect which crosses Hamilton Bank on the southern Labrador Shelf was occupied in July of 2000 (Fig. 14). Temperatures across this region ranged from 0°C at 30-m depth to between 4-5°C at the surface. Temperatures below 50-m depth were generally sub-zero °C corresponding to the CIL over most of the shelf, except near bottom where they range from 1-2°C. Near the shelf break temperatures increase to over 3°C. Temperature anomalies in the surface layer ranged from 0.25-1°C above normal near-shore, but were up to 1°C below normal over Hamilton Bank. These colder than normal temperatures extended to the bottom over the bank but were near normal below 225 m depth in the offshore regions. Salinities in the near shore region and across most of the shelf were fresher than normal with anomalies ranging from 0.75 near shore at the surface to around 0.4 on Hamilton Bank. Offshore of the shelf break salinities were near normal at depth and above normal in the upper water column.

Makkovik Bank and Beachy Island (Nain Bank)

The Makkovik Bank transect on the mid-Labrador Shelf was occupied in July of 2000 (Fig. 15). Surface temperatures ranged from 0°C at 30-m depth to between 2-3°C at the surface. Temperatures below 30-m depth were generally sub-zero °C over the shelf but increased to above 0°C on the outer edge of the Bank and to >3°C on the shelf slope. Temperature anomalies in the surface layer were up to 1°C below normal but near normal over the rest of the water column on the bank and generally above normal in the offshore regions. Salinities were generally <32 near surface to >33 on the bank and >34 in the offshore regions. These values were below normal over the bank and above normal in the offshore regions.

The Beachy Island transect which crosses Nain Bank on the mid-Labrador Shelf was also occupied in late July of 2000 (Fig. 16). Temperatures along this transect were slightly warmer than that observed along the Makkovik Bank transect with surface values over 3°C and the area of water with temperatures below –1°C much less than that on Makkovik Bank. Offshore temperatures were very similar along both transects. Except for slightly fresher water near the surface, salinities along the both transects were also very similar. Insufficient data were available to calculate anomalies along the Beachy Island transect.

Cold Intermediate Layer (CIL) Time Series

As shown above in the cross-shelf contour plots, the vertical temperature structure on the Newfoundland Continental Shelf during late spring through the fall months is dominated by a layer of cold sub-zero °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 frontal region denoted by a strong horizontal temperature and salinity gradient near the edge of the continental shelf. Figure 17 shows the time series of CIL cross-sectional area defined by the 0°C contour for waters along the Flemish Cap, Bonavista, White Bay and Seal Island transects during mid-summer.

Along the Bonavista transect during the summer of 2000 the CIL extended offshore to about 220 km, with a maximum vertical extent of about 200 m, corresponding to a cross-sectional area of about 27 km^2. This value was about normal compared to the previous 4 years with below normal values corresponding to warm ocean conditions. From 1990 to 1994 the CIL area was above normal reaching a peak of more than 60% during the cold year of 1991. The CIL area along the Seal Island section was slightly above normal during 2000 compared to about 49% below normal during 1999. 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 section during 2000 the CIL was below normal similar to the 1999 and along the White Bay transect the CIL was about average. In general, the total cross-sectional area of sub-zero °C water on the Newfoundland Shelf during 2000 appeared below normal in the south on the Grand Bank and above normal on Hamilton Bank (Fig. 17).

Geostrophic Circulation and Transport

The temperature and salinity data from the summer 2000 survey were used to calculate geostrophic currents relative to 300 m along the sections discussed above (Fig. 18). The geostrophic component of the speed of the southward flowing Labrador Current along these transects generally show distinct inshore and offshore branches. The inshore branch is much weaker than the shelf-slope offshore branch and is usually restricted to the inshore troughs within approximately 50-100 km of the coast. Typical geostrophic current speeds in these regions range from 0.05-0.10 m/s. The much stronger offshore branch is normally located at the shelf break in water depths generally greater than 500 m. The offshore distance and the width of the current vary according to the underlying topography. Along the Seal Island and Bonavista transects, for example, the core of the offshore branch is about 100 km wide, centred at about 225 km offshore over the 500-m isobath, while off Makkovik and Nain Banks the width of the current is approximately 50 km centred at about 125 km offshore. In the offshore branch, current speeds range from 0.05 m/s at 175-m depth to greater than 0.2 m/s in the upper water column. Currents over mid-shelf, on Hamilton Bank for example, sometimes reverse direction flowing north with speeds generally less that 0.05 m/s. The geostrophic flow perpendicular to the Flemish Cap transect show the well-known features of the circulation. The strong baroclinic component of the offshore branch of the Labrador Current near the edge of the Grand Bank, the general anticyclonic circulation around the Cap and the northward flowing water of the North Atlantic Current east of the Cap are evident (Fig 18). In general, geostrophic currents along the Labrador Shelf (Seal Island, Makkovik Bank and Nain Bank) appear stronger than on the eastern Newfoundland Shelf with speeds over 0.30 m/s offshore from Nain Bank for example.

The historical (1950-2000) summer (July-August) temperature and salinity data along the Seal Island, Bonavista and Flemish Cap transects were used to compute a time series of geostrophic volume transport through each section. A common reference level of 135-m was chosen for these calculations since this was the deepest level common to all three transects that did not intersect the bottom, thus eliminating potential problems associated with a bottom reference level. Also, the main interest was to examine variations in volume transport during recent ocean climate changes on the continental shelf. Short-term climate changes generally result in variations in upper layer shelf stratification due mainly to salinity changes resulting from increased ice formation and melt. This determines in part, the magnitude of the shelf-slope density front and hence the strength of the geostrophic component of the Labrador Current. The time series of volume transport of the offshore branch of the Labrador Current for the three transects (Fig. 19) show large interannual variations with an average transport of between 0.4-0.5 Sv (1 Sv = 10^6 m^3/s) to the south, relative to 135 m. In general, the time series indicate higher than average transport during the late 1950s and into the 1960s, lower than average values during the cold period of the early 1970s and to a lesser extent during the cold period of the mid-1980s. During the late 1980s the transport increased to above average values, which for the most part continued into the mid-to-late 1990s. Except for the Bonavista transect, the transport in the offshore branch of the Labrador Current during 2000 increased slightly over the 1999 values.

Summary

In general, the below normal trends in temperature and salinity established in the late 1980s on the Newfoundland Shelf reached a peak in 1991. This cold trend continued into 1993 but started to moderate during 1994 and 1995. During 1996 temperature conditions were above normal over most regions, however, summer salinity values continue to be slightly below the long-term normal. During 1997 to 1999 ocean temperatures continued to warm over most areas, with 1999 one of the warmest years in the past couple of decades. In summary, during 2000 ocean temperatures were cooler than 1999 values, but remained above normal over most areas continuing the trend established in 1996. Salinities during 2000 were similar to 1999 values, generally fresher than normal throughout most shelf regions, which is a continuation of the trend observed during most of the 1990s.

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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.

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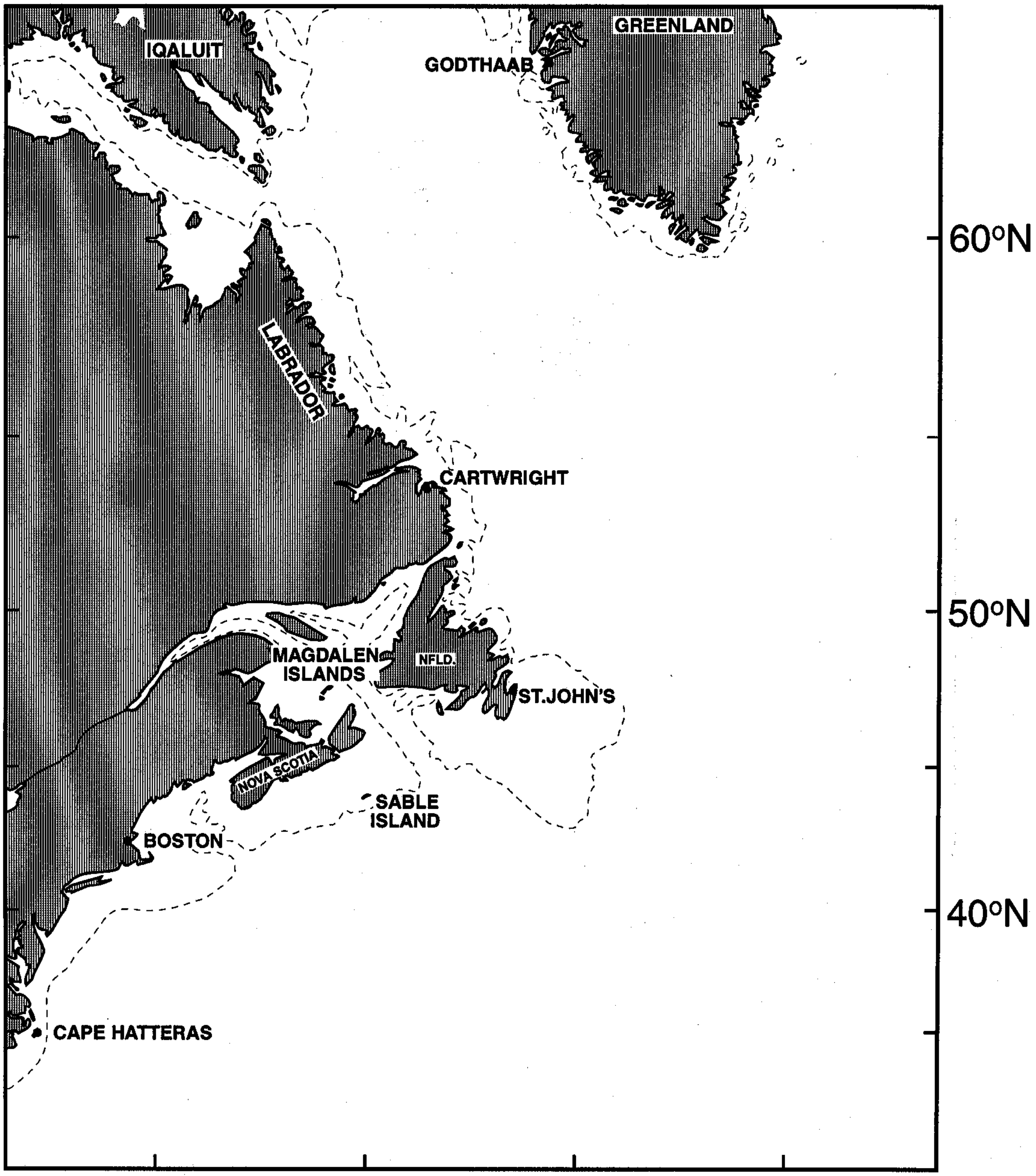


Fig. 1. Northwest Atlantic showing coastal air temperature stations. The dashed line denotes the 200 m isobath.

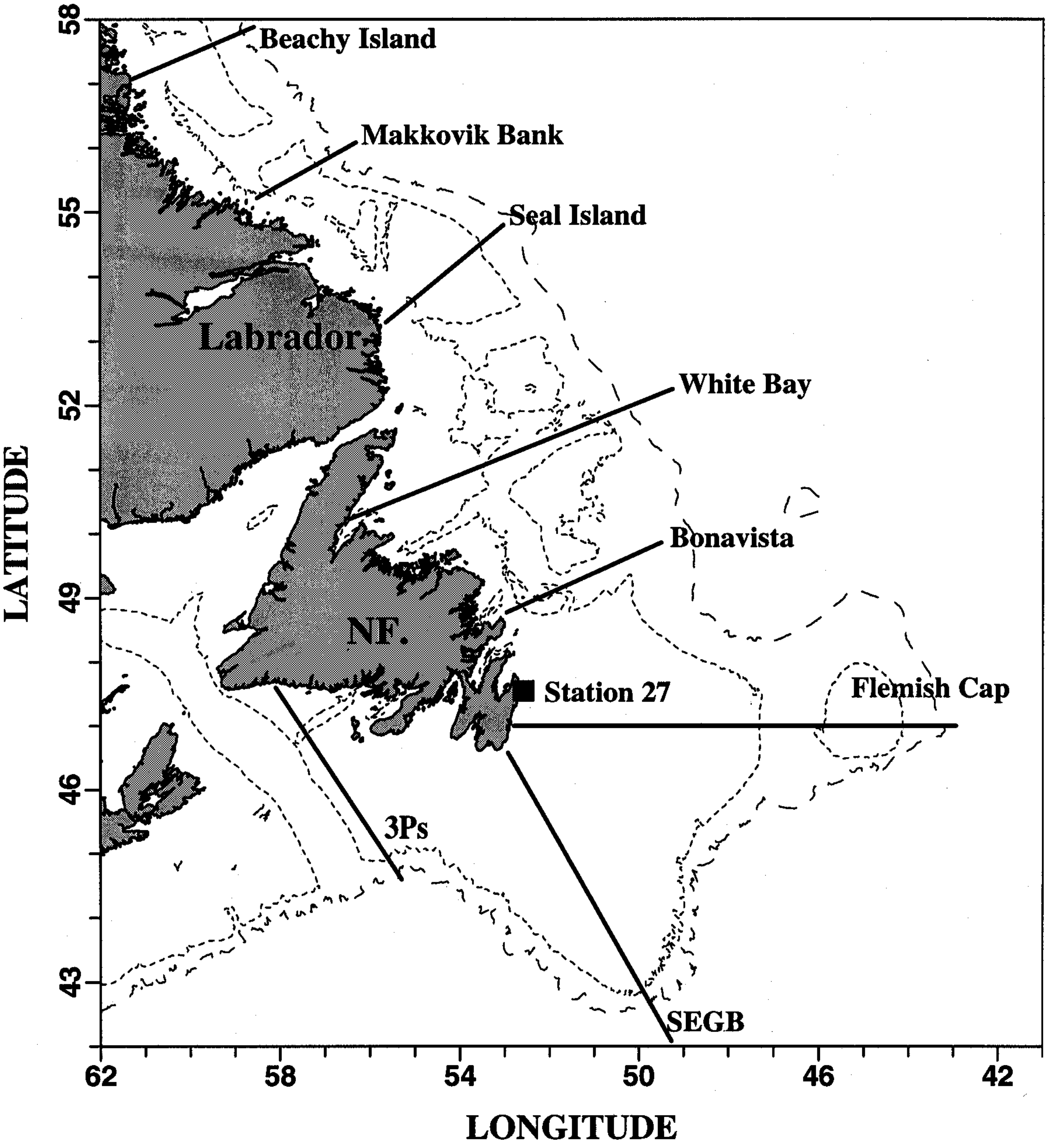


Fig. 2. Location map showing the positions of standard monitoring sections on the Newfoundland and Labrador Shelves. The location of Station 27 is also shown. Bathymetry contours are 300 and 1000 m.

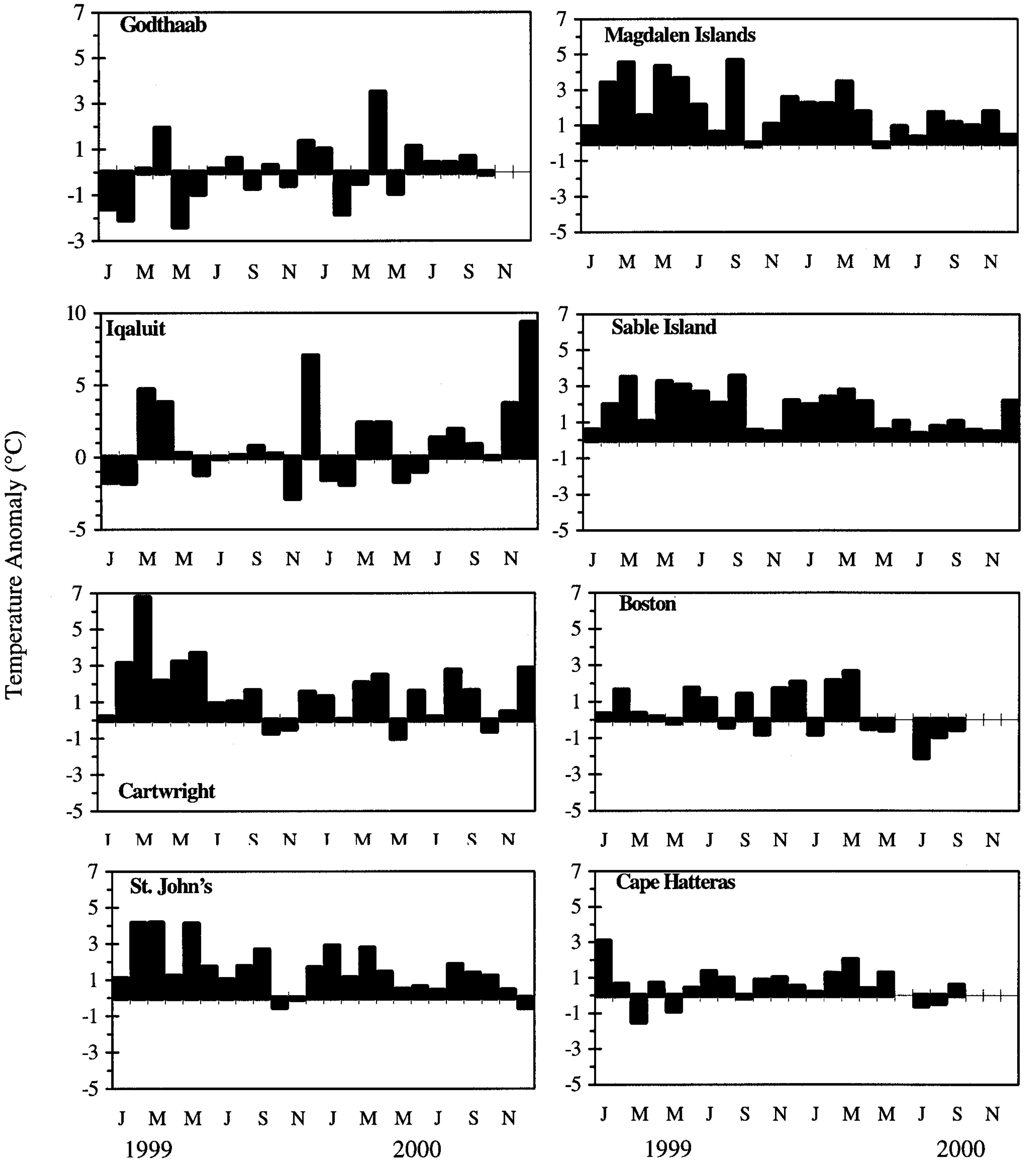


Fig. 3. Monthly air temperature anomalies in 1999 and 2000 at selected coastal sites (see Fig. 1 for locations).

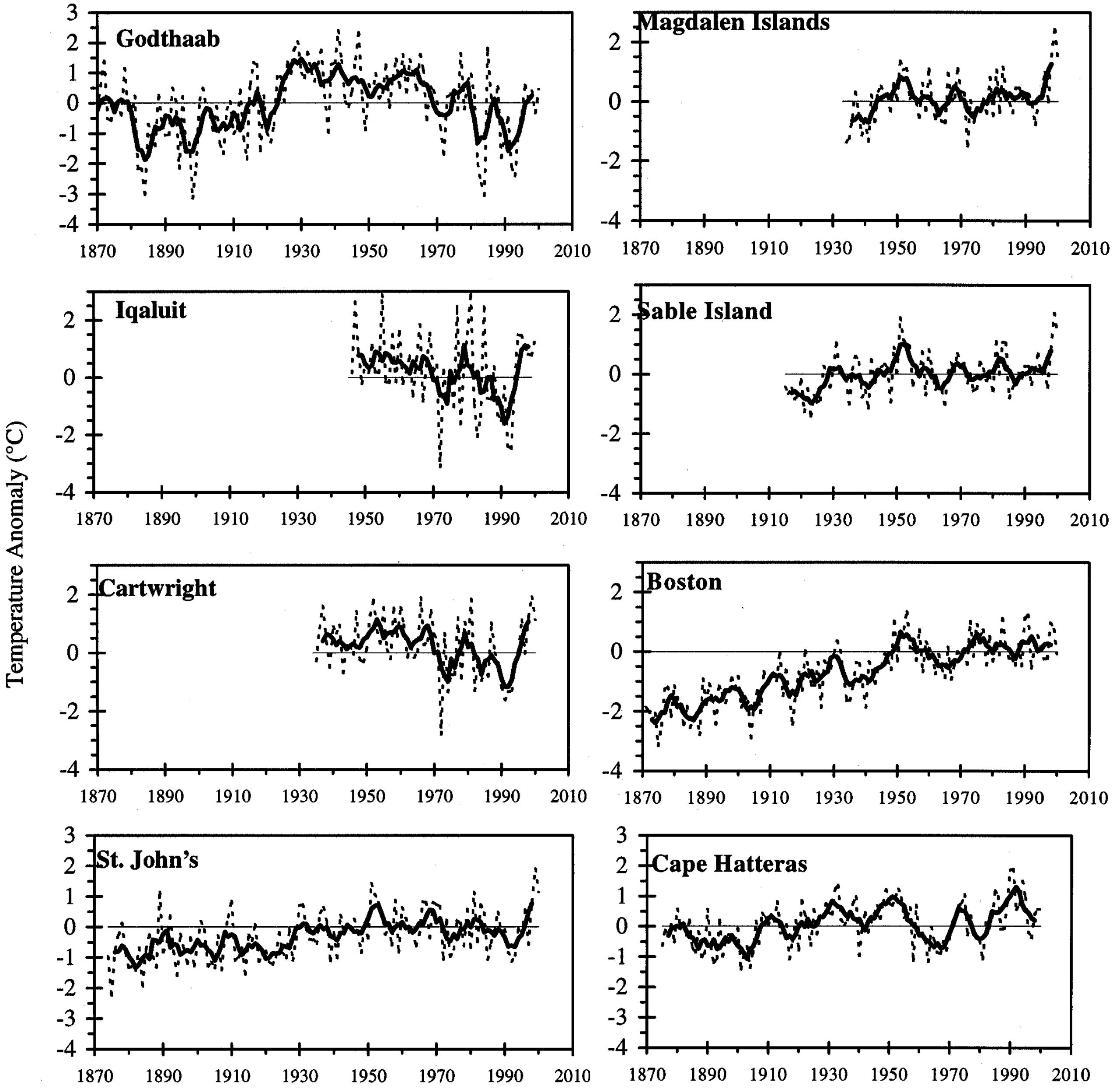


Fig. 4. Annual air temperature anomalies (dashed line) and 5-yr running means (solid line) at selected sites.

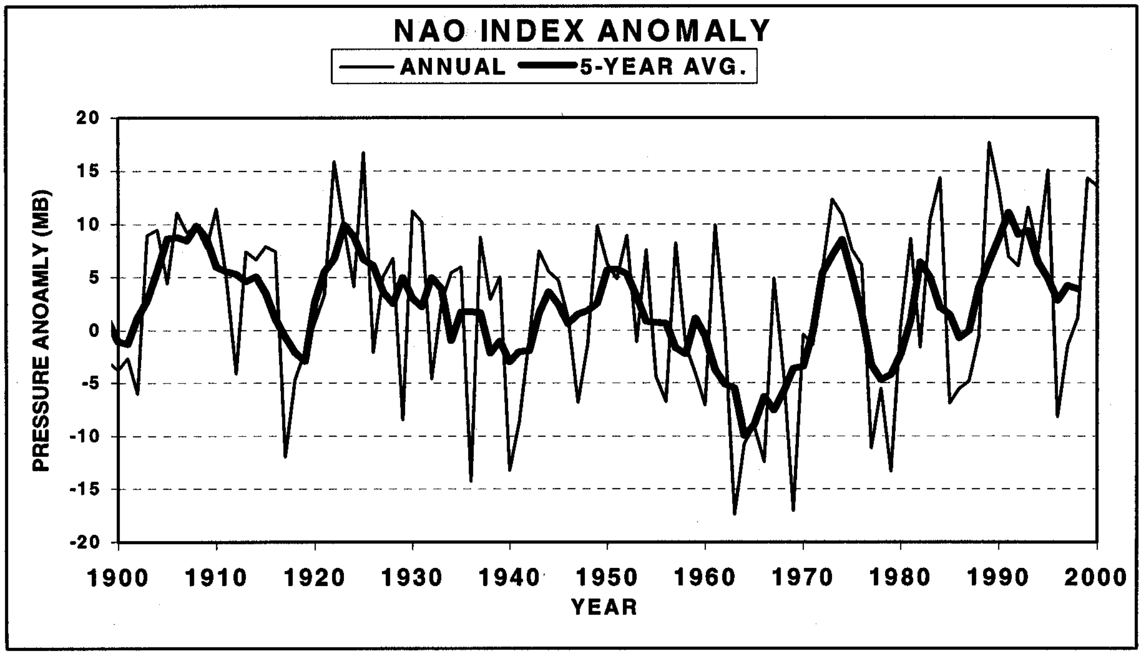


Fig. 5. Anomalies of the North Atlantic Oscillation Index, defined as the winter (December, January, February) sea level pressure at Ponta Delgada in the Azores minus Akureyri in Iceland, relative to the 1961-90 mean.

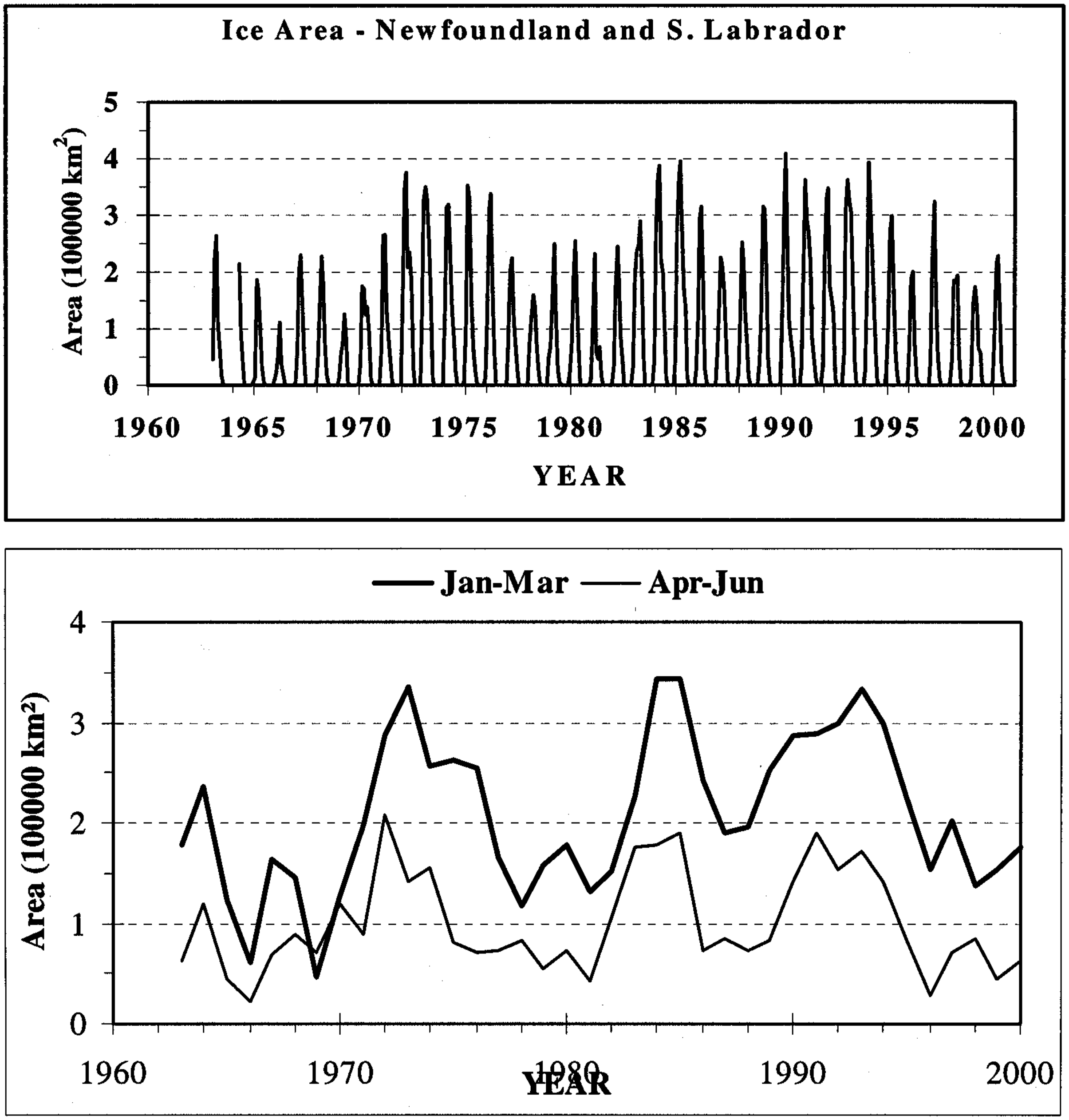


Fig. 6. Time series of the monthly mean ice area off Newfoundland and Labrador between 45°N- 55°N (top panel) and the average ice area during the normal periods of advancement (January-March) and retreat (April-June) (bottom panel).

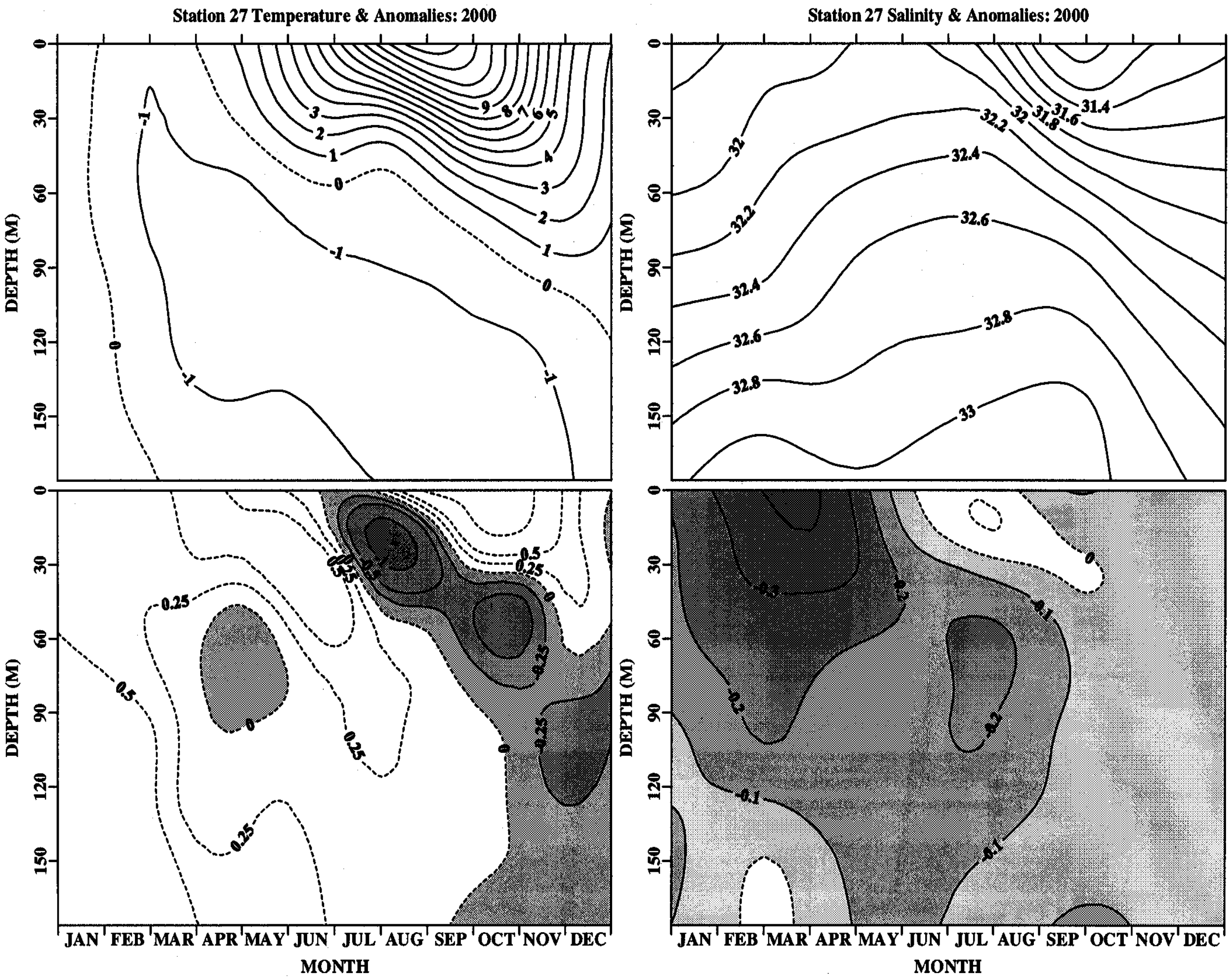


Fig. 7. Monthly temperatures (in °C) (left panels) and salinity (right panels) and their anomalies at Station 27 as a function of depth for 2000.

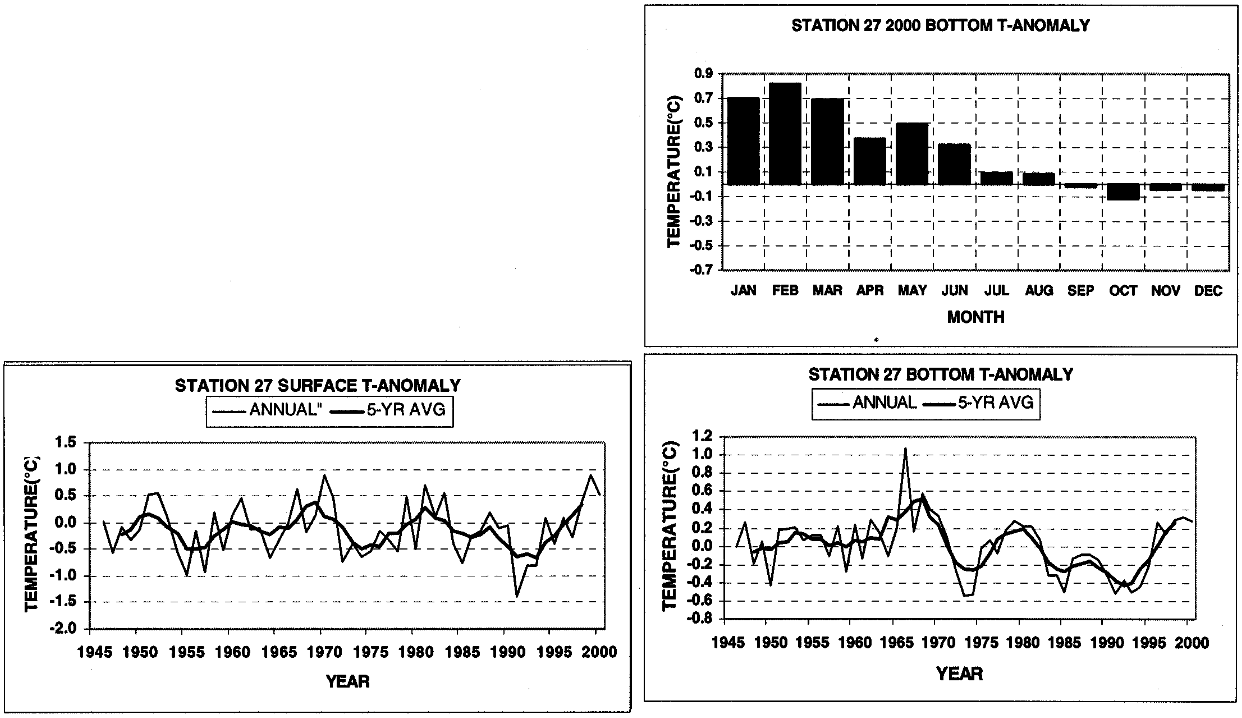


Fig. 8. Monthly surface and bottom temperature anomalies at Station 27 during 2000 (top) and their annual anomalies with 5-year running means (bottom).

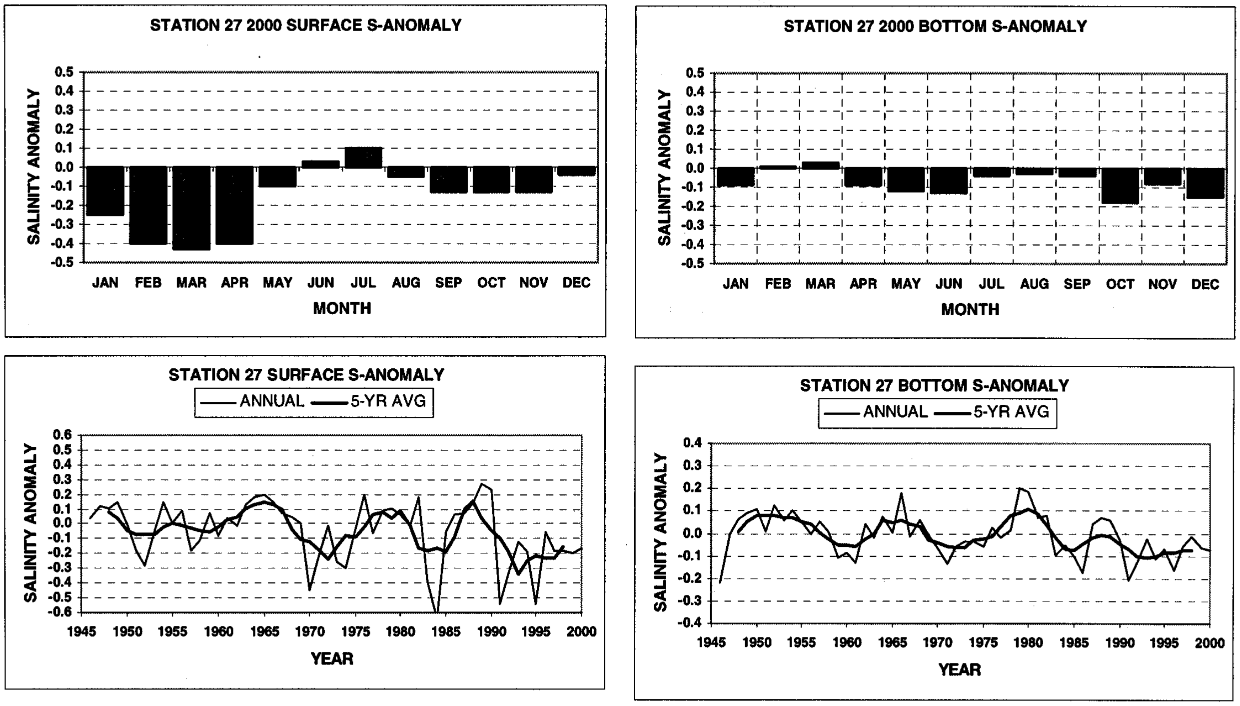
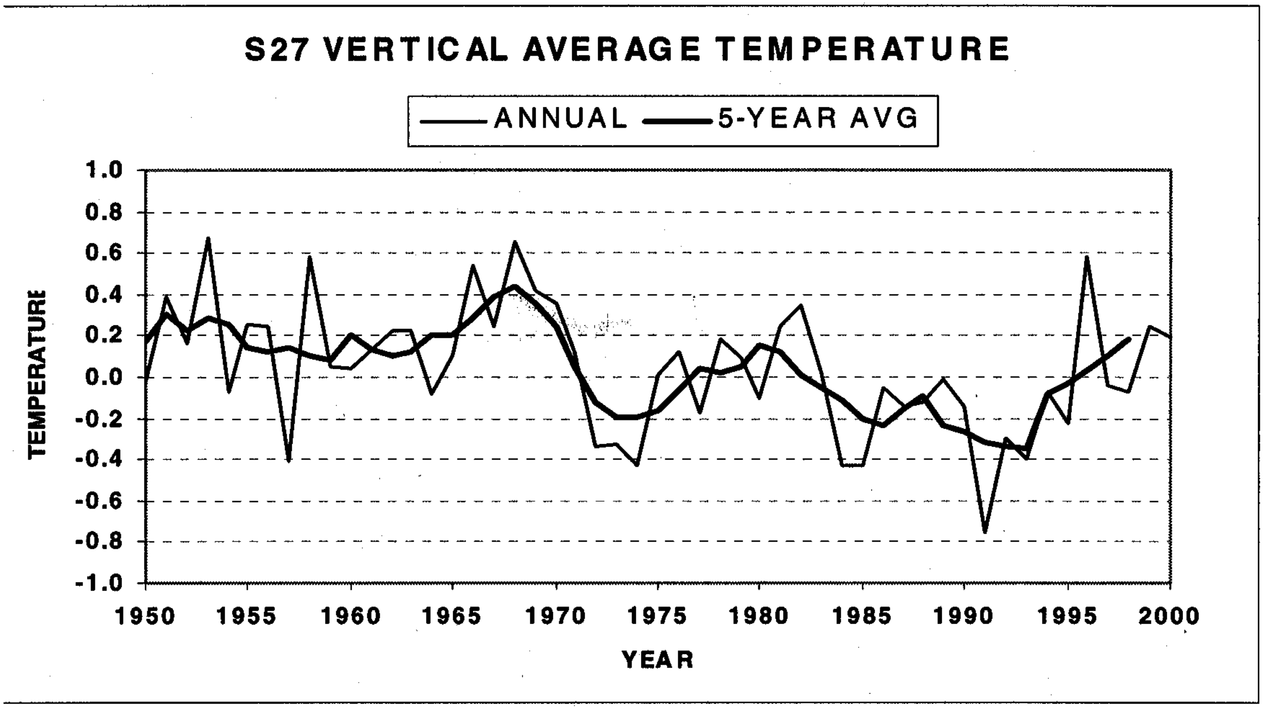


Fig. 9. Monthly surface and bottom salinity anomalies at Station 27 during 2000 (top) and their annual anomalies with 5-year running means (bottom).



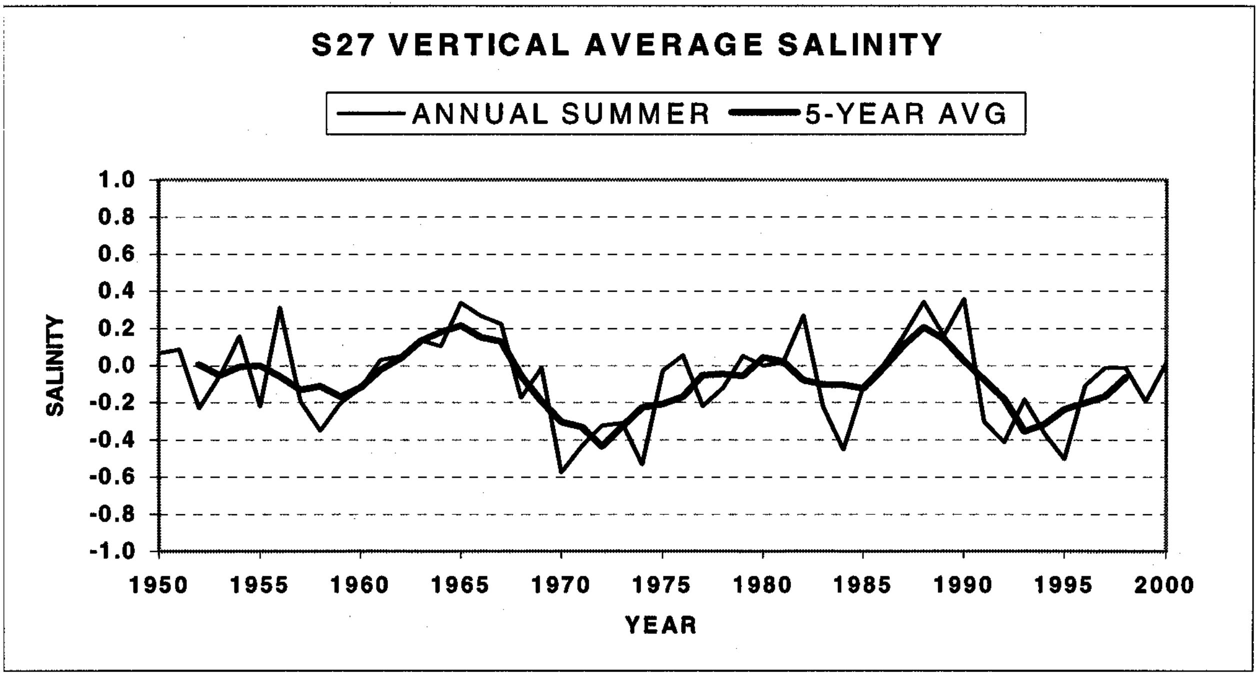


Fig. 10. The annual vertically averaged (0-176 m) Station 27 temperature anomalies and the vertically averaged (0-50 m) summer (July-Sept.) salinity anomalies. The heavy lines are the 5-year running means.

