Oceanography Committee **ICES CM 2002/C:08**

Report of the

Working Group on Oceanic Hydrography

Halifax, Canada
18–21 March 2002

International Council for the Exploration of the Sea

Conseil International pour l'Exploration de la Mer

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TABLE OF CONTENTS

Section **Page**

Section	Page

1 SUMMARY OF WGOH 2002

1) A one-day mini-symposium on Arctic and Sub-Arctic Oceanography, chaired by Ross Hendry of BIO, started the meeting. Abstracts of talks are presented as Annex D.
2) A further day of national reports followed, resulting in the 2001/2002 ICES Annual Ocean Climate Status Summary (IAOCSS), which was prepared from the regional climate reports. This is available at http://www.ices.dk/status/
3) In summary, the North Atlantic Oscillation (NAO) Index has been slowly recovering to positive values since the extreme negative value of 1996. However, during the winter preceding 2001 it again became negative. The response seen throughout the ICES area to the 1996 switch of the NAO has not been observed in 2001, probably due to a different pattern of sea level pressure over the North Atlantic. In 2001 the pattern exhibited a large weak positive anomaly stretching from northern Scandinavia to Newfoundland.
4) New sources of data, such as the Reynolds SST climatology and the ICES data centre itself, are being considered in order to enhance the IAOCSS report. This is ongoing.
5) The uses of environmental information in the fish assessment process was considered. This topic will be continued in the WGOH sponsored Theme Session W, at the 2002 ASC, entitled "Fishery and Environmental Management – Is There a Role for Operational Oceanography?"
6) The 2001 ICES Symposium on Hydrobiological Variability in the ICES Area, 1990–1999 was reviewed, as well as progress towards publication of the proceedings volume.
7) The request from ICES, for the WGOH to review the report listing relevant marine bio-ecological variables and indicators suitable for operational use, was responded to.
8) An update on ASOF was presented, along with proposals for two new future activities of the WGOH (storage of water samples, and isopycnal melding of data).
9) Dr A Lavin (Spain) was proposed as the new Chair of WGOH.
10) The Working Group will meet next year in Bergen, Norway, 31 March – 3 April 2003.

2 OPENING

The Working Group on Oceanic Hydrography (WGOH) was hosted by the Ocean Sciences Division of the Bedford Institute of Marine Science in Halifax, Canada between 18–21 March 2002. The Working Group was welcomed to the Institute by the Director of Science, Dr Mike Sinclair, and by the Working Group's local member, Ross Hendry. After a brief introduction to the Institute the business of the meeting began.

3 A MINI-SYMPOSIUM ON ARCTIC AND SUB-ARCTIC OCEANOGRAPHY

The meeting commenced with a one day Mini-symposium on Arctic and Sub-Arctic Oceanography, chaired by Ross Hendry, Ocean Science Division. At the 2001 meeting of the Working Group on Oceanic Hydrography at the Marine Research Institute in Reykjavik, Iceland, it was recognized that high-latitude Northern Hemisphere processes are receiving special attention within the scientific community at the present time. These activities are of interest to many members of the WG and their home institutions. As a result, the Working Group approved a suggestion to hold a mini-symposium focusing on ongoing activities and plans for future work in the Arctic and sub-Arctic in conjunction with the 2002 Working Group meeting. The presentations were organized thematically as follows:

Introduction

A Regional Perspective on DFO's Arctic Strategy. *Peter Jones, Fisheries and Oceans Canada, Bedford Institute of Oceanography, Dartmouth, NS, Canada) (DFO, BIO).*

Exchanges with the Arctic Ocean

Transport of Atlantic Water through the Barents Sea. *Harald Loeng (Institute for Marine Research, Bergen, Norway).*

The historic Kola section in the eastern Barents Sea. *Vladimir Ozhigin (PINRO, Murmansk, Russia).*

Basin scale Arctic Ocean circulation

Radionuclides as tracers of arctic circulation. *John Smith (DFO, BIO).*

Tracing Arctic Ocean waters *Peter Jones (DFO, BIO).*

Ice and fresh water outflow

Overview of Ocean Science Division's Ice Programs. *Simon Prinsenberg (DFO, BIO).*

Ice flux through Fram Strait and the atmospheric driving forces. *Svein Østerhus (Geophysical Institute, Bergen, Norway).*

Modelling the Marginal Ice Zone. *Tom Yao (DFO, BIO).*

Sub-Arctic processes

Convection and restratification in the Labrador Sea. *John Lazier (DFO, BIO).*

Hydrographic Structure and Transport in the Greenland Sea. *Stephanie Ronski (Alfred-Wegener-Institut, Bremerhaven, Germany).*

Interannual variations of flow from the Nordic Seas to the Atlantic Ocean. *Bob Dickson (CEFAS, Lowestoft, UK).*

Canadian Archipelago throughflow

High Arctic moored measurements: heat and salt fluxes through Barrow Strait. *Jim Hamilton (DFO, BIO) (presented by Simon Prinsenberg).*

Measurement systems for Arctic studies. *George Fowler (DFO, BIO).*

Circulation and hydrography in Baffin Bay. *Charles Ross (DFO, BIO).*

Modelling Arctic Archipelago Circulation and Tides. *David Greenberg (DFO, BIO).*

Future plans and general discussion

The Arctic/Subarctic Ocean Fluxes Programme. *Bob Dickson (CEFAS, Lowestoft, UK).*

Patterns of Arctic/Subarctic transport in models and plans for field work west of Greenland. *Peter Rhines (University of Washington, Seattle, Washington, USA).*

Future of Arctic research at BIO. Simon Prinsenberg *(DFO, BIO).*

Brief overview of U.S. Arctic programs. *John Calder (NOAA, Arctic Research Office, USA).*

The symposium was then followed by a general discussion. Abstracts of the talks are presented as Annex D.

This is the second year that the WGOH has commenced with a day of scientific presentations, jointly by members of the WGOH, and by scientists from the host organisation. It appears to be a successful development, and encourages a broader interaction between ICES scientists and a wider community, as called for in the ICES strategic plan.

4 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. Dr Gilles Reverdin (France) had been contacted, and for the first time a French report was submitted to the WGOH (Annex E). It is hoped that Dr Reverdin may attend the 2003 WGOH. THE WG welcomed several new attendees at the 2003 meeting; Hjalmar Hatun (Faroe), César Gonzalez-Pola (Spain), and Stephanie Ronski (Germany).