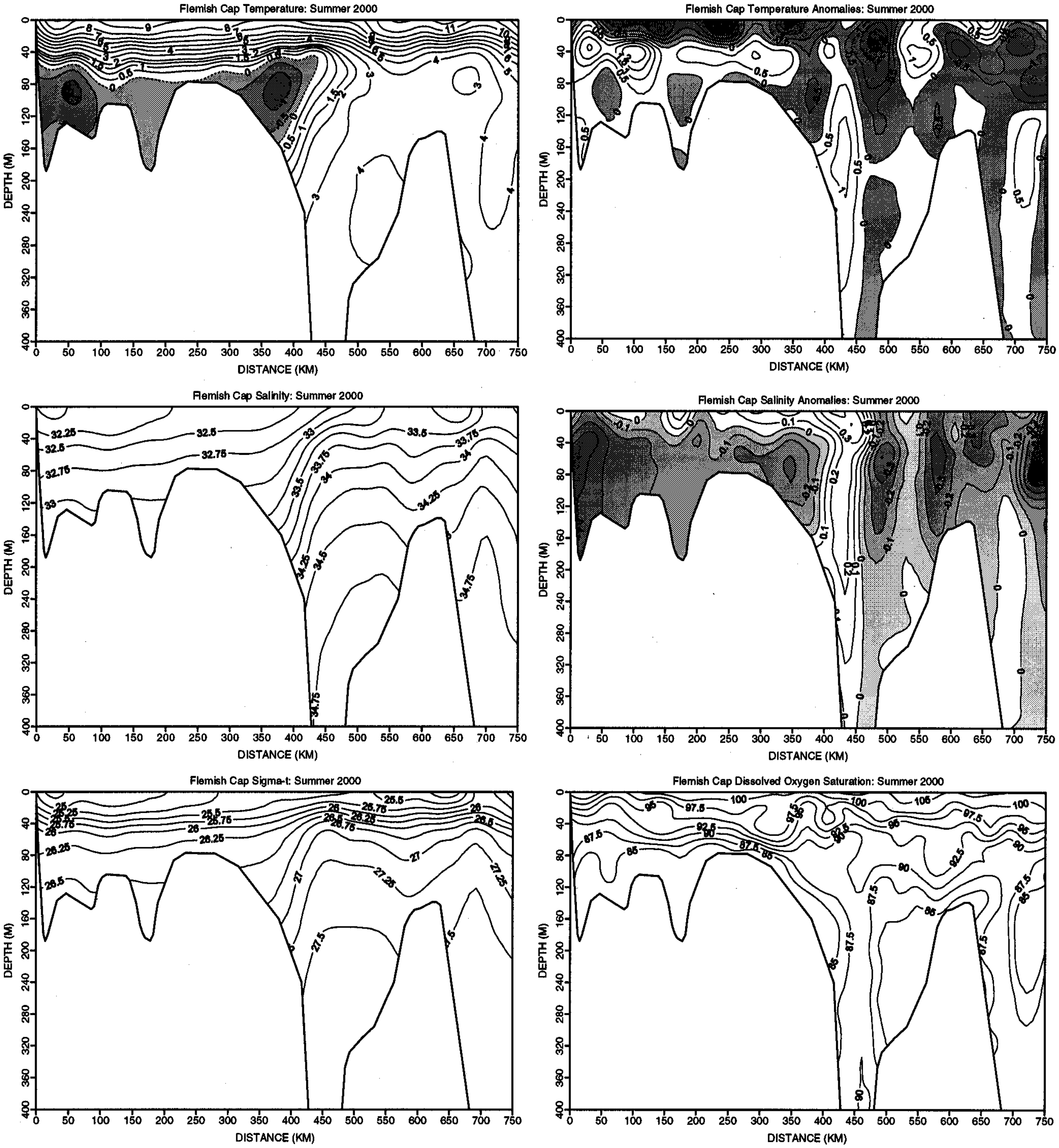


Fig. 11. Contours of temperature and salinity and their anomalies, sigma-t and dissolved oxygen saturation along the standard Flemish Cap transect during the summer of 2000.

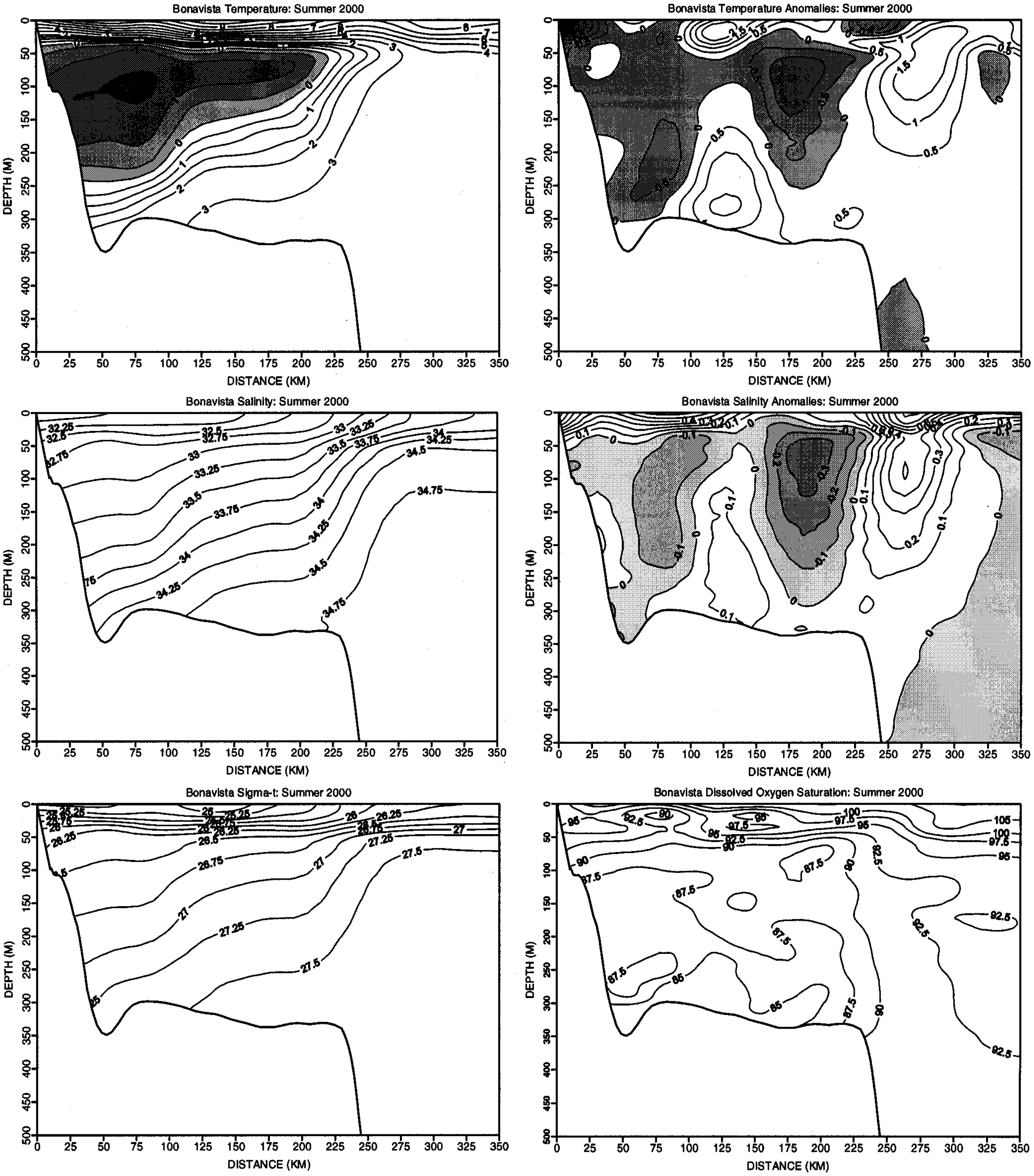


Fig. 12. Contours of temperature and salinity and their anomalies, sigma-t and dissolved oxygen saturation along the standard Bonavista transect during the summer of 2000.

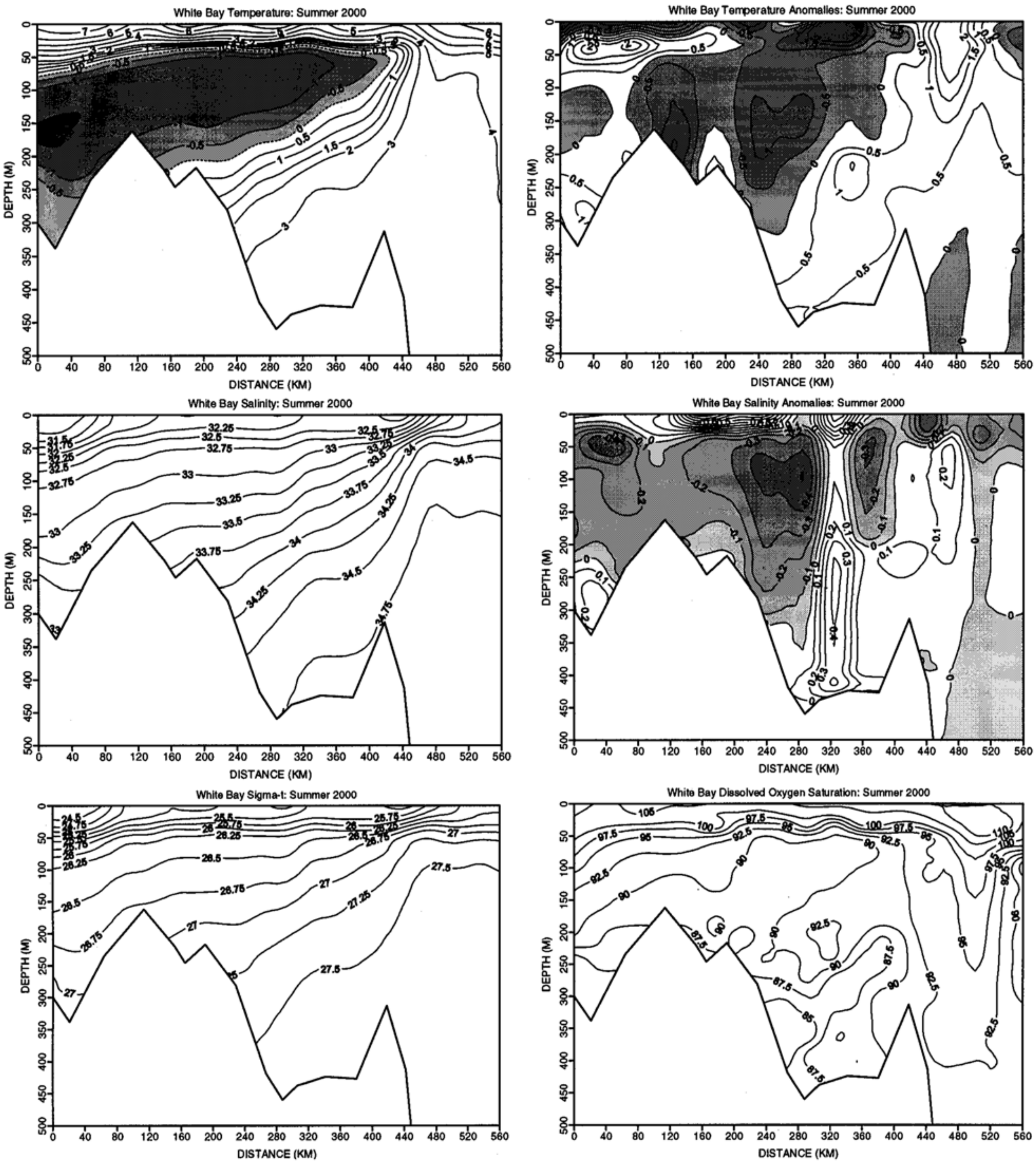


Fig. 13. Contours of temperature and salinity and their anomalies, sigma-t and dissolved oxygen saturation along the standard White Bay transect during the summer of 2000.

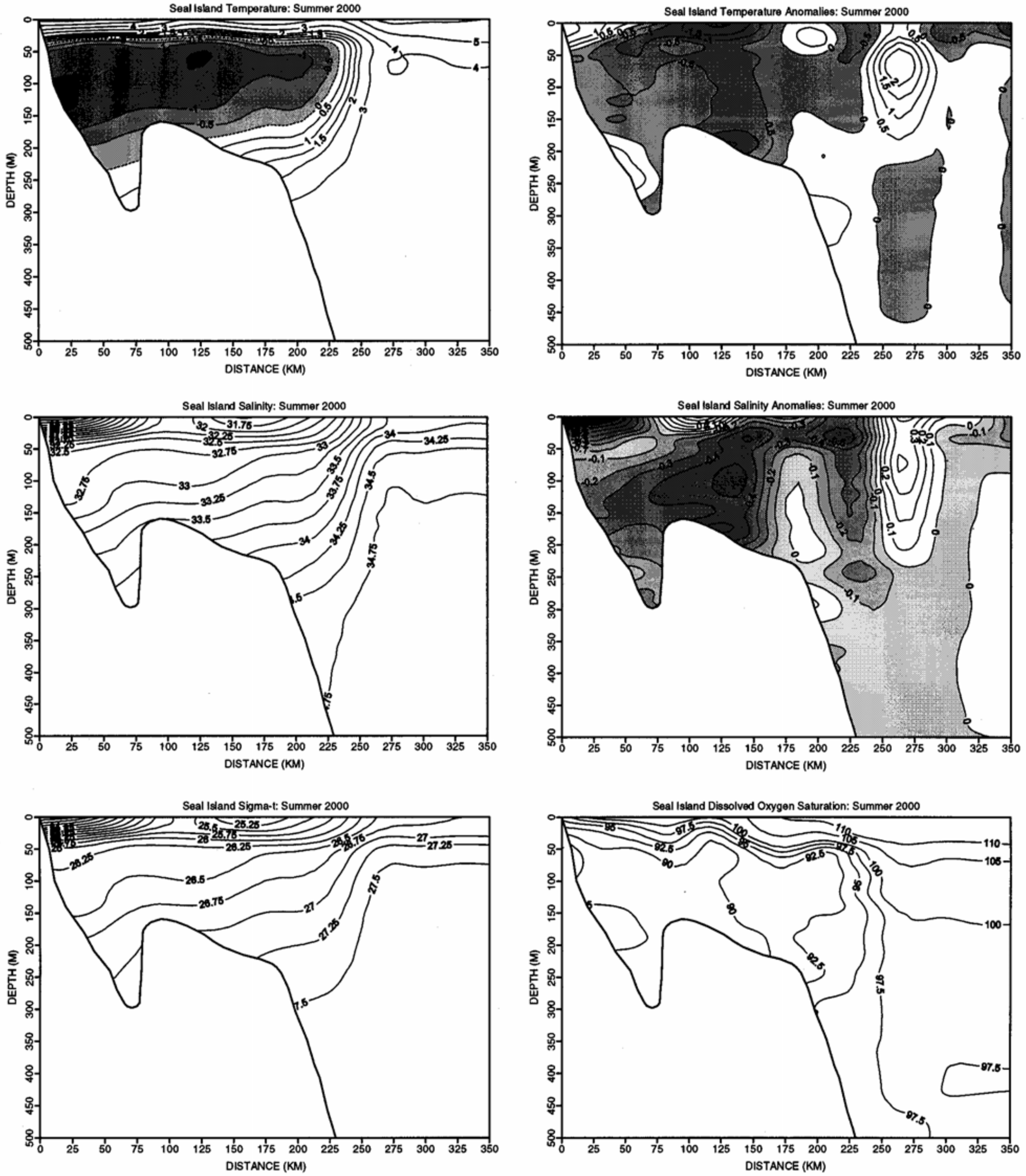
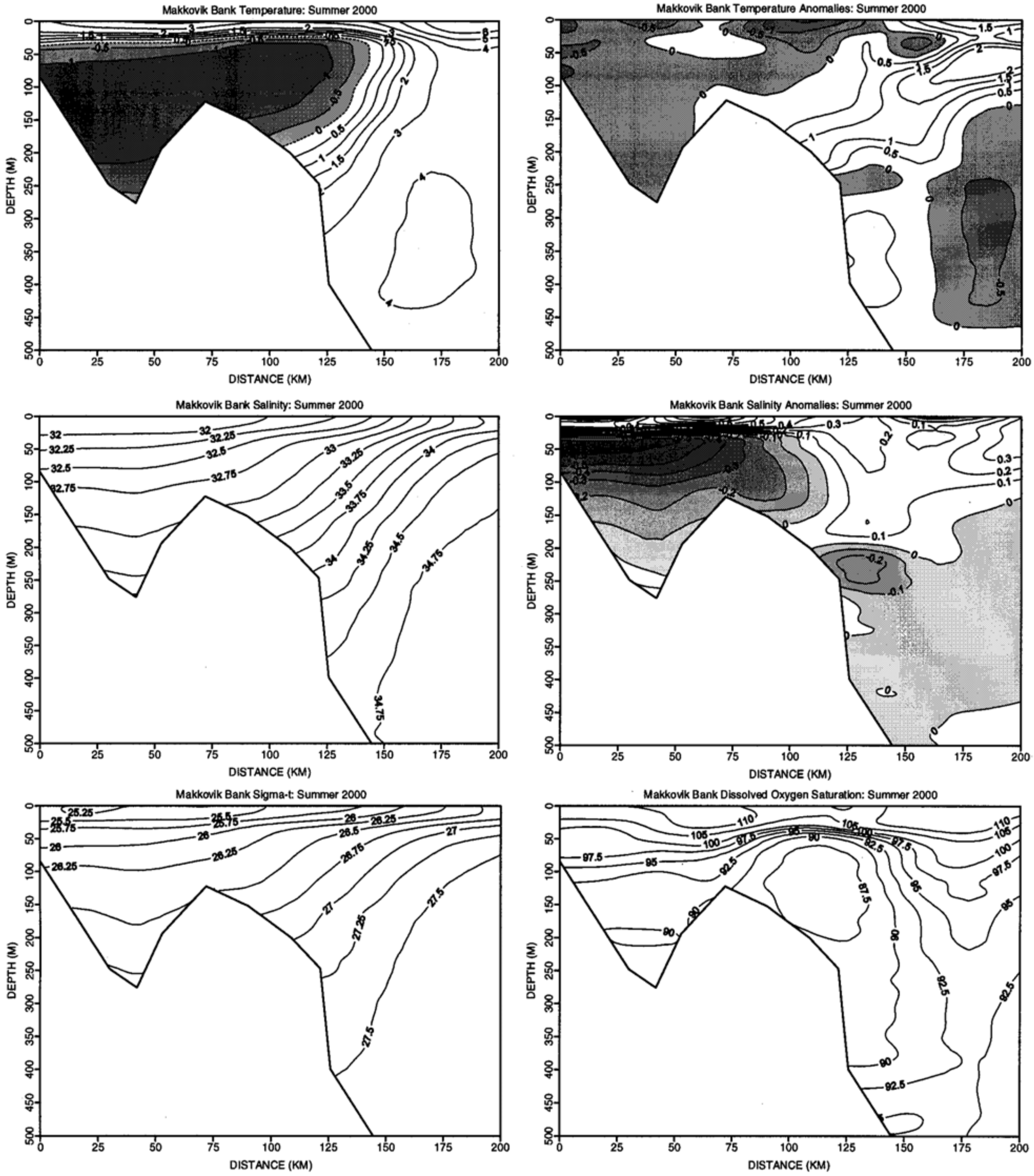


Fig. 14. Contours of temperature and salinity and their anomalies, sigma-t and dissolved oxygen saturation along the standard Seal Island transect during the summer of 2000.


Makkovik Bank Temperature: Summer 2000

Makkovik Bank Temperature Anomalies: Summer 2000

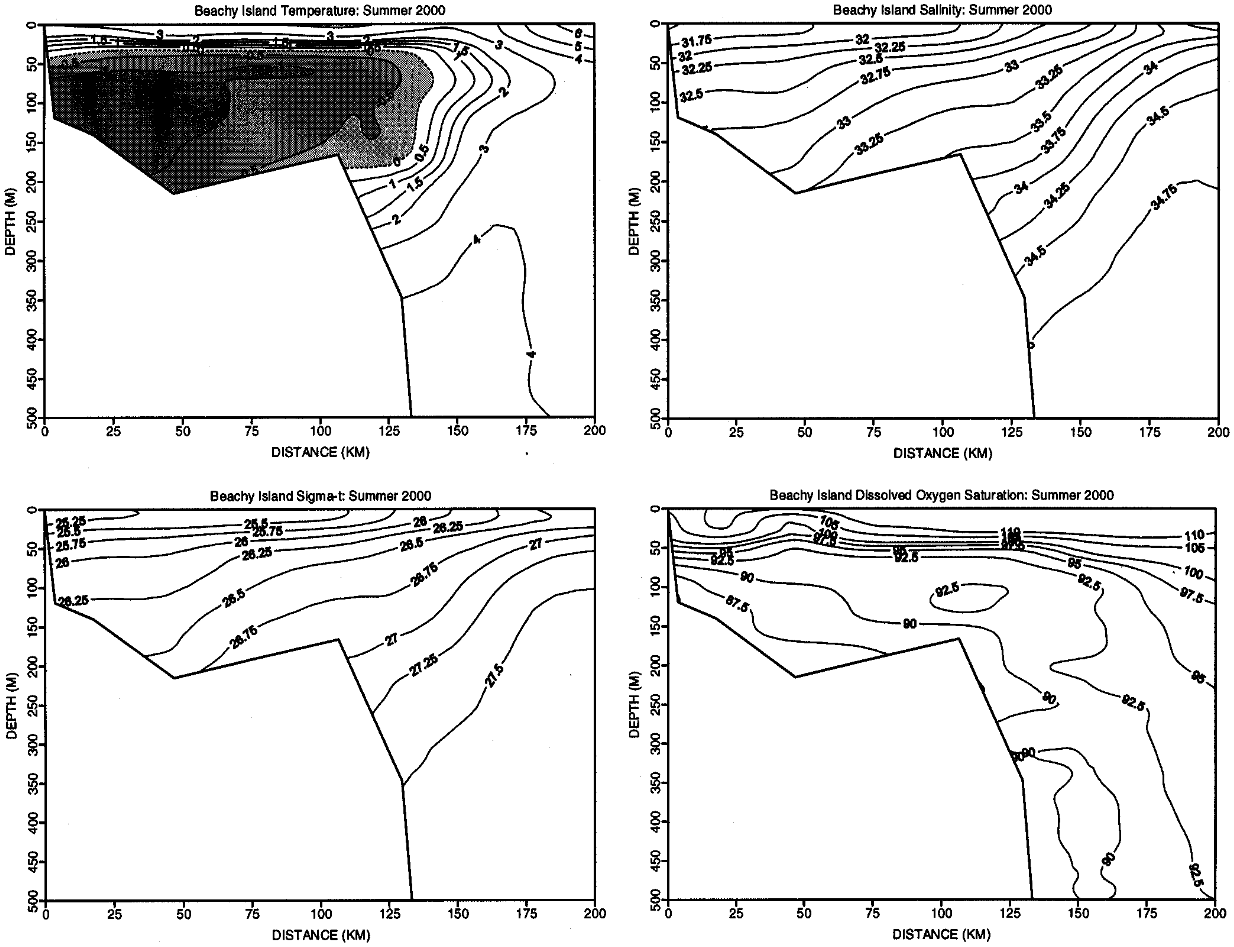
Makkovik Bank Salinity: Summer 2000

Makkovik Bank Salinity Anomalies: Summer 2000

Makkovik Bank Sigma-t: Summer 2000

Makkovik Bank Dissolved Oxygen Saturation: Summer 2000

Fig. 15. Contours of temperature and salinity and their anomalies, sigma-t and dissolved oxygen saturation along the Makkovik Bank transect during the summer of 2000.



Beachy Island Temperature: Summer 2000

Beachy Island Salinity: Summer 2000

Beachy Island Sigma-t: Summer 2000

Beachy Island Dissolved Oxygen Saturation: Summer 2000

Fig. 16. Contours of temperature, salinity, sigma-t and dissolved oxygen saturation along the Standard Beachy Island transect during the summer of 2000.

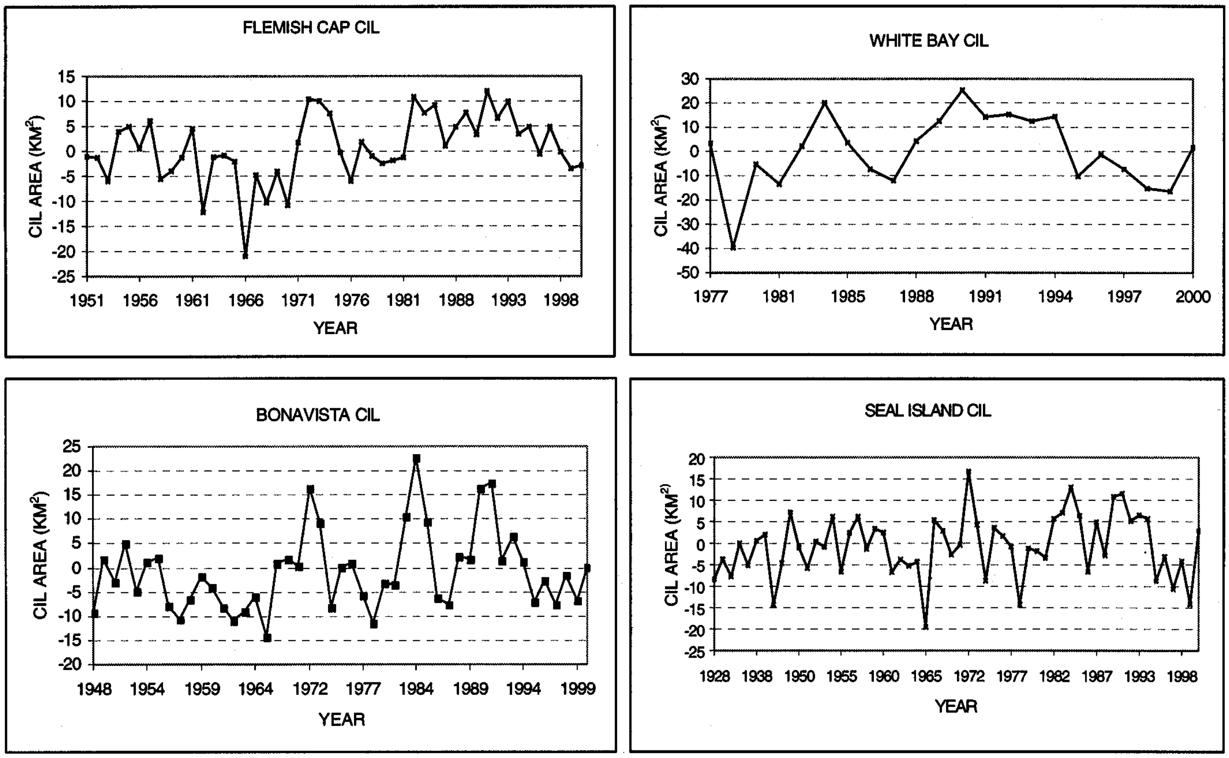


Fig. 17. Time series of CIL cross-sectional area anomalies along the Flemish Cap, Bonavista, White Bay and Seal Island transects during the summer of 2000. The anomalies are references to the 1961-1990 mean.

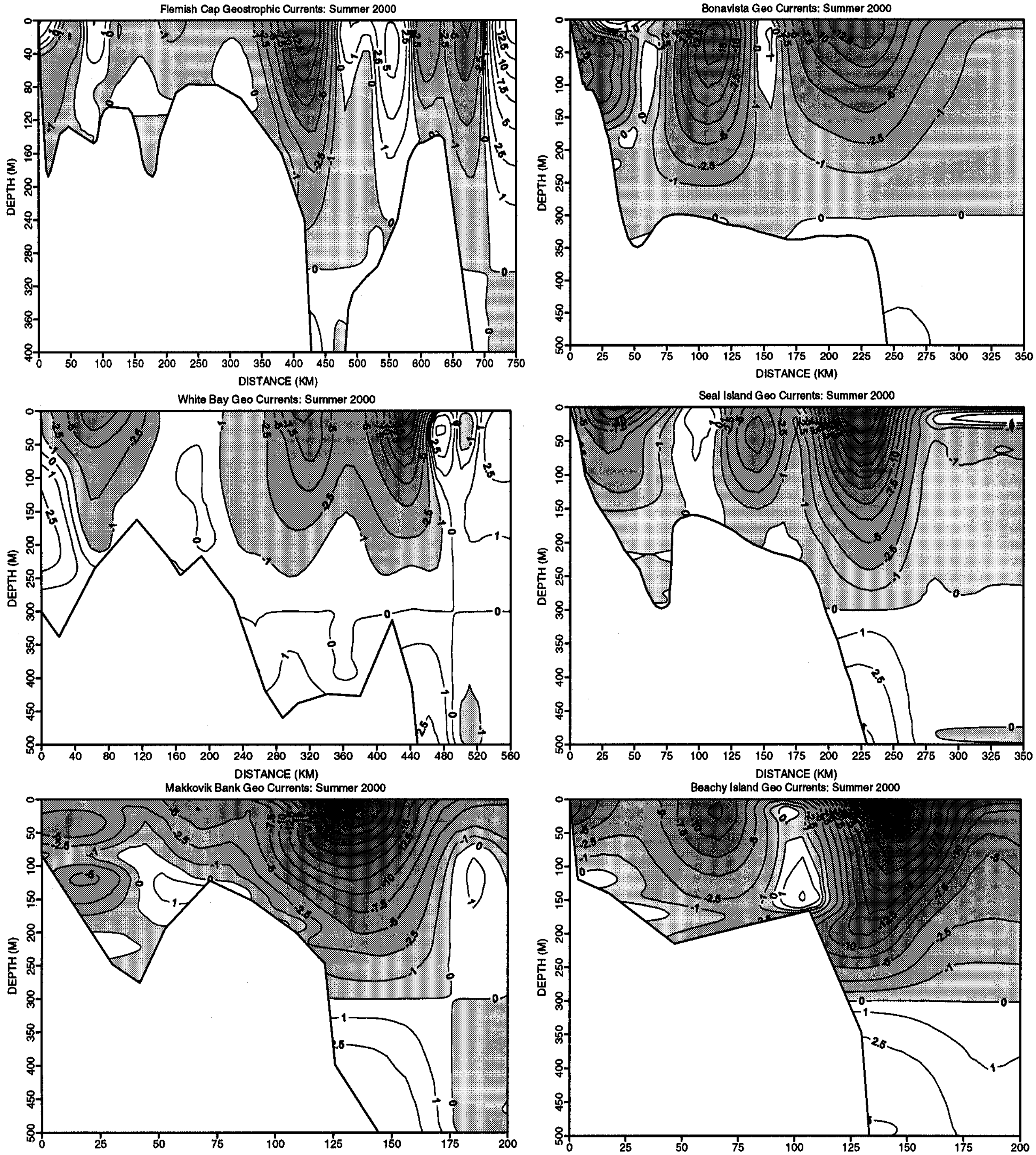


Fig. 18. Contours of geostrophic currents (in cm/s) along the Flemish Cap, Bonavista, White Bay, Seal Island, Makkovik Bank and Beachy Island transects during the summer of 2000. Negative shaded values are southward.

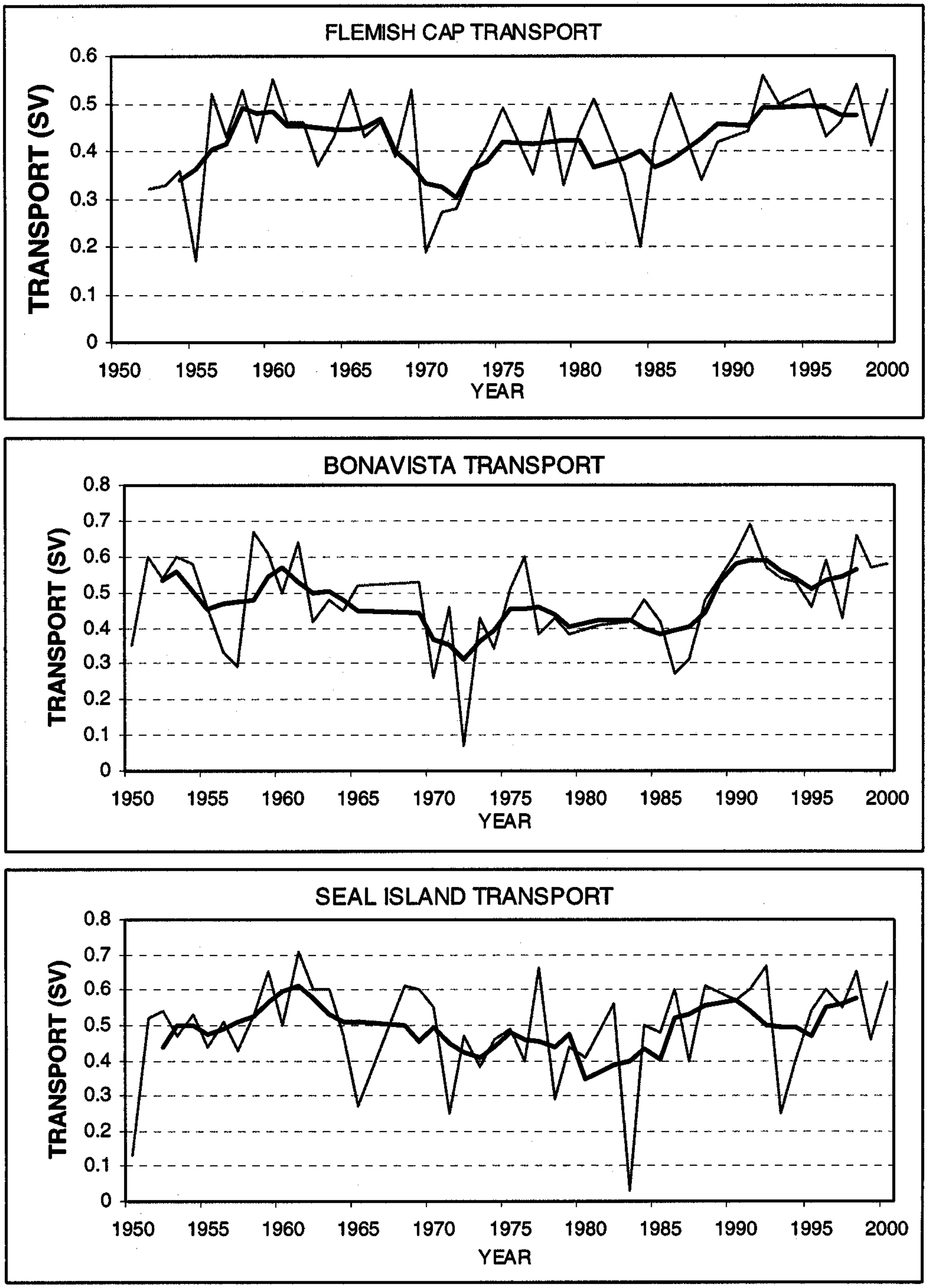


Fig. 19. Time series of geostrophic transport (10^6 m^3/s) relative to 130-m depth of the offshore branch of the Labrador Current through the Seal Island, Bonavista and Flemish Cap transects.

ANNEX L: AREA 2B (LABRADOR SEA) CANADIAN REPORT

Labrador Sea properties in early Summer 2000

R.A. Clarke[1], R.M. Hendry[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 20 May - 8 June, 2000 on Expedition HUD 2000009 on board CCGS Hudson. Chief scientist was Glen Harrison of Ocean Sciences Division. Due to a delay in sailing and to ice conditions, 10 of the 28 standard hydrographic stations on the Labrador Sea Section were not sampled. Four additional stations were added south of the ice on the Labrador shelf side.

Figure 1 shows a map of the Labrador Sea with station positions for the 2000 AR7W occupation (solid circles). The position of a current meter mooring maintained over the past few years in the central Labrador Sea near the OWS Bravo site in is marked with an open star. Selected TOPEX/POSEIDON ground tracks are also shown.

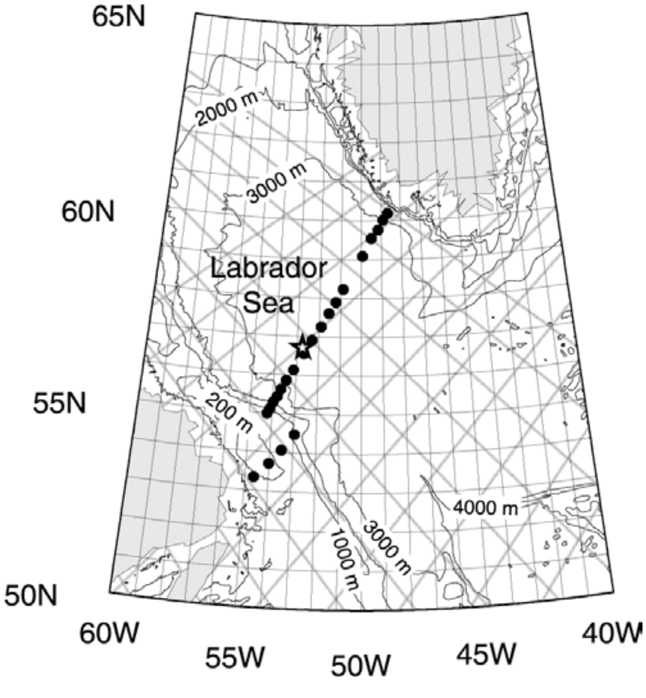


Figure 1 : Map of the Labrador Sea showing CTD station positions for the 2000 AR7W occupation (solid circles), central current meter mooring position (open star), and selected TOPEX/POSEIDON ground tracks.

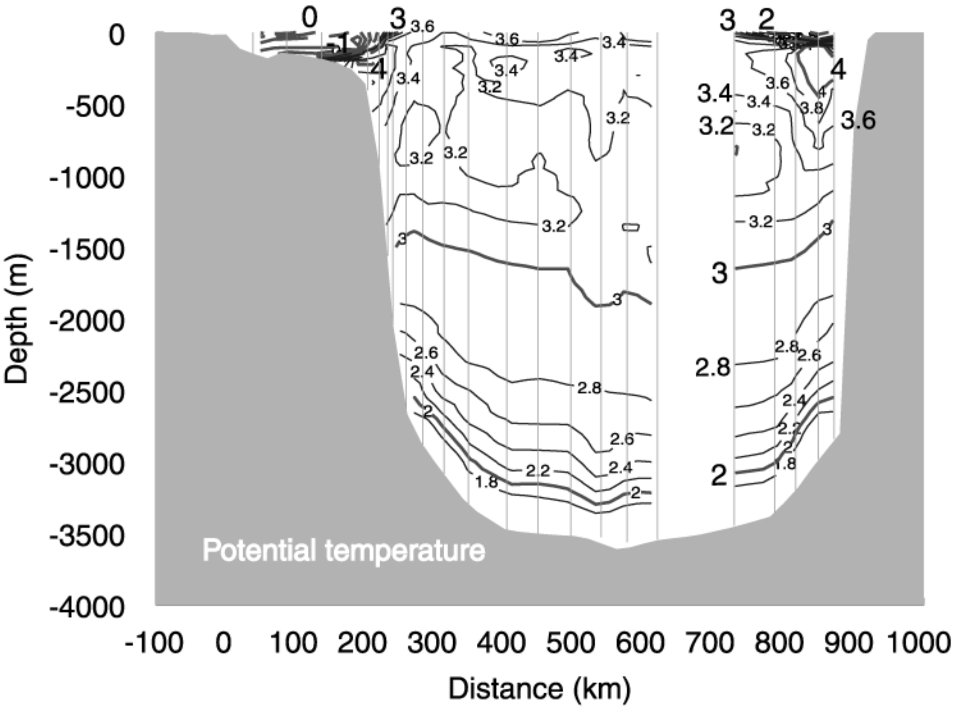
The oceanographic data collected in the cruise reveal significant changes in the water mass structure and properties since the last occupation of the Labrador Sea line in 1999. Contoured sections of potential temperature and salinity for the Year 2000 section are shown in Figures 2a and 2b. The following is a summary of the unique features of the sea water properties of the Labrador Sea as it was seen in the first cruise of the XXI century:

Labrador Sea Water (LSW) in the upper 1000 m showed a cooling trend, with temperatures up to 0.3 C cooler than observed in 1999. The convection that took place in the winter (Feb-Mar) of 2000 was not as intense as that in the early 1990's. Nevertheless, the water originating as the result of the 2000 convection dominates the layer between 200 m and 1000 m, indicating that the convection of the last winter penetrated on average 300 m deeper than that of the winter before. This resulted in the further reduction of the volume of the deep LSW. The recent formation of the LSW is 0.02 fresher than its analogue found the previous year (1999). The net result was a somewhat denser upper-layer LSW mass. Associated changes in steric sea level are discussed below.

Deeper LSW formed as the result of deep convection due to a series of severe winters between 1988 and 1993 is still present in 2000. However, since 1994 the core of this water is steadily getting warmer and saltier with a rate about 0.07 C/year and 0.008, respectfully. In 2000 it was warmer and saltier than in the previous years (2.9 C and 34.86).

The Northeast Atlantic Deep Water (NEADW, underlying the deep LSW) and Denmark Straight Overflow (DSOW, bottom water) substantially freshened and became colder over the last four years. It is noteworthy that this tendency was steady through the years. DSOW is the freshest (34.86) and coldest (at places below 1.1 C) in the history of deep observations in the Labrador Sea. Due to the opposite tendencies in the deep LSW and NEADW the difference between properties of these waters is the smallest since the late 1980's.

On site 16 (the central Labrador Sea) we found the most recent formation of the LSW about 600 m deeper than the neighbouring stations, spanning between 1000 m to 1600 m. High horizontal density gradient around the station suggests that this structure is associated with an intense anticyclonic eddy. There was another relatively homogeneous mixed layer between 100 m and 900 m with temperature and salinity 3.3 C and 34.83, respectfully. This layer was not typical for the other stations. It could be produced at the time when the eddy was formed as the result of convergence and mixing of relatively warm and salty water (presumable from the eastern part of the region) with the fresher surface water. This extends to the bottom, causing temperature near the bottom to increase. However, the eddy did not have a significant affect on the deep LSW.



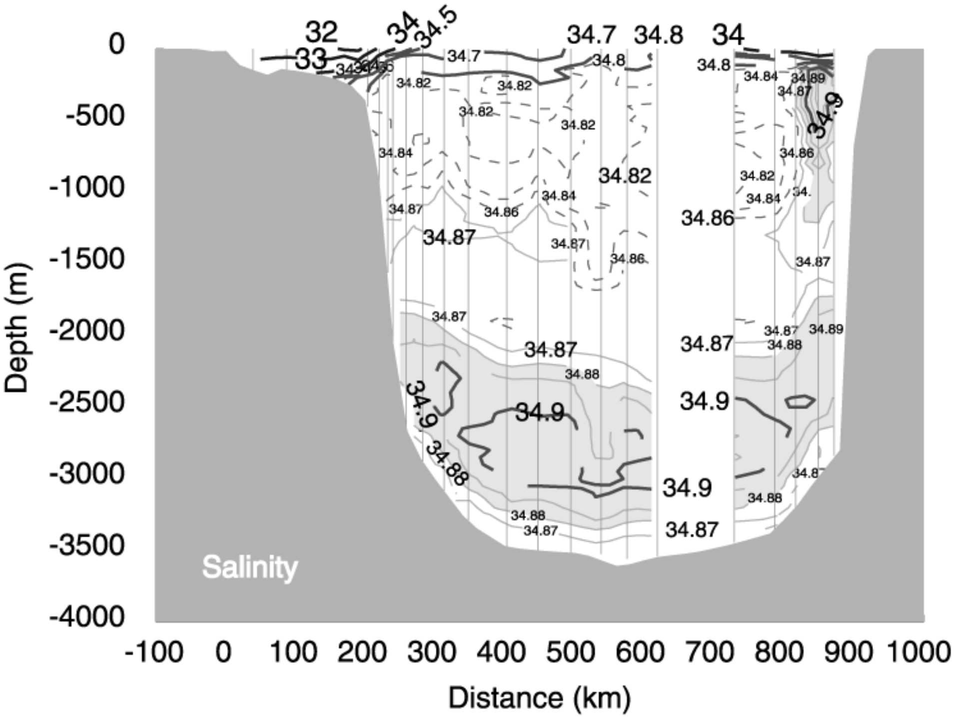
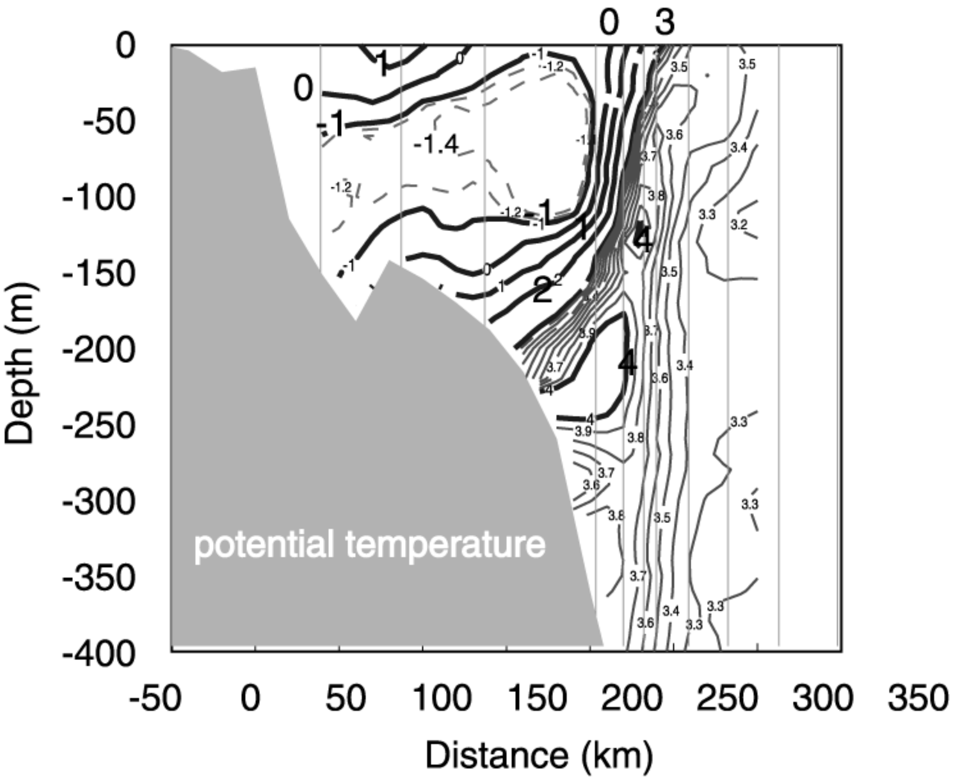


Figure 2a (upper) Potential temperature section from HUD2000009, 24 May - 5 June 2000.

Figure 2b (lower) Salinity section for HUD2000009. Shaded areas mark salinity greater than 34.88.



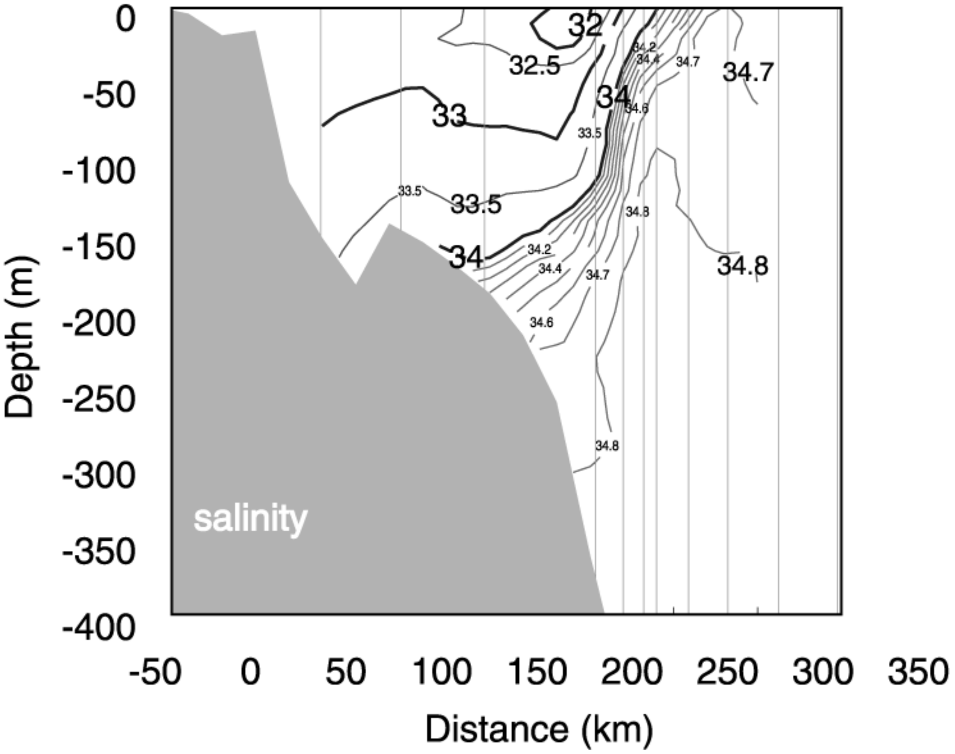


Figure 3a (upper) HUD2000009 Labrador Current potential temperature section.

Figure 3b (lower) HUD2000009 Labrador Current salinity section.

Sea level changes in the central Labrador Sea from TOPEX/POSEIDON altimetry

Time series of sea level at the site of the central mooring were extracted from the Maps of Sea Level Anomaly altimeter data products (MSLA) produced by the French Archivage, Validation et Interprétation des données des Satellites Océanographiques (AVISO) (http://www-aviso.cls.fr/). Data were available for the period October 22, 1992 through August 11, 2000. The seasonal signal was removed by fitting annual and semiannual harmonics. A low-pass filtered times series was produced using a squared second-order Butterworth filter with a 1-year cut off period.

Figure 4 show time series of the original 10-day samples from the MSLA product and the low-pass filtered series. The low frequency sea level time series shows a decrease by nearly 0.06 m during the approximately year-long interval between the 1999 and 2000 AR7W occupations [Hudson 99022: July 1-11, 1999; HUD2000009: May 24 - June 6, 2000].

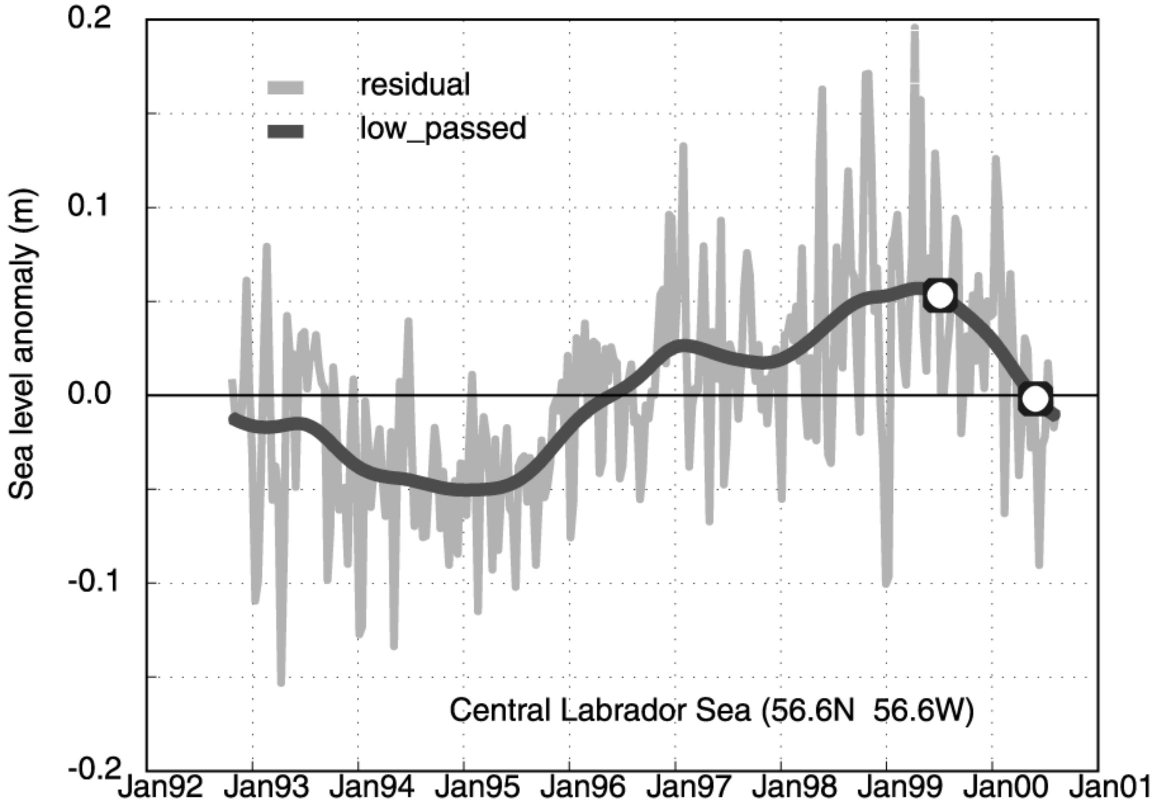


Figure 4: TOPEX/POSEIDON sea level anomaly at the central Labrador Sea mooring site. A fitted seasonal cycle has been removed to create a residual time series (grey line). The black curve is the low-pass filtered signal. The open circles correspond to the dates of the 1999 and 2000 AR7W occupations.

Figure 5 shows a gridded representation of the changes in potential density on the AR7W section between the 2000 and 1999 occupations. The unshaded areas indicating positive changes (2000 denser than 1999) dominate. The largest changes (excluding the seasonal layer) are noted in the upper 500 m. The associated decrease in steric height is in qualitative agreement with the noted decrease in sea level between the two occupations.

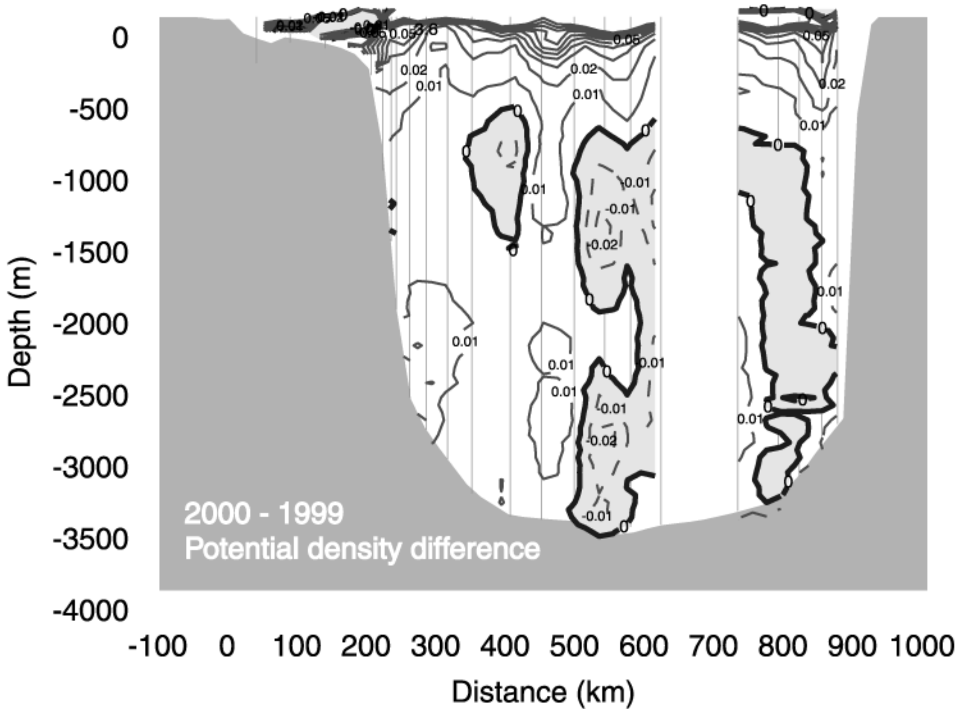


Figure 5: Changes in potential density on AR7W between July 1999 and May-June 2000.

Acknowledgment

The altimeter products used were produced by the CLS Space Oceanography Division as part of the European Union' Environment and Climate project AGORA (ENV4-CT9560113) and DUACS (ENV4-CT96-0357) with financial support from the CEO programme (Centre for Earth Observation) and Midi-Pyrenees regional council. The associated CD ROMs are produced by the AVISO/Altimetry operations center.

Cruise reports for previous AR7W transect cruises can be found at http://dfomr.dfo.ca/science/ocean/woce/DOGrep.html.

[1] Fisheries and Oceans Canada, Bedford Institute of Oceanography, P.O. Box 1006, Dartmouth, NS, Canada B2Y 4A2

clarkea@mar.dfo_mpo.gc.ca
lazierj@mar.dfo-mpo.gc.ca
hendryr@mar.dfo-mpo.gc.ca
[2] BDR Research Ltd., P.O. Box 652, Station M, Halifax, NS, Canada B3J 2T3
yashayaevi@mar.dfo-mpo.gc.ca

ANNEX M: AREA 3 (ICELANDIC WATERS) ICELANDIC REPORT

Hydrographic Status Report 2000

Svend-Aage Malmberg and Héðinn Valdimarsson
Marine Research Institute, Reykjavík

Iceland is situated at the meeting place of warm and cold currents (Fig. 1), 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 Atlantic.

The different hydrographic conditions in Icelandic waters are also reflected in the atmospheric or climatic conditions in and over the country and the surrounding seas, mainly through the Icelandic Low and the Greenland High (Fig.4). 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 2000 revealed in general favourable temperatures and salinities as in the 2-3 previous years. The salinity in the warm water from the south was as since November 1997 higher than was observed over the last decades (Figs. 2 and 3) but though slightly lover than in 1998-1999. These conditions were evident in a moderate inflow of Atlantic water into North Icelandic waters in 1998, when there was a low saline surface layer in the upper 50-150 m above the warm inflow beneath as since 1996 (Figs. 4 and 5).

In 1999 and 2000 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 (Figs. 4 and 6). High temperatures in North Icelandic waters along with a relatively strong impact of high saline Atlantic water are further demonstrated in continuos recordings of sea-surface temperature at the island Grímsey 1987-2000 (Fig. 7) revealing relatively high temperatures during winter 1998, 1999 and 2000 as well as summer 2000.

The cold water north, north-east and east of Iceland in the East Icelandic Current was in 2000 as in 1999 relatively far offshore. In general even higher temperature and salinity values were found than 1999 with salinities around 34.8 which is well above the critical value which prevents convection (Figs. 2 and 8).

These mild conditions in Icelandic waters in 2000 (Fig. 9) follow extremely cold conditions in 1995, improving in 1996 and 1997, and continuing to do so in 1998 and 1999, but showing a slight decrease in 2000. Observations in February 2001 revealed continuing favourable hydro-biological conditions in Icelandic waters.

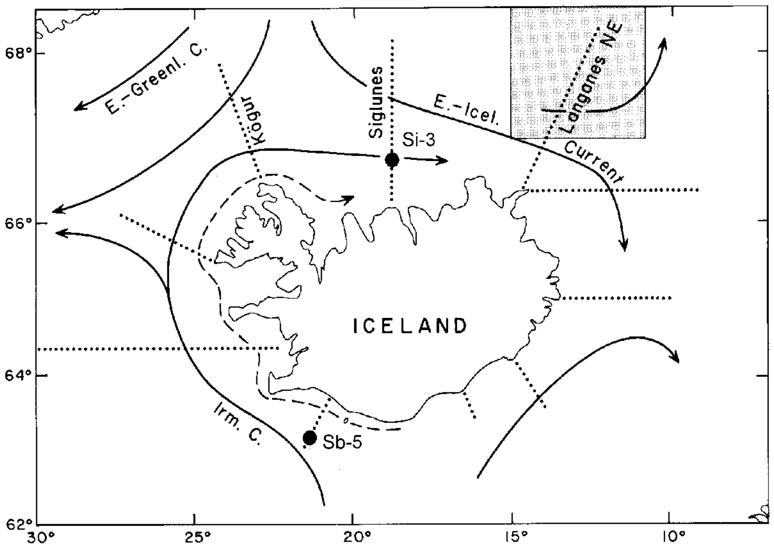
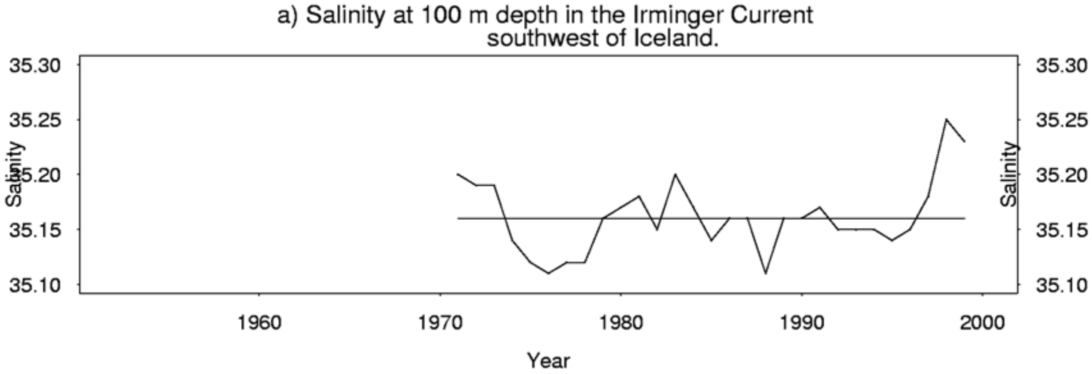


Figure 1. Main currents and location of standard hydro-biological sections in Icelandic waters. Selected areas and stations dealt with in this report are indicated.



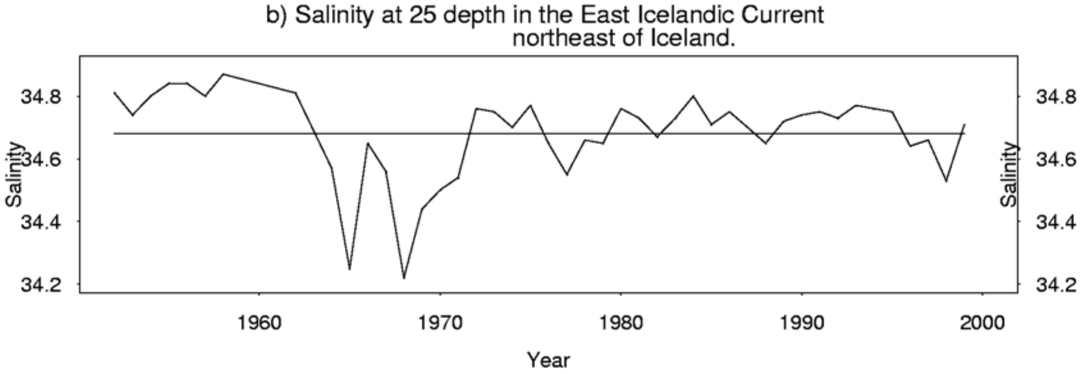


Figure 2. Salinity deviations in spring at

a. 100 m depth in the Irminger Current south of Iceland (Sb-5) 1971-2000.

b. 25 m depth in the East Icelandic Current north-east of Iceland 1952-2000.

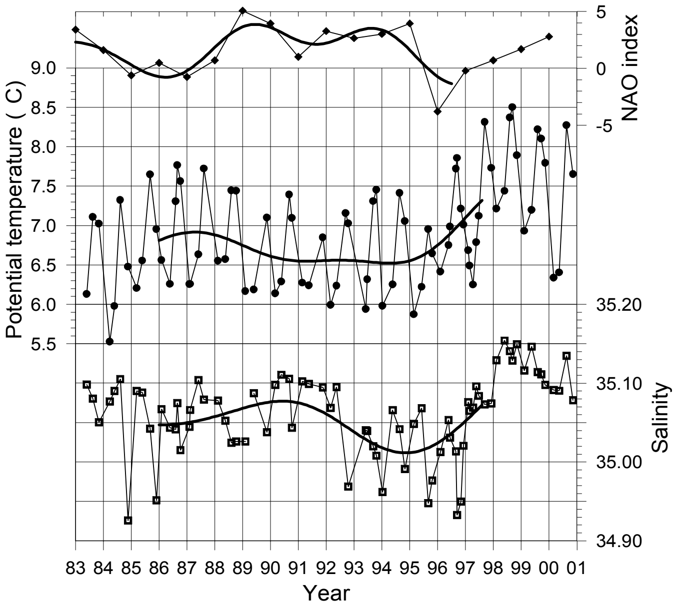
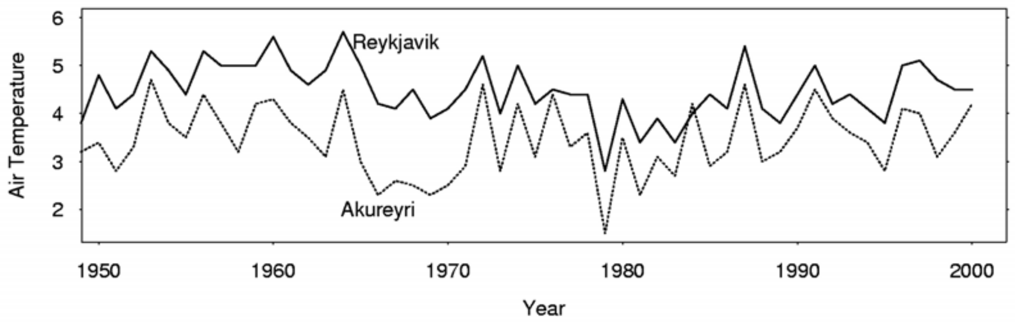


Figure 3. Time series of the NAO index, mean temperature and salinity of the upper 200 m for station 9 of Faxaflói section 1983-2000 - annual and 5-year Gaussian filtered values. (Mortensen and Valdimarsson 2000).

a) Air temperature in Akureyri and Reykjavik.



b) Station Si 3, Temperature and Salinity at 50 m depth.

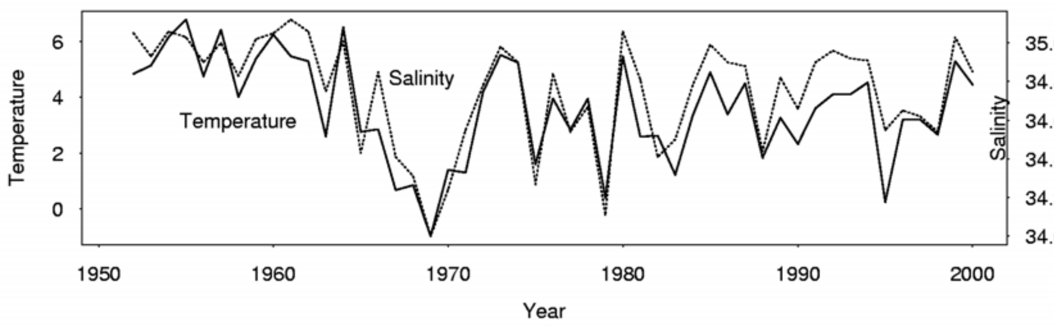


Figure 4.
a. Mean annual air-temperatures in Reykjavík and Akureyri 1950-2000.
b. Temperature and salinity at 50 m depth in spring at Station Si-3 in North Icelandic waters 1952-2000.

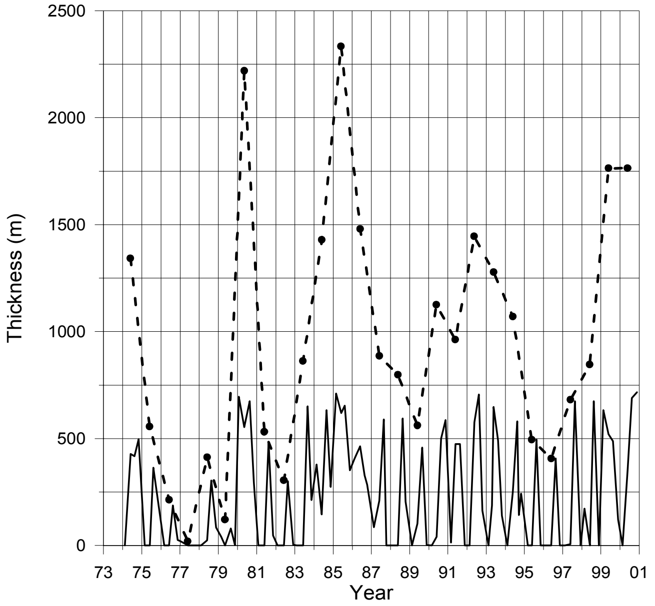


Figure 5. Atlantic layer thickness (t>3°C, s>34.9) in North Icelandic waters (Siglunes section, Si-2,3 and 4), seasonally and accumulated annually 1974 - 2000. (Mortensen 1999).

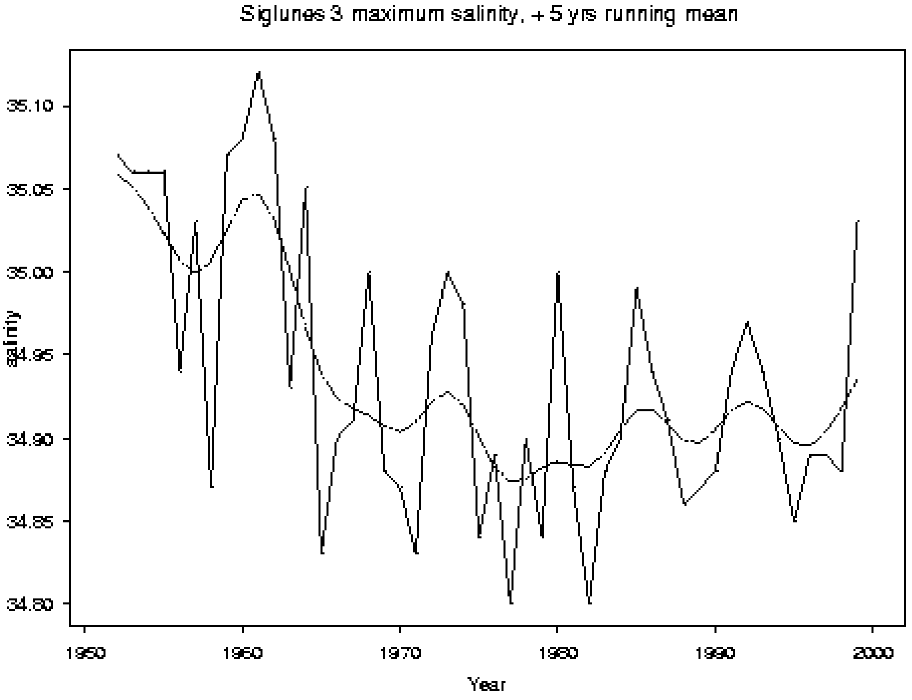


Figure 6. Maximum salinity in the upper 300 m in spring at station Si-3 in North Icelandic waters 1952-2000 and 5 years running mean.

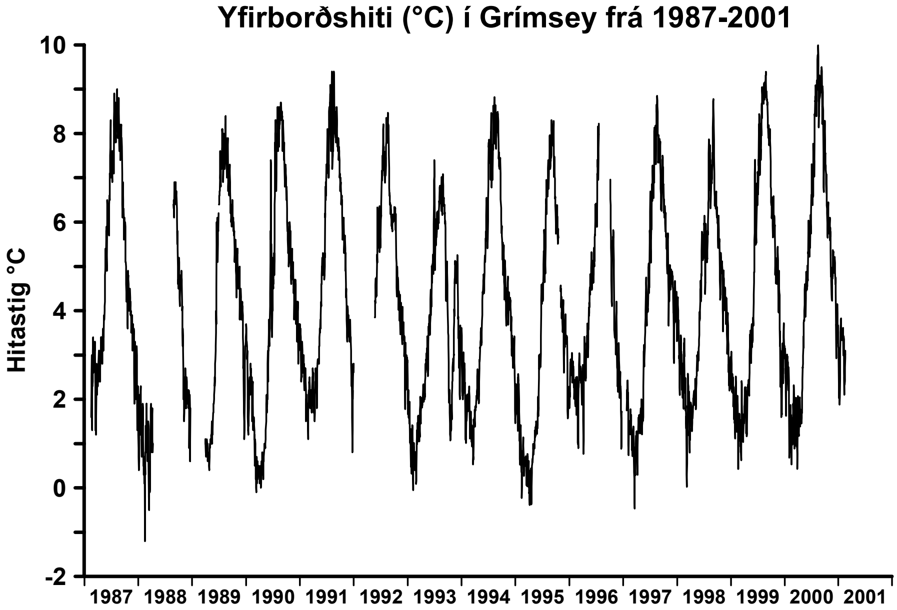


Figure 7. Annual and seasonal variations in the sea-surface temperatures at Grímsey, North Icelandic waters 1987-2001.

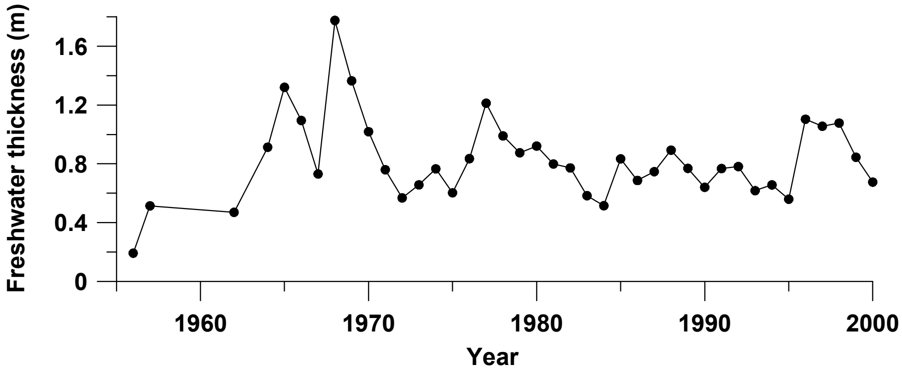


Figure 8. The fresh water thickness at Langanes NE 4 above 150 m, relative to salinity of 34.93 in May/June 1956-2000. (Jónsson 1999).

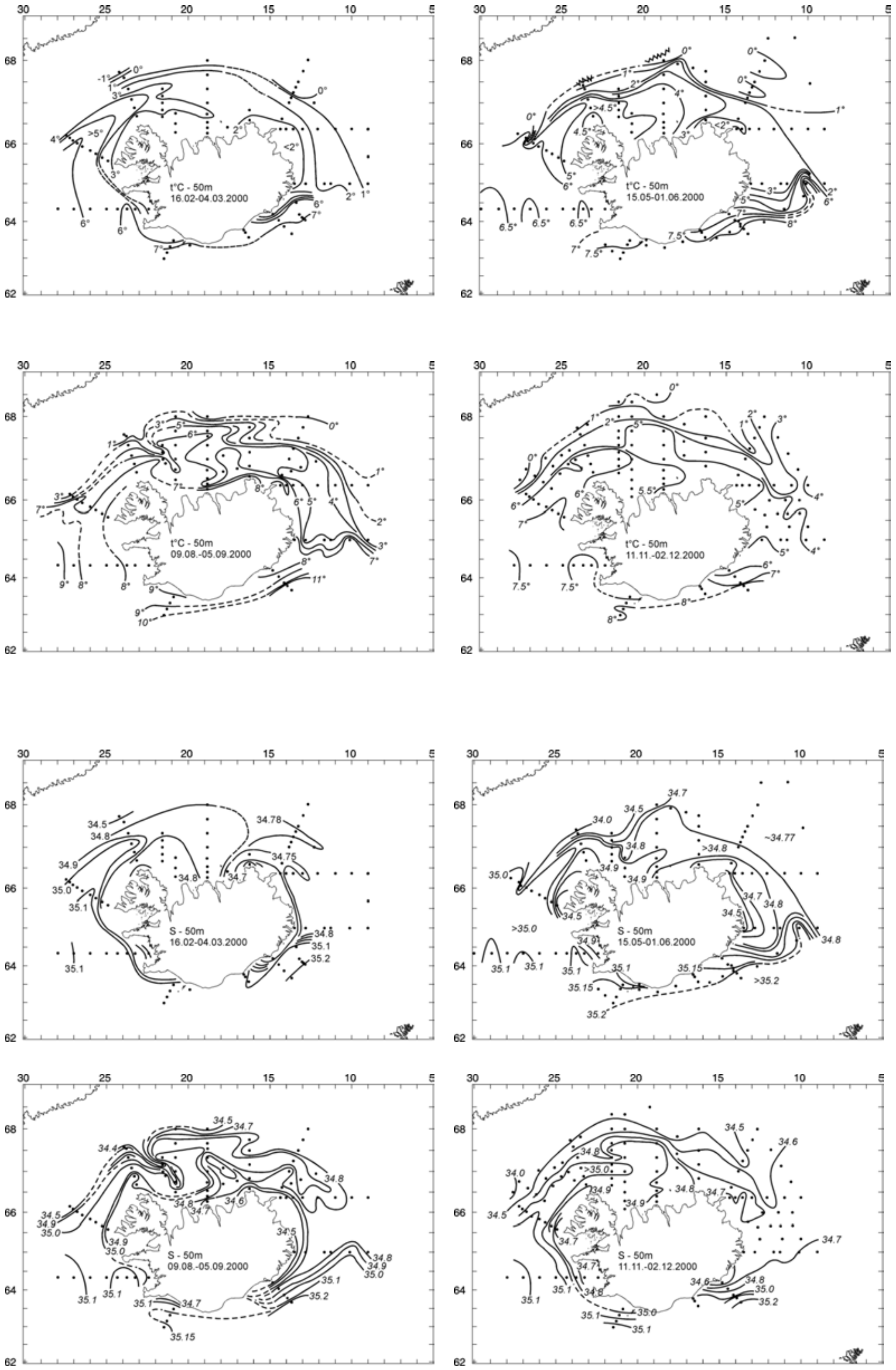


Figure 9. Temperature and salinity at 50 m depth in Icelandic waters in February, May/June, August and November/December 2000.

ANNEX N: AREA 4 (BAY OF BISCAY AND EASTERN ATLANTIC) SPANISH REPORT

Spanish Standard Sections

A. Lavín* and J. M. Cabanas** Instituto Español de Oceanografía
*Centro Costero de Santander P.B. 240 39080 Santander Spain
** 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. Four 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 2000 are similar to those of 1998 and 1999. The annual mean air temperature over the southern Bay of Biscay during 2000 has remained at nearly the same value as during the two preceding years, at 14.7°C, 0.3ºC over the 1961-2000 average (Figure 1). However, positive anomalies in the annual cycle appear in February, the whole of spring, August, September and, above all, December. During this last month air temperature was 2.9ºC higher than the historic mean. Anomalous high frequency and intensity of southwesterly winds are responsible for this. In Figure 2 anomalies in monthly mean air temperatures are shown over the annual cycle in the Santander (Instituto Nacional de Meteorologia).

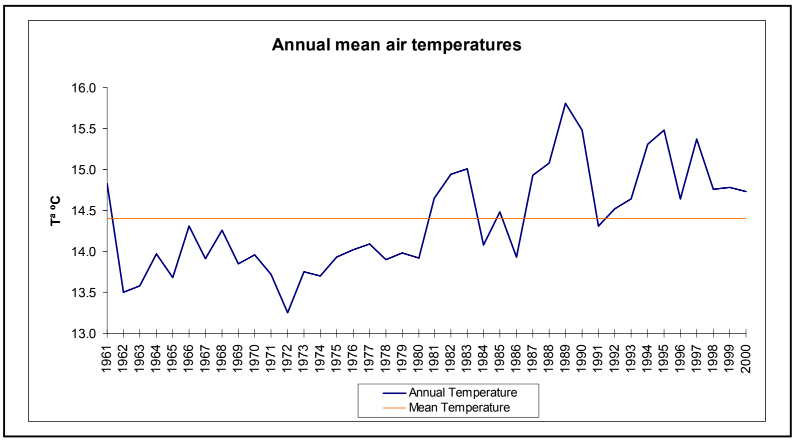


Figure 1

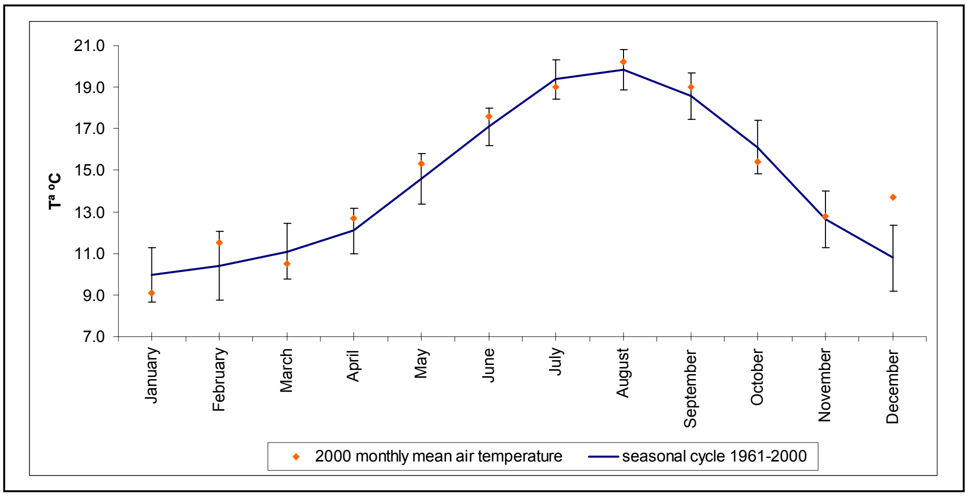


Figure 2

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 and 1999 have a very low influence of upwelling, and only after June does nitrate concentration reach around 6µmol/l below 40 m. During winter 2000 the entire water column has high nitrate concentration as occurred during winter 1995.

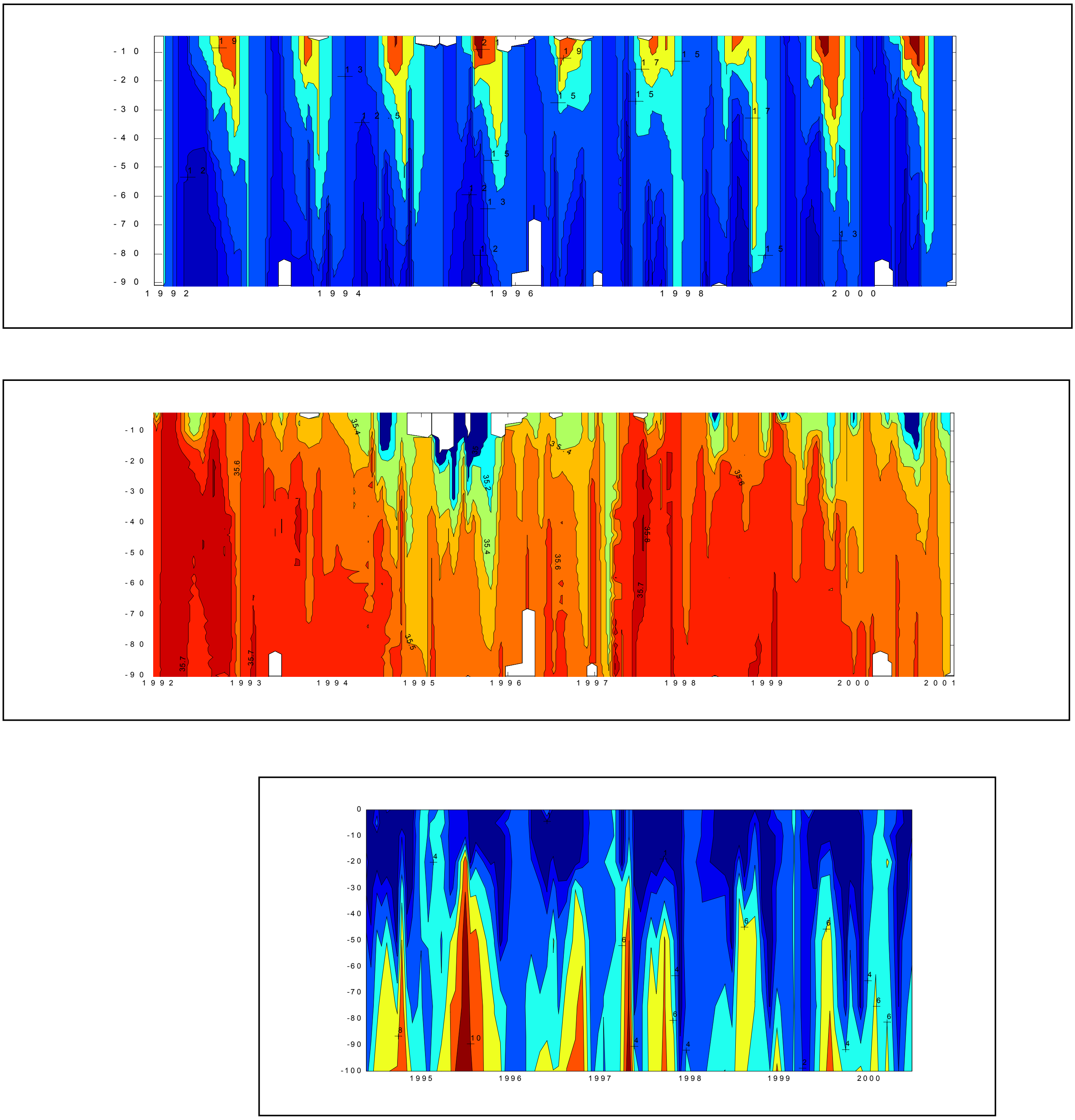
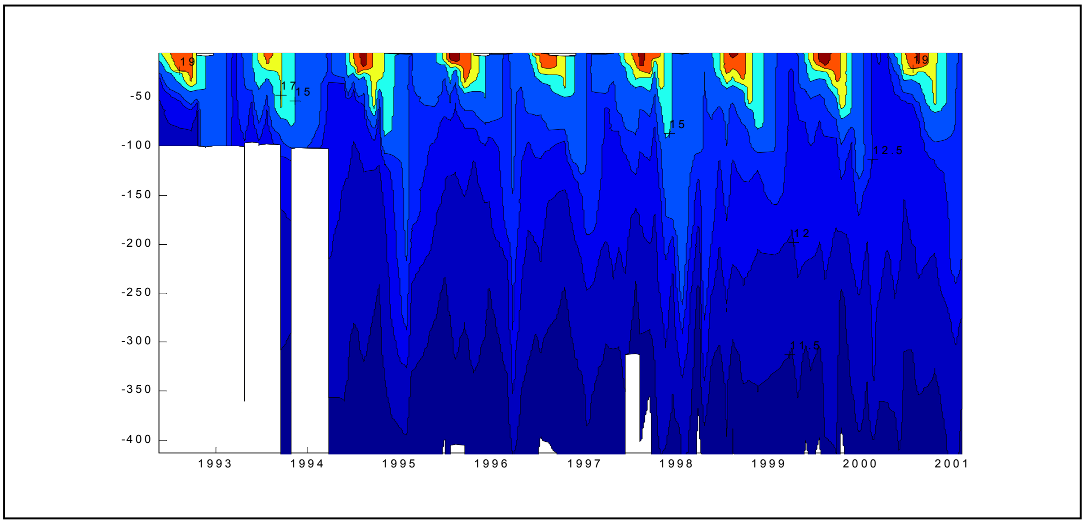
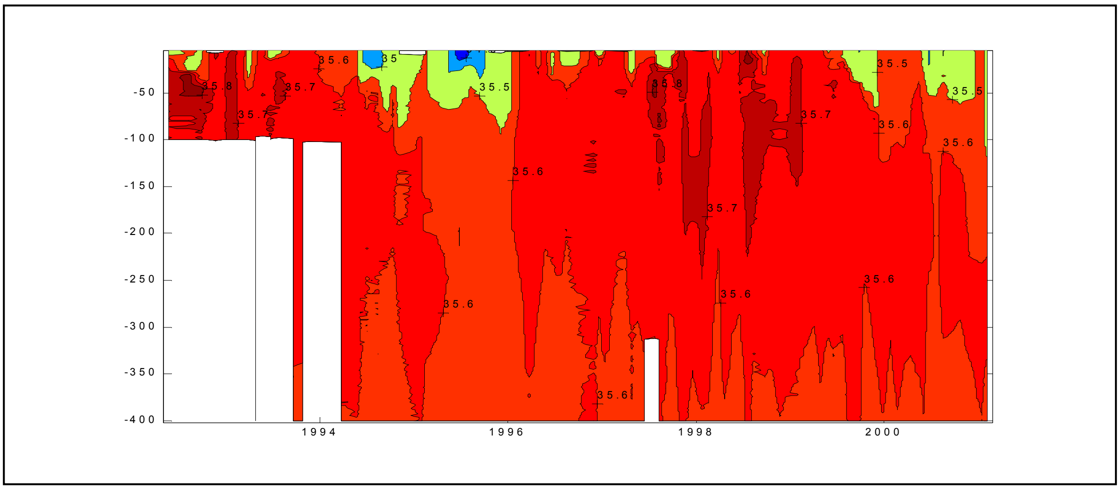


Figure 3

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 autumn mixing is marked until

400 m depth. The 11.5ºC isotherm reached 400 m in winter 1996, autumn 1997/winter 1998, autumn 1999 and winter 2001. The period of low salinity in the upper waters (1994-1995) occurs again in 1999-2000, although not so pronounced. Below the mixed layer, salinity falls from 1992 to 1995 and increases again to 1997/1998 before falling once more until 2000. 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. During winter 2000 the entire water column has high nitrate concentration, which does not seem to have its origin in previous upwelling due to the poor nitrate concentration in the preceding season.