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

This is a standard item of the WGOH, and is the basis for the main work of the Working Group, and its product the ICES Annual Ocean Climate Status Summary (IAOCSS). Unlike previous years, it is not intended that a detailed account of the national reports be presented here. All national reports are presented here as Annexes E to T, 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 U). 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 NAO: The North Atlantic Oscillation (NAO) index has been slowly recovering to positive values since the extreme negative value of 1996. However, during the winter preceding 2001 it again became negative. The response seen throughout the ICES area to the 1996 switch of the NAO has not been observed in 2001, probably due to a different pattern of sea level pressure over the North Atlantic. In 2001 the pattern exhibited a large weak positive anomaly stretching from northern Scandinavia to Newfoundland.

Area 1: Ocean temperatures off West Greenland showed considerable warming during the summer and autumn of 2001. This warming was similar to that observed during the 1960s. Anomalously high salinities were observed in the off-slope surface waters during the autumn.

Area 2: Annual mean air temperatures over all areas of the Northwest Atlantic were above normal during 2001, but decreased compared to the records set in 1999. The amount of sea ice on the eastern Canadian continental shelf continued to be below normal for the fourth consecutive year. Except for southern areas of the Newfoundland and the northern Scotian shelves, ocean temperatures were above normal, continuing the warm trend established in the late 1990s.

Area 2b: The upper layers of the Labrador Sea were observed to be warmer, saltier, and less dense in the summer of 2001 compared with conditions in 2000. These changes seem to be due largely to the inflow of Atlantic waters. There is no evidence that convective overturning during the winter of 2000–2001 reached depths greater than 400–500 m.

Area 3: In Icelandic waters there were relatively high temperatures and salinities, as there have been for the previous 3–4 years following the very cold years of 1995 and 1996. However, 2001 temperatures and salinities were slightly cooler and fresher than in 1999 and 2000.

Area 4: The Bay of Biscay continued to show a progressive decrease in salinity, which began in 1999. Averaged upper water layer temperature was low compared to values obtained during the last decade, whereas yearly averaged air temperature remained at the same level as the preceding three years.

Area 5: The Rockall Trough began to cool and freshen slightly during 2001, although both temperature and salinity remained high compared to the long-term mean, with values similar to previous peaks in the early 1980s.

Area 6: The temperature and salinity of Atlantic water passing through the Faroe Bank Channel and across the Iceland-Faroe Ridge have remained fairly constant since 1997.

Area 7: With respect to the last four decades, Atlantic waters in the Faroe Shetland Channel are generally warming and becoming more saline. However, there was little change between 2000 and 2001.

Areas 8 and 9: In terms of the surface temperatures of the North Sea, 2001 was generally warmer than normal. The summer of 2001 exhibited a reduced influence of Atlantic water in the northern North Sea and also in the Southern Bight. The low salinities in the southern North Sea suggest stronger than normal run-off from the continental rivers. The Baltic outflow south-west of Norway in summer 2001 was stronger than normal.

Area 9b: In the Baltic, surface waters generally became fresher due to high freshwater inputs following a wet winter. Surface temperatures were warmer than average. There were deep-water inflows into the Baltic Sea from the North Sea in the autumn of 2001.

Area 10: In the Norwegian Sea conditions continued a long term warming trend, and in 2001 the area occupied by Atlantic water was the greatest since 1991.

Area 11: The Barents Sea was warmer than average during 2001, but the temperature gradually decreased throughout the year from nearly 1°C to just 0.1°C above average. The ice condition was therefore favourable.

Area 12: Conditions in the Greenland Sea were generally warmer and more saline in 2001 compared to 2000. Although on average winter convection went down to 800m, in small isolated patches convection reached 2500m.

Prognosis: Though March is still in progress at the time of writing, the winter NAO index for 2002 is likely to show a limited recovery from 2001, in an overall pattern across the ICES area, which is unlike the classical dipole pattern normally observed. Hence we may expect continued near average conditions in most areas, with room for surprises.

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

The draft IAOCSS (Annex U – text only) was discussed by the Working Group, and its contents agreed. Dr P Holliday (UK) must be thanked for helping prepare the 2001 IAOCSS.

7 REVIEW OF NORTH ATLANTIC CLIMATOLOGIES (TOR C)

Unfortunately Dr S Bacon (UK), the proposer of this agenda item, could not attend the 2002 WGOH. It is hoped he will be able to participate in the 2003 meeting, and conclude this item. However, Annex V presents a comparison between the Reynolds 2º x 2º SST climatology, and the relevant *in situ* time series as used by the WGOH. This is presented to encourage intersessional work during 2002/2003, and to facilitate discussions at the 2003 meeting.

In addition, Tom Rossby (USA) supplied the discussion presented in Annex W, for a potential US contribution to the IAOCSS. This is also to be discussed at the 2003 meeting.

8 EVALUATION OF THE ICES INTERACTIVE DATA SUMMARY PRODUCT (TOR D)

Again, unfortunately Dr H Dooley could not attend the 2002 WGOH. Some progress on this agenda item had been made following the 2001 WGOH, and it is hoped that, in conjunction with intersessional work under the agenda item above, progress can be reported at the 2003 meeting.

9 USES OF ENVIRONMENTAL INFORMATION IN THE FISH ASSESSMENT PROCESS (TOR E)

Environmental observations and ocean climate variability indices are routinely collected and complied by fisheries laboratories in many ICES member countries throughout the North Atlantic. Currently, the most direct use of these data has been to monitor environmental conditions and ocean climate change in the North Atlantic. However, in many countries the fundamental reason why these data sets are compiled is to increase our understanding of ecosystem dynamics and environmental influences on fish production. To date, environmental information is used only in a qualitative way in the fish stock assessment process in most, if not all countries.

A review of how Atlantic Canada currently incorporates environmental information into the regional fish stock assessment process and how this information is disseminated to scientists, managers and stakeholders in the fishing industry was presented. The presentation focused on three aspects, which included (1) environmental data collection and dissemination of information to scientists, managers and stakeholders in the fishing industry (2), a survey of environment-stock relationships and preliminary efforts at stock predictions and (3) a brief summary of how the fish stock assessment process currently uses environmental information.

It was noted that trends in the oceanographic environment appear to be significantly correlated with trends in production in several fish species inferred from commercial fisheries (CPUE) and assessment surveys (Survival and Recruitment). This preliminary work indicate that environmental factors may be important at early life history stages for northern shrimp, snow crab, lobster, salmon and other species in Newfoundland waters. Using this information, SAS ARIMA models were used to explore relationships between production in crustacea and changes in the oceanographic environment. Forecasts can be developed by including current and past values of environmental data in addition to using the auto-correlation within the stock response time series, however the uncertainty in the predictions are generally large. Nevertheless, the information can be a valuable addition to a suite of indicators used to assess current status and future prospects for a particular resource.