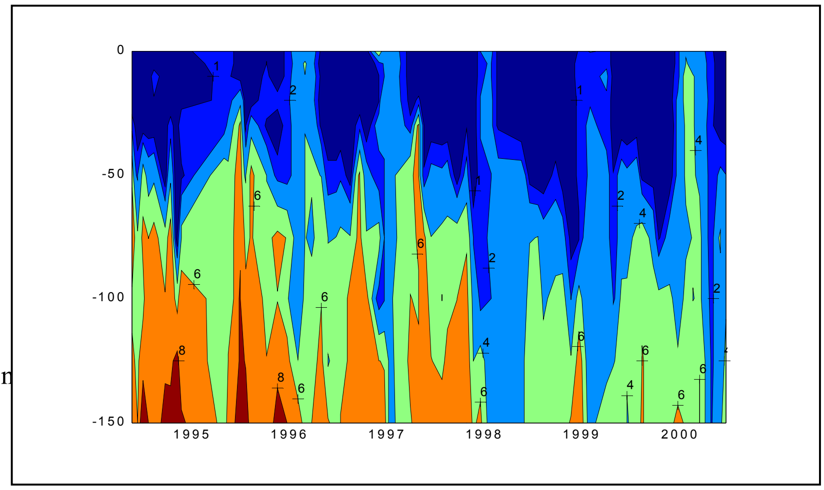


Figure 4
Sea temperature and salin

In Figure 5, the time series of temperature and salinity at 10 m depth over the shelf are presented. 2000 presents cold winter and spring temperatures and warmer summer ones. Salinity retains the trend of falling values with a marked decrease during summer. In Figure 6 the time series of temperature and salinity at 100 m depth over the shelf-break (600 m depth) are presented. Winter 2000 presents smaller temperature increases than in 1992, 1997 and 1998, but during autumn 2000 the increase was lower than in most years. The lack of sampling at the end of the year may have prevented its detection, but sampling early in 2001 did not detect it either. Salinity behaviour is very interesting. Autumn–winter changes mark the year’s mean values. Strong inflow of salty water in 1995-1996 marks a saltier period in the southern Bay of Biscay. In 1997-1998 this seems to increase slightly. During 1999-2000 and 2000-2001, advection of fresher water seems to drive the reduction in salinity during the period.

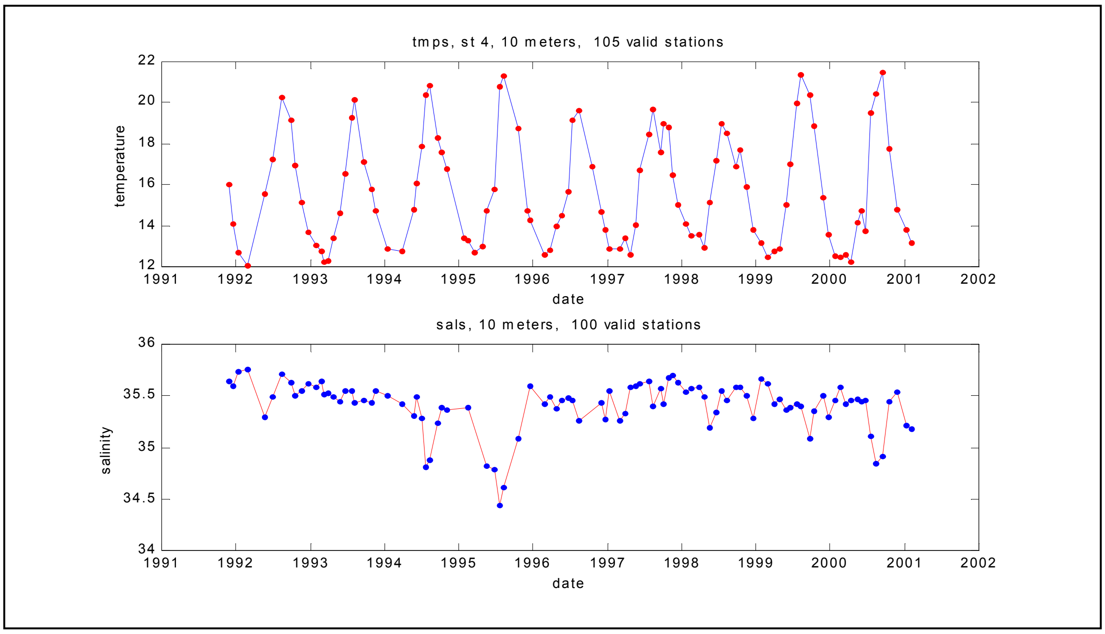


Figure 5

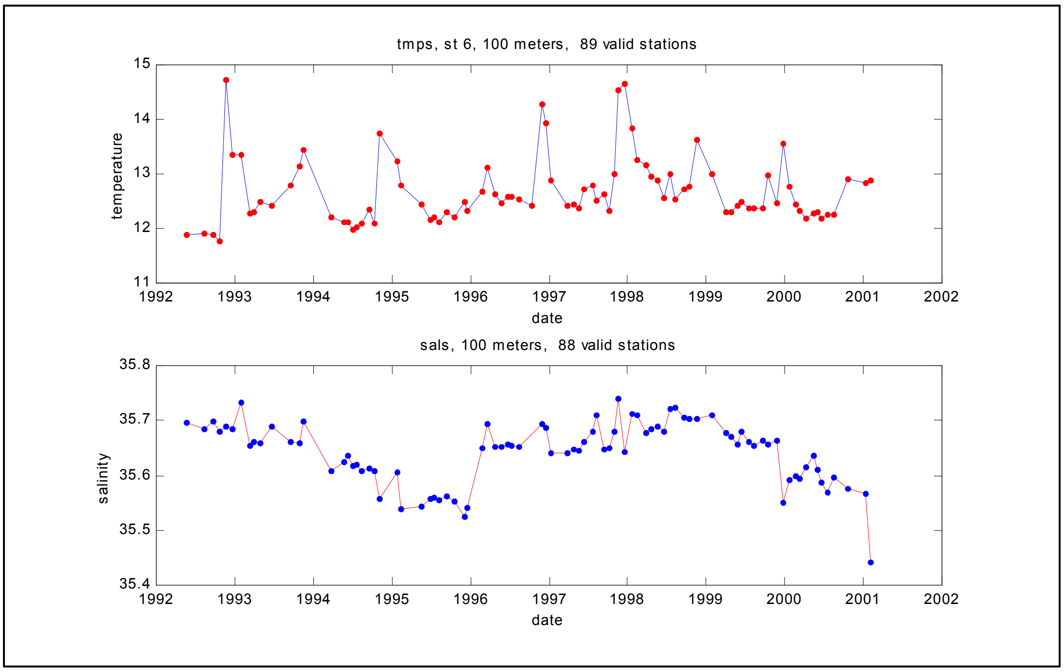


Figure 6

Using cubic splines we have fitted the seasonal cycle of the 1992-2000 time series at 10 m depth over the shelf (Figure 7). During 2000 air temperatures were mostly below the mean value in winter, as were sea surface temperatures mainly in January and April, where sea temperature at 10 m depth was below the standard deviation of the mean value. Air temperatures were higher than the mean during spring and late summer, but sea temperatures at 10 m were only above the mean in September, 2.5ºC over the monthly mean (Figure 7). June 2000 marked a low value due to an upwelling event. Sea temperatures at the surface layer (10 m depth) show that the amplitude of the seasonal cycle between winter and summer was 9.1ºC, the largest in the sampled period, with a yearly mean temperature of 15.6ºC (Figure 8). The colder winter and spring, even when the summer was warm, determine the year's low mean temperature, one of the coldest in the decade. The behaviour is similar to that of 1995 and 1999. The difference is that while 1995 was the warmest atmospheric year in the period sampled and with the highest NAO index of the decade, 1999 and 2000 were standard atmospheric years for the last decade, without such strong atmospheric forcing and a positive NAO index. Fitting the time series of splines, taking the annual mean and examining the trend, at station 4 we found an increase in temperature of 0.02ºC/year at 10m depth between 1992 and 2000 (Figure 8) and of 0.01ºC/year at 90 m depth. At station 6, there is no increase at 10 m depth, but temperature is higher at 90 m depth (0.02ºC/year) from 1994 to 1999 (Figure 9). The increase is of 0.03ºC/year at 200 m, disappearing at 500 m depth. There are also changes in water masses in the southern Bay of Biscay.

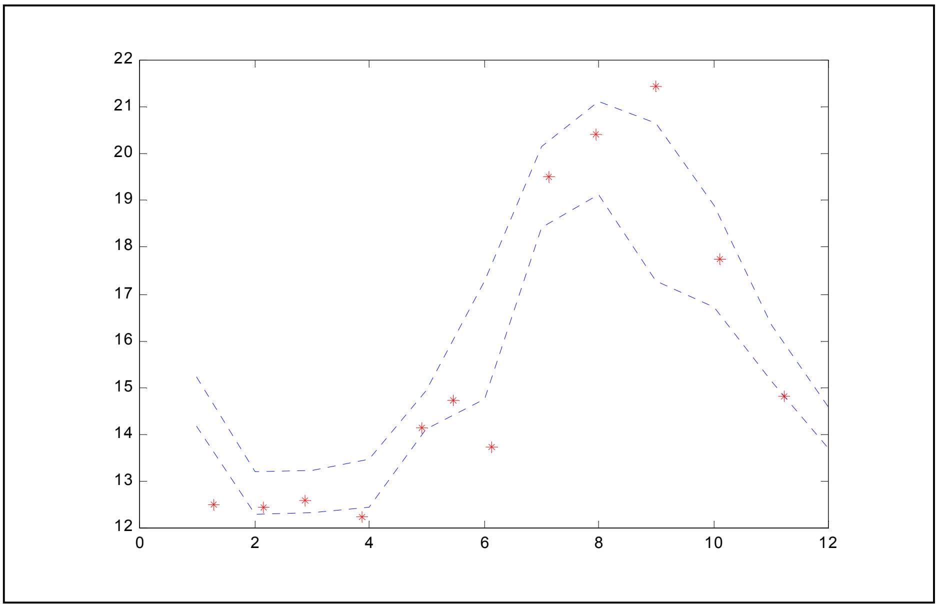


Figure 7

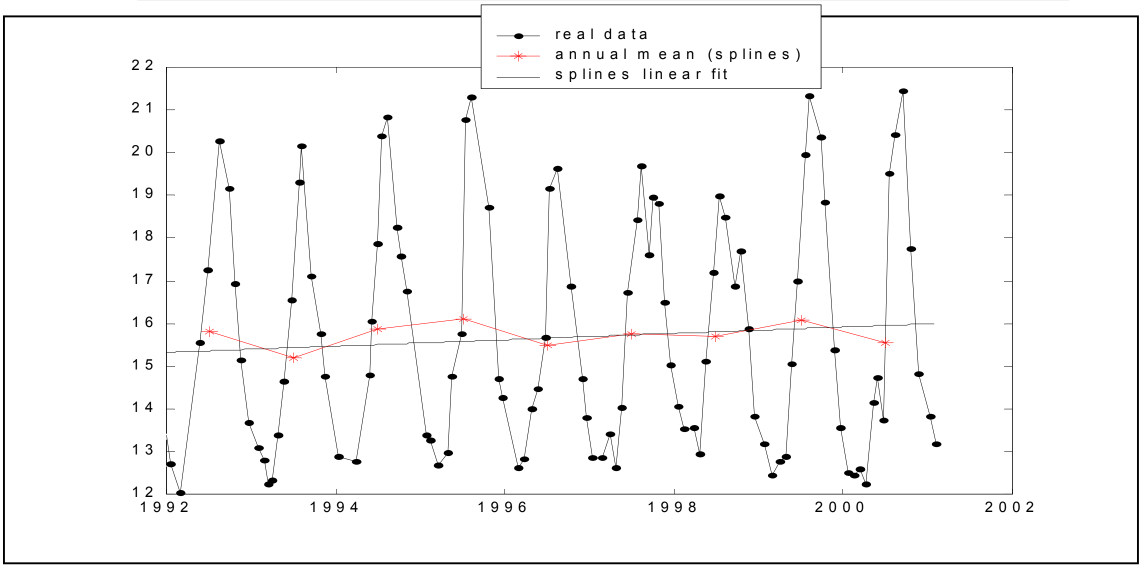


Figure 8

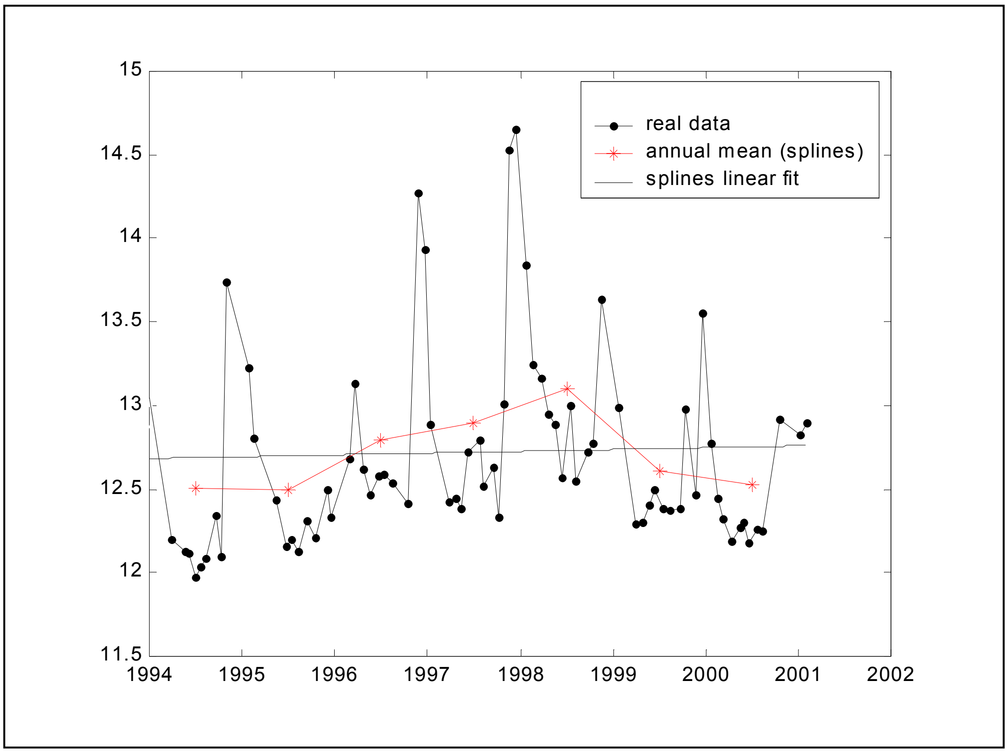


Figure 9

In a detailed study of winter/spring temperatures (Figure 10), we found 1998 to be the warmest in the sampled period, while 2000 was one of the coldest years, together with 1992 and 1993. This winter-spring period has a great influence on egg and larval survival.

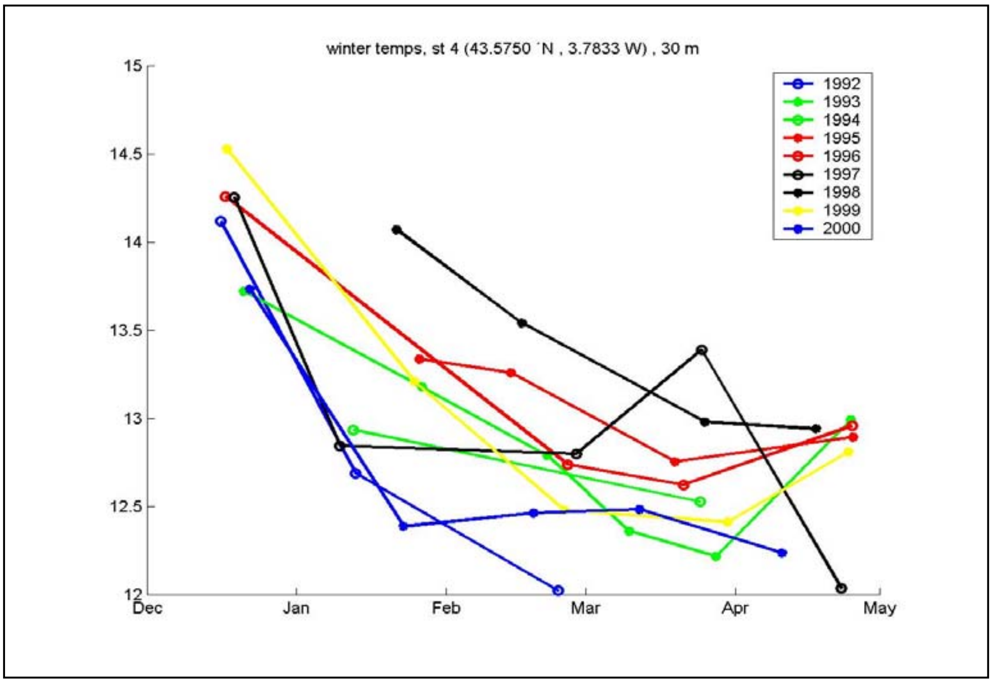


Figure 10

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, (Figure 11 A) and from 100 to 500 m (Figure 11 B). The upper part shows the seasonal cycle in heat content, while the deep part shows a high signal in late autumn or early winter.

During 2000 the total heat content (Figure 11 C) is lower than the previous years, in which the values were high in autumn 1997/winter 1998. In the upper 100 m layer, winter 2000 was the coldest in the decade, even colder than 1999 (as shown in Figure 10). The heat content in January, February and March is very low (around 5 x 10 ^{7} J m^{-3}). From 100 to 500 m the situation reverses and winter 2000 presents the highest values since late 1997/early 1998 and the poleward current event detected in winter 1996 (See also Figure 4). Spring/summer presents an intermediate value and the autumn warming is poorly detected due to the lack of measurements. Winter 2001 is plotted to give an idea of the autumn warming (Figure 11).

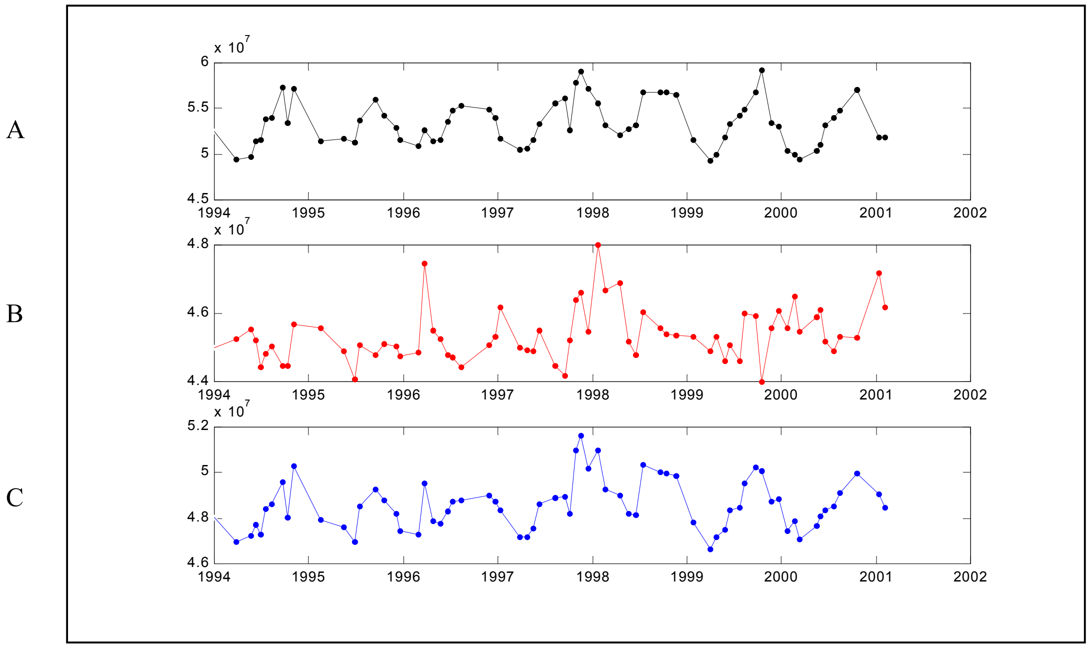


Figure 11

Vigo Standard Section

Contours of temperature, salinity over the shelf (94 m depth) in the Vigo section from 1994 to 2000 are presented in Figure 12. 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 and October-November when warmer water covers the shelf. During the rest of the period the water column is mixed. Salinity contours show high salinity in 1996, 1997 and 2000 due to the poleward current and sporadically in spring-summer due to seasonal upwelling events. The highest values were found during spring-summer 1997 and 2000 spreading into the rest of the year. Autumn 1997/winter 1998 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. From summer 1998 most of the water column was cold, which seems to be due to strong upwelling. The poleward current was weak during autumn 1998 and 1999 and more intense in autumn 2000.

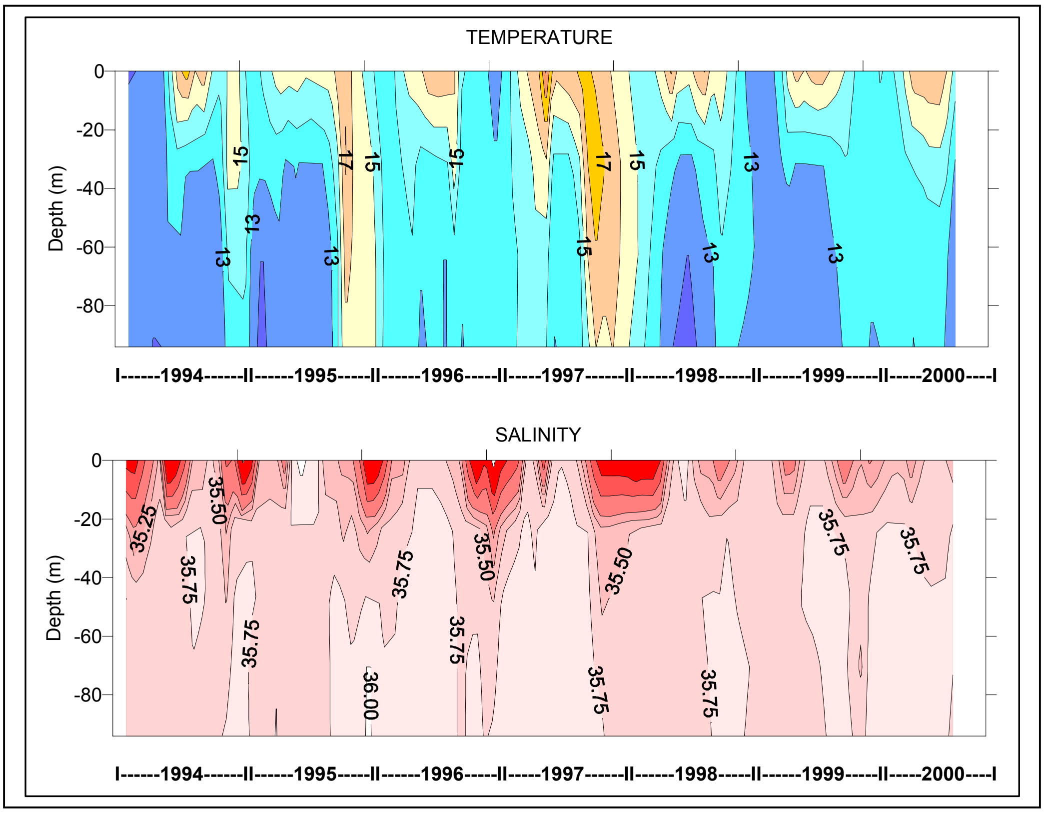

TEMPERATURE
Depth (m)
0
-20
-40
-60
-80
15
17
15
15
17
15
13
13
13
15
13
13
13
I------1994------II------1995-----II------1996-----II-----1997------II------1998-----II------1999-----II-----2000----I
SALINITY
Depth (m)
0
-20
-40
-60
-80
35.25
35.50
35.75
35.75
36.00
35.75
35.75
35.50
35.50
35.75
35.75
35.75
35.75
I------1994------II------1995-----II------1996-----II-----1997------II------1998-----II------1999-----II-----2000----I

Figure 12

ANNEX O: AREA 4 (BAY OF BISCAY AND EASTERN ATLANTIC) DUTCH REPORT

Heating of the sub-arctic gyre?

Hendrik M. van Aken

Netherlands institute for Sea Research, P.O. box 59, 1790Ab Den Burg/Texel, the Netherlands
aken@nioz.nl

Introduction

Within the framework of the Dutch contribution to CLIVAR the Netherlands Institute of Sea Research at Texel will survey the former WHP A1E/AR7E section in the North Atlantic between the Irish continental shelf and the Greenland shelf at 60ºN. The purpose of these surveys is to monitor climate related changes in the hydrography and circulation of the sub-arctic gyre in the North Atlantic Ocean. These surveys will take place every 2 years, coincident with surveys of the former A2 line by BSH, Hamburg (K.P. Koltermann).

From 26 September to 19 October 2000 RV Pelagia has carried out the survey of the A1E/AR7E line (Figure 1). This line has also been surveyed in 1991 by RV Tyro and RV Charles Darwin. The western part of the section, west of 31ºW, was also surveyed by RV Meteor in 1991, 1994, 1997 and 1999, and by RV Valdivia in 1992, 1995 and 1996. The eastern part of these German surveys followed a more southern course, skimming the southern slopes of the Rockall-Hatton Plateau in stead of crossing this plateau.

The 2000 section

The potential temperature along the section is shown in Figure 2, while Figure 3 gives the October 2000 salinity distribution. The warm and saline Atlantic Water (S > 35.0) is found in the upper layers between the European shelf and the western flank of the Mid-Atlantic Ridge (MAR). The salinity minimum, connected with the presence of a core of Labrador Sea Water (LSW) is visible in the Iceland Basin (20-31°W), while in the centre of the Irminger Basin (34-41°W) a structure is observed with two salinity minima, at 750 and 1500 dbar respectively. In the Rockall Channel a deep salinity minimum (S < 34.93) is present at pressures of 1900 to 2300 dbar which is not visible with the current spacing of the iso-lines. The Iceland Scotland Overflow water (ISOW) flowing southwards along the eastern slope of the MAR has a temperature down to 2.5°C and a salinity between 34.95 and 35.00. In the Irminger Basin the salinity of the northward flowing ISOW along the western flank of the MAR has decreased to 34.90 to 34.95, at a potential temperature of 2.75 to 3.0°C. The Denmark Strait Overflow Water along the Greenlandic slope has temperatures down to below 1.0°C and salinities between 34.85 and 34.90. Near the top of the Greenlandic continental slope subducted Atlantic Water is observed, characterized by a sub-surface salinity maximum. This water is assumed to originate from the Irminger Current along the MAR, brought to the Greenlandic slope by the cyclonic circulation in the Irminger Sea. This Atlantic Water is separated by the polar front from the cold and fresh water (S < 32.5, Q < 1.5°C) in the East-Greenland Current At a large scale the □-S structure of the upper waters and the permanent thermocline hardly have changed since 1991, but for shallow seasonal effects. The most striking difference in the spatial hydrographic structure between 1991 and 2000 is the presence of two cold, low salinity and low potential vorticity cores (PV is not shown here) in the centre of the Irminger Sea. Such a two core structure was not observed in any of the sections, surveyed during the WOCE fieldwork phase (1990-1997). However Sv.-A. Malmberg (pers. comm.) has informed us in the past that the resulting figure 8 form of the isohalines was quite common for the Irminger Sea in the fifties and early sixties. Further details are discussed below

Differences 2000-1991

A first view of the quantitative differences between 2000 and 1991 can be gained from the graph of temperature and salinity at a pressure of 500 dbar (Figure 4). This pressure level is deep enough to miss most of the temperature variability due to direct air-sea interaction. In the Rockall Channel deep convection in late winter regularly reaches 900 m, but the coinciding temperature changes are small. In the Rockall Channel differences in temperature and salinity at 500 dbar between 2000 and 1991 are relatively small, compared to the Iceland Basin. There large differences in potential temperature and salinity are observed (□□$_{2000\text{-}1991} > 1.0$°C, □S$_{2000\text{-}1991} > 0.05$). However the □□S structure in the Iceland Basin hardly differed between both years. The increase of □ and S can be explained by a westward shift of the North Atlantic Current and the sub-arctic front of about 100 to 300 km. In the Irminger Basin salinity at 500 dbar hardly differed between 2000 and 1991, while a small temperature increase can be observed (□□$_{2000\text{-}1991} \approx 0.3$°C). This seems to be a recovery from the very cold conditions in 1991.

The difference in the 2-D distribution of temperature and salinity along the section is shown in Figures 5 and 6. The upper 200 dbar is left out of the analysis to get rid of the strong seasonal differences between both cruises. The 1991 survey was carried out in April, at the end of the winter-period. Surface waters were therefore much colder in 1991 than in 2000. In the Rockall Channel the temperature is nearly everywhere higher in 2000 than it was in 1991. Only between 2000 and 2500 dbar, where the LSW connected salinity minimum is found the temperature decreased. There the salinity also went down since 1991. The large temperature differences from 1991 to 2000 between 1000 and 1500 dbar (> 1°C) are connected with a lowering of the position of the permanent thermocline. In the permanent thermocline salinity decreases downwards. The apparent deepening of the thermocline in the Rockall Channel therefore also leads to an increase in salinity, concurrent with the temperature increase. Only in the upper 350 m and along the European continental slope the salinity has decreased since 1991.

In the Iceland Basin potential temperature and salinity decreased at the level of the low salinity LSW core. The strong decrease in salinity and temperature between 500 and 1200 dbar near 30°W is due to the presence of a warm core eddy in 1991. In the ISOW layer near the bottom temperature increased slightly (0 to +0.1°C), while the salinity shows a small (<0.025) salinity decrease. In general the water above 1200 increased in temperature and salinity.

In the Irminger Sea the upper 1550 dbar heated up since 1991 while the salinity change was small and did not show a clear large scale pattern. Below that level a general cooling was observed, concurrent with a decreasing salinity. The DSOW along the Greenlandic slope has cooled over 0.2°C since 1991. The observed heating along the foot of the MAR is due to the presence there of recirculating DSOW in 1991, which was absent in 2000.

The Central Irminger Sea

For the central Irminger Sea there are data available along our section for the years 1991 (3 cruises), 1992, 1994, 1995, 1996, 1997 and 2000 (the 1999 data are not yet public). This allows us to discus the temporal development of the hydrography with more detail (see also Bersch et al., 1999). In Figure 7 property-property plots are shown, displaying the relations between potential temperature, salinity, and potential vorticity. Low-salinity cores, which are also characterized by a potential vorticity minimum, are considered to be characteristic for convectively formed water types. According to common wisdom this water in the Irminger Sea has been formed in the Labrador Sea, but we do not want to rule out the possibility of local deep convection in the Irminger Sea (Pickart, 2000). During the Tyro survey of April 1991 it was observed that the potential temperature in the centre of the Irminger Sea (bottom pressure > 3000 dbar) was constant within 0.03°C in the layer between 200 and 2300 dbar. When we follow the development of the water mass structure displayed in figure 7, we see that in 1991 the potential vorticity minimum coincided with the salinity minimum, at a potential temperature of 3.00°C. In 1992 the potential temperature at the salinity minimum had decreased to 2.95°C. In 1994 the potential vorticity and salinity minimum was found at Θ=2.85°C, while the potential vorticity in that minimum had decreased with a factor 2, evident for the import of a new vintage of recently formed LSW (Bersch et al., 1999). From 1994 to 1997 the Θ-S structure in the centre of the Irminger Sea hardly changed. The potential vorticity had its lowest value in 1995; from that year onwards it increased steadily. Compared with the situation in 1997, the hydrographic structure was drastically altered in 2000. Now two cores with salinity and vorticity minima can be observed at potential temperature values of 2.95 and 3.45°C. These cores can be identified as the salinity minima at 1500 and 750 dbar, mentioned above. Oxygen observations (not shown) indicated that these cores also coincided with oxygen minima, characterized by Apparent Oxygen Utilization values of 39 and 24 μmol/kg respectively. The former value is about 15 μmol/kg higher than the 1991 values in the salinity minimum core and about 12 μmol/kg higher than the 1997 values. The salinity in the lower minimum is about 0.02 higher than the values observed in 1997, while the potential vorticity in that core has about doubled between 1997 and 2000. Bersch et al. (1999) have proposed that the ongoing change in hydrography of the Irminger Sea between September 1991 and 1996 is due to the increased spreading of a new vintages of LSW, formed in the Labrador Sea in the winters of 1988 to 1994. Apparently a strong erosion of the LSW core in the Irminger Sea has started after 1997. According to M. Bersch (pers. comm) advection of anomalously warm and saline water from the Iceland Basin into the Irminger Sea occurred early 1998. This can be recognized by the westward shift of the sub-arctic front in the surface layers, observed in 2000. Possibly the strong erosion of the LSW core above 1500 dbar since 1997 is also connected with this westward frontal shift. The newly formed shallow core at 750 dbar in 2000 may be interpreted as either a new low density vintage LSW, advected into the area, or as mode water formed locally by convective mixing in winter.

The salinity maximum below the LSW low salinity core derives its properties from the ISOW which passes the MAR through the Charlie-Gibbs Fracture zone, whereas the cold end point is influenced by the presence of DSOW. The properties of the ISOW core in the Irminger Basin also show temporal variability on inter-annual time scales. While in 1991 and 1992 the Θ-S properties of the ISOW core hardly changed, in 1994 a strong temperature and salinity decrease in isopycnals can be observed from the LSW core to the cold end point water type. The decrease of salinity in the S-maximum, connected with the ISOW core has continued until 1997. At the deepest levels the salinity increases slightly from 1994 to 1997. In 2000 the salinity of the ISOW core hardly has changed since 1997, while at the deepest levels a return to the 1994 temperature is observed.

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Bersch., M, J. Meincke, and A. Sy (1999) Interannual thermohaline changes in the northern North Atlantic 1991-1996. Deep-Sea Research II, 46, 55-75

Pickart, R.S. (2000) Is the Labrador Sea Water formed in the Irminger Basin? WOCE Newsletter 39, 6-8.

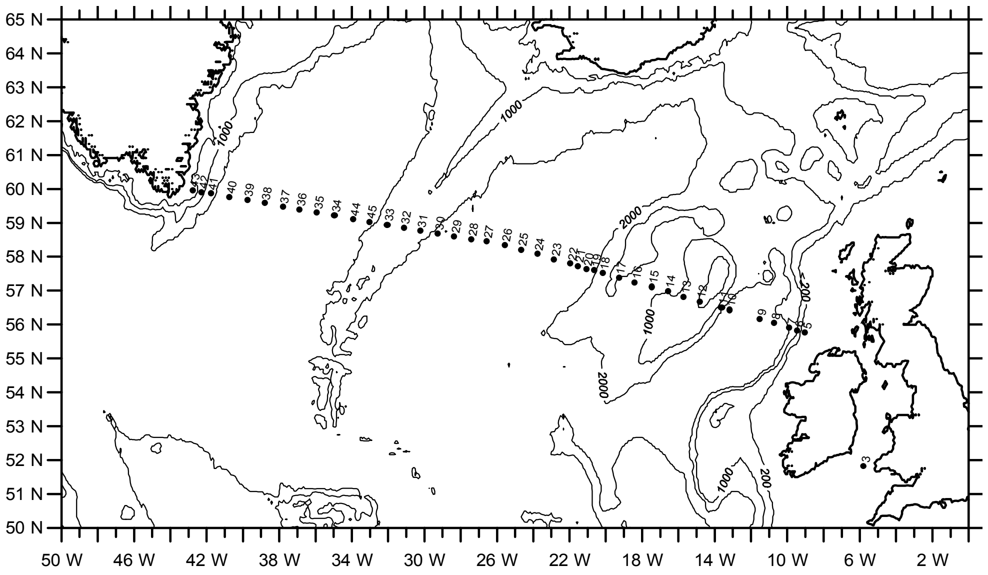


Figure 1. Positions of the CTD stations, occupied during RV Pelagia cruise 169 from 26 September to 19 October 2000.

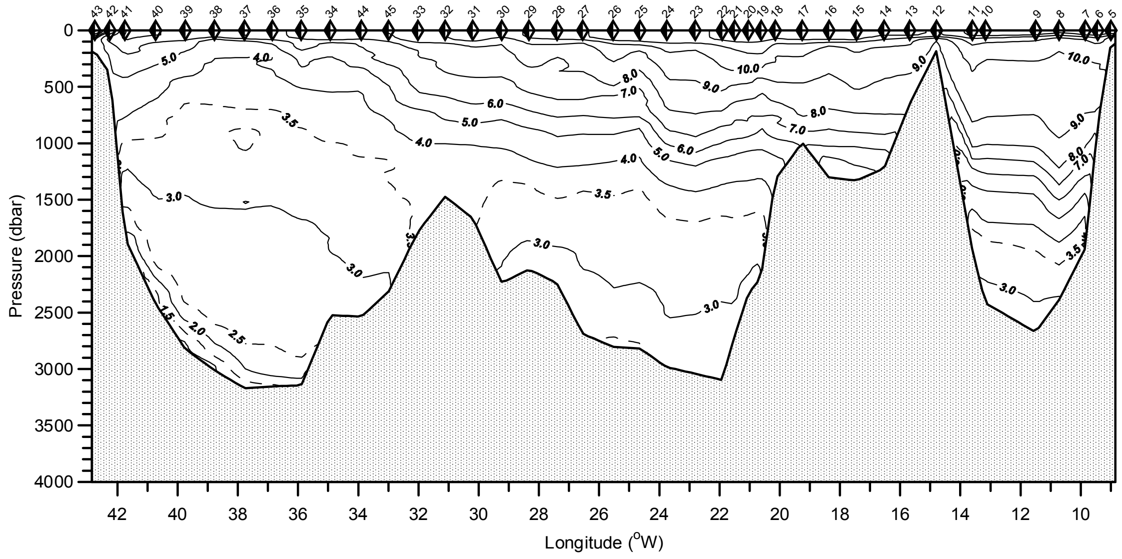


Figure 2. Distribution of the potential temperature during RV Pelagia cruise 169 in September-October 2000.

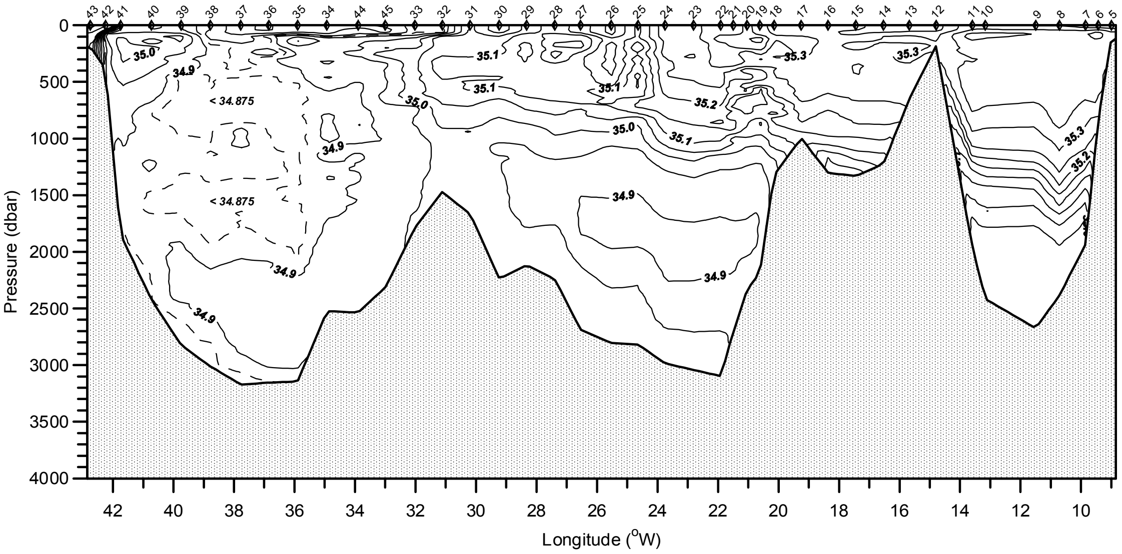


Figure 3. Distribution of the salinity during RV Pelagia cruise 169 in September-October 2000.

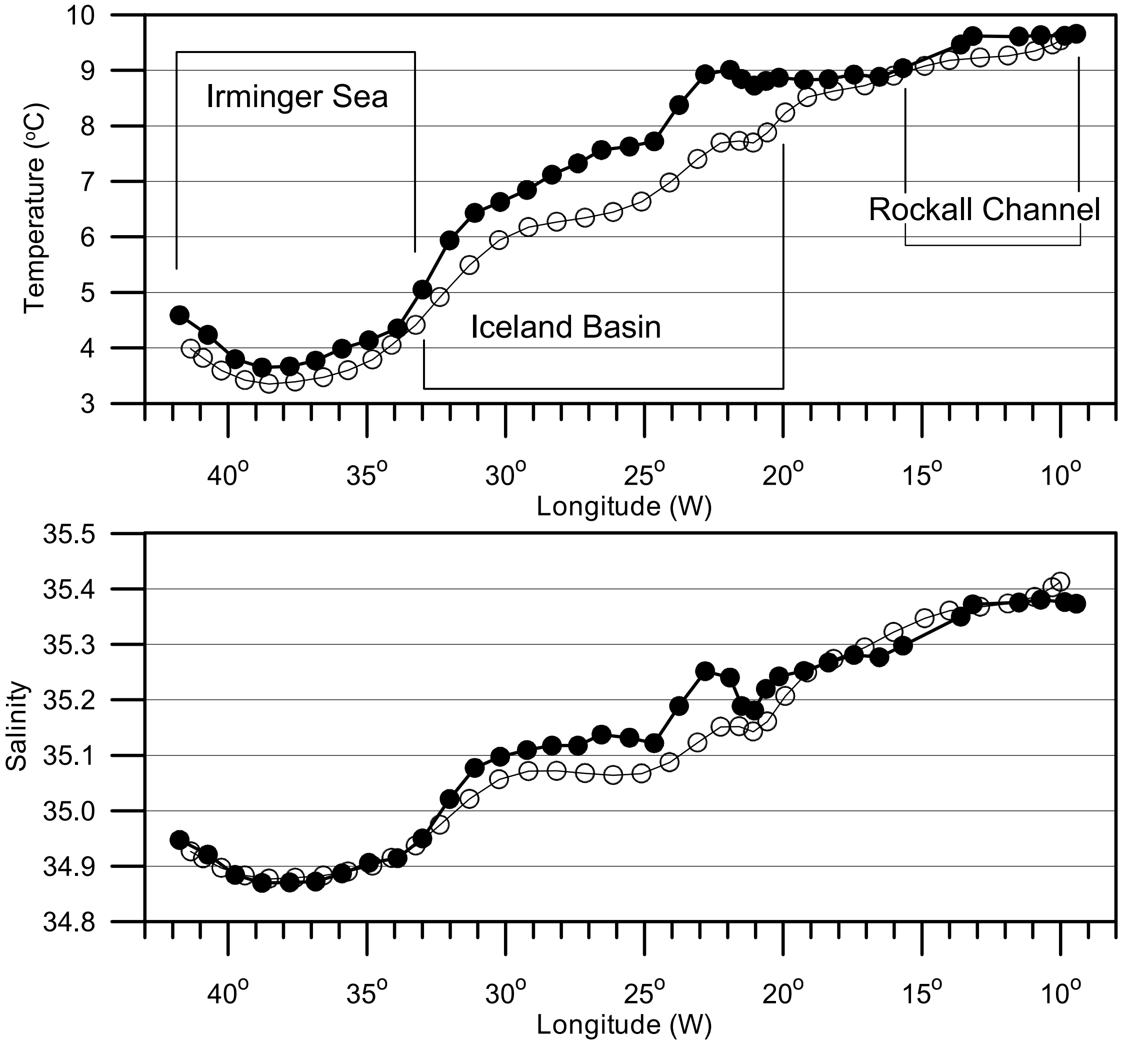


Figure 4 Potential temperature (upper panel) and salinity (lower panel) at a pressure of 500 dbar along the AR7E section as a function of longitude for 1991 (open circles) and 2000 (black dots.). For the 1991 data the smoothed mean values of the cruises of RV Tyro and RV Charles Darwin were used.

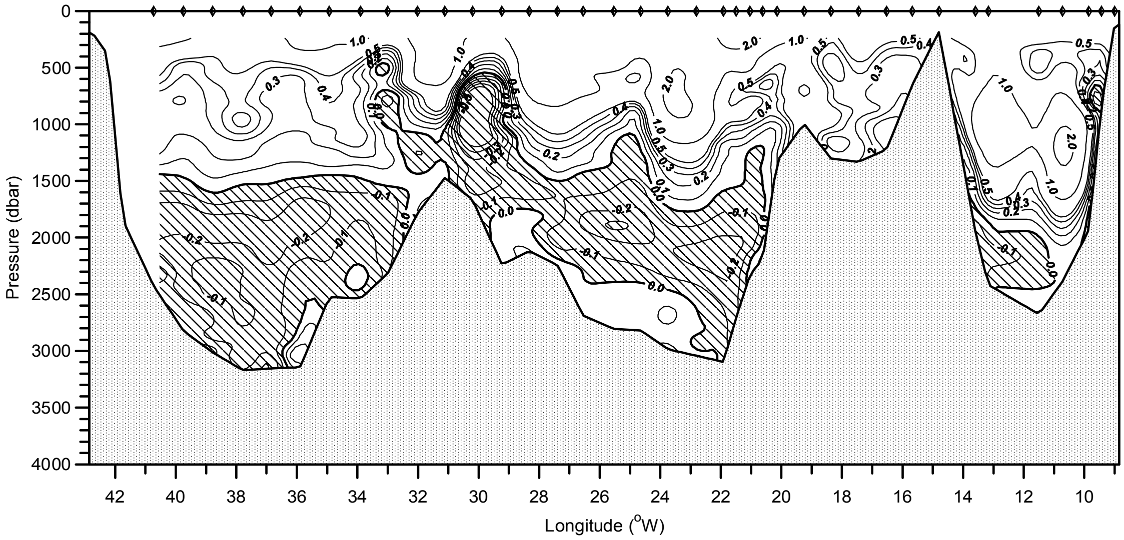


Figure 5. Distribution of the difference in potential temperature between 2000 and 1991. The hatched area has become cooler since 1991. Data from the upper 200 dbar were not used in the analysis. In 1991 no data were available over the Greenlandic continental slope due to the presence of pack ice.

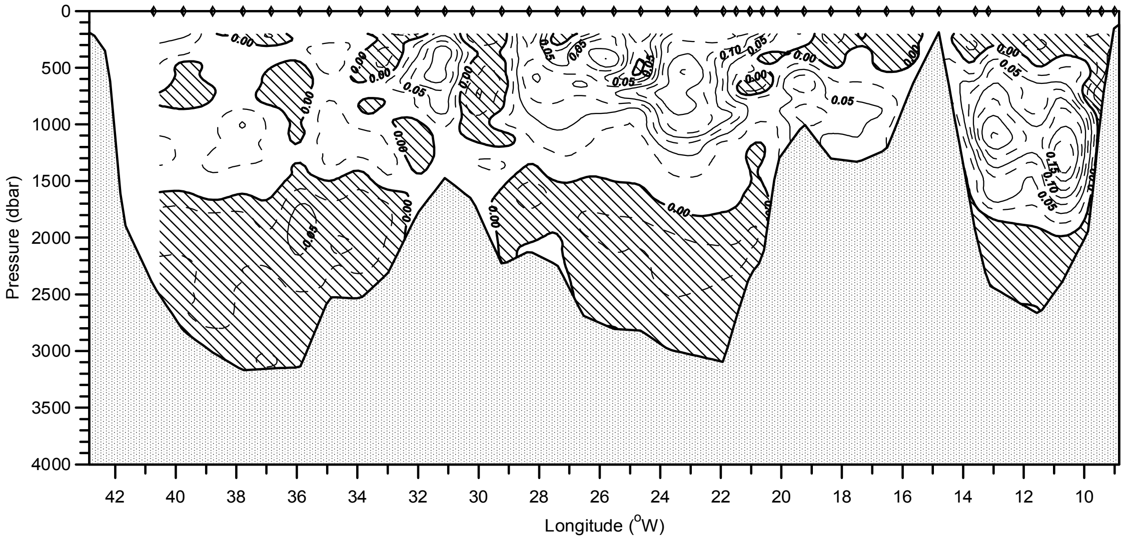


Figure 6. Distribution of the difference in salinity between 2000 and 1991. The hatched area has become fresher since 1991. Data from the upper 200 dbar were not used in the analysis. In 1991 no data were available over the Greenlandic continental slope due to the presence of pack ice.

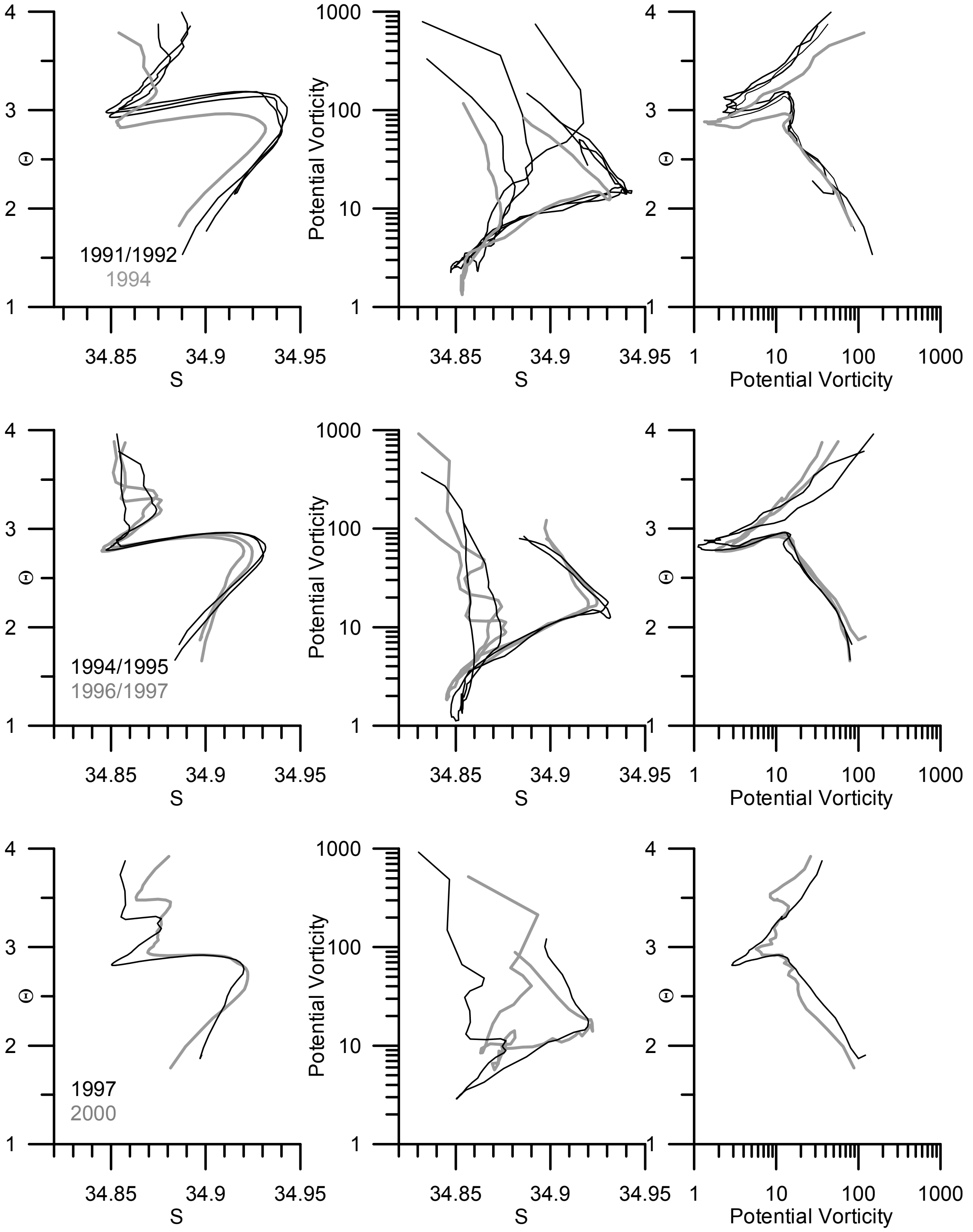


Figure 7 Property-property plots for the centre of the Irminger Sea for successive periods, with one year overlap.

ANNEX P: AREA 5 (ROCKALL TROUGH) UK REPORT

Rockall Trough Standard Section:
Hydrographic Status Report 2000

N. Penny Holliday
Southampton Oceanography Centre, European Way, Southampton, SO14 3ZH, UK
nph@soc.soton.ac.uk

Introduction

The UK occupies a section between Scotland and Iceland via Rockall once per year as part of the NERC funded Core Strategic Programme at SOC. In addition the Ellett line section (Scotland to Rockall) is occupied on an opportunistic basis by the Marine Laboratory (Aberdeen) and annually by the Dunstaffnage Marine Laboratory (original keepers of the Ellett Line). The purpose of the Ellett line is to monitor the northward flow of warm saline water towards the Nordic Seas; the purpose of the SOC extension to Iceland is to monitor the northward flow of the NAC water through the Iceland Basin, the formation of local mode waters, and the return of the dense overflow water.

In 2000 the Ellett line was occupied twice; once in January/February by SOC and DML (reported to the last WGOH meeting) and in May by MarLab. This report outlines the May 2000 section and updates the time series of properties and transports of the Ellett Line. The Rockall to Iceland section was not occupied in 2000 (due to inclement weather in Jan/Feb) and hence is not reported here.

The May 2000 Ellett Line Section

The potential temperature, salinity, density (sigma0) and Θ-S of the section are shown in Figure 1. The sections show the seasonal thermocline has developed and the homogeneous winter mixed layer observed in February has already been replaced by more stratified ENAW (Eastern North AtlanticWater). The salinity maximum seen in the upper 500m spreads across the whole section (apart from the shallow water on the continental shelf and the Rockall Plateau). This is somewhat atypical for the section; generally it has high salinity cores on the shelf break (the shelf edge current) and west of the Anton Dohrn Seamount (the west Rockall Trough current). Below the permanent thermocline lies the Labrador Sea Water (LSW)which slowly circulates in a cyclonic sense. The core of the LSW lies at approximately 1800dbar.

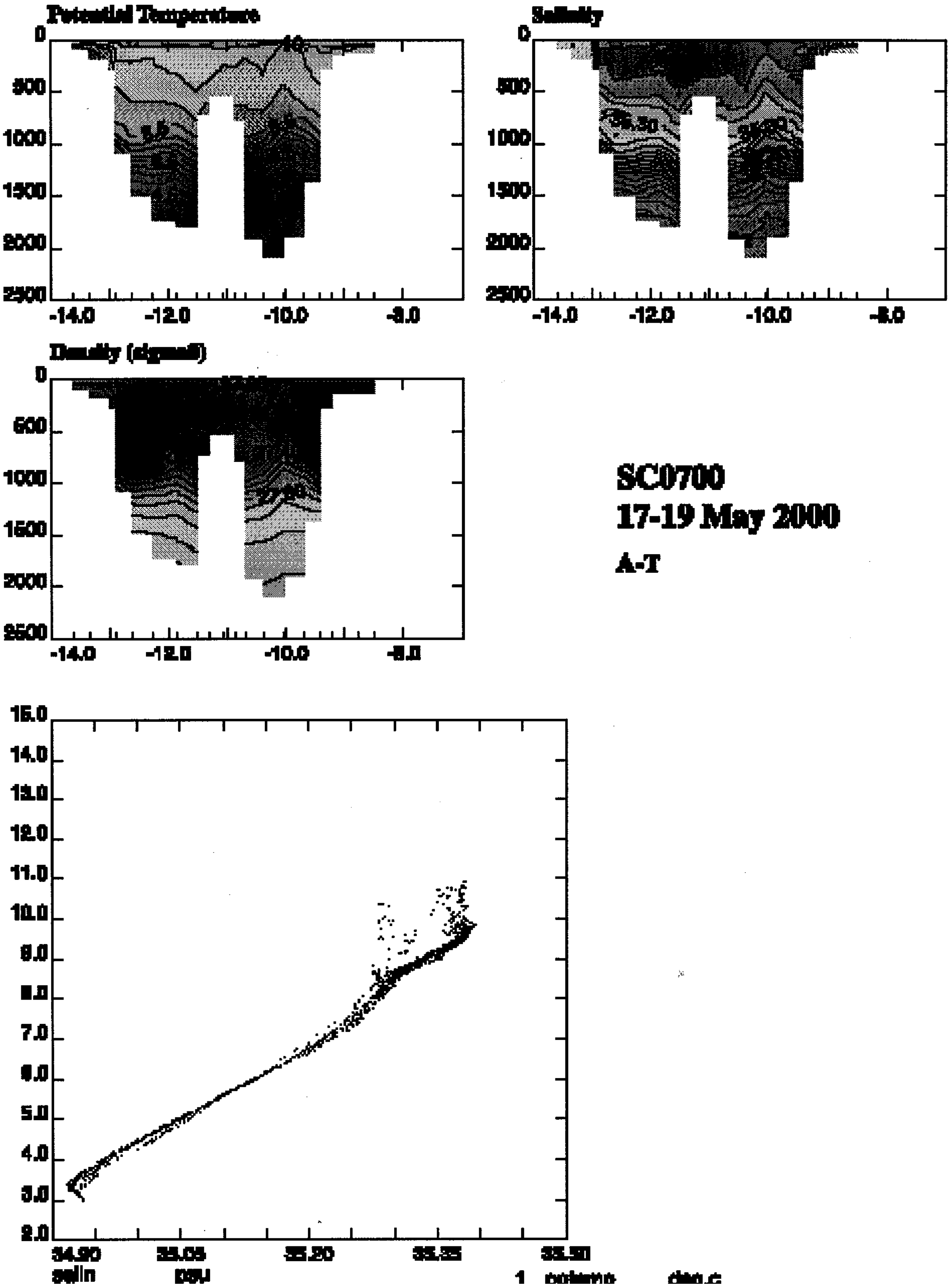


Figure 1. Properties of the May 2000 occupation of the Ellett line. Potential temperature contour intervals of 0.5°C; salinity contour intervals of 0.025; density contour intervals of 0.05.

The Updated Time Series of Rockall Trough Properties

The May 2000 occupation shows a small downturn in the salinity and temperature of the de-seasoned ENAW, though they both remain high compared to the rest of the time series, with salinity being as high as the previous maximum in 1983 (Figure 2).

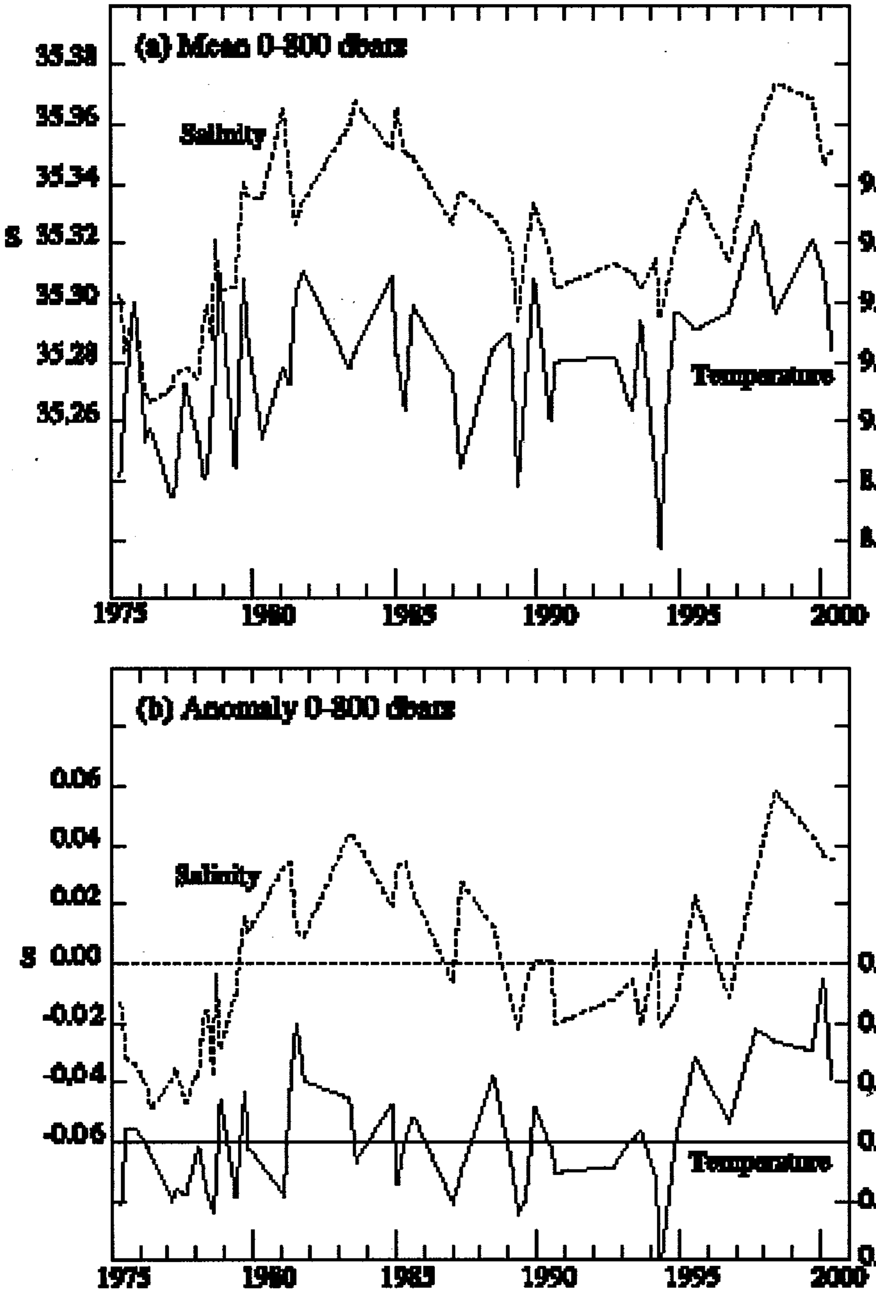


Figure 2. Time series of the ENAW a) the mean temperature and salinity 0-800dbar; b) the temperature and salinity anomalies from seasonal means.

The LSW properties show no significant change since the last incursion of "fresh" LSW in 1990 (Figure 3).

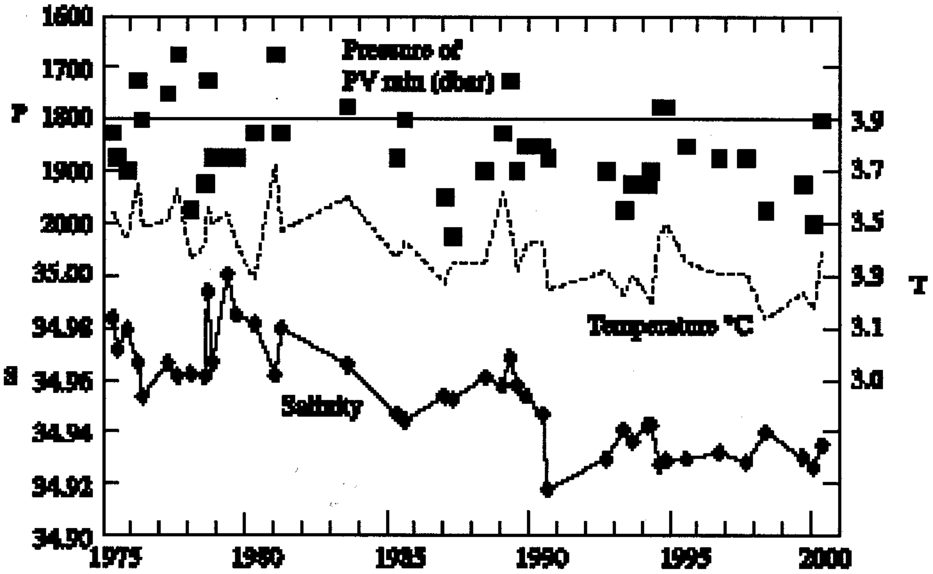


Figure 3. Time evolution of the Labrador Sea Water "core" as indicated by a minimum in potential vorticity. Solid line and filled diamonds are LSW salinity; dashed line is LSW temperature; filled squares are the pressure of the LSW PV minimum.

The estimated baroclinic transport across the section (referenced to 1200dbar, see Holliday et al 2000 for details) in May 2000 was slightly higher than the mean of the series at 4.4 Sv (mean is 3.8 Sv). Figure 4 shows the transport time series based only on occupations that completed the section from Rockall to the continental shelf.

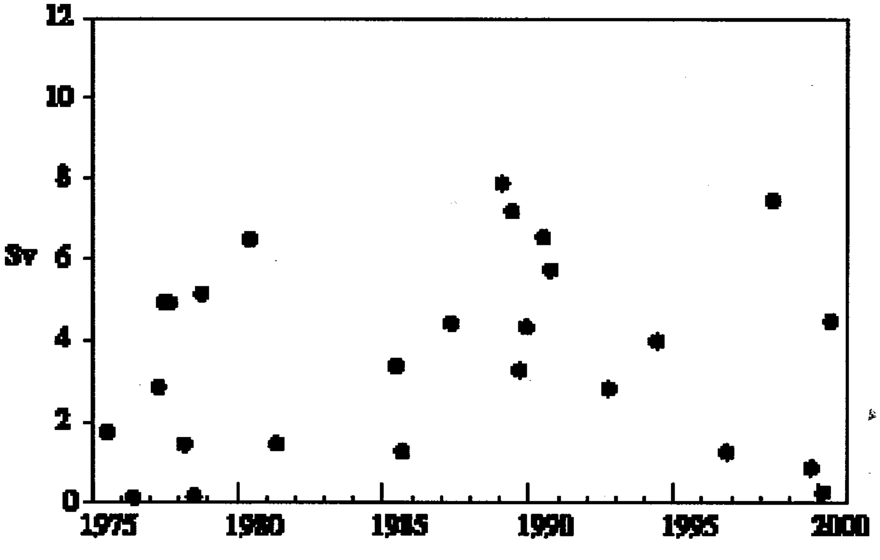


Figure 4. Baroclinic transport across the Ellett line (referenced to 1200 dbar, positive values represent northwards transport).

Reference: Holliday, N.P., R.T. Pollard, J.F. Read, and H. Leach 2000 Water mass properties and fluxes in the Rockall Trough; 1975 to 1998. Deep-Sea Research I, 47/7, p1303-1332.

ANNEX Q: AREA 8 AND 9 (NORTHERN AND SOUTHERN NORTH SEA) ICES REPORT

2000 IBTS-Quarter 1 Hydro-chemistry Survey

Seven ships involved in the 2000 IBTS quarter 1 survey contributed hydrographic data. These consist of 383 stations worked between 13 January and 14 March. Nutrient data were supplied from 115 stations, contributions being received from two ships (Argos, Scotia and Tridens). Data quality was good. The supplied Michael Sars dataset, includes data in addition to those at which IBTS trawls were undertaken. Additional hydrographic and nutrient data were received from a Corystes (UK) cruise, and these were added to the analysis. As a result 649 stations including 335 nutrient stations were used in this report. Additional nutrient samples were collected by Michael Sars but these have not yet been submitted.

Charts of the distribution of bottom temperature and salinity are given in Figs 1 and 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 2000 is provided as Table 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 3 5-year running mean temperature reveal the high spatial coherence in the temperature time series, based on the ten locations given in Table 1. In particular the sustained cooling around 1980 and the warming around 1990 is clearly demonstrated. The warning following cooling in the mid 1990s has continued.

Charts from the 2000 IBTS-1 survey are also published on the ICES website at 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+nitrite and nitrite will follow later, after more data (in particular from the Michael Sars) have been received.

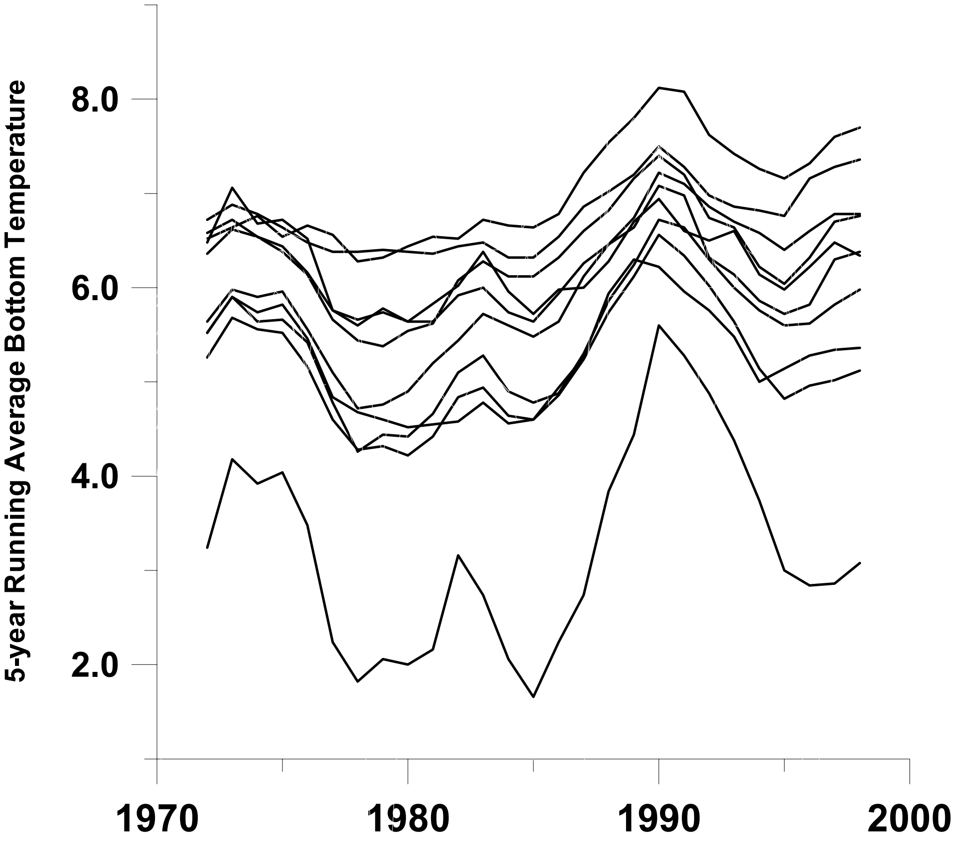
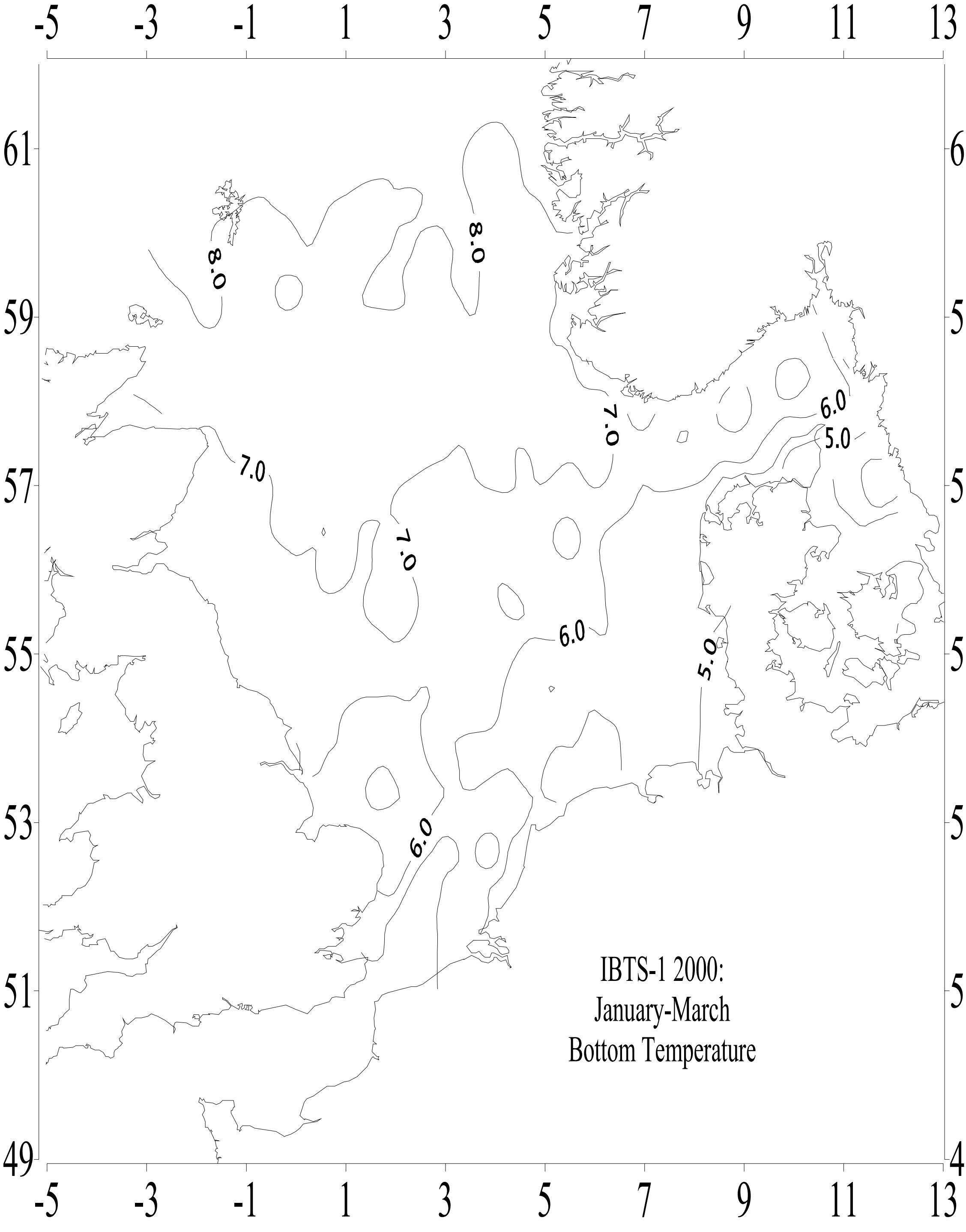


Figure 3 Five-Year averages of temperature at each of the ten locations in Table 7.1



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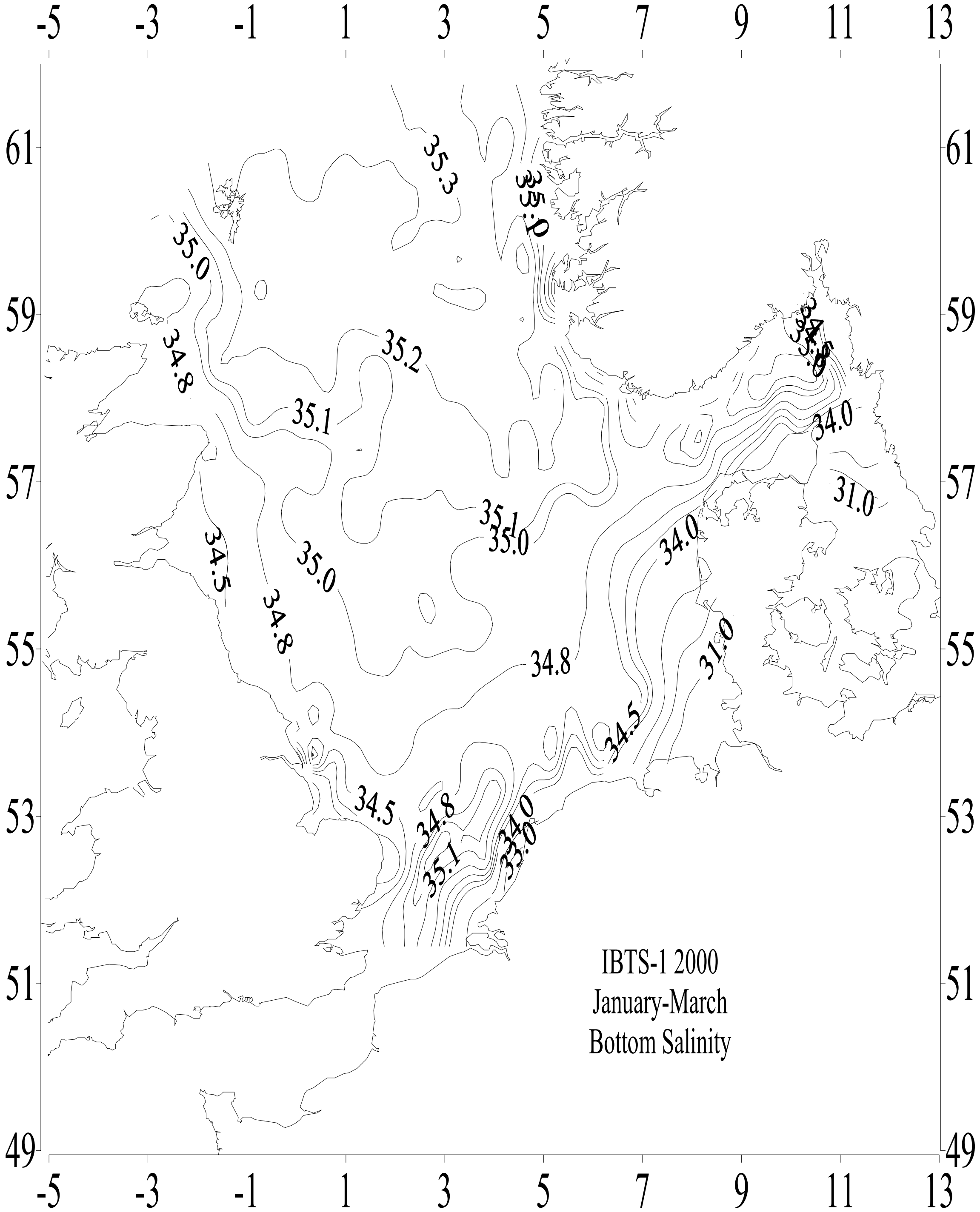
IBTS-1 2000:
January-March
Bottom Temperature

Figure 1



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IBTS-1 2000
January-March
Bottom Salinity

Figure 2

Time series data of bottom temperature and salinity during IYFS/IBTS(1) 1970-2000

Location	1		2		3		4		5		6		7		8		9		10	
Position	60N2E		57.5N0E		57.5N2E		57.5N4E		55N0E		55N2E		55N4E		550N8E		540N3E		52.5N3°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
2000	8.0	35.30	7.4	34.98	7.4	35.14	7.1	35.21	6.7	34.83	6.8	35.01	6.1	34.92	5.1	31.88	6.1	34.72	7.2	35.18

Table 7.1

ANNEX R: AREAS 8 AND 9 (NORTHERN AND SOUTHERN NORTH SEA) GERMAN REPORT

Surface Temperatures of the North Sea in 2000

Gerd Becker and Peter Loewe

An annual mean SST of 10.4°C made 2000 the 6th warmest year on the record dating to 1971.

Exempting June and July, North Sea SSTs exceeded climatological monthly means at all times and all over the place. Spatio-temporal monthly means assumed ranks between 2 and 6 within the 30-year observational record.

The seasonal warming in June averaged only 1.4K which is 50% short of the usual heating rate. This caused the jump-like change from anomalously warm conditions in May to a widespread cold anomaly that grew even more intense in July making it the 4th coldest July since 1971. The mean SST of 13.4 °C remained 2.1K behind the 2nd warmest July of 1999.
While usually seasonal cooling sets in around mid-August, August 2000 was special in that a belated extreme increase in SST of 2K occurred which exceeded the average heating rate by 200%. This again was associated with a rapid return to anomalously warm conditions. The warm anomaly strengthened during fall which underlines the significance of too warm SSTs in fall during the past decade of the 1990s.

Additional information is available at http://www.bsh.de/Oceanography/Climate/Climate.htm

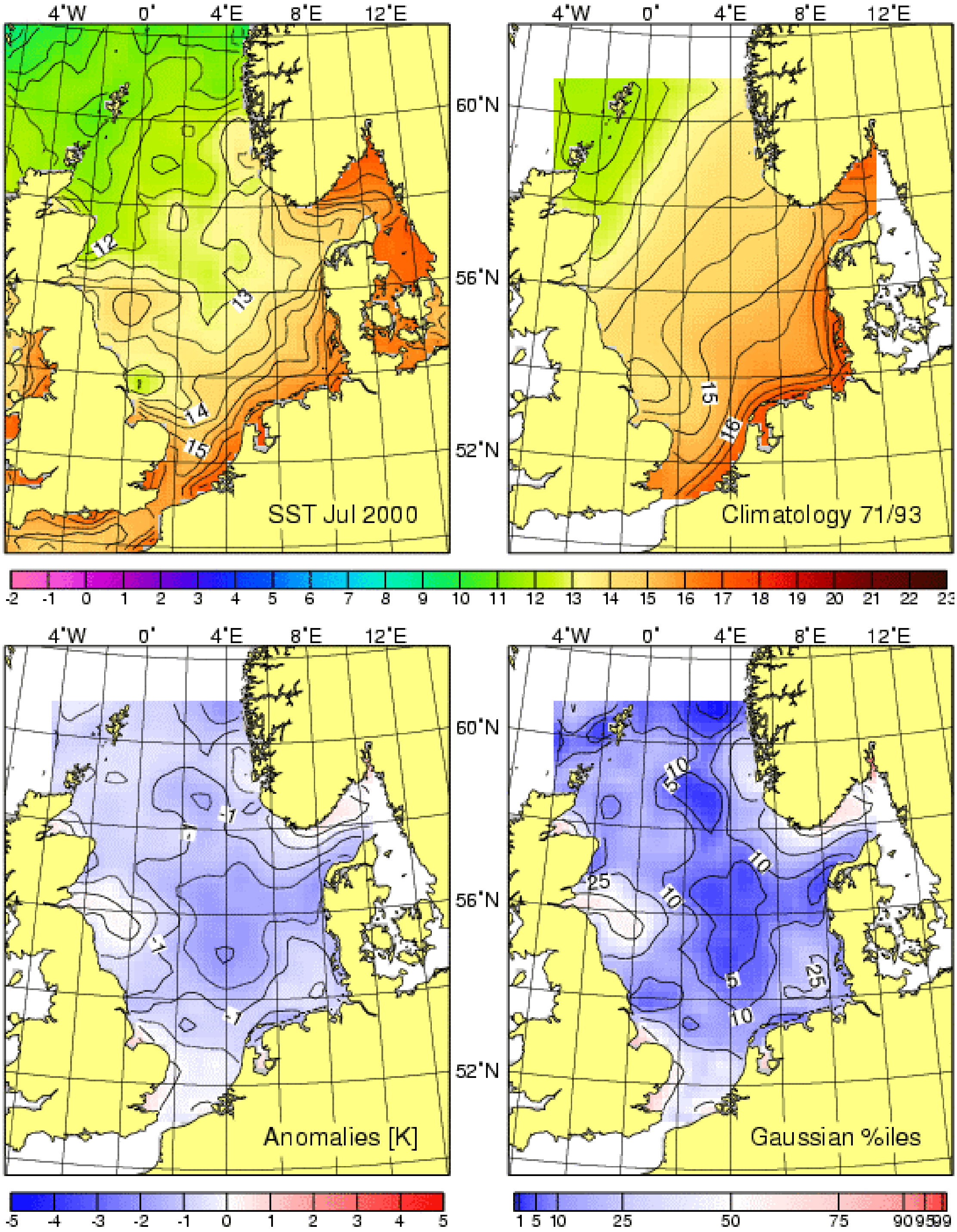


Figure 1: North Sea SSTs and SST anomalies in July 2000. Percentiles (bottom right) give the area under the unit normal distribution between –inifinity and the standardized anomalies. P-values below 10% suggest that the expected average occurrence of such strong or stronger a cold anomaly is less than 10%.

Surface salinities of the North Sea in summer 2000

During a cruise of RV "Gauss" in the summer of 2000 (9 to 23 August), unusual oceanographic conditions were observed in the North Sea. Towed CTD (Delphin) and thermosalinograph data showed an inflow of low salinity water from the Baltic Sea/Skagerrak region spreading much farther than usual into the central and northern North Sea, as far as the Shetland Islands (Fig. 2). The Delphin data from the 58° N transect show that the low-salinity water did not spread beyond the upper 20 m layer (Fig. 3).

The cause of the strong inflow of Baltic Sea water into the North Sea was increased precipitation and river discharges into the Baltic. With predominantly northwesterly to northerly winds, which generally weaken the circulation system in the North Sea, Baltic Sea water flowed far westward in July. The weakened circulation system in the North Sea also led to a reduced inflow of Atlantic water into the North Sea. No Atlantic water was observed in the surface layer (down to 30 m) between the Shetland Islands and the Norwegian coast. Also the inflow of Atlantic water between the Orkney and Shetland Islands, characterized by salinities exceeding 35, was unusually weak. Similar conditions had been observed in 1987 (Dooley, pers. com.).