Currently, environment and fish stock relationships are presented and discussed at regional assessments for many species. Environmental summaries and possible environmental influences on the resource are usually included in the assessment proceedings and in the stock status reports for a number of species, including invertebrates and Atlantic cod. In addition, indices of environmental conditions are normally included in the traffic-light spreadsheet summaries for some stocks, which influences decisions on the reported status and outlook for some species. It was noted however, that environmental information is still used only qualitatively in the assessment process in Canada. New initiatives of the Department of Fisheries and Oceans fisheries oceanography committee (FOC) and through efforts of the Atlantic Zonal Monitoring Program (AZMP) will consider methods to incorporate both biological and physical oceanographic information (process orientated effects) into the assessment process.

10 PUBLICATION OF THE PROCEEDINGS OF THE ICES SYMPOSIUM ON HYDROBIOLOGICAL VARIABILITY IN THE ICES AREA, 1990–1999 (TOR F)

The 2nd ICES Decadal Symposium was held at the Royal College of Physicians, Edinburgh on August 8–10 2001 and was highly successful, attracting a full programme of 42 selected talks and 55 posters describing the variability of the plankton, fish, ocean and atmosphere of the ICES area during the 1990s. It was held in partnership with a one day ‘Achievements Symposium’ on 7 August celebrating 70 years of the CPR Survey. Active canvassing attracted a total of 17 corporate and institutional sponsors to allow the Symposia to be conducted within budget. Around 184 individuals participated overall, with 155 attending the Decadal meeting.

It is a design feature of these Decadal Symposia that we use the occasion to honour five individuals who have worked to maintain the time-series on which our knowledge and these discussions are based, and on this occasion the scientists honoured were John Lazier, (BIO, Dartmouth, N.S., Canada), Svend-Aage Malmberg (MRI, Reykjavik, Iceland), David Ellett (DML, Oban, Scotland), Johan Blindheim (IMR, Bergen Norway) and Leo Otto, (ex-NIOZ, The Netherlands). Though ill health prevented David Ellett from attending, Stig Fonselius and Odd Saelen whose contribution was celebrated at the original Mariehamn Symposium in 1991, were able to participate once again on this occasion.

The Decade of the 1990s was a most unusual one in the climatic history of the North Atlantic in which, during the early 1990s, the North Atlantic Oscillation (NAO) evolved to positive values unprecedented in the instrumental record. In fact, in his invited keynote address, Dr Phil Jones of the Climate Research Unit, UEA, suggests that the recent amplification of the NAO from the 1960s to the 1990s may be unique even in proxy records of 500 years duration. The latter part of the decade was hardly less spectacular; following a rapid drop to extreme low-index values in the winter of 1996 (again, one of the largest year-on-year changes of record), the two main pressure-anomaly cells of the NAO pattern showed a marked tendency to shift eastwards in the last winters of the Decade. As the principal recurrent mode of atmospheric forcing in the Atlantic Sector, such extreme patterns of NAO behaviour were associated with changes of large amplitude throughout the ocean-atmosphere system of the Atlantic. As varied examples of that response, we note that in the early 1990s, the storm index for the southern Norwegian Sea rose to a 100-year maximum, an extreme freshening visited the two dense overflows, the transport of the eastern overflow slackened by 25%, convection in the Labrador Sea reached to unprecedented depths contributing to a full-depth change in the NW Atlantic that is thought to be the largest of the modern oceanographic record, the main Atlantic gyre circulation spun up to a century-long maximum as did the transport of Atlantic water passing through the Faroe-Shetland Channel, and the warmth recorded off the northern Norway rose to a 40-year peak. As might also be expected, the ecosystem of ocean and shelf responded to these changes, as one presentation after another revealed.

Following the full programme of talks, the main points of the four subject-area sessions were summarised for the meeting by their respective Chairs: Jens Meincke (Physical Environment), Franciscus Colijn, (Plankton), Keith Brander (Fish) and Benjamin Planque (the Biscay–Iberia special focus area).

The Convenors conclude that the original and primary aim of providing a 'state description' of the ICES Area was still a valid and valuable purpose for these Decadal Symposia. Though it is not practicable to cover exactly the same subject matter each decade, it remains a useful format to act as a replacement for the Annales Biologiques series. Certain aspects of the Symposium design were also confirmed to be appropriate; for example the decision to hold sessions in sequence rather than in parallel was amply justified by the occasions on which results described in one discipline were observed to mesh with those of another. However this is not to say that change is unwelcome. In particular a new and more-applied aim is developing which is worth encouraging. Specifically, ways of relating the changing ecosystem to variability in the physical environment are now being identified with sufficient confidence that it seems appropriate to adopt that aim as a second formal task of these Symposia. It is suggested that by 2011, it might be appropriate to include a session specifically aimed at describing and testing the best of these relationships in stock assessment. The ICES website www.ices.dk/symposia/decadal3 will be made available to receive participants' comments on the success or otherwise of the present format and ideas for the design and content of a 3rd Decadal Symposium in 2011.

Guidelines for the preparation of texts had been circulated to contributors well in advance of the Symposium by the Editorial Panel under Bill Turrell so that the majority of texts were already prepared to the specified format by the time of the meeting. The review process for talks and posters is underway and it is intended that publication will take place within one year. In its meeting of January 2001, the Bureau approved the use of the ICES Marine Science Symposium series for this purpose.

Altogether an interesting and stimulating event which amply repaid the proactive efforts of the 12-person steering group in designing the programme, and the substantial effort in support by George Slesser and David Moore (FRS Marine Laboratory Aberdeen), Stephen Dye, Charlotte Perks and Philip Stoddart (CEFAS Lowestoft), Heike Wohlert (IFMH, Hamburg) and Diane Lindemann and Judith Rosenmeier, (ICES). After closing remarks by the General Secretary and by the President of ICES, the meeting closed at 1700h, 10 August 2001.

11 REVIEW PROGRESS TOWARDS PRODUCING EDUCATIONAL PUBLICATIONS (TOR G)

Under this agenda item a discussion was held on how to increase the awareness of the IAOCSS, and disseminate information. The development of the Manual for Zooplankton Identification, developed by the ICES Working Group on Zooplankton Ecology was discussed as a model of a possible product from the WGOH. It was concluded that any such product (e.g., ocean atlas, regional oceanographic descriptions) would not be appropriate for this group to produce at the present time. Apart from all members undertaking to increase the web links to the IAOCSS pages, it was concluded that no further work on this agenda item was possible.

12 PREPARE A SUMMARY REPORT LISTING RELEVANT MARINE BIO-ECOLOGICAL VARIABLES AND INDICATORS SUITABLE FOR OPERATIONAL USE (TOR H)

The EuroGOOS/ICES workshop on "Biecological Observations in Operational Oceanography" was held from 6–8 April 2000. The workshop identified a number of products from bioecological monitoring, some of which already results from existing models. Other products have to be developed. Initiation and support of research projects to develop such products is seen as tasks of EuroGOOS. In addition, the workshop felt that visualisation of data analyses and model results should be given more importance to ensure wide use and easy access to operational oceanographic products. The following list prepared by the workshop is relevant to be reviewed by WGOH:

From physical monitoring:

- High frequency measurements of many physical variables e.g., temperature, salinity, turbidity, turbulence, currents, tides, wave height etc.
- Monitoring and forecasting of stratification patterns
- Systematic quantification of oceanic inflow/outflow to European shelf seas and the Baltic Sea (product from existing models)
- Transport patterns by eastern boundary/shelf edge current (product from existing models?)
- Timing and intensity of spring stratification (spring bloom) (product from existing models?)
- Measurements of the area/volume of Norwegian deep water areas (research necessary)
- Size of physically defined feeding areas for many fish species, e.g., salmon, herring, cod (temperature and salinity important in this context, research necessary)
- Parameterisation of deep water formation in the North Atlantic (product from existing models)

From long-term monitoring of climate change:

- Evaluation of physical oceanographic and associated economic and social impacts for different periods of the future (research necessary)
- Evaluation of regional and global consequences of North Atlantic THC shutdown
- Feedback effects from ecosystems to physical climate models

User involvement in the sampling strategy is of great value and must be given priority. The workshop recommended that an improvement of interaction between marine scientists/operational agencies and politicians/public can be achieved through elaboration of a summary report that includes all marine bioecological variables and indicators suggested for operational use by groups of scientists should be made available for discussions with end- users by GOOS, EuroGOOS and ICES.

Ecosystem considerations in fish stock assessment will be more important in the future and will require a new type of data in fish stock assessment. In this context the workshop recommended multiply scientific efforts to identify ecological variables and models that can be shown to a have a significant effect on fish distribution and abundance. Once these ecosystems variables have been established, EuroGOOS and ICES should cooperate to determine a monitoring strategy, especially regarding spatio-temporal resolution and precision. As extreme events can have distinct effect on biological organisms even at very short periods of duration, high temporal resolution of certain measurements might be necessary.

It is highly recommended to adopt an integrated sampling strategy that co-ordinates different monitoring types and schemes whenever possible (e.g., remote sensing and cruises). Such an approach requires intercalibration of related data and relies on the standardisation of the methods and minimum quality requirements.

13 ANY OTHER BUSINESS

13.1 ASOF Update

Dickson (UK) presented an update on the Arctic-Sub Arctic Ocean Flux Array (ASOF). At the 2001 Working Group meeting in Reykjavik, a previous text described, "developing plans for an Arctic-Sub Arctic Ocean Flux Array (ASOF)" as ASOF began to move from Science Plan towards Implementation. Here we aim briefly to describe important developments that have taken place since then in the funding of ASOF and associated programs, and to provide a calendar of ASOF- or-ASOF-related next steps in the outlook period.

Regarding ASOF-East, which aims to measure the two-way ocean exchanges between the Arctic Ocean and the N Atlantic through the Nordic Seas, the principal news has been the apparent success of the bid for EC funding of ASOF.

In mid-October 2001, a three-part ASOF-EC cluster bid was submitted to EC FP-5 under the "Energy, Environment and Sustainable Development Programme", to cover exchanges through Denmark Strait [ASOF-EC (W)], Fram Strait – Barents Sea [ASOF-EC (N)], and Faroe-Shetland Channel [ASOF-EC (W) or "MOEN"], respectively. In late December 2001, all three elements of the Cluster bid were given a provisional 'GO' rating by the Research Director General of the European Commission, and we now await the decision of the EC Programme Committee on the confirmation of funding for each element of that ASOF Cluster (due late February 2002). Though funding amounts have still to be finalised on this Framework-5 bid, the ASOF-East program is now sufficiently assured to begin negotiations for the inclusion of a successor ASOF bid in the 6th EC Framework Programme, 2002–6. Following earlier announcements, the EC is expected to ask for Expressions of Interest for Integrated FP-6 Projects in April, with a submission deadline of June 2002 [http://europa.eu.int/comm/research/nfp/networks-ip.html].

The SIO: LDEO "Consortium on Ocean's Role in Climate: Abrupt climate changes study" (CORC ARCHES) of the NOAA Global Change Program continues to contribute moderate but vital funding to support direct measurements of Denmark Strait Overflow speed and layer thickness off SE Greenland and this phase of the program will continue to December 2005. Both the Norwegian NOClim Project and the UK RAPID thematic program of NERC have a similar, though not identical, focus to that of ASOF on the role of the high-latitude ocean on the Thermohaline Circulation and hence on climate. The former has a greater emphasis on process studies than ASOF; while the latter extends its operations further south than the ASOF southern bound to measure the rate of the Atlantic Meridional Overturning Circulation. Both will nonetheless supplement ASOF research in the main ASOF study area (Figure 1). RAPID which is a £20 million project over 6 years (2002–2007) has advertised 28 March and 15 June 2002 as its closing dates for outline and full bids respectively [http://rapid.nerc.ac.uk]. NOClim is running at 5M NOK per year 2000–2002 but is likely to continue through 2006 [http://www.noclim.org]. NOClim tasks 6 and 7 on long observational ocean time-series are most congruent with the interests of ASOF.

The ASOF-West component is currently debating and prioritising the content of its Implementation Plan. Though the separation between ASOF-West and ASOF-East is based less on geography than on funding, ASOF West will nonetheless expect to develop programs to study some of the most important, unknown and intractable elements of the entire ASOF study, including the flow of freshwater through the passages of the Canadian Arctic Archipelago, the fate of these waters in the Davis Strait and Labrador Sea, the changes in character and thickness of Labrador Sea Water with time and the influence of all these ocean-change components on the rate of the Atlantic overturning Cell, ------modelled but so far unobserved. The ASOF – West effort forms a subprogram of the US Study of Environmental Arctic Change (SEARCH), itself developing towards implementation. In view of the importance of freshwater fluxes to both studies, a significant and most helpful development has been the Announcement of Opportunity by the NSF Office of Polar Programs for research bids on the "Arctic Freshwater Cycle: Land/Upper Ocean Linkages" that was made in late February 2002. The program description "emphasises particularly the research planning of the Arctic/Subarctic Ocean Fluxes (ASOF…)" and makes explicit mention of its intention to understand the "Arctic freshwater system and its connections with the subpolar oceans and arctic environmental change". Full proposals are due June 3 2002 [see http://www.nsf.gov].