As early as May/June 2000, during a cruise of RV "Gauss" into the North Atlantic, the BSH had found that the subpolar gyre extended farther east than usual. This observation, together with the fact that a 10 to 30 percent weakening of North Atlantic Current transports was observed during the same cruise, is thought to be linked to the salinity decrease in the northern and central North Sea.

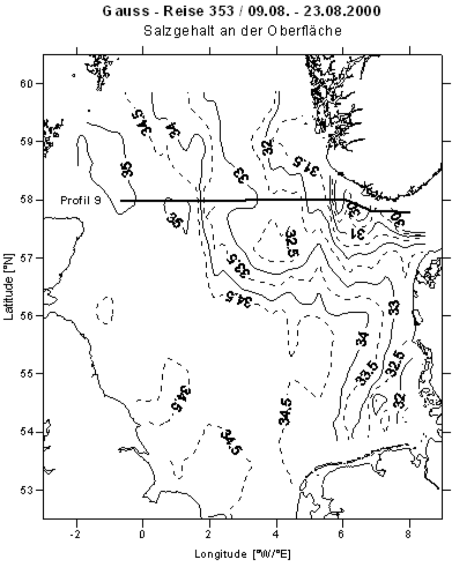


Figure 2: Surface salinities (4 m depth thermosalinograph data) 9 to 23 August 2000

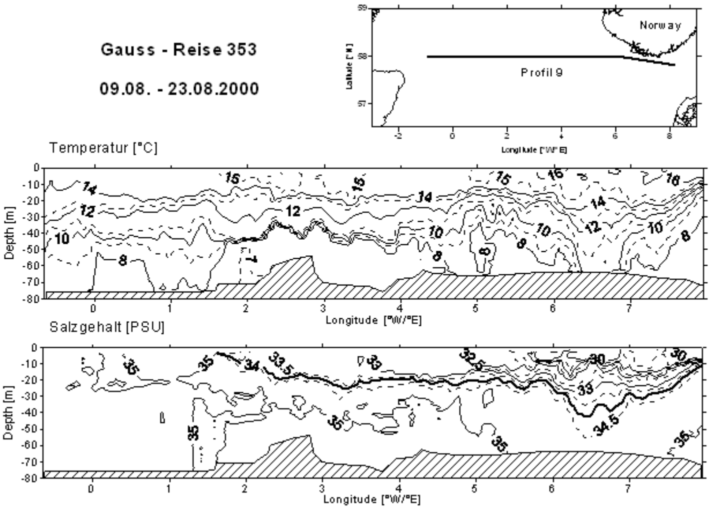


Figure 3: Temperature and salinity section 58° N (towed CTD-Delphin data)

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

Norwegian Sections

Harald Loeng, Institute of Marine Research,
P.O. Box 1870 Nordnes, 5817 Bergen, Norway

Summary

Reduced inflow of Atlantic water in 1999 and early 2000, lead to decreasing temperature in the North Sea, northern Norwegian Sea and the western Barents Sea in 2000. In the eastern Barents Sea the temperature was well above the average due to delayed cooling. There was an increasing temperature in the southern inflow area to the Norwegian Sea during the last half of 2000. Fig. 1 shows all Norwegian standard sections and fixed oceanographic stations.

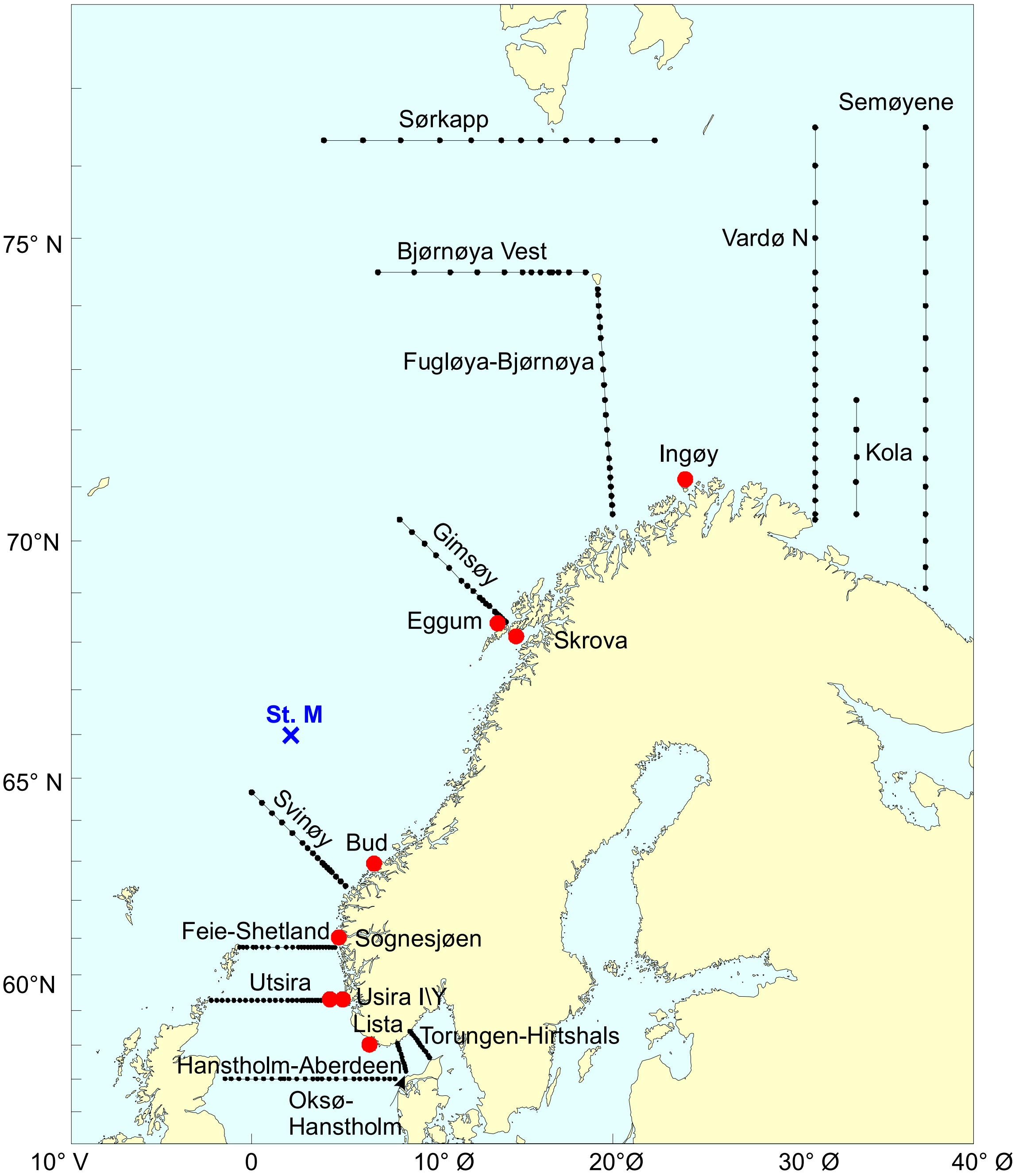


Fig 1. Standard sections and fixed oceanographic station worked by Institute of Marine Research, Bergen. The University of Bergen is responsible for station M, while the Kola section is operated by PINRO, Murmansk (ANON 2001)

The Norwegian Sea

The inflow of warm Atlantic water to the Norwegian Sea is still at a relatively high level. In combination with a warm autumn and first part of winter 2000/2001, temperatures above average are expected in the eastern part of the Norwegian Sea, as well as in the deeper layers along the Norwegian Coast in 2001. The western part of the Norwegian Sea is still influenced by relatively fresh and cold Arctic water. There is, however, an increased influence of Atlantic water in the upper layer of the central part of the Norwegian Sea north of Lofoten.

Fig.2 shows the development in temperature and salinity in three different sections from south to north in the Norwegian Sea (Fig. 1). 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. Compared with 1999, the temperature increased in the Svinøy-section while it decreased both in the Gimsøy and Sørkapp sections. The temperature was above the trend-line for the Svinøy- section, while it was below for the two other sections. Compared with the long-term average, the two southernmost sections had temperatures above the long-term average, while the temperature in the Sørkapp-section has been close to the long-term mean since 1996. The salinity showed the same trend as the temperature in 2000.

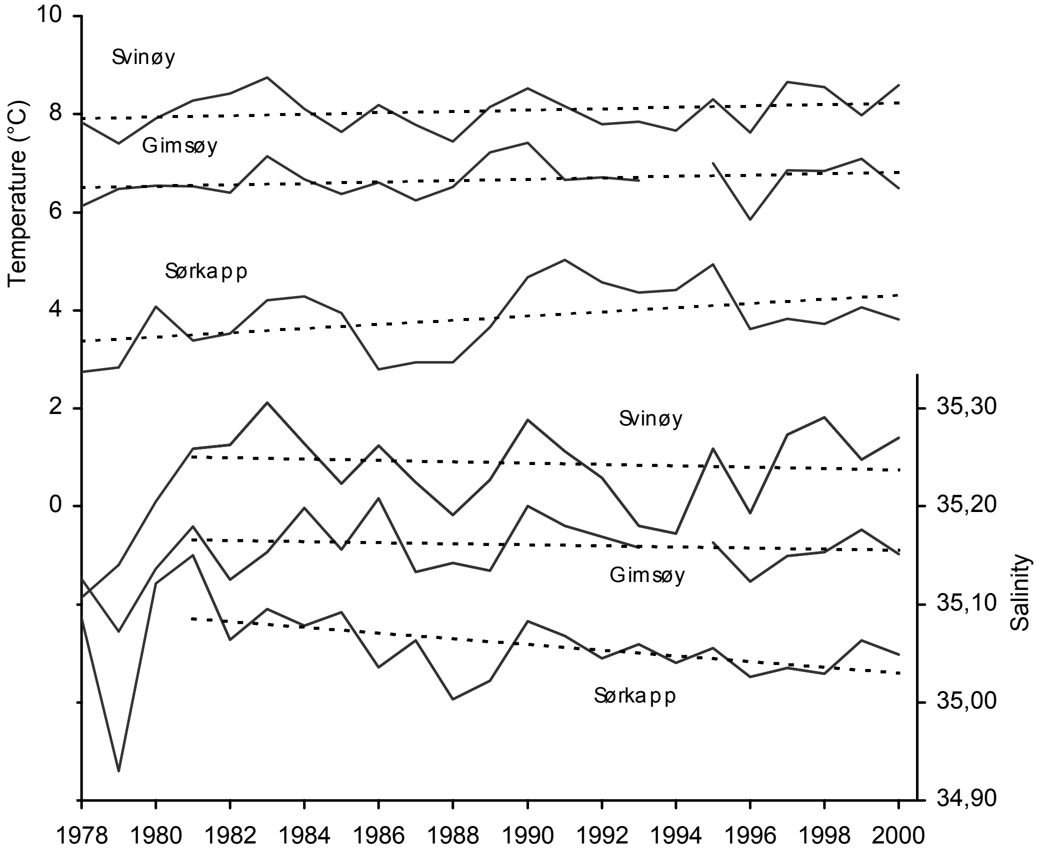


Fig.2. Temperature and salinity, observed in July/August in the core of Atlantic water in the sections Svinøy-NW, Gimsøy-NW and Sørkapp-W, averaged between 50 and 200 m depth. (ANON 2001)

The area of Atlantic water (defined with S>35.0) in the Svinøy-section has been calculated. The mean temperature within the limited area has also been calculated, and the results are shown in Fig. 3. There are considerable variations both in the area of Atlantic water distribution and its temperature. The distribution area of Atlantic water has decreased since the beginning of 1980s, while the temperature has shown a steady increase. During the years 1997-1999 the temperatures were the highest observed in this time series, while there was a considerable drop in temperature in 2000. While the area of Atlantic water has decrease with approximately 20% since early 1980s, the temperature has increased 0.5°C during the same period.

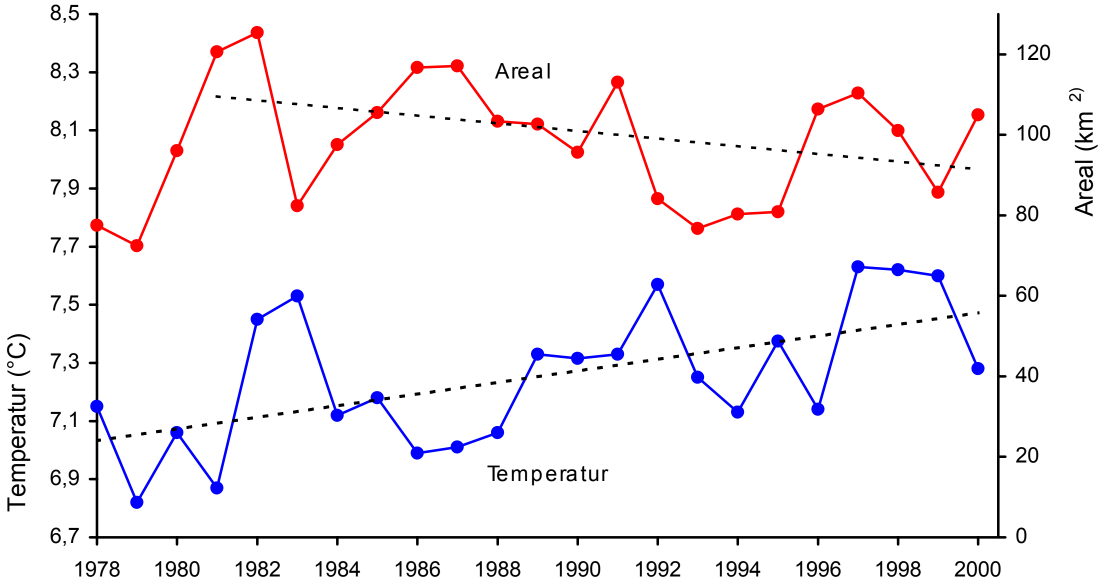


Figure 3. Time series of area (in km^2) and averaged temperature (blue) of Atlantic water in the Svinøy section, observed in July/August 1978-2000.

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, current measurements are carried out in the Fugløya- Bear Island section.

Fig. 4 shows the temperature and salinity anomalies in the Fugløya-Bear Island section in the period from 1977 to January 2001. 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 2000 the temperature increased rapidly to 1.1°C above the average, and thereafter dropped gradually to be just above the average during autumn 2000 (0.1°C in October). In January 2001 the temperature was 0.5°C above the average, which is a smaller increase in the temperature anomaly than the two previous years.

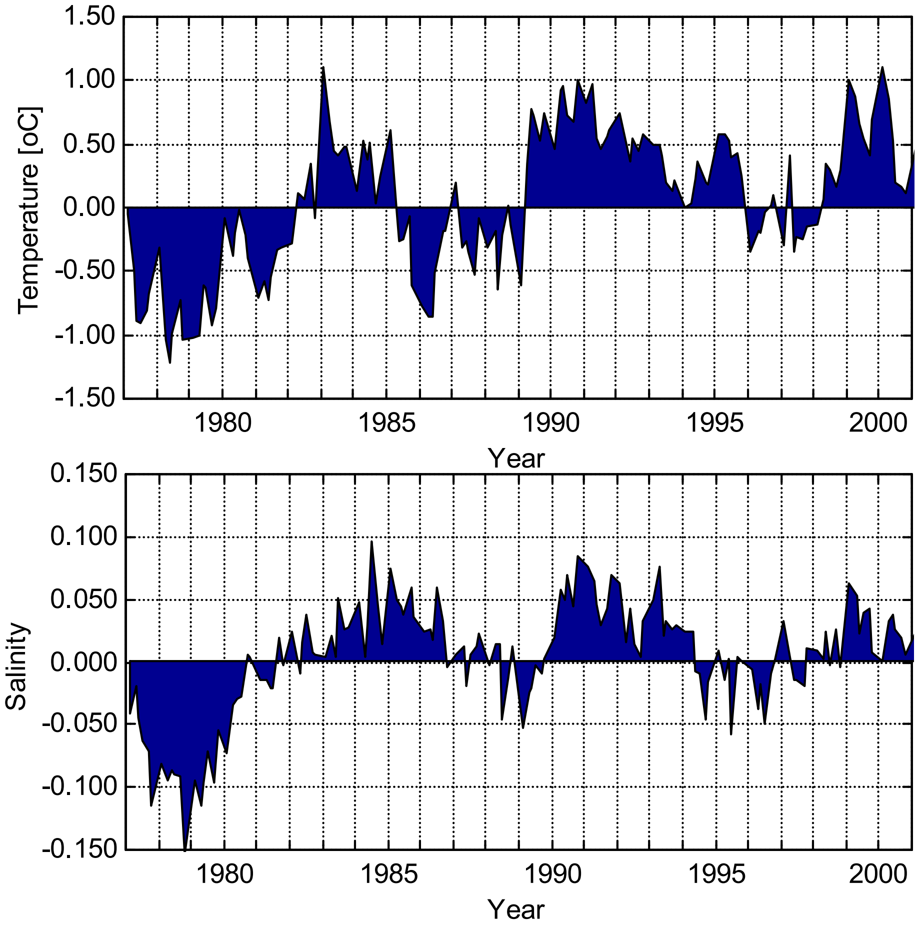


Fig. 4. Temperature anomalies (upper panel) and salinity anomalies (lower panel) in the section Fugløya – Bear Island (ANON 2001).

Fig. 5 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 (about one year), but usually the sea ice distribution in the eastern Barents Sea respond a bit later than in the western part. 2001 had less ice than the average, and the difference between 1999 and 2000 was due to slightly less ice in most of the Barents Sea during the winter.

The observed current in the section Fugløya-Bjørnøya is predominantly barotropic, and reveals large fluctuations in both current speed and lateral structure (Ingvaldsen *et al.,* 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.

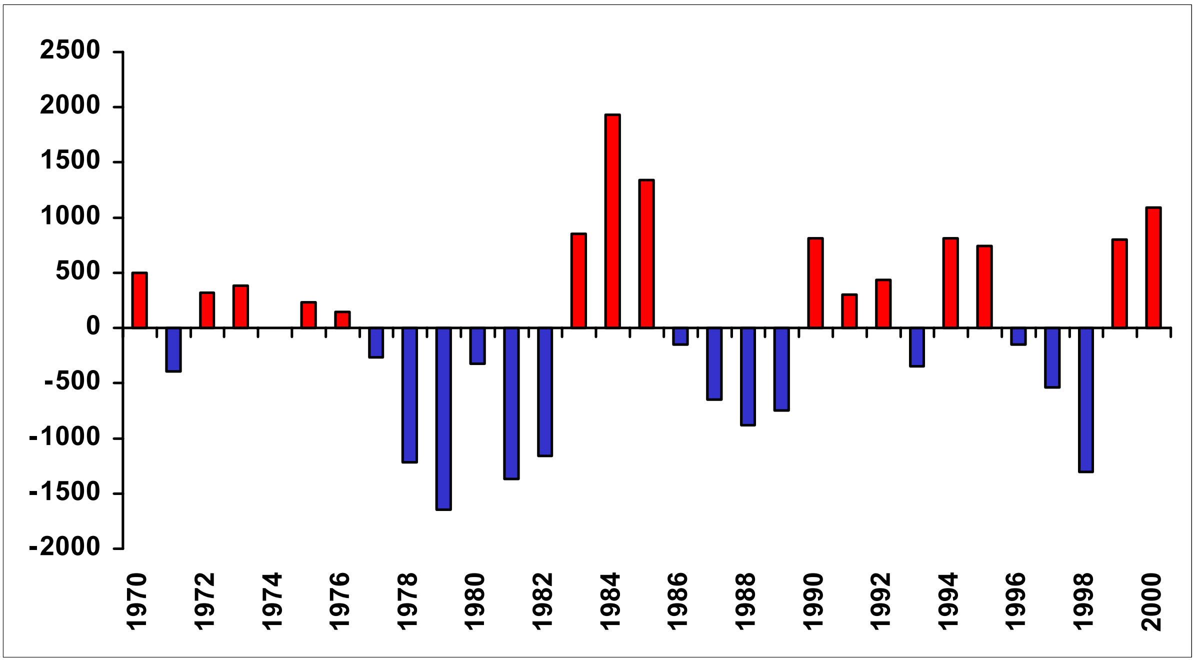
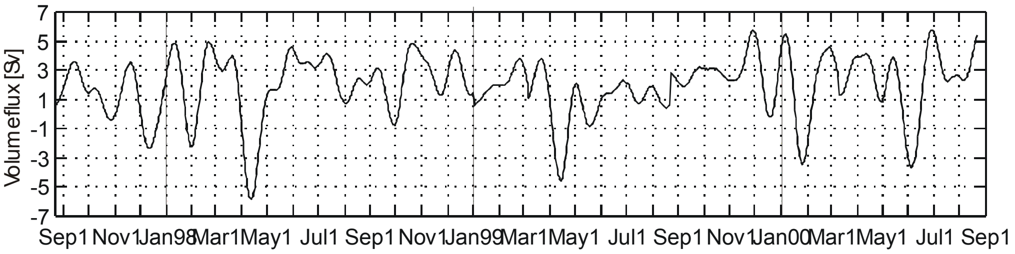


Fig. 5. Ice index for the period 1970-2000. Positive values means less ice than average, while negative values show more severe ice conditions (ANON 2001).

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.

The time series of volume and heat transports reveal fluxes with strong variability on time scales ranging from one to several months (Fig. 6). 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. The recirculation seems to be more stable at a value of something near 1 Sv, but with interruptions of high outflow episodes. High outflows occurred in April both in 1998 and 1999. In 2000 there were two periods with strong outflow, one in January and a second one in June. These outflow events are most probably linked to variations in the atmospheric pressure field as indicated by (Ådlandsvik and Loeng, 1991). The outflow events may have great impact on the import of zooplankton from the Norwegian Sea to the Barents Sea as described by Loeng and Ingvaldsen (2001).



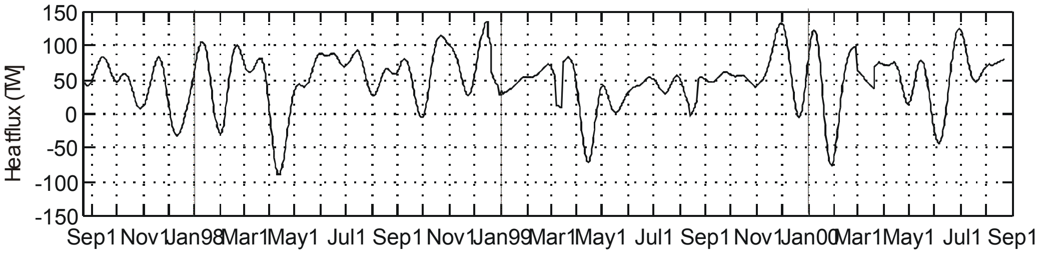
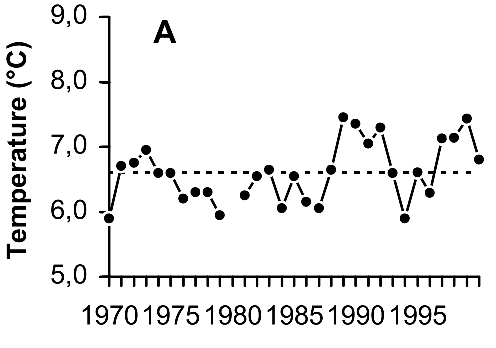


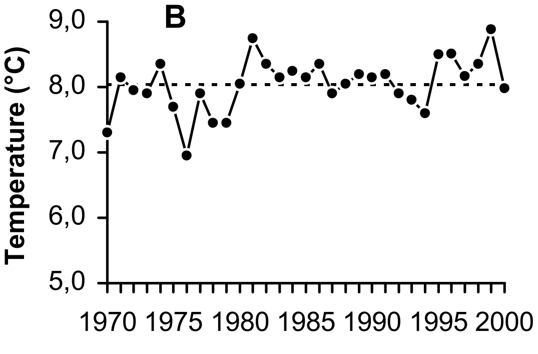
Figure 6. Total volume flux (upper panel) and total heat flux across the section (lower panel). All data have been lowpass filtered over 30 days (Ingvaldsen, pers. com.)

North Sea

The upper layer of the North Sea was warmer than average in 2000, except for the summer months. A warm autumn, combined with an increased influx of water from the south, resulted in unusually high temperatures in the upper 100m along the Norwegian coast. Fig. 7 shows the development of temperature and salinity at two positions, one near bottom in the northwestern part of the North Sea and the second 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. The average temperature at the plateau is 1-2°C lower that in the core of the inflowing Atlantic water (Fig. 7). Also the salinity is slightly lower at the plateau. At the plateau, there has been a continuous increase both in temperature and salinity from 1996 to 1999, while decreasing values were observed in 2000. The development is relative similar in the core of the Atlantic inflow. At both positions, the values from 2000 were rather close to the long-term average.

The Skagerrak coastal water is defined with salinity between 25.0–32.0. Water with lower salinity is defined as brackish water. Along the coast of southern Norway, there was brackish water in the surface layer from April to June. Also in the last half of October, lot of brackish water was observed due to very high precipitation over southern Scandinavia. The temperature in the upper layer of the coastal water was above the average the whole year. Especially, high temperatures were observed in November and December 2000. There was a relatively small exchange of water in the deep basin of Skagerrak. The inflowing water in 2000 had a relatively high temperature and salinity. The temperature is the highest since early 1990s, which was the warmest period observed in the deep water of Skagerrak. The density of the new basin water, however, is low, and a new inflow is therefore expected to take place in 2001 (ANON 2001).





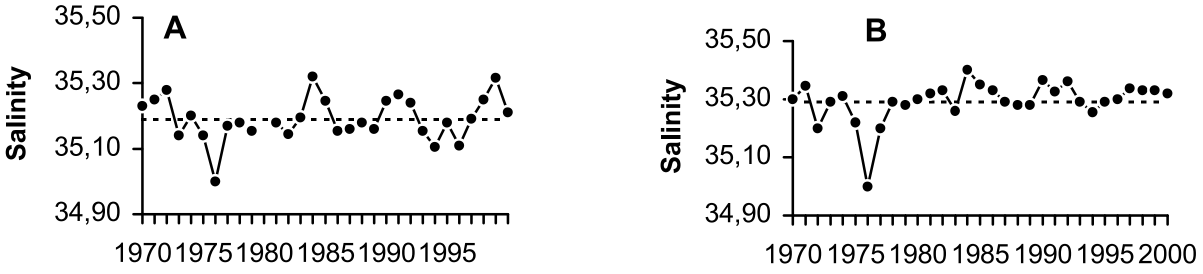


Fig. 7. Temperature and salinity near bottom in the northwestern part of the North Sea (A) and in the core of Atlantic water at the western shelf edge of the Norwegian Trench (B) during the summers of 1970-1999 (ANON. 2001).

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ANNEX T: AREA 11 (BARENTS SEA) POLISH REPORT

Report from r.v. 'Oceania' cruise AREX2000

by J. Piechura
Institute of Oceanology PAS, Sopot 81-712, Powst. Warszawy 55,
e-mail piechura@iopan.gda.pl

Hydrographic Data

From June 23 till July 14 fourteen CTD transects were performed, comprising the area between 69°30'N and 78°N and 001°E and 020°E (Fig. 1). In the Sorkapp region and at the northwestern part of the Svalbard shelf more dense coverage was made. Data were collected by use of a Seabird 9/11+ CTD probe.

VM-ADCP Data

During the entire cruise the vessel-mounted 150-kHz ADCP (RD Instruments) data were collected providing a quasi-continous currents measurements along the ship's track. ADCP does not measure current close to the sea surface, in our case in 0-16 m layer. The depth bin length was set to 8m. The ADCP data were averaged in 5 minutes ensembles – equivalent to 0.75 km horizontally at the ship's speed of 5 knots. These setting produce the random error in the horizontal density component of about 0.95 cm/s (RDI 1989).

Most of the measurements were done in the region where depth is bigger then the range of ADCP bottom-track (*ca*. 500 m) so we had to rely on navigation as a reference. In such case the crucial parameter for quality of data is misalignment angle. To solve this problem transects were run partly in the shelf region where bottom-track and navigation reference were available at the same time and allow us to compute misalignment angle. The procedure was repeated for each transect due to gyrocompass error (Osiński 2000).

The ADCP data were not detided what does not produce any significant error in deep region. At the same time in shallow areas, where tidal currents play significant role data were not presented so far.

Current measurements included into computation were collected when the ship was moving with speed in the range of 4-6 knots and with no change in direction. The minimum per cent good pings in the ensemble (Pg) was set to 75 and error velocity to 10 cm/s. ADCP reached the maximum depth of measured currents at about 500 m but due to quality control it was reduced to only 150 m.

Results

Broad stream of Atlantic Water, over 300 miles wide at the southernmost section, is narrowing on its way northward to less than 100 miles (Fig. 1). Very narrow stream of Atlantic Water at 75°N is caused by strong eddies - both cyclonic and antycyclonic. The core of Atlantic Waters is situated at the depth of about 100m in average (Fig. 2). On the western side of the stream and in cyclonic eddies around Bear Island and Sorkapp the core is found at the depth of *ca* 50-60m. In the centres of anticyclonic gyres it is pushed down to the depth more than 200m, reaching maximum depth of nearly 300m at 76° and 013°40'E. This very strong anticyclonic eddy together with intensive cyclonic one to the west of Sorkapp results in big horizontal gradients of temperature and salinity and large baroclinic transport to the southeast.

Maximum temperature in the core of Atlantic Waters, reaching about 8-9°C in the south, very slowly decreases to *ca* 6°C at the entry to the Fram Strait (Fig. 1). Its salinity drops very little as well from about 35.16 psu to 35.08 psu in the same area. Atlantic Water occupies most of the passage between Norway and Bear Island and part of the Bear Island - Sorkapp opening, namely the Storfjordrenna.

ADCP data (Fig. 3) generally confirm circulation patterns indicated already by T, S distributions (Fig. 1 & 2). There are signs of many eddy-like features, both cyclonic and anticyclonic, what results in frequent reversing of current direction and opposite flows along the measured sections. The strongest currents were observed along the continental slope and speed over 50 cm/s in the surface layer was recorded here. Second area of high current speeds is located in close vicinity of ridges and fracture zone. In the area contured by 73°N and 73°30'N and 005°E and 008°E strong currents are crossing Mohn's Ridge and leaving research area to the west. Probably these waters come back to the area farther north between 75°N and 76°30'N. That could be the reason why at more northerly transect N (76°30'N) transport is significantly higher than found farther south at transect KK (75°N, Fig. 5). Strong currents were measured in the northern part of Svalbard shelf, where Knipovich Ridge comes close to the continental slope and the deep area narrows. To the north of Knipovich Ridge currents turn to the west and even partly back to the south. Coming to the Fram Strait one branch of the WSC turns right, one left and another back to the south. Comparing currents at 50, 100 and 150 m depths one can see that the circulation pattern is preserved at all these depths. Current speed is decreased but only in the southern part, while approximately north of 76° the high values are maintained as well.

Volume transport in 150 m surface layer calculated from ADCP data (Fig. 5) show decrease of the northward transport from over 7 Sv in the south to below 1 Sv in the north and southerly directed transport behaves alike. There are also some exceptions like increase of northward transport between 75°N and 76°30'N. As it was mentioned earlier some additional inflows from the west could happen. Another explanation could be that transect along 75°N is too short in western direction and do not catch all transport to the north. Increase of southbound transport at the mouth of Isfjord could be caused by freshwater outflow from that fjord.

Calculated geostrophic currents above the 1000 db reference level (Fig. 4) at most sections reveal alternatively changing directions. This fact confirm great role of the mesoscale eddy-like structures, travelling with the main stream of Atlantic Water to the north. The strongest baroclinic forcing occurred along the continental slope where the main stream of Atlantic Water can be found. Calculated current's speed varies there from 15-20 cm/s in the south to 30-40 cm/s in the north. The second strongest branch of Atlantic Water was located mostly at the western side of our transect, along the ridges. Exceptionally weak baroclinic currents and transport were observed at the Barents Sea side, between Norway and Bear Island in particular. Calculated speed of geostrophic currents was not higher than 5-10 cm/s. Most probably the barotropic forces were dominating there.

Similar values were obtained at section Bear Island-Sorkapp except the area immediately to Sorkapp, where estimated current's speed exceeded 30 cm/s.

Calculated volume, heat and salt transport of Atlantic Water are presented in Table 2 and at Fig. 6. Net geostrophic transport of Atlantic Water toward the north decreases from about 7 Sv in the south to about 2 Sv at northern transects. At the northernmost section (79°50'N) net transport is directed to the southeast.

Amount of heat transported by Atlantic Water similarly falls down from *ca* 130×10^{12}W to *ca* 30×10^{12}W thus about 100×10^{12}W is lost to the atmosphere, to the Barents Sea and surrounding waters. Relative salt transport (above salinity of surrounding waters - 34.92 psu) also decreases about five times from more than 1000×10^3kg/s to *ca* 200×10^3kg/s. Corresponding data for the Barents Sea border show very small net transport of volume (below 1 Sv), heat (17×10^{12}W) and salt (75×10^3kg/s) to the east. Calculations for section U, bordering the measured area at western side and running from 78°N to 79°30'N and 000° to 003°E, reveal the westward transport equal 1.3 Sv, about 12×10^{12}W and 80×10^3kg/s volume, heat and salt respectively.

Summary

Calculated geostrophic currents as well as those measured by ship-mounted ADCP confirm existence of numerous mesoscale cyclonic and anticyclonic eddies in the main stream of the WSC. Moreover, the movement of the whole this system along the continental slope is observed. It is difficult to quantify shares of baroclinic and barotropic forcing but both have great influence on resulting flow, so has the bottom topography.

Northward stream of Atlantic Water brings huge amount of heat and salt to high latitudes; on its way from northern shores of Norway to the Fram Strait it looses about 100×10^{12}W of heat and 800×10^3kg/s of salt.

Obtained result are very preliminary, data are very fresh and will be processed further.

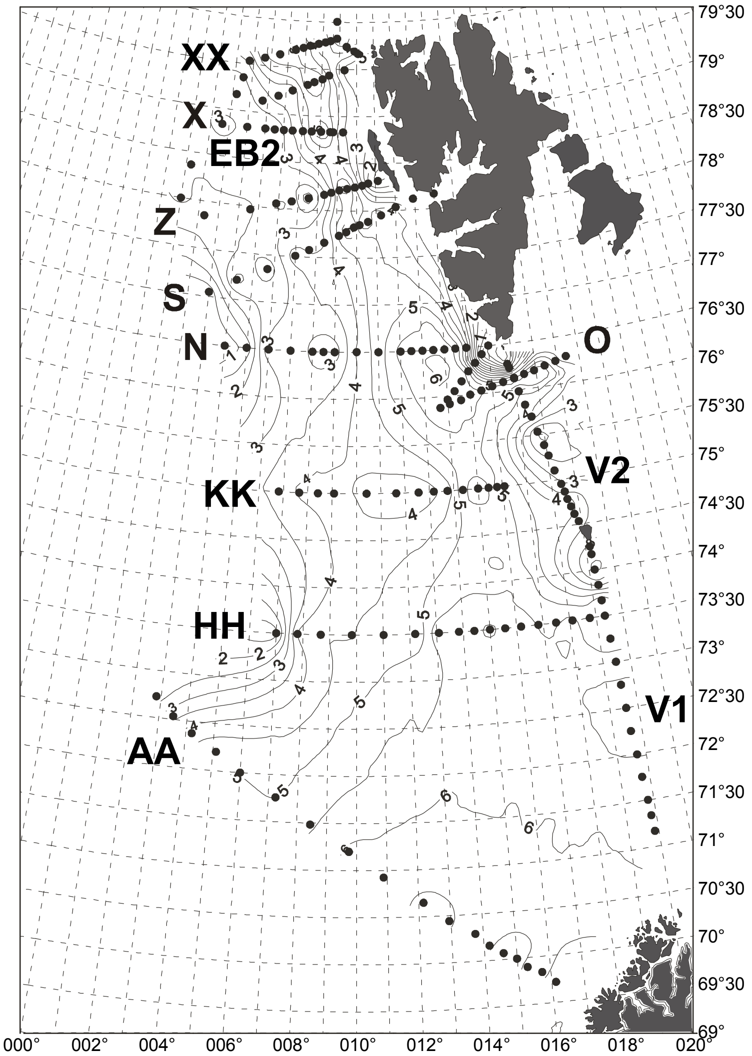


Fig.1 Horizontal distribution of potential temperature at the depth of 100 m.

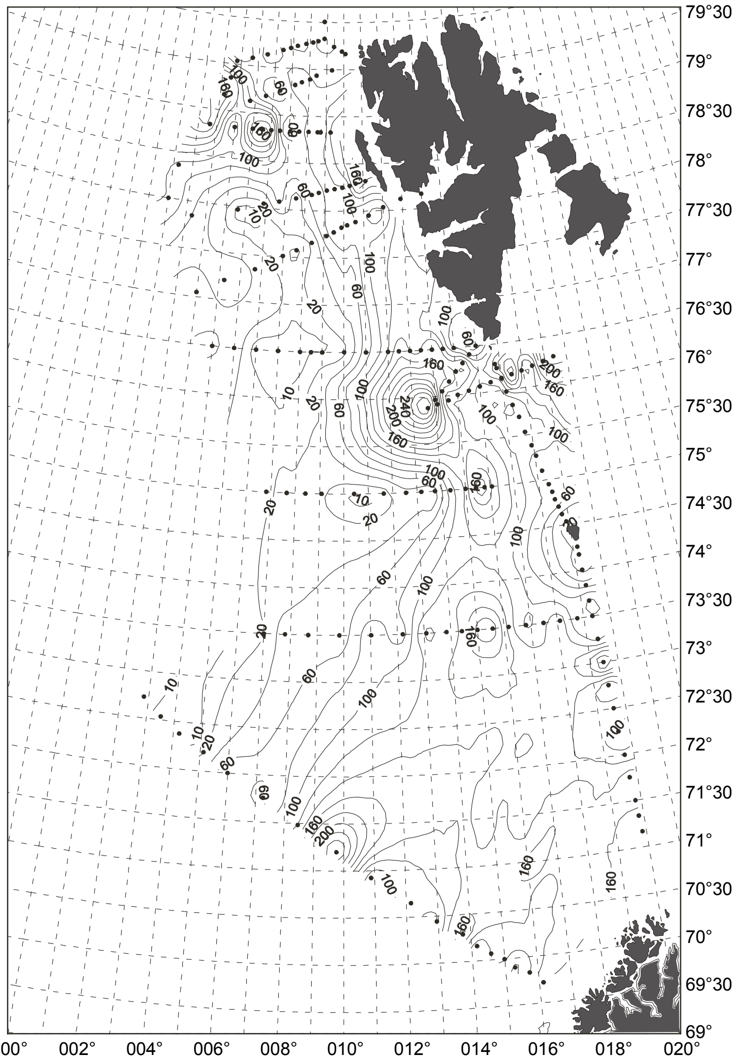


Fig.2 Horizontal distribution of the maximum salinity depth.

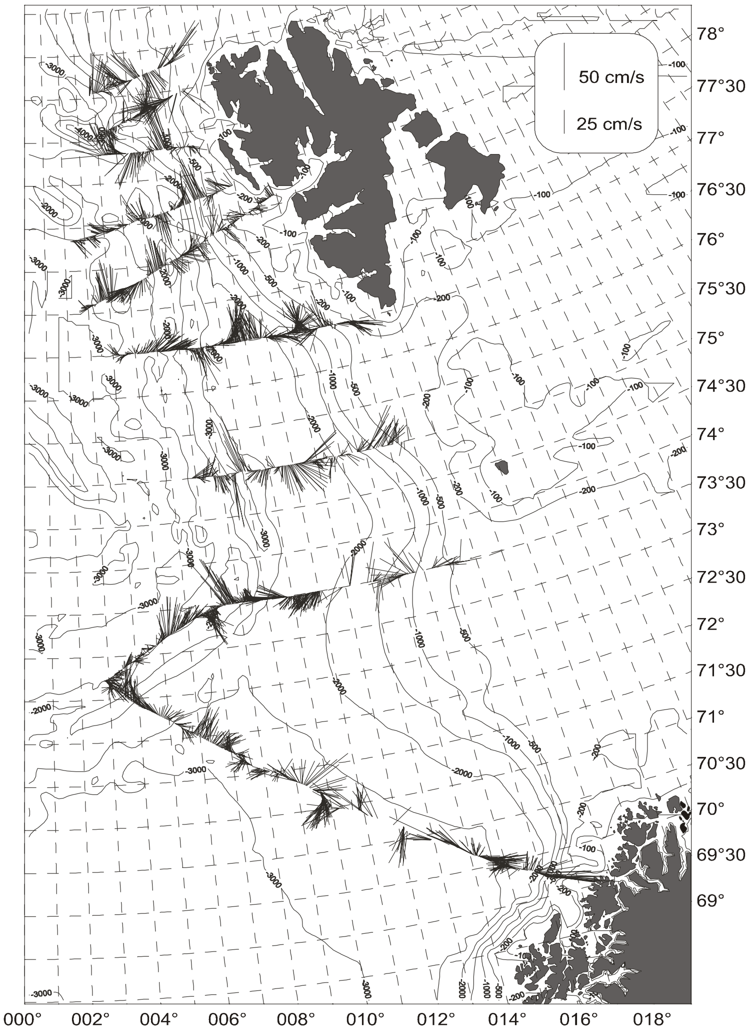


Fig.3 Current sticks at 150 m level.

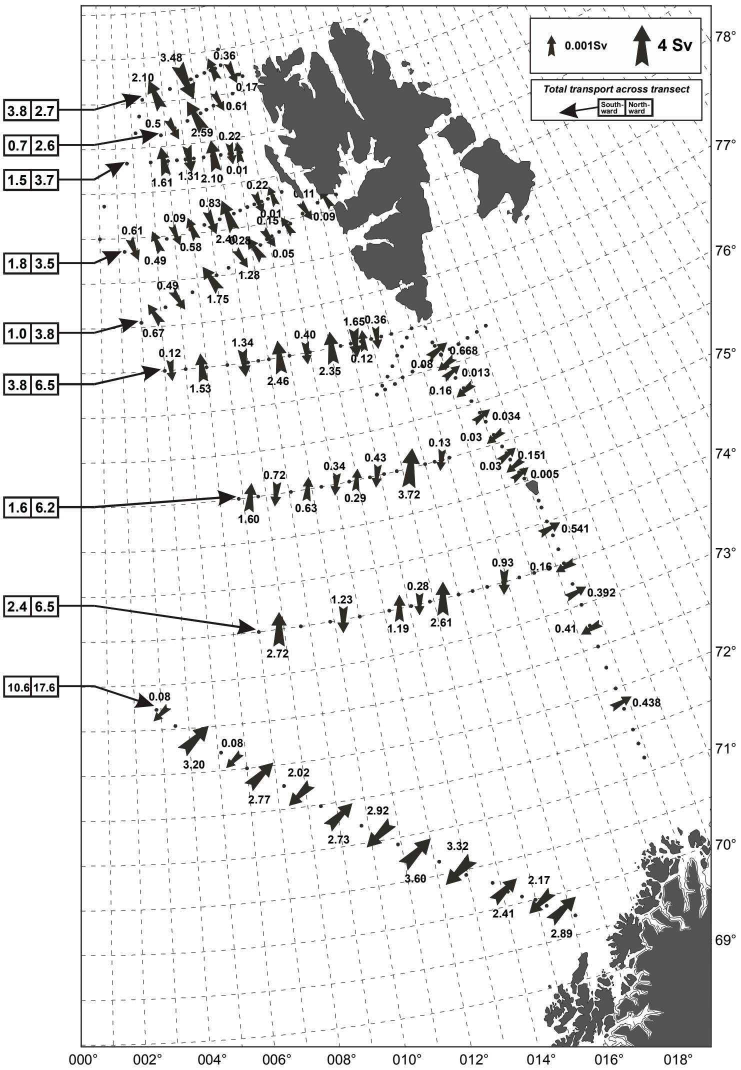


Fig.4 Calculated geostrophic transport across measured transects in upper layer of 1000 m.