ASOF therefore has interests in a number of developing lines of work and funding as it moves towards implementation. The calendar presented as Annex X outlines the next steps in terms of key meetings and deadlines.

See http://asof.npolar.no/ for further information.

13.2 A Proposal to the ICES WGOH for Sampling and Long-Term Storing of Water for Future Tracer Analysis

The proposal, presented in Annex Y, from Prof. B. Hansen (Faroe Islands), is for WGOH members to store water samples for future tracer experiments. This proposal should be considered intersessionally, and discussed at the 2003 meeting.

13.3 A Proposal to the ICES WGOH for Isopycnal Melding of Hydrographic Surveys

Prof. T Rossby (USA) proposed an activity for the WGOH in order to better utilise the data its members collect. This is presented as Annex Z, and should be discussed at the 2003 meeting.

13.4 Next Chair

It was proposed that Dr A Lavin (Spain), be recommended as the next Chair of WGOH.

14 DATE AND PLACE OF NEXT MEETING

Harald Loeng (Norway) kindly extended to the Working Group an invitation to Bergen in 2003. The Working Group will meet there during 31 March – 3 April 2003. It is proposed that a one-day mini-symposium be held to discuss recent work on regional ocean climate variability of relevance to WGOH, including process studies and modelling. The Bjerkens collaboration will be asked to help co-ordinate the meeting.

15 RECOMMENDATIONS

a) The 2002/2003 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 Cooperative 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 an ICES web product. As such it cannot be easily cited, or recognised 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** (Chair: to be decided) will meet Bergen, Norway, 31 March - 3 April 2003 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 Service Hydrographique 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 two proposals for new work by WGOH members; 1) to undertake long term storage of water samples, 2) to undertake an isopycnal analysis of *in situ* data.

Supporting Information

<table>
<tr><td>Priority:</td><td></td></tr>
<tr><td>Scientific Justification:</td><td>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 Group on Oceanic Hydrography. This agenda item will allow Working Group OH 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 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 intersessionally. 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) These two new business items were proposed by Prof. Hasen (Faroe Islands) and Prof. Rossby (USA) for further discussion by the group (see Annex Y and Z of 2002 report).</td></tr>
<tr><td>Relation to Strategic Plan:</td><td>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.)</td></tr>
<tr><td>Resource Requirements:</td><td>a) 1 day Working Group OH meeting. Pre-prepared national reports from members.
b) 5 days Chair's time to edit. Agenda item discussion (2–3 hours Working Group OH meeting)
c) Pre-meeting preparation (Bacon, UK). Agenda item discussion (1–2 hours Working Group on Oceanic Hydrography meeting)
d) 5 days ICES Oceanographer
Total = 4 days meeting time</td></tr>
<tr><td>Participants:</td><td>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) Rossby (USA) and Hansen (Faroe) lead. All members</td></tr>
</table>

Secretariat Facilities:	a) 1 day ICES Oceanographer to prepare IBTS / Skagerrak report b) 2 days ICES Oceanographer to put report onto ICES web site d) 2 days ICES Oceanographer
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 2002 WGOH MEETING

2C08 The Working Group on Oceanic Hydrography [WGOH] (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; [ALL]

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

c) conclude the review of North Atlantic climatologies and their availability and usage, and additional data sources for the ICES Annual Ocean Climate Summary; [BACON]

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; {DOOLEY, ROSSBY, TURRELL]

e) review the current methods and uses of environmental information in the fish assessment process;[COLBOURNE]

f) review progress on the publication of the proceedings of the ICES Symposium on Hydrobiological Variability in the ICES Area, 1990–1999; [DICKSON]

g) review progress towards producing educational publications; [ALL]

h) prepare a summary report listing relevant marine bio-ecological variables and indicators suitable for operational use.[ALL]

WGOH will report by 30 April 2002 for the attention of the Oceanography Committee.

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 Group OH. This agenda item will allow Working Group OH 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 Group OH 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 Group OH, 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 Group OH should remain informed about this work, and may contribute to ICES / GOOS initiatives.

h) Increasingly underway ADCP measurements are being acquired from research vessels (e.g., Canadian vessels on the Newfoundland shelf) and ships of opportunity (e.g., 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 Group OH 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 Group OH it was suggested that one role of the Working Group OH 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.

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ANNEX D: ABSTRACTS FROM THE MINI-SYMPOSIUM ON ARCTIC AND SUB-ARCTIC OCEANOGRAPHY

A Regional Perspective on DFO's Arctic Strategy

E. P. Jones

Fisheries and Oceans Canada, Bedford Institute of Oceanography, Dartmouth, NS, Canada

In Canada, Federal Government labs concerned with ocean and earth sciences were created to support economic and other national goals such as northern development, transportation, and sovereignty. Those drivers continue through to today, with perhaps a slightly expanded vision of what they include, e.g., climate change.

Work by Canadian Federal Government scientists dates back to the early twentieth century and began with mapping and bathymetric surveys. In the post World War II period, hydrographic and oceanographic surveys in the high Arctic were conducted throughout the entire Archipelago using icebreakers and motivated to a large degree to demonstrate sovereignty in these regions. During the 1970s and 1980s, BIO scientists regularly carried out ship and ice camp based research in the Arctic from July through October.

Program review and 30–40% funding cuts in the 1990s caused a major withdrawal from Arctic programs. Nevertheless, activities, though reduced, were not halted. They included the 1994 Canada-US Arctic Ocean Sections Expedition, and included participation in several European expeditions, in SHEBA, and now in coordinated programs like CASES and SBI.

Over the past few years, we in Federal Government labs were encouraged to develop Arctic Science Strategies in search of new funding. This culminated in a major planning initiative in 2000–2001for scientific research in the Arctic. This initiative has not yet been acted upon, but there is an improved atmosphere regarding Arctic research, and it is hoped that earlier efforts and expectations will be sustained and expanded.

Tracing Arctic Ocean Waters

E. P. Jones

Fisheries and Oceans Canada, Bedford Institute of Oceanography, Dartmouth, NS, Canada

The Arctic Ocean helps shape global thermohaline circulation in two ways. It contributes deep water formed within the Arctic Ocean to the northern part of the Global Conveyor Belt. And it influences the density of the water close to the surface in the Nordic and Labrador seas through the export of freshwater to these regions.

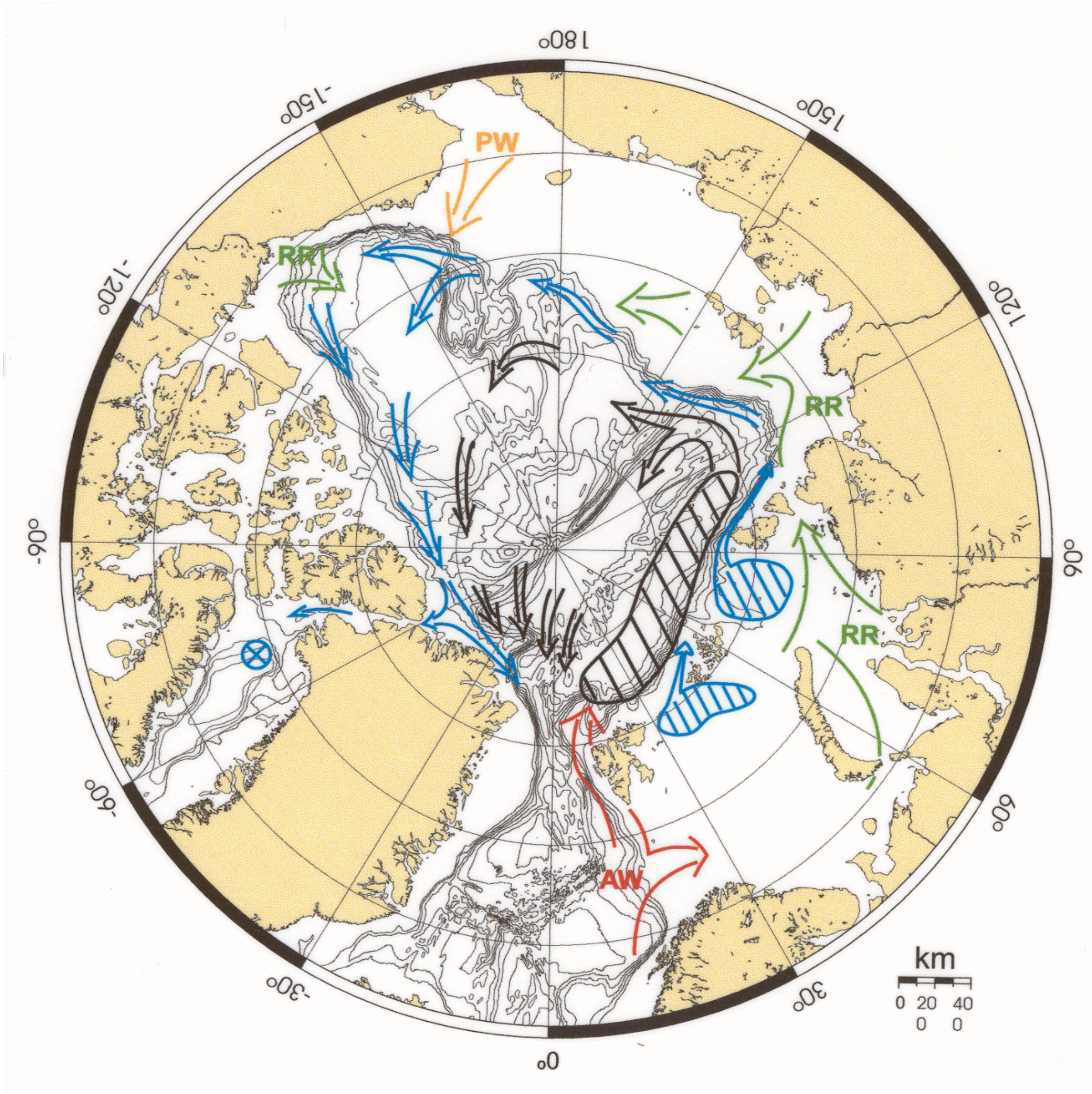
The Arctic Ocean can also shape the climate within and outside the Arctic Basin by what goes on within Arctic Basin. If the permanent ice cover were to diminish significantly or disappear, the Arctic atmosphere would be much altered though interactions with open water. The amount of heat stored in the Atlantic Layer is many times more than that required to completely melt the ice pack. What is preventing this heat from reaching the ice is the strong density gradient, the halocline, between the Polar Mixed Layer and the Atlantic Layer.

This presentation focuses on tracing the circulation of the halocline and Polar Mixed Layer waters within the Arctic Ocean and on tracing the fresh water in the Polar Mixed Layer as it exits the Arctic Ocean into the North Atlantic.

A recent view of halocline formation was that an “embryonic” halocline is formed as Atlantic water entering the Arctic Ocean encounters and melts ice, becoming fresher and colder. Ice formed in winter mixes the near surface waters until fresh river runoff caps this halocline north of the coast and prevents winter convection from reaching it, thus resulting in the Lower Halocline. An additional contribution to the halocline that forms the Upper Halocline comes from Pacific water that is modified in the shallow shelf seas north of Siberia. Recently a second source of Lower Halocline water was identified as coming from water formed in the Barents Sea. This water closely follows the Eurasian coast, then spreads and makes up most of the Lower Halocline in the Canada Basin. All three halocline components can be seen exiting the Arctic Ocean through Fram Strait east of Greenland.

Using nutrients as tracers, the relatively fresh Pacific source water can be followed as it exits the Arctic Ocean through the Canadian Arctic Archipelago west of Greenland and through Fram Strait east of Greenland. The near surface (top

100 m) water leaving the Arctic Ocean through the Canadian Arctic Archipelago and through Fram Strait east of Greenland is nearly 100% Pacific source water with some additional river runoff and sea ice melt water. The river runoff plus sea ice melt water component can be distinguished in plots of the Pacific fraction vs. salinity.



Lower Halocline Circulation. Black represents the Fram Strait branch; blue represents the Barents Sea contribution.

Measuring and Modelling the Freshwater and Heat Fluxes through the Canadian Arctic Archipelago

Simon Prinsenberg, Jim Hamilton, George Fowler and Dave Greenberg

Fisheries and Oceans Canada, Bedford Institute of Oceanography, Dartmouth, NS, Canada

(additional information: www.mar.dfo-mpo.gc.ca/science/ocean/seaice/public.htm)

The international Climate Variability and Predictability (CLIVAR) and the Arctic Subarctic Ocean Flux (ASOF) programs have identified the determination of the flow of Arctic Ocean Surface water into Baffin Bay and Labrador Sea on the North Atlantic Oscillation and the Atlantic Thermohaline Circulation as an important research foci. To elucidate its role in the global climate system and contribute to the goals of the international Arctic Climate System Study (ACSYS), a BIO field and modelling project is studying the variability of the heat and freshwater fluxes passing through Canadian Arctic Archipelago. It consists of summer fieldwork in the Archipelago supported by Can. Coast Guard icebreakers, instrumentation development to address special requirements associated with the surface outflow in an area with a seasonal ice cover and numerical modelling to aid in the interpretation of the processes contributing to observations. Observations will calibrate the numerical model simulations, which in turn will provide the total fluxes through the Archipelago as not all straits can be instrumented.