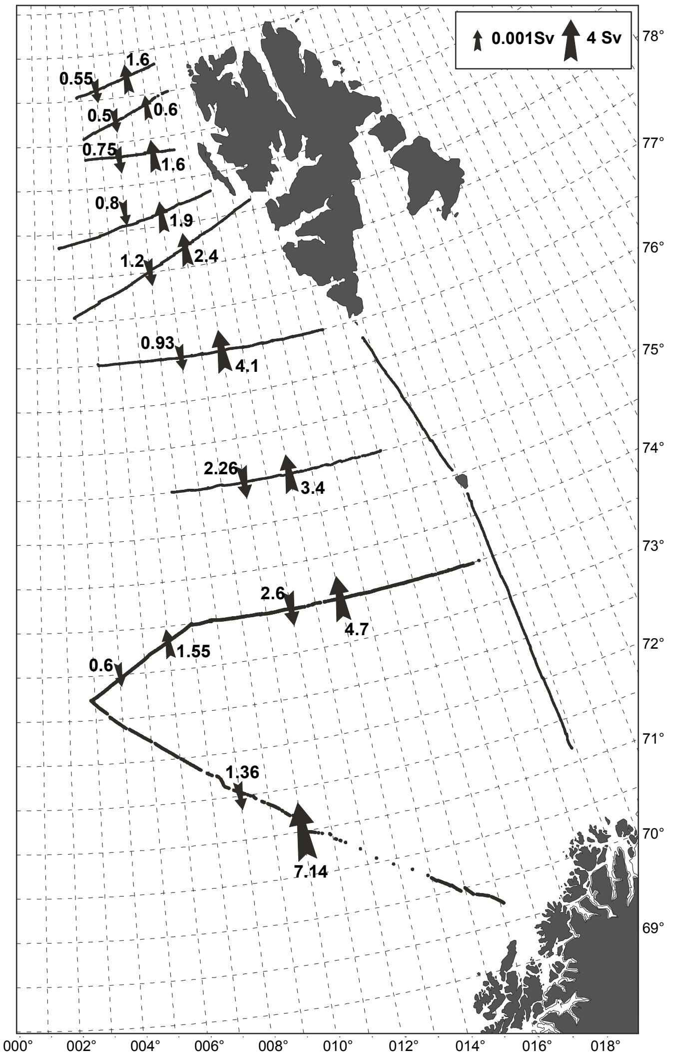


Fig.5 Measured total transport (ADCP data) across transects.

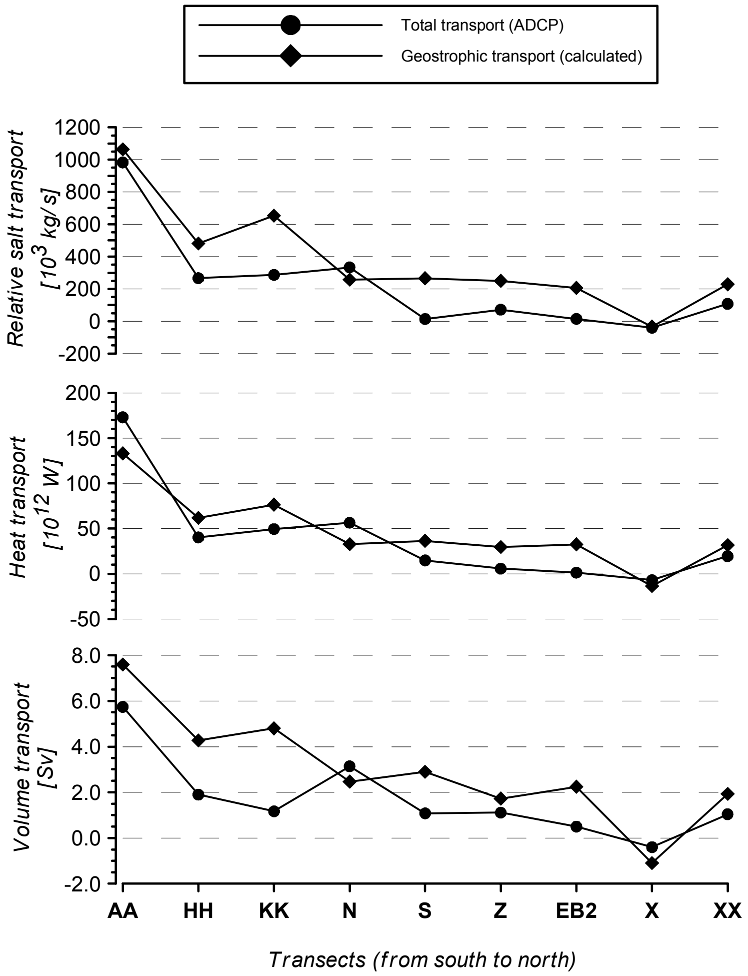


Fig.6 Geostrophic and total transport of volume, heat and salt across measured transects.

ANNEX U: 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

Position of main Russian standard sections in the Barents Sea is given in Fig.1. The Kola Section (along 33°30'E longitude) is the most regularly occupied one. In the year 2000 it was occupied 11 times. Measurements along the other sections were taken 2-4 times throughout the year.

In 2000, the oceanographic conditions in the Barents Sea were closely related to the large-scale atmospheric circulation that caused a predominance of the warm air masses over the sea.

The air temperature over the sea at the beginning of the year was on the whole higher than normal by 2-4°C. In March-May, temperature decreased to the long-term mean level over most of the sea. During summer months (June-July) the thermal state of air masses was close to its long-term mean or slightly (1-2°C) above normal. A considerable rise in the air temperature positive anomalies (3-4°C) was observed over the entire Barents Sea in autumn.

The ice conditions in the Barents Sea in 2000 were much more favourable than in 1999 and the most favourable over the recent ten years. Throughout the year the ice coverage was much lower than normal and no ice practically occurred over the sea in summer (July-September). At the end of the year, due to a higher heat content of water and to a transport of air masses from the south, the ice formation processes were retarded, and the areal coverage was lower than long-term mean.

The sea surface temperature (SST) in 2000, in contrast to 1999, was characterized by predominance of positive anomalies and their spatial uniformity. Especially this was typical of the winter-spring period when warmer-than-normal temperatures spread all over the Barents Sea. During the subsequent period (April-August) a decrease in the SST was observed in the western sea, as well as a rise in the positive anomalies in the southeast. At the end of the year the trends were opposite, however, the SST notably exceeded the long-term mean over the entire sea.

Increased transport of heat by the warm currents appeared to be the main feature of the oceanographic conditions in the Barents Sea in 2000. In contrast to the previous year, higher amount of heat entered the southern and eastern Barents Sea. Maximum positive anomalies of depth-averaged temperature in the Atlantic waters were observed during the winter-spring period. Further, slow decrease in temperature to the level slightly exceeding the long-term mean was observed in the southwestern Barents Sea. At the same time, considerably warmer-than-normal temperatures were typical of the northwestern and eastern areas.

Temperature variations in the Kola Section in 2000 (Fig.2) were similar to those of SST in the western Barents Sea. Depth-averaged (0-200 m) temperature of the Coastal and Main branches of the Murman Current was considerably higher than normal throughout the year. Maximum positive anomalies (0.9-1.0 °C) were observed in January-February 2000. In summer and autumn (July-October) temperature decreased to 0.5-0.6 °C above normal. A significant increase in temperature occurred in November. In January-February 2001 positive anomalies reached 0.9 °C. Thus, 2000 was a warm year; annual temperature in the Kola section (0-200 m) was 0.7 °C above the long-term mean (Fig. 3). Temperature decrease is expected in the Barents Sea, however, 2001 will be a moderately warm year.

The Norwegian Sea

Oceanographic observations along the standard sections in the southern and central Norwegian Sea have been carried out by PINRO in June since 1959. Unfortunately, these areas were not surveyed in June 2000. A number of standard sections were occupied in the northern sea only in July (Fig.4). No surveys have been carried out in these areas since the beginning of the 90s. The Section 11-C is regularly occupied during the 0-group fish survey in late August - early in September. Measurements along this section were taken two times in 2000.

The Icelandic Low determined weather conditions over the Norwegian Sea. Air temperature over most area in the first half of the year was 1-2 °C lower than normal or close to the long-term mean. Beginning from August, the southerly winds steadily prevailed that contributed to a rise in the air temperature and to its positive anomalies (1-2 °C) in autumn.

In January-April, the SST in the eastern sea was 0.3-0.5 °C higher than normal. In the central, southern and western areas it was close to the long-term mean or lower (to –0.5°C). In summer the SST over most sea was low, with the negative anomalies reaching 0.5-0.6 °C. Substantial heating of the sea surface layer in August-September resulted in positive SST anomalies (0.3-0.6 °C) in autumn, especially in the central Norwegian Sea.

Oceanographic conditions in the northern Norwegian Sea in July and in August-September 2000 were characterized by warmer-than-normal temperatures in the upper 200-meter layer (Figs.5-6). Such conditions were probably caused by the intensified transport of warm Atlantic water by the Norwegian Current. Significant increase in salinity, compared to preceding years, gives another evidence of enhanced transport of Atlantic water northward. Oceanographic conditions in the northern Norwegian Sea during summer 2000 were close to those of the early 90s.

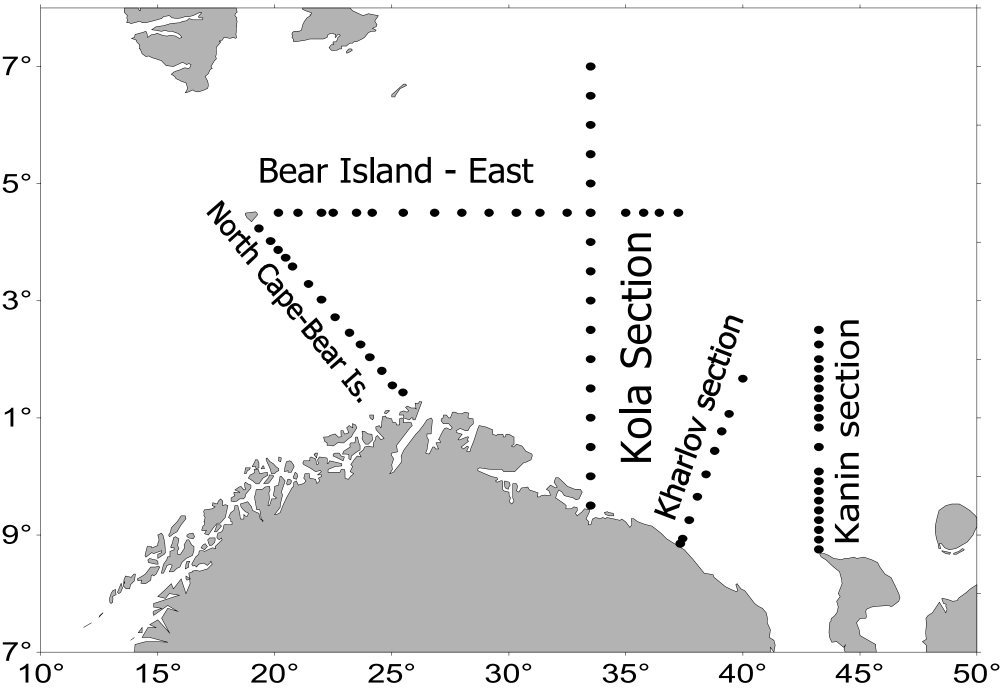


Fig. 1. Main Russian standard sections in the Barents Sea

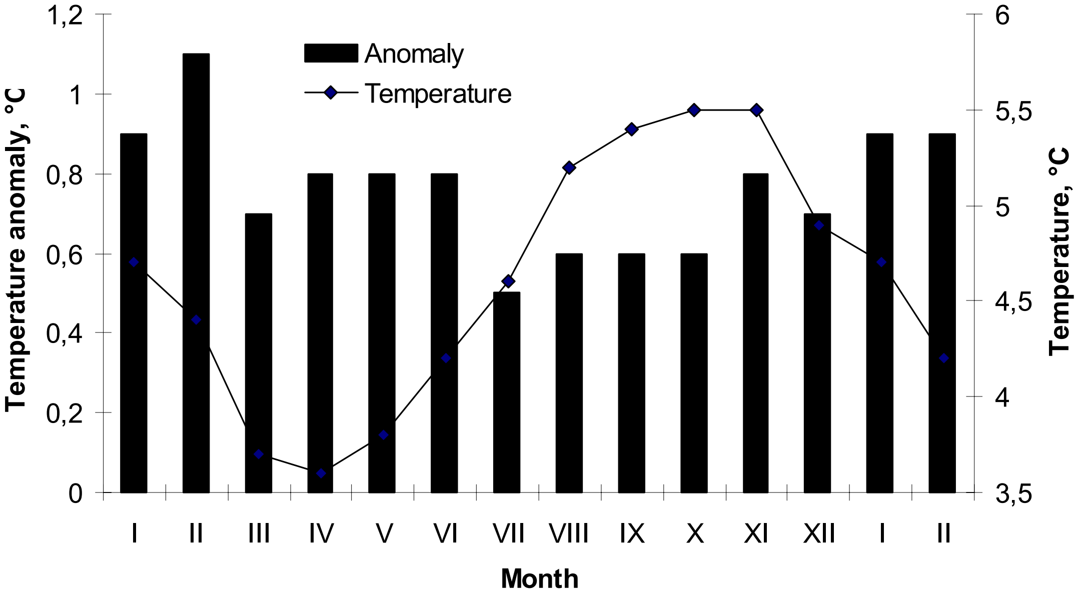


Fig. 2. Monthly mean temperature and its anomalies in the 0-200 m layer in the Kola Section in 2000 and at the beginning of 2001

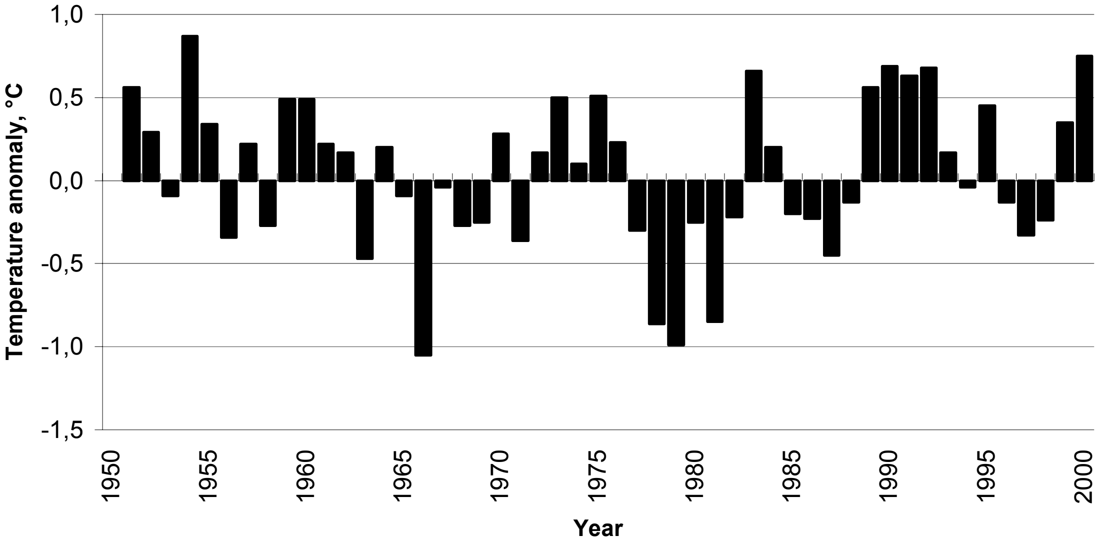


Fig. 3. Yearly mean temperature anomalies in the 0-200 m layer in the Kola Section in 1951-2000

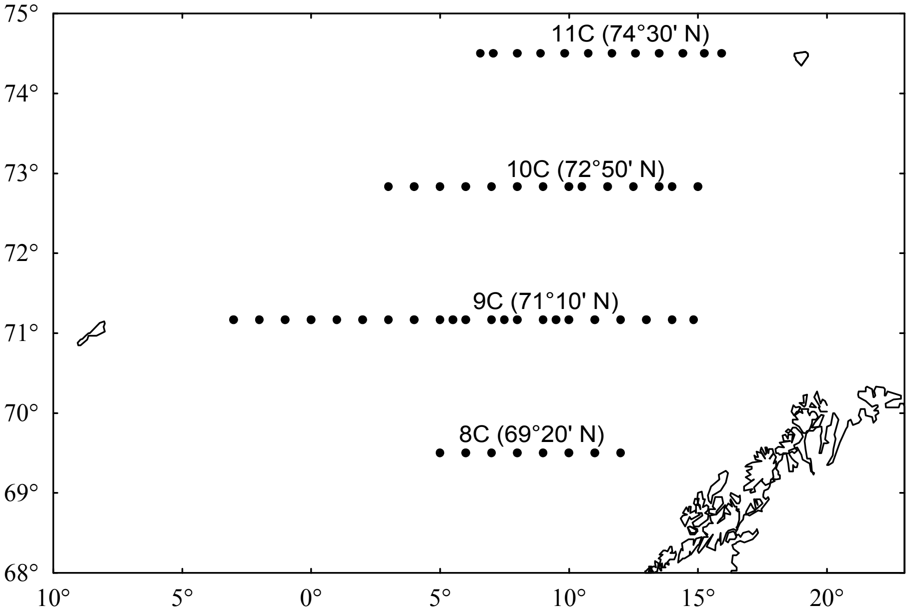


Fig. 4. Standard sections and stations in the Norwegian Sea occupied in June 2000

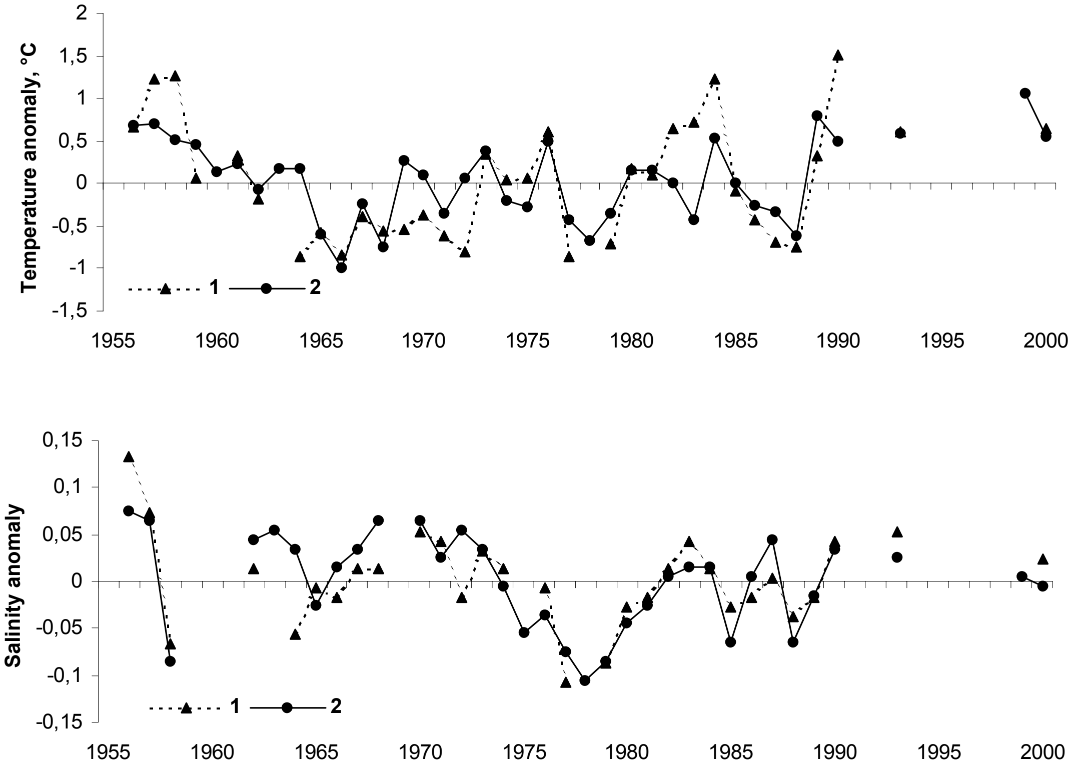


Fig. 5. Temperature and salinity anomalies of Atlantic water of the Norwegian Current in the section 11-C (0-200 m) in July 1966-2000: 1- Middle Branch (74°30′N, 09°50′-12°35′E); 2 – Eastern Branch (74°30′N, 13°30′-15°55′E);

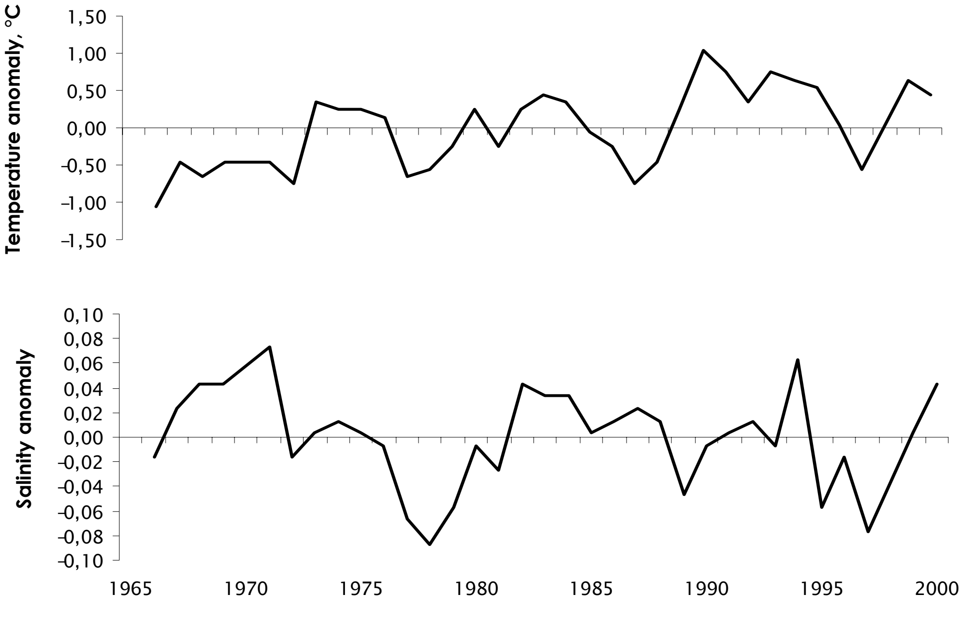


Fig. 6. Temperature and salinity anomalies of Atlantic water of the Norwegian Current in the section 11-C (74°30′N, 06°34′-15°55′E) (0-200 m) in August-September 1966-2000

ANNEX V: AREA 12 (GREENLAND SEA) GERMAN REPORT

Hydrographic conditions in the Greenland Sea and Fram Strait

Report by E. Fahrbach
Alfred Wegener Institute for Polar and Marine Research, Postfach 12 01 61, 27515 Bremerhaven, Germany

The hydrographic conditions in the Greenland Sea and Fram Strait were monitored by several institutions since many years, e.g. the Norwegian Polar Institute and the Alfred Wegener Institute. Here we present time series compiled from a variety of data sets to describe the longer term variability of the properties of Atlantic Water in the Greenland Sea. We distinguish between the northward flowing "original" Atlantic Water in the eastern part of the area and the return flow in the west. Two sections were used (Fig.1). The data from the southern one along 75° N were provided by G. Budeus (AWI). The northern section is located approximately at 79°N, but varied slightly in different years. During the last years the Fram Strait sections were measured in the framework of the European Union MAST III Programme VEINS (Variability of Exchanges in the Northern Seas). The properties were calculated by U. Schauer and H. Rohr. Earlier values were supplied by M. Marnela and Bert Rudels from the Finnish Institute of Marine Research. Additional data were obtained from the ICES Data Centre in Copenhagen. The effort to add data from earlier years is still going. It is planned to continue the time series. Cruises are scheduled for 2001.

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 Fig. 2. 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. 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+.

The variations of the water mass properties in Fram Strait are displayed in Fig. 3. Mean temperatures and salinities are given 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 Polar Water in the East Greenland Current (EGC) between 3°W and the Greenland shelf. It has to be noted that the data from Fram Strait are scattered from spring to autumn and consequently affected by the annual cycle which is most pronounced in the upper layers. Therefore, the observation time indicated in the figure has to be taken into account.

We did not draw lines between the data points, because the annual repeats during the recent period indicate that the interannual variability might be as intensive as the decadal variation. Therefore we have to take into account that during the data poor period interannual fluctuations might have occurred. This is of particular importance if the time series from the two areas are compared, because the data were partly measured in different years.

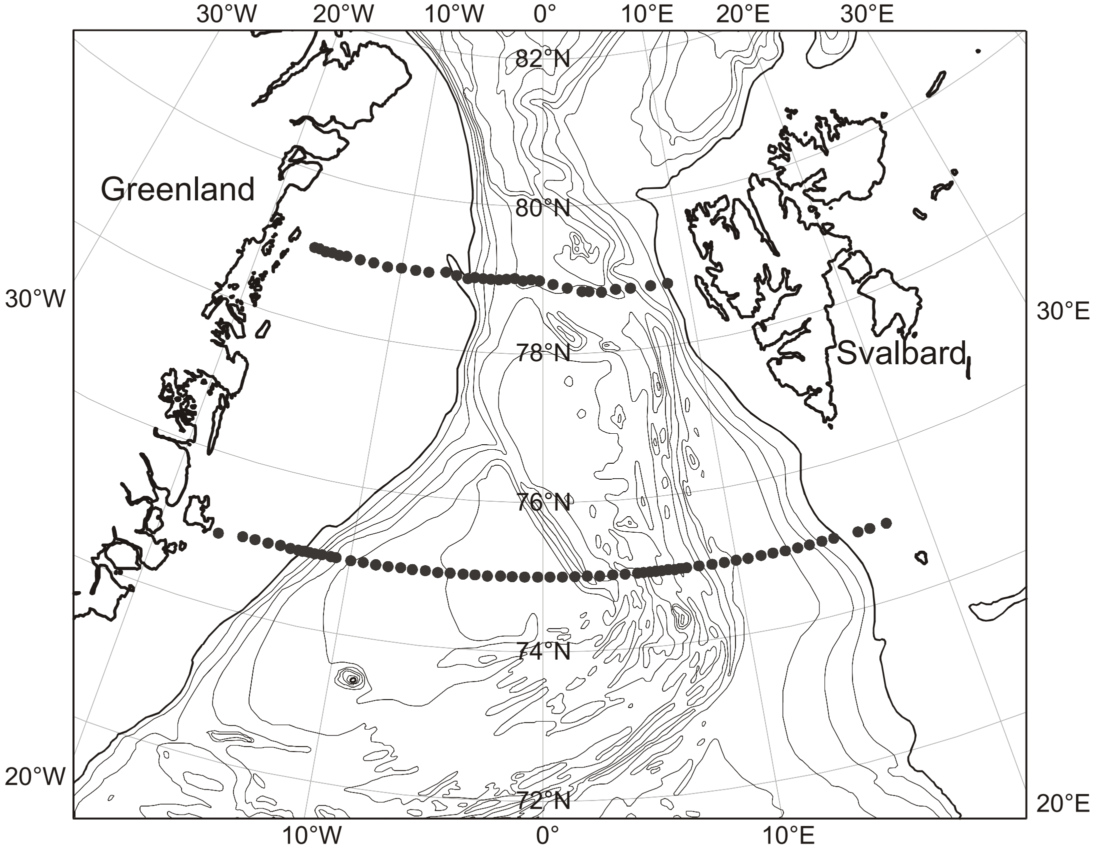


Fig 1: Map with the positions of the CTD sections carried out at 75° N in the Greenland Sea and in Fram Strait.

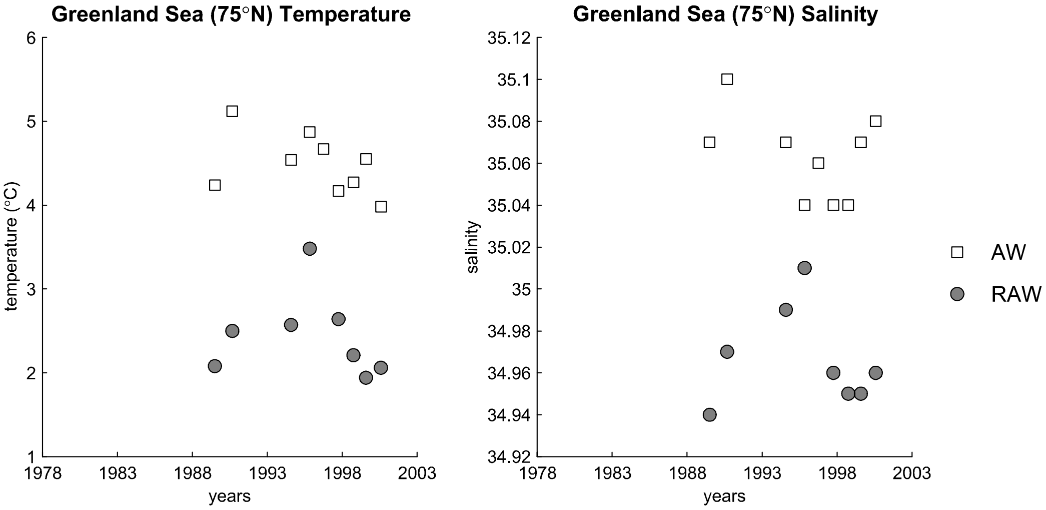


Fig. 2: The variations of the properties of the Atlantic Water (AW) and the Return Atlantic Water (RAW) observed on the CTD-transects at 75°N supplied by G. Budeus.

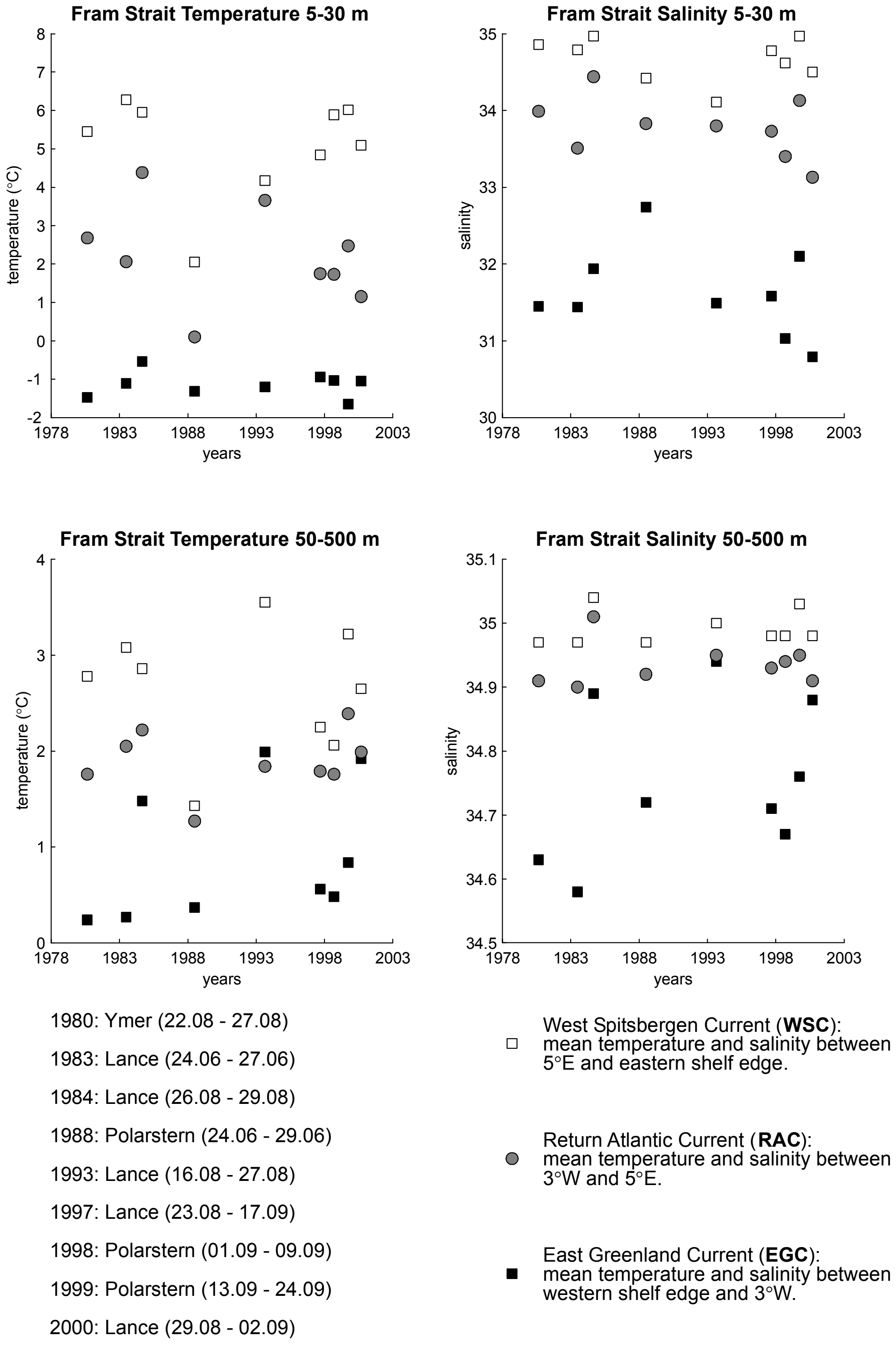
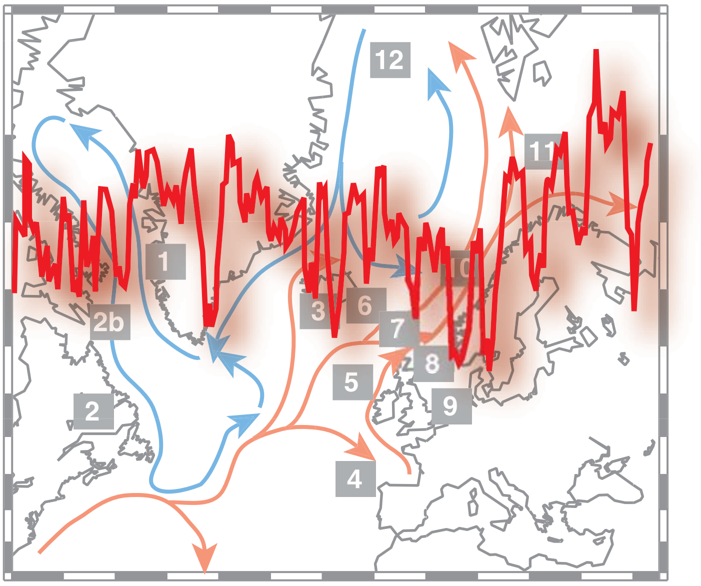


Fig. 3: The variations of the mean temperatures and salinities in Fram Strait in the West Spitsbergen Current (WSC), the Return Atlantic Current (RAC) and the East Greenland Current (EGC). The values were supplied by U. Schauer (AWI), H. Rohr(AWI) and M. Marnela from the Finnish Institute of Marine Research.

ANNEX W – IAOCSS 2000/2001

The Annual
ICES Ocean Climate Status Summary
2000/2001



Prepared by the
Working Group on Oceanic Hyrography

Editors
Bill Turrell and N. Penny Holliday

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The 2000/2001 ICES Annual Ocean Climate Status Summary

Overview

The North Atlantic Oscillation (NAO) Index continued to recover to positive values up to and including winter 2000 (winter is defined by the year of the January), though with some indication of an eastward shift in the NAO dipole pattern. The result was that most parts of the area under review showed moderate or warm conditions in 2000. Though the climatic data set for winter 2001 is not yet complete, early indications are that the NAO index has undergone a sharp return to negative conditions.

Surface temperatures off West Greenland were relatively warm during the summer of 2000 due to mild atmospheric conditions. Stronger inflows of polar water were noted.

Ocean conditions in the Northwest Atlantic cooled slightly during 2000 relative to 1999 values, but were near or above normal in most areas. Sea-ice extent also increased slightly over the light ice conditions of 1999. An increased southward transport of polar waters was noted on the Labrador shelf.

The surface waters of the Labrador Sea were observed to be slightly cooler, fresher and denser in the summer of 2000 compared to 1999. More convection and overturning took place in the Labrador Sea during the 2000 winter than in recent years, but not as intense as during the early 1990s.

In Icelandic waters, 2000 revealed in general relatively high temperatures and salinities as in the last 2-3 years, following the very cold years of 1995 and 1996, although temperatures were also cooler than 1999 in this area.

The annual mean air temperature over the southern Bay of Biscay during 2000 remained at nearly the same value as during the two preceding years. Surface waters were slightly cooler and fresher than in previous years.

Early 2000 saw a peak in the temperature of surface waters in the Rockall Trough, caused by an influx of unusually warm water into the region. By the spring of 2000 the temperature had dropped somewhat, though remained above the long-term mean.

2000 was the sixth warmest year since 1971 in the North Sea, in terms of annual mean sea surface temperature. All months were warmer than average, except for June and July. There was evidence of a large input of freshwater from the Baltic.

Since 1996, temperatures are increasing in the southern and central Norwegian Sea. In 2000 the warming continued at the southern section while a cooling occurred at the central section. In the northern Norwegian Sea the temperature since 1996 has been close to the long-term average.

The temperature in the Barents Sea decreased from 1°C above average during early winter to 0.2°C in the autumn. In the eastern Barents Sea stayed high during the whole year.

A larger than normal inflow of Atlantic water results in warmer and more saline conditions in the eastern Greenland Sea.

Prognosis

There are indications that in the winter 2000/2001 the "recovering" NAO Index will have undergone a further rapid reversal to negative values. If correct we can expect warming in the NW Atlantic and cooling in the east.

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) knowledge of its past and present behaviour forms an essential context for the interpretation of observed ocean climate change in 2000.

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

When we consider the winter NAO index for the present decade, and the present decade in the context of this century (Figure 1), the 1960s were generally low-index years while the 1990s are high index years. There was a major exception to this pattern occurring between the winter preceding 1995 and the winter preceding 1996, when the index flipped from being one of its most positive values to its most negative value this century. The index rose from the extreme low, and the recovery continued during the winter preceding 2000. Thus 2000 has a positive NAO index. during winter

However, although the simple index continued to increase back to positive values during the winters preceding 1999 and 2000, the actual pattern of the NAO over the ICES area did not recover to a "normal" distribution expected during high NAO years, but was rather displaced towards the east or northeast. This subtle change had most impact in the northwest Atlantic, where instead of a chill and strong north-westerly airflow promoting cooling there, as it did in the early 1980s and 1990s, any north-westerly airflow was mainly confined to the east of Greenland, while the Labrador Sea was occupied by light or southerly anomaly-winds (ICES 2000).

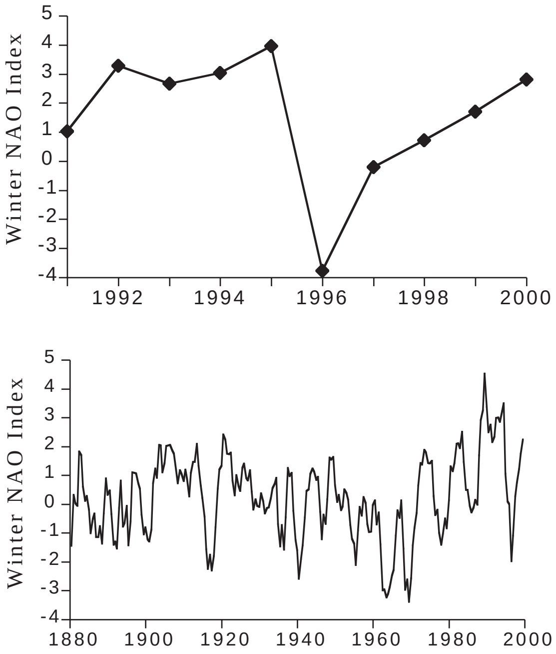


Figure 1. *The winter NAO index in terms of the present decade (upper figure) and the present century (lower figure - a 2 year running mean has been applied).*

It would appear that the winter of 2000/2001 might be exhibiting another sudden reversal similar to that seen in 1995/1996. Text Box 1 has the details. However, Text Box 2 adds a cautionary note about over-interpreting the simple NAO index.

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).

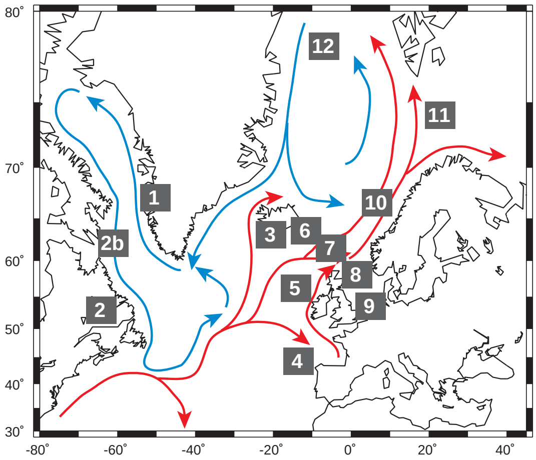


Figure 2*. Schematic of the general circulation of the North Atlantic in relation to the numbered areas presented in the 2000/2001 Annual ICES Ocean Climate Status Summary. The blue(light grey) arrows indicate the cooler waters of the sub-polar gyre. The red (dark grey) arrows show the movement of the warmer waters in the sub-tropical gyre.*

Text Box 1 - The NAO in winter 2001: early indications of a sharp return to NAO-Negative conditions

Background

The characteristics of the NAO and many aspects of the ocean's response were described in the equivalent context-setting sections of previous ICES Annual Ocean Climate Summaries. 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 large and rapid decrease in winter 1995–1996 and both the 1999 and the present IAOCSS describe the recovery to more positive values since then. Though the March 2001 atmospheric pressure values are not available at the time of writing, the evidence is that the "recovering" NAO Index will be found to have undergone a further rapid reversal to negative values.

The NAO in winter 2001

Figure 3 describes the Atlantic distribution of sea level pressure anomaly in (a) December 2000, (b) January 2001 and (c) February 2001 respectively, with panel (d) showing the December to February composite (NCEP/NCAR Reanalysis data from the NOAA-CIRES Climate Diagnostics Centre: www.cdc.noaa.gov/Composites). In every month but especially in December and February, the NAO dipole pattern is configured in such a way that the more northerly (southerly) cell exhibits a positive (negative) sea level pressure anomaly, so that the composite is strongly NAO-negative. With centres over Iceland-Greenland and Azores-Biscay, it is difficult to detect any marked difference from the classical EOF-1 sea level pressure anomaly distribution.

Monthly values of the Jones Gibraltar-Iceland index (www.cru.uea.ac.uk) are listed for December 2000 and January 2001 only, as –1.41 and + 0.02 respectively, but inspection of the individual monthly maps confirms that because of the locations of Lisbon and Gibraltar in relation to the southern pressure-anomaly centre, the Gibraltar-Iceland pressure pair is likely to record a smaller pressure difference than Lisbon-Iceland.

Ocean Response

The return to strongly NAO-negative conditions, however briefly it lasts, is likely to have an important bearing on the ocean and ecosystem response. This stems from the dominant role of the winter NAO in driving both, and in particular its control of all three of the factors that alter the ocean's circulation (wind speed and direction, evaporation minus precipitation and the fluxes of sensible and latent heat). The responsiveness of the ocean is now known to be sufficiently rapid to reflect even short-term annual changes in the NAO. The large-amplitude but short-lived drop in the Index in 1996 showed that a clear response was evident in a wide range of parameters, including 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 sea temperatures and cod recruitment of the southern North Sea.

Though the NAO pattern for the full winter is not yet available and though the ocean's response has still to be worked through, this interim report is compiled both as a pointer to the sorts of environmental changes that are likely to appear in our observations. Text Box 2 adds a cautionary note about over-interpreting the simple NAO index.