For the 2000–2001 mooring deployment, the array was modified to increase coverage along the south shore and in the middle of the channel. A total of 5 ADCPs, 13 CTD units and 9 acoustics releases were used. Upward Looking Sonars (ULS) have not been used as most of the time the ice is land-fast and the fresh-water flux as ice is estimated to be 10% relative to that in the water column. Special high accurate 3-axis flux gate compasses had to be installed within the ADCP floats due to the proximity of the magnetic pole. These were developed by the project to overcome the problem of measuring directions in the low horizontal magnetic field found in the Archipelago. Since the freshwater and heat fluxes increase towards the surface, a large fraction of the total water column fluxes are missed with the present instrumentation. To overcome this, a subsurface mooring housing a CTD profiler (called the ICYCLER) was designed and build to profile the surface (0–50m) water properties under the mobile pack ice for a year. It was deployed on February 2002 in the southern Gulf of the St. Lawrence for a 4-month test before it will be used as part of the Archipelago array at the south side of the strait.

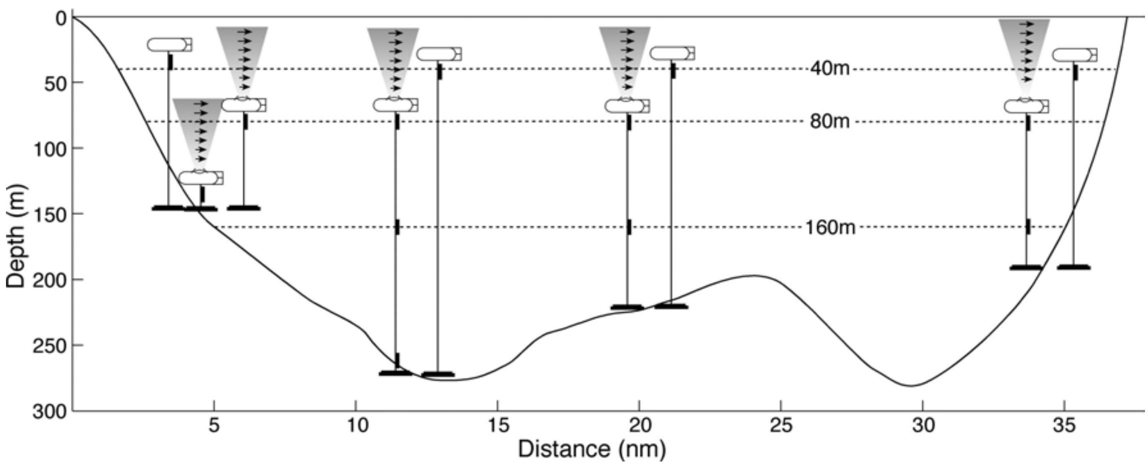


Figure A.D.1. Mooring array of August 2001 to August 2002 in Lancaster Sound.

Results from the 1998–99 and 1999–2000 mooring data shows that tidal and mean currents are similar to those measured to the west in central Barrow Strait in the early 1980s. There is a strong seasonal cycle in the current, salinity and temperature fields from open water to land-fast ice conditions. Atmospheric forcing (5–6 day period) of the currents is felt over the total water column but weakens during the wintertime when the area is ice-covered. Fluxes have been calculate from the arrays by assuming for now that both the southern and northern arrays contribute for half the transect's width. The table below shows the mean annual and seasonal fluxes for 1999 to 2000, with Q as heat flux, M as mass flux and F as freshwater flux. If Lancaster Sound represents 40% of total flux through the Archipelago (as model results indicate), then the total mean mass flux is 1.7Sv of which less than 10% is freshwater.

	Q(J/s)	M(m^3/s)	F(m^3/s)
Year	-3.90E+12	6.66E+05	4.20E+04
Fall	-1.21E+12	2.09E+05	1.74E+04
Winter	-3.49E+12	5.93E+05	3.66E+04
Spring	-4.07E+12	6.40E+05	3.93E+04
Summer	-8.14E+12	1.45E+06	8.69E+04

The finite element model has been used to simulate the tides as well as the barotropic transports through the Archipelago in response to a 10cm surface set-up of the Beaufort Sea relative to Baffin Bay. Tides within the Archipelago are affected by both the Arctic and Atlantic Ocean tides. The model tidal height simulations compare well with observations and show that the stronger Atlantic tide affects the Archipelago water level past the shallow sills and interferes there with the weaker Arctic tide. Pressure data from the CTD modules show that during the ice-covered season, the tides decrease in magnitude and occur earlier, since relatively more of the earlier incident tide remains than the reflected tide is present in wintertime. The model simulations show that there is a noticeable shift in M2 phase and changes in amplitude, resulting from differences in the extent of the ice cover. This is primarily in areas near existing amphridromes where the tidal amplitude is low. There was little effect of the ice extent variation on the barotropic transport. Future plans are to investigate the time-variant response of transports to atmospheric time scale forcing, introduce baroclinic effects into the finite element model, and connect the model to a dynamic and thermo-dynamic ice model.

Modelling the Marginal Ice Zone

Tom Yao

Fisheries and Oceans Canada, Bedford Institute of Oceanography, Dartmouth, NS, Canada

A Hibler ice model is coupled to the Princeton ocean model to investigate ice-ocean interactions in the marginal ice zone. A monthly climatology from the NCEP/NCAR reanalysis provides the atmospheric forcing. Two examples are considered. The first example is the ice edge, which is characterised by melting and convergence of ice. The melting ice cools and freshens the ocean. The position of the ice edge is maintained by enhanced horizontal mixing within the ocean, suggesting a role for ice in mixing freshwater from the shelf to the interior. The second example is the coastal polynya, where winds blowing off coasts cause relatively light ice conditions. Within the polynya there is increased heat loss to the atmosphere and increased ice growth accompanied by brine convection. The early clearing of ice in the spring and the enhanced vertical mixing help make polynyas regions of high ocean productivity. The North Water in northern Baffin Bay is implicated in the formation of Baffin Bay bottom water.