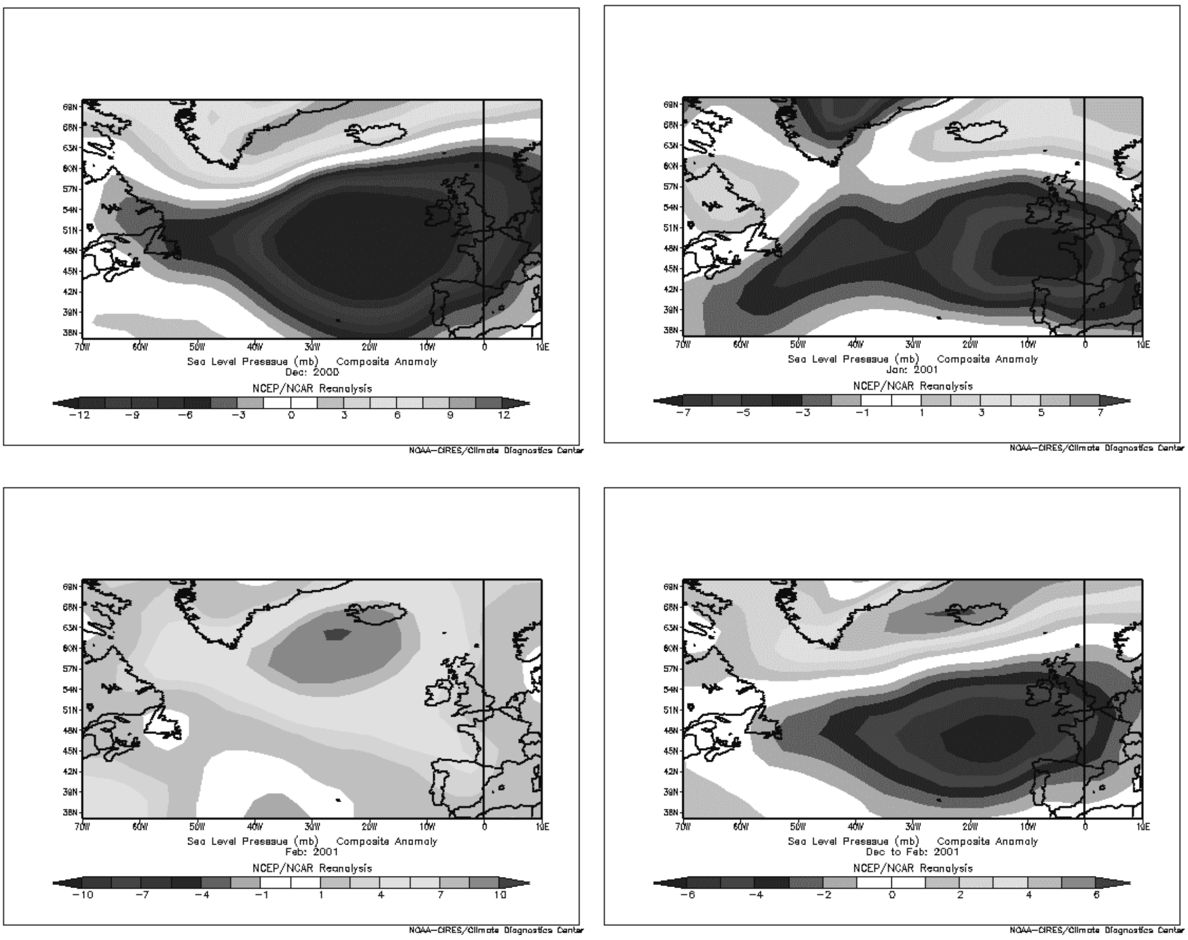


Figure 3. The NAO in winter 2001 - The Atlantic distribution of sea level pressure anomaly in (a) December 2000, (b) January 2001 and (c) February 2001 respectively, with panel (d) showing the December to February composite (NCEP/NCAR Reanalysis data from the NOAA-CIRES Climate Diagnostics Centre: www.cdc.noaa.gov/Composites).

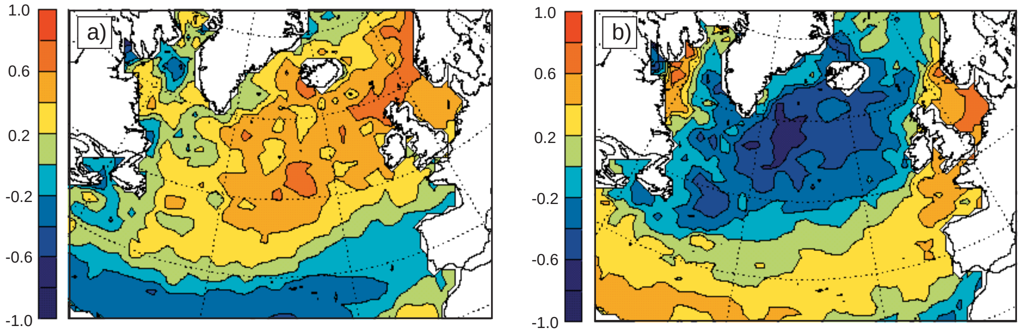


Figure 4. *The NAO in winter 2001 - Spatial distribution of the Pearson correlation coefficient between the NAO Index and (a) local winter scalar wind speed (ms^{-1}) and (b) local sea surface temperature (°C) for the period 1950-1995. Winter is taken as the months January to March. Kindly provided by Ben Planque, IFREMER, Nantes, pers comm.*

Text Box 2: Is the North Atlantic Oscillation always the dominant control on Atlantic variability?

In many of the regional summaries in this, and past, ICES Annual Ocean Climate Status Summary, we describe possible associations between various parameters of Atlantic hydrography and the winter behaviour (pattern and amplitude) of the NAO. As one of the most robust recurrent modes of atmospheric behaviour on Earth, the NAO dictates much of the climate variability from the eastern seaboard of the United States to Siberia and from the Arctic to the tropical Atlantic, especially during boreal winter. Further, from the mid-1960s to the 1990s, which includes our best and most-recent hydrographic record, the NAO Index has been observed to amplify slowly between one extreme state and the other in an instrumental record that extends back to at least 1865.

However, there are areas and times when the influence of the NAO will be less dominant in our long-term records. For example:

Warm Period 1925-1960:

During the middle decades of the century there was a notable warm period in the North Atlantic, lasting from 1925 until 1960, when the dominance of the NAO decreased temporarily, allowing a quite different set of physical controls to drive a protracted change through the northern Gyre of the North Atlantic. This regional event had some of the largest dislocations ever observed in the Atlantic ecosystem (See the 2001 ICES WGOH for more details).

Zones of Minimal Correlation:

Areas such as the Rockall Trough lie on the zone of minimal correlation between centres of significant correlation with the NAO, which are found to it's east and west (Figure 4). In general we can expect this to be one area where the NAO bears little obvious relation to hydrographic change.

Chaotic Variability:

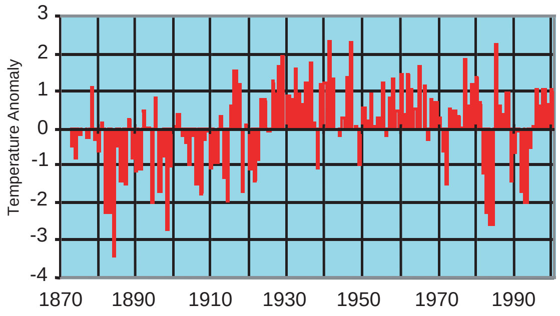
Even in an area of maximum responsiveness to the NAO, the NAO is not the only or even the main control on ocean variability. Over the Atlantic as a whole, though the NAO accounts for substantially more than any other pattern of variability, it still explains only around one-third of the total variance in winter sea level pressure, and the chaotic nature of the atmospheric circulation means that, even during periods of strongly positive or negative NAO index winters, the atmospheric circulation typically exhibits significant local departures from the idealized NAO pattern.

Finally, it is worth stressing that we do not yet know the causes of longer-term NAO behaviour, the periods when anomalous NAO-like circulation patterns persist over many consecutive winters, or the fact that the magnitude of the recent upward trend is unprecedented in the observational record. Whether such low frequency (interdecadal) NAO variability arises from interactions of the North Atlantic atmosphere with other, more slowly varying components of the climate system such as the ocean, whether the recent upward trend or eastward shift in the NAO reflect a human influence on climate, or whether the longer time scale variations in the relatively short instrumental record simply reflect finite sampling of a purely random process, are topics of considerable current interest. However, we can say that we have almost certainly not experienced the full range of possible NAO variability!

Regional Descriptions – Area 1 - West Greenland

West Greenland lies within the area, which normally experiences cool conditions when the NAO index is positive. However, although the index has been positive since 1996, and in the winter 1999/2000 recovered to the level of extreme positive values experienced in the early 1980s and especially in the early 1990s, conditions around Greenland remained warm. In 2000 the annual mean air temperature in Nuuk was -0.80°C, which is about 1°C above normal (Figure 5), confirming that an anomalous NAO pattern was still influencing the area. Changes in the ocean climate in the waters off West Greenland generally follow those of the air temperatures. The relatively mild atmospheric conditions were reflected in the mean temperature on top of Fylla Bank in the middle of June (Figure 6), with the 2000 temperature value (T=2.45°C) being the fifth highest temperature 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.

In summary, oceanographic conditions off West Greenland during the summer 2000 were characterised by high surface temperatures due to mild atmospheric conditions and a relatively high inflow of Polar Water. Pure Irminger Water was absent during the summer of 2000 even in the Cape Farewell region, but reappeared as far north as 64°N by the autumn.



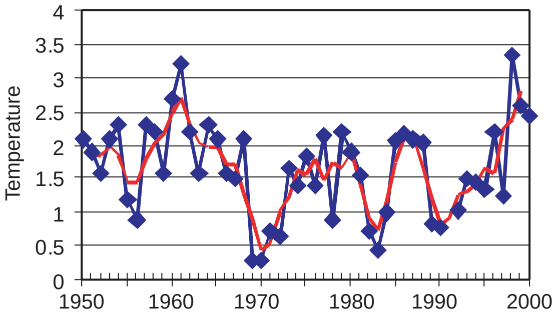


***Figure 5**. Area 1 - West Greenland. Anomaly in the annual mean air temperature observed at NUUK for the period 1873 to 2000. (The anomaly is taken relative to the mean temperature for the whole period).*

***Figure 6**. Area 1 - West Greenland. Time-series of mean temperature (observations and 3 year running mean) on top of Fylla Bank (0 - 40 m) in the middle of June.*

Area 2 – Northwest Atlantic

Oceanographic conditions in this region are to a large degree determined by the strength of the winter atmospheric circulation over the northwest Atlantic. In general, when the normal cyclonic circulation is weak during the winter months, corresponding to a negative NAO index, warm saline ocean conditions generally predominate.

During 2000 annual mean air temperatures cooled slightly over the record high values of 1999 in many regions of the northwest Atlantic. Maximum air temperature anomalies occurred from southern Labrador to the Scotian Shelf, where values were up to 2°C above their long-term (1961–1990) means. Seasonally, air temperatures in these areas were above normal for the majority of 2000. Air temperature in the northern most regions warmed slightly over 1999 values.

Sea ice on the Newfoundland and Labrador Shelves during 2000 generally appeared on schedule but left early, resulting in a shorter duration of ice than normal. The ice coverage in these areas during 2000 was lower than average but increased slightly over 1999. Off eastern Newfoundland, the depth-averaged ocean temperature ranged from a record low during 1991 (high NAO index in preceding winter), a near record high in 1996 (following the reversal in the preceding winter to the near record low NAO index), and above the long-term (1961–1990) average in 1999 and 2000. Summer salinities, which were below normal during most of the early 1990s, returned to near normal values during 2000.

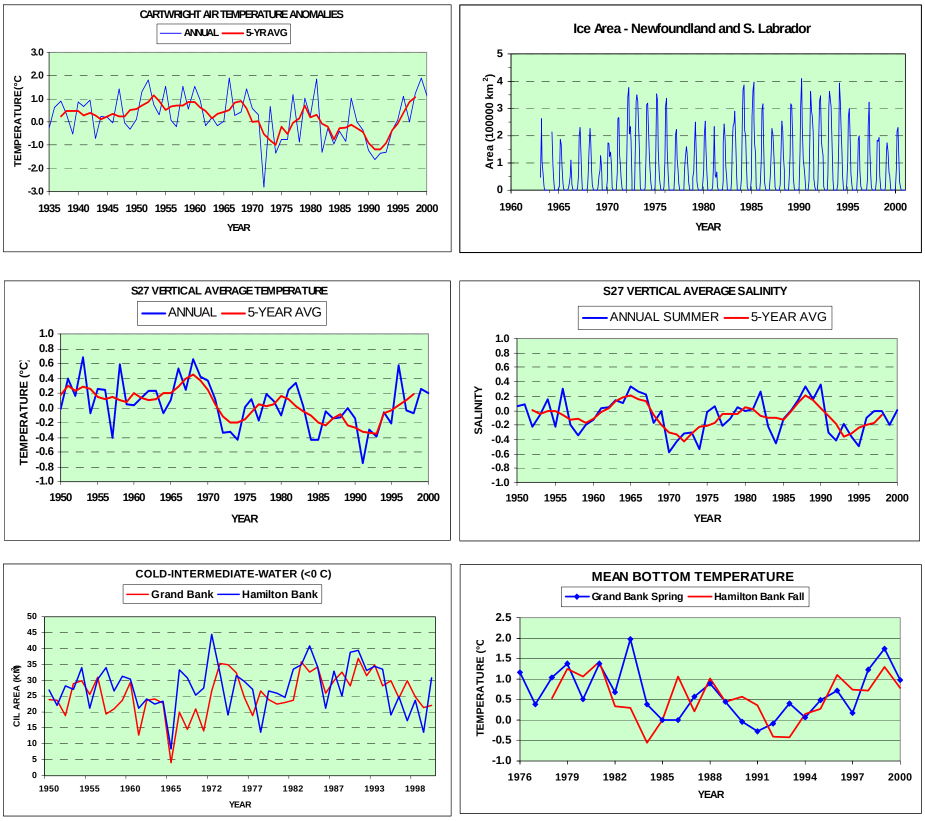


Figure 7. *Area 2 – Northwest Atlantic. Annual air temperature anomalies at Cartwright on the Labrador Coast, sea-ice area off Newfoundland and Labrador between 45°N-55°N, the depth-averaged Station 27 annual temperature and summer salinity anomalies, the time series of cold intermediate layer (CIL) on the Grand Bank of Newfoundland and Hamilton Bank off southern Labrador and the annual mean bottom temperatures on the Grand Bank and Hamilton Bank.*

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 centigrade water. This winter-cooled water remains trapped between the seasonally heated upper layer and the warmer shelf-slope water throughout the summer and autumn 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 2000, the CIL remained below normal in southern regions (Grand Bank) but increased to above normal on the southern Labrador Shelf.

Annual mean bottom temperature for the Grand Bank and Hamilton Bank have recently increased over the lows of the early 1990s, with average values during 1999 >1.5°C on the Grand Bank and >1°C on the southern Labrador Shelf. During 2000 mean bottom temperatures decreased over 1999 values by about 0.5°C.

In general ocean conditions in the north-west Atlantic during 2000 cooled slightly over 1999 values but still ranged from near normal to warmer than normal over most areas.

Area 2b – The Labrador Sea

The Labrador Sea is part of the North Atlantic located between Greenland and the Labrador coast of eastern Canada. Cold, fresh waters of polar origin circle the Labrador Sea in a counter-clockwise current system that includes both the northward flowing West Greenland Current on the eastern side and the southward flowing Labrador Current on the western side.

Wintertime cooling and evaporation increase the density of surface waters in the central Labrador Sea. In some years, the wintertime density increase is so large that the surface layers overturn, a process that has been observed to penetrate to depths as great as 2000 m. The temperature, salinity, and density of Labrador Sea Water formed by these overturning processes vary from one year to another depending on the winter conditions. The intermediate-depth Labrador Sea water mass created in this way spreads throughout the northern North Atlantic.

Cold winters and strong winds during the high NAO-index conditions of the first half of the 1990s gave rise to the formation of a notably dense, deep Labrador Sea water mass. Since that period, relatively warm winters have produced only shallow convection. The convection that took place in the 1999–2000 winter dominated the layer between 200 m and 1000 m. The newly produced water mass penetrated 300 m deeper on average than during the previous winter. The upper 1000 m showed a cooling and freshening trend, up to 0.3°C cooler and 0.02 fresher in 2000 than in 1999. The associated density increase of the upper kilometre of the Labrador Sea was accompanied by a 5 cm lowering in sea level, according to TOPEX/POSEIDON altimeter measurements. Summer 2000 sea level was lower than observed since the end of the intense cooling period of the early 1990s (Figure 8).

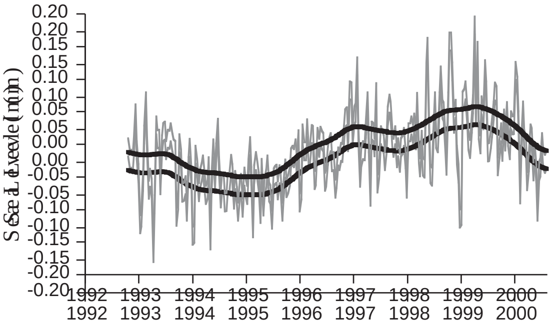


Figure 8. *Area 2b – Labrador Sea. Central Labrador Sea TOPEX/POSEIDON sea level (56.6N, 52.6W). Thin line – residual after seasonal cycle removed. Thick line – smoothed residual.*

Area 3 – Icelandic Waters

Iceland is situated at the meeting place of warm and cold currents (Figure 9), which meet in this area because of its geographical position and the location of submarine ridges (parts of the 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°C 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 Atlantic.

The hydrographic conditions in Icelandic waters in 2000 revealed in general relatively high temperatures and salinities as in the last 2-3 previous years. The salinity in the warm water from the south was higher than has been observed over the last decades, and these conditions have been evident since 1997. This was further evidence of the Atlantic inflow into North Icelandic waters (Figure 10).

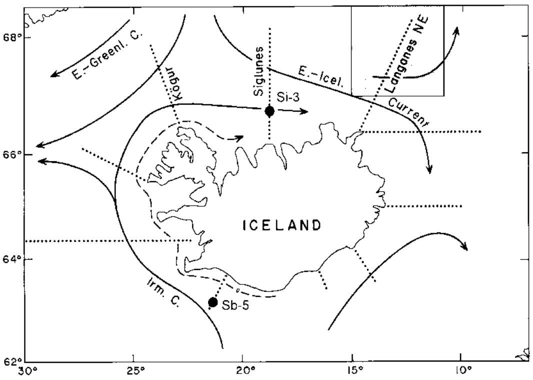


Figure 9. *Area 3 - Icelandic waters. Main currents and location of standard hydro-biological sections in Icelandic waters.*

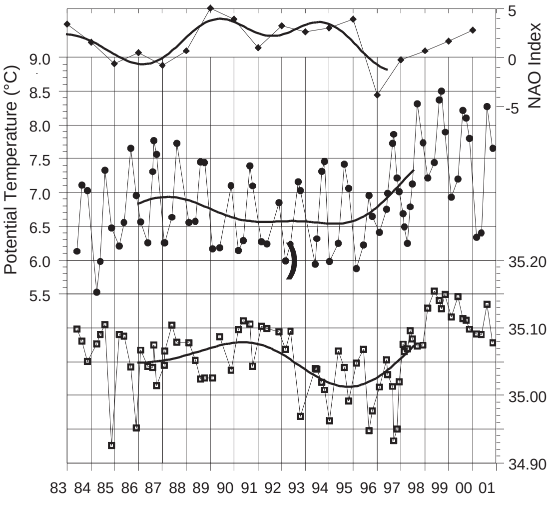


Figure 10. *Area 3 - Icelandic waters. Time series of the NAO index, mean temperature and salinity of the upper 200 m for station 9 of Faxaflói section 1983-2000 - annual and 5-year Gaussian filtered values.*

The cold waters north and north-east of Iceland in the East Icelandic Current was in 2000 as in 1999, relatively far offshore, and had salinities of around 34.8, which is well above a critical value which prevents overturning. These mild conditions in Icelandic waters in 2000 follow extremely cold conditions in 1995, improving in 1996 and 1997, and continuing to do so in 1998 and 1999, but showing a slight decrease in 2000.

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 southern Bay of Biscay during 2000 remained at nearly the same value as during the two preceding years, at 14.7°C, 0.3ºC over the 1961–2000 average (Figure 11).

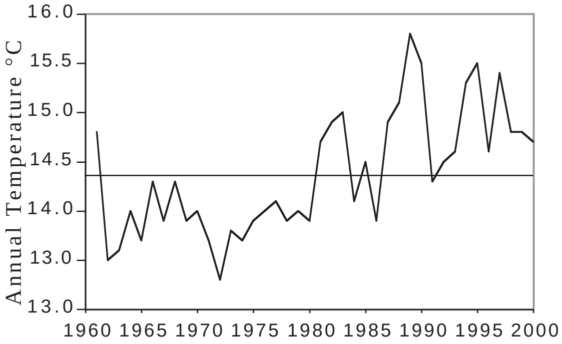


Figure 11. *Area 4 - Bay of Biscay and Eastern Atlantic. Annual mean air temperatures at Santander, northern Spain. (Data courtesy of Instituto Nacional de Meteorología).*

However, positive anomalies in the annual cycle appear in February, the whole of spring, August, September and, above all, December. During this last month air temperature was 2.9ºC higher than the historical mean. These high air temperatures reflect the pattern of sea level pressures found in December for the southern area (see Figure 3 upper left).

In terms of sea temperatures, 2000 was not a warm year. However, it had the greatest amplitude in the seasonal cycle of seawater temperature at 10 m (9.1°C) with the coldest winter of the decade, and the warmest September with temperatures 2.5ºC above the 1992-2000 mean. At this depth, the 2000 annual mean was 15.6°C, which was lower than the previous year. Upper water salinity in the Bay of Biscay, which was increasing from a low salinity event in 1995, reached an apparent maximum around 1997/1998 and has decreased since then. This behaviour was also found at 200 m depth.

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 (500 m) Wyville-Thomson ridge. It is one pathway by which warm North Atlantic upper water reaches the Norwegian Sea, where is converted into cold dense overflow water as part of the thermohaline overturning in the North Atlantic. The upper water column is characterised by poleward moving Eastern North Atlantic Water, which is warmer and saltier than waters of the Iceland Basin, which also contribute to the Nordic Sea inflow. Below 1200 m the deep Labrador Sea Water is trapped by the shallowing topography to the north, which prevents through flow but allows recirculation within the basin.

Early 2000 saw a peak in the de-seasoned upper ocean temperatures in the Rockall Trough. Thought to be caused by an influx of unusually warm water into the region, the mean temperature of the upper ocean was more than 0.5°C above the long-term mean (since 1975), with most of the warming having taken place from 1995 to 2000 (Figure 12). By May 2000 the temperature had dropped somewhat, though remained 0.2°C above the long-term mean.

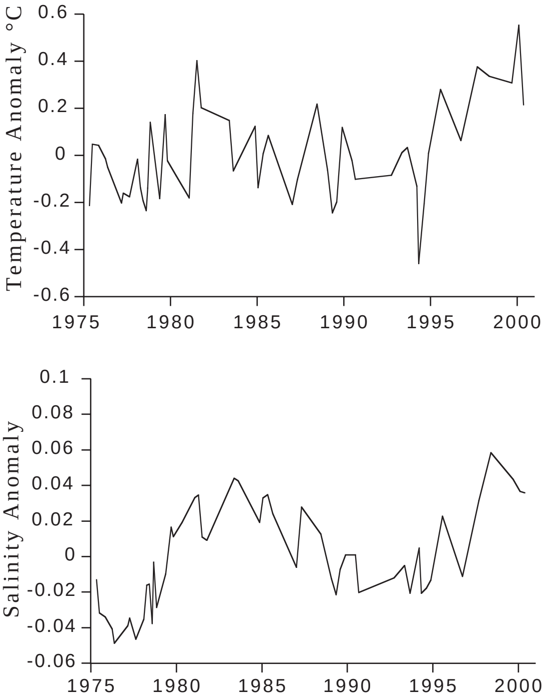


Figure 12. *Area 5 - The Rockall Trough. Salinity and temperature anomalies for the upper ocean (0-800 m) of the northern Rockall Trough (average across the section, seasonal cycle removed)*

The salinity has fallen from the peak in 1998, which reached 0.06 above the mean; though by mid 2000 it was still as high as the previous peak in 1983 (0.04 above the 25-year mean). Both temperature and salinity appear to be following a cyclical trend with a period of about 15 years.

The deep Labrador Sea Water (below 1200 m) was unchanged from the previous year; the long-term trend is of decreasing salinity (0.25 per decade) and slowly decreasing temperature (0.08°C per decade) reflecting periodic input of fresher, cooler water from outside the basin.

Area 7 –- Northwest European Shelf

The northwest European shelf edge, west and north of Scotland, is dominated by the poleward flowing slope current, carrying Atlantic water towards the Norwegian Sea. This water is the principle source for water crossing onto the shelf, and into the North Sea.

The 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 13) were observed in the spring of 1998 but have remained fairly constant, although cooler, since then. The salinity of the Atlantic water reached a maximum in 1998, and has since been reducing.

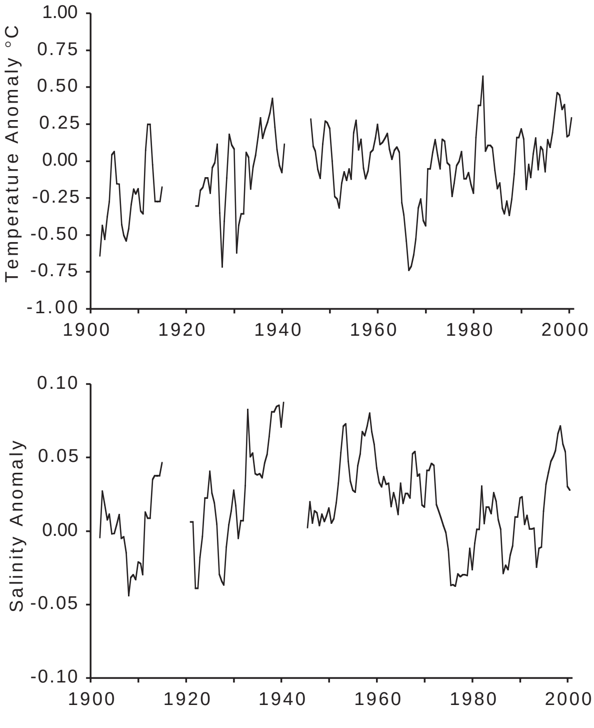


Figure 13 (right). *Area 7 - Northwest European shelf edge. Temperature and salinity anomalies in the surface Atlantic waters lying within the slope current north of Scotland.*

Area 8 and 9 – Northern and Southern North Sea

The oceanographic measurements made during the quarter 1 (January-March 2000) ICES International Bottom Trawl Survey (IBTS) show that North Sea conditions were again very similar to recent years. Temperature and salinity continued at high levels, especially in the northern North Sea, though not quite so high as in the record year of 1998. Overall average temperatures have been higher by up to 1°C following the late-1980s (Figure 14a).

Conditions immediately east of the entrance to the English Channel (Figure 14b) show marked interannual fluctuations in response to changes in the volume of Atlantic inflows to the North Sea through the Channel. Most of the 1990s have witnessed a fairly sustained presence of Atlantic water in this area, apart from around 1995-1996. Changes in winter atmospheric circulation patterns are the likely cause of these variations. Time series from ten North Sea locations, including these two, can be viewed and downloaded from http://www.ices.dk/ocean/project/data/iyfsmaps/time/.

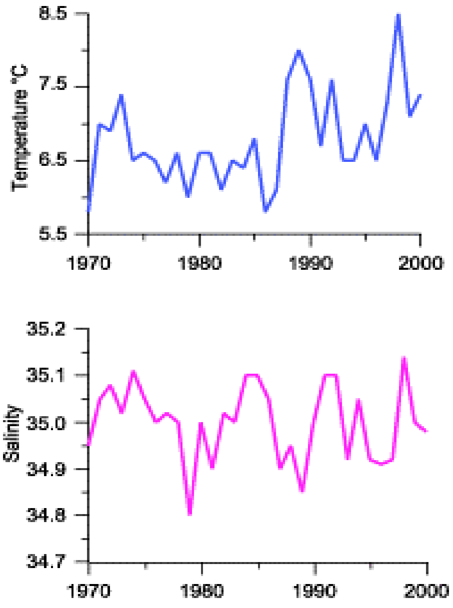


__Figure 14a.__ Area 8 - Time series of temperature and salinity at a location in the NW North Sea (57°30'N 0°E) during the ICES IBTS Quarter 1 Surveys.

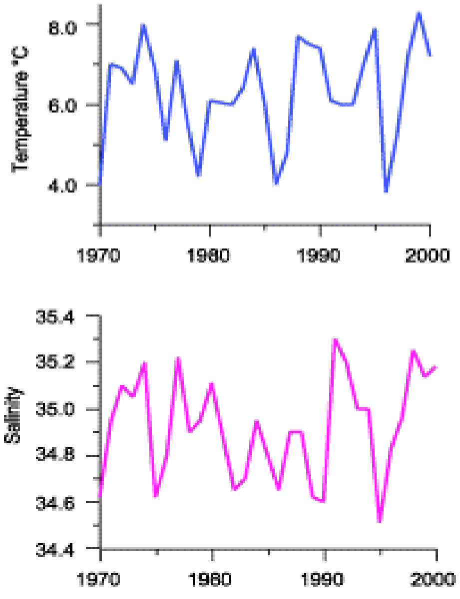


Figure 14b. Area 9 *- Time series of temperature and salinity at a location in the SE North Sea (52°30'N 3°E) during the ICES IBTS Quarter 1 Surveys.*

In terms of the surface temperatures in the North Sea in 2000, the annual mean SST of 10.4°C made 2000 the 6th warmest year on the record dating from 1971. Except for June and July, North Sea SSTs exceeded climatological monthly means at all times and at all locations. The seasonal warming in June averaged only 1.4°C, which is 50% short of the usual heating rate. This caused the jump-like change from anomalously warm conditions in May to a widespread cold anomaly that grew even more intense in July making it the 4th coldest July since 1971 (Figure 15). The mean SST of 13.4 °C remained 2.1°C behind the 2nd warmest July of 1999. While usually seasonal cooling sets in around mid-August, August 2000 was special in that a belated extreme increase in SST of 2°C occurred which exceeded the average heating rate by 200%. This again was associated with a rapid return to anomalously warm conditions. The warm anomaly strengthened during the autumn, which underlines the significance of warmer than normal autumn SSTs during the decade of the 1990s. Additional information is available at http://www.bsh.de/Oceanography/Climate/Climate.htm

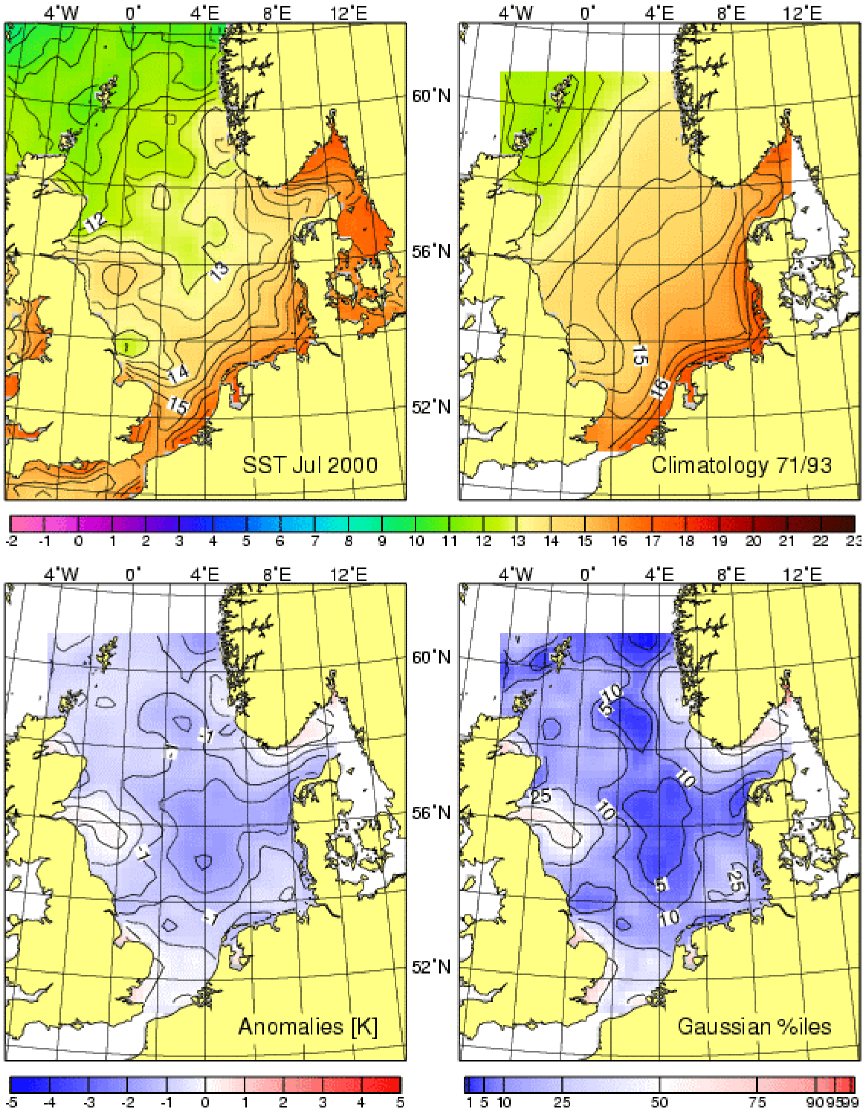


__Figure 15.__ Areas 8 and 9 - North Sea SSTs and SST anomalies in July 2000. Percentiles (bottom right) give the area under the unit normal distribution between -infinity and the standardised anomalies. P-values below 10% suggest that the expected average occurrence of such strong or stronger a cold anomaly is less than 10%

Area 9b – Skagerrak and Baltic

The year 2000 was characterised by large rates of precipitation, especially during the summer and late autumn. In Sweden the mean temperature over the year was one of the highest ever recorded, with an especially mild autumn. These weather conditions were also reflected in the hydrographic observations.

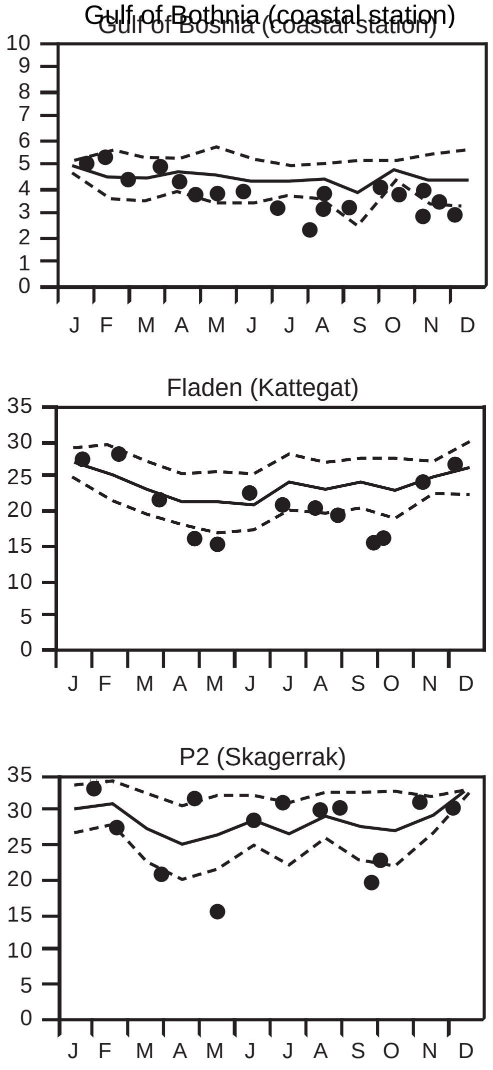


Figure 16. *Area 9b - Skagerrak and Baltic. Surface salinity in the Gulf of Bothnia (coastal station), Fladen (Kattegat) and Skagerrak (dots). In this figure mean values (from the period 1986-1995) are also given (black lines) as well as the associated standard deviations (dashed lines).*

In the Gulf of Bothnia very low values of the surface salinity were measured at the end of July and in the autumn (Figure 16). In Kattegat and Skagerrak the lowest values of the surface salinity were found in late spring and early autumn (Figures 16b and 16c). These events followed periods of large fresh-water flux through Oresund and the Belts.

In the Baltic Proper the tendency over the last 20–25 years has been towards decreasing values of the surface salinity, following a peak of in the late 1970s (Figure 17). East of Gotland, the sea surface temperature was around 3° C above normal in December. Higher than normal surface water temperatures were observed in many areas at the end of the year.

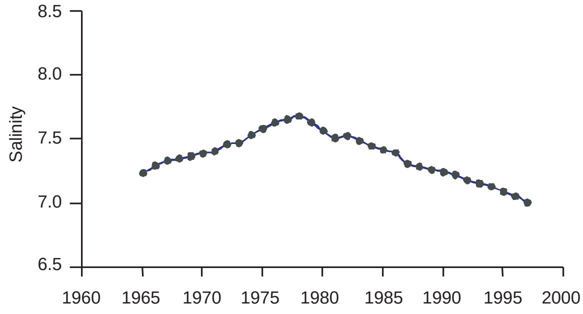


Figure 17. *Area 9b - Skagerrak and Baltic. Surface salinity east of Gotland. A 5-yr running mean has been applied.*

Area 10 – Norwegian Sea

In the southern and central Norwegian Sea a warming has taken place since 1996. In 2000 the warming continued at the southern section while a cooling occurred at the central section (Figure 18). In the northern Norwegian Sea the temperature since 1996 has been close to the long-term average but below the long-term trend.

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 18) amounts to 0.94° C since 1978, compared to 0.31° C at the southern section (63° N). The salinity trend is also strongest in the north, with decreases of 0.06 since 1981 compared to 0.02 at 63° N.

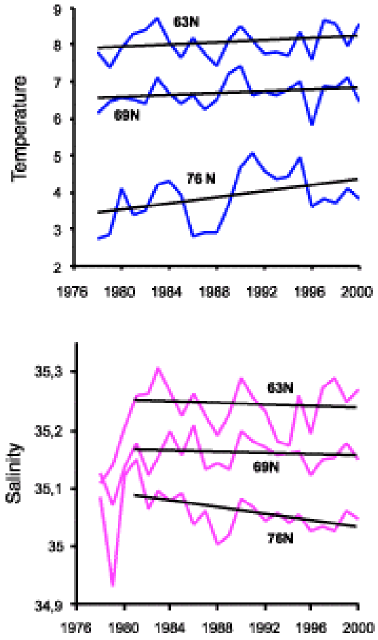


Figure 18 (right). *Area 10 - The Norwegian Sea. Average temperature and salinity above the slope at three sections, Svinøy (approx. 63°N), Gimsøy (approx. 69°N) and Sørkapp (approx. 76°N), representing the southern, central and northern Norwegian Sea.*

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 volume and water mass properties, particularly in heat content and consequently ice coverage.

After a period with high temperatures in the first half of the 1990s, 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 19), while the temperature in the eastern areas stayed below the average during 1998 (Figure 20). From the beginning of 1999 there was a rapid temperature increase in the western Barents Sea, which also spread to the eastern part of the Barents Sea.

During 2000 the temperature decreased from almost 1°C above average to 0.2°C in the autumn. In the eastern Barents Sea, however, the temperature was more than 0.5°C above the long-term mean during the entire year of 2000. Early indications suggest that the status at the beginning of 2001 is the same as during autumn 2000.

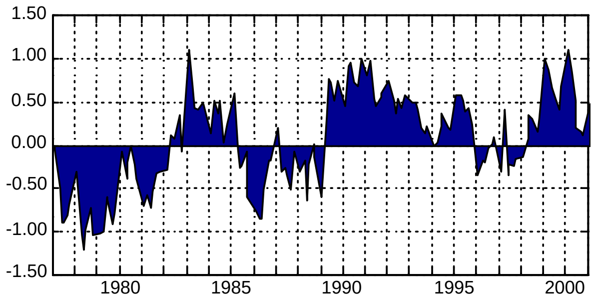


Figure 19. Area 11 - Barents Sea. *Temperature anomalies in Atlantic inflow through the section Norway- Bear Island in the western Barents Sea.*

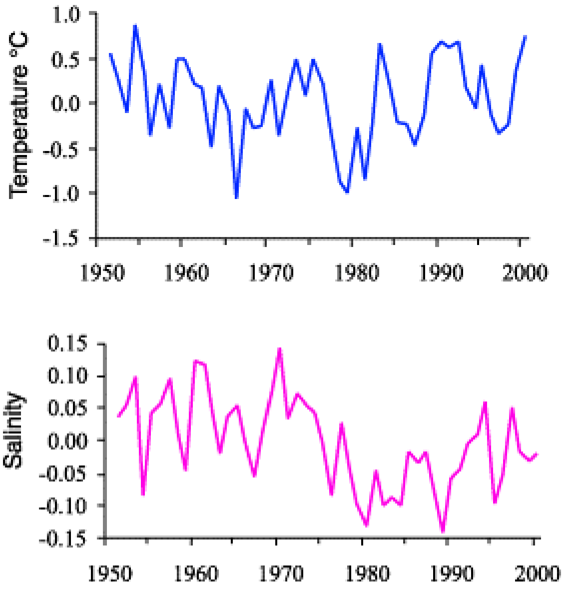


Figure 20. *Area 11 - Barents Sea. Temperature and salinity anomalies in the Kola section (0-200m).*

Area 12 – Greenland Sea (West Spitsbergen Current)

On the eastern side of the Greenland Sea, the thickness of the Atlantic Water layer within the West Spitsbergen Current at the 76°30'N in summer 2000 was larger than in previous years. Water temperature and salinity were a little higher as well (Figure 21). All values were also higher than in the period 1991–1996.

At the latitude 78° N summer 2000 values of temperature, salinity and Atlantic Water layer thickness were only slightly higher than during summer 1999, but show significant increase comparing to summer 1997 when measurements first started (Figure 22).

Summer 1997 was exceptional, as observations indicate very low temperatures, salinities and layer thickness of Atlantic Water. This could have been caused by strong inflow of polar waters from the Storfjordrenna, but very low temperatures and salinities further north could also suggest that it could have been a more general phenomenon.

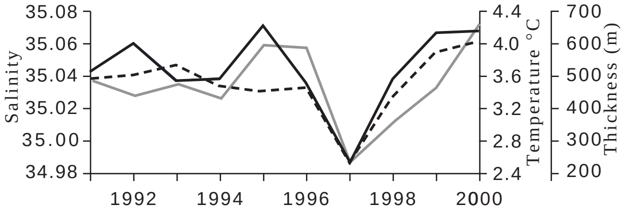


Figure 21. *Area 12 - Greenland Sea (West Spitsbergen Current). Mean salinity (dashed line), temperature(black line) and Atlantic Water layer thickness (grey line) at 76° 30'N.*

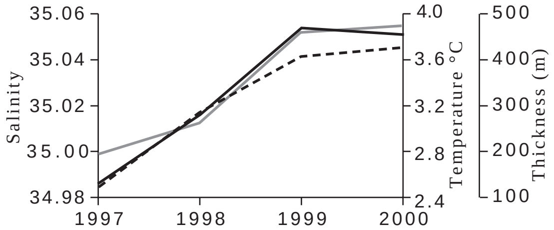


Figure 22. *Area 12 - Greenland Sea (West Spitsbergen Current). Mean salinity (dashed line), temperature (black line) and Atlantic Water layer thickness (grey line) at 78°N.*