Circulation in Baffin Bay

C.K. Ross

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The results of 16 year-long moorings in Baffin Bay and 5 3-year moorings across Davis Strait were presented. The data confirmed that there is a cyclonic circulation around Baffin Bay with inflow on the Greenland slope of Davis Strait and from north of Smith Sound. Outflow extended across Davis Strait from Baffin Island to the deepest part of the strait near the Greenland slope. The currents were often, but not always, subject to annual variations. An additional surprise observation was that the strongest currents were observed at about 1000m, well below the maximum sill depth connecting Baffin Bay to the Labrador Sea. The 3-year average net volume transport through Davis Strait was 2.4 x 10^6 m^3s^{-1} consisting of 0.7 x 10^6 m^3s^{-1} flowing northward in eastern Davis Strait and a southward transport over the western portion of 3.1 x 10^6 m^3s^{-1}.

Modelling Arctic Archipelago Circulation and Tides

David Greenberg

Fisheries and Oceans Canada, Bedford Institute of Oceanography, Dartmouth, NS, Canada

As part of Canada's commitment to the international Global Ocean Observing System (GOOS), permanent tide gauges are being installed in the Arctic. A primary goal is to obtain high quality, levelled sea surface data to look at long term changes in sea level and slopes that would indicate changes in transport patterns. This presentation looks at progress in using a three-dimensional barotropic finite-element model to help in the analysis of the data. The model is used to examine how the complex tides change with seasonal ice cover, how the transport varies with the period of the sea level difference between the Arctic and the Atlantic, and how the sea level signal of the Arctic Ocean is transmitted through the Archipelago.

ANNEX E: FRENCH REPORT

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Repeated hydrography:

For the international climate CLIVAR, LPO (Brest) will conduct a cruise every two years between the Iberian Peninsula and Cape Farewell. This cruise is expected to contribute to the monitoring of the meridional overturning and associated transports. Oceanographic stations will be conducted from the surface to the bottom with CTD, L-ADCP and measurements of nutrients and dissolved inorganic and organic carbon. The first cruise will be conducted on 6 June –7 July 2002 (P.I., Herle Mercier, LPO).

A repeated CTD section across the Bay of Cadiz has been repeated once a year (SHOM/ LPO) along 8 20´W since 1999. The last repeat will be in July 2002, with hope to restart sampling in 2005. The section includes CTD; L-ADCP stations from surface to bottom, and was aimed at a survey of the water masses and their circulation in this region close to the Straits of Gibraltar. Not having at least a seasonal sampling however implies that it is difficult to separate the effect of mesoscale variability from the signals relevant for climate. An experiment starting in 2005 will be designed for the monitoring of the Mediterranean water entering in the Atlantic Ocean.

Coastal surveys are carried every year on the shelves in the Gulf of Biscay (IFREMER/DEL) both in the spring and the autumn (October-November).

France contributes to the ARGO project of profiler floats with more than 100 floats to be deployed in the North Atlantic before September 2002 with temperature and conductivity sensors. The floats are mostly of a French model, PROVOR. They are expected to live four years and to profile every 10 days from their parking depth usually at 2000 m to the surface where they transmit the data through Argos (www.ifremer.fr/coriolis)

France contributes to the surface water hydrographic sampling by equipping ships-of-opportunity with thermosalinographs and taking on selected transits surface samples for later analyses of nutrients, dissolved inorganic carbon or plankton. Some of these vessels also drop XBTs. Currently, 10 merchant vessels providing data in the Atlantic are part of this network supervised by IRD. The lines are between Le Havre (or Rotterdam) and Cape Town, Buenos Aires, as well as to Cayenne (French Guyana). In addition, the Nuka Arctica operating mostly between Aalborg (Denmark) and Nuuk (Greenland) is equipped, as well as three vessels on a round-the-world line calling in the Atlantic sector in Algeciras, Rotterdam, Le Havre, New York and Panama. LEGOS is also involved with the surface sampling on the Skogafoss between Iceland and North America (the ship main ports of call are in Newfoundland, Boston and Norfolk) (Figure A.E.1). The sampling with thermosalinographs has started on the different lines between 1993 and 1997. Observers taking samples embark every three months on the Skogafoss, as well as on the Contship London (Le Havre to New Caledonia). In addition, three research vessels operating part of the time in the Atlantic are transmitting data (R/V Atalante, Thalassa and Suroit). An example of a time series is presented based on the data on the Nuka Arctica along 60N between the Faeroe-Shetland Channel and Cape Farewell (notice that there is no data between January and March) (Figure A.E.2). In addition, France deploys occasional surface drifters equipped with salinity or other sensors, usually for identified projects. Four Carioca drifters were deployed during POMME in early 2001, which have been recovered (after drifts of 6 months to 13 months), and which salinity data seem of high quality. However, attempts with other drifters have not provided usable results.

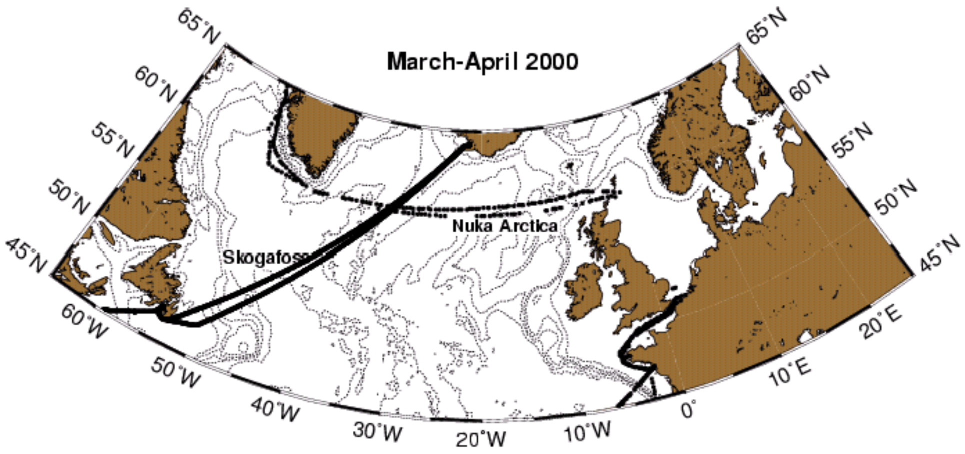

Figure A.E.1. Real-time surface sampling in the subpolar gyre in March-April 2001 from the ships Nuka Arctica and Skogafoss (in March, the Nuka Arctica went between Rotterdam and Algeciras, and in April between Aalborg and west Greenland).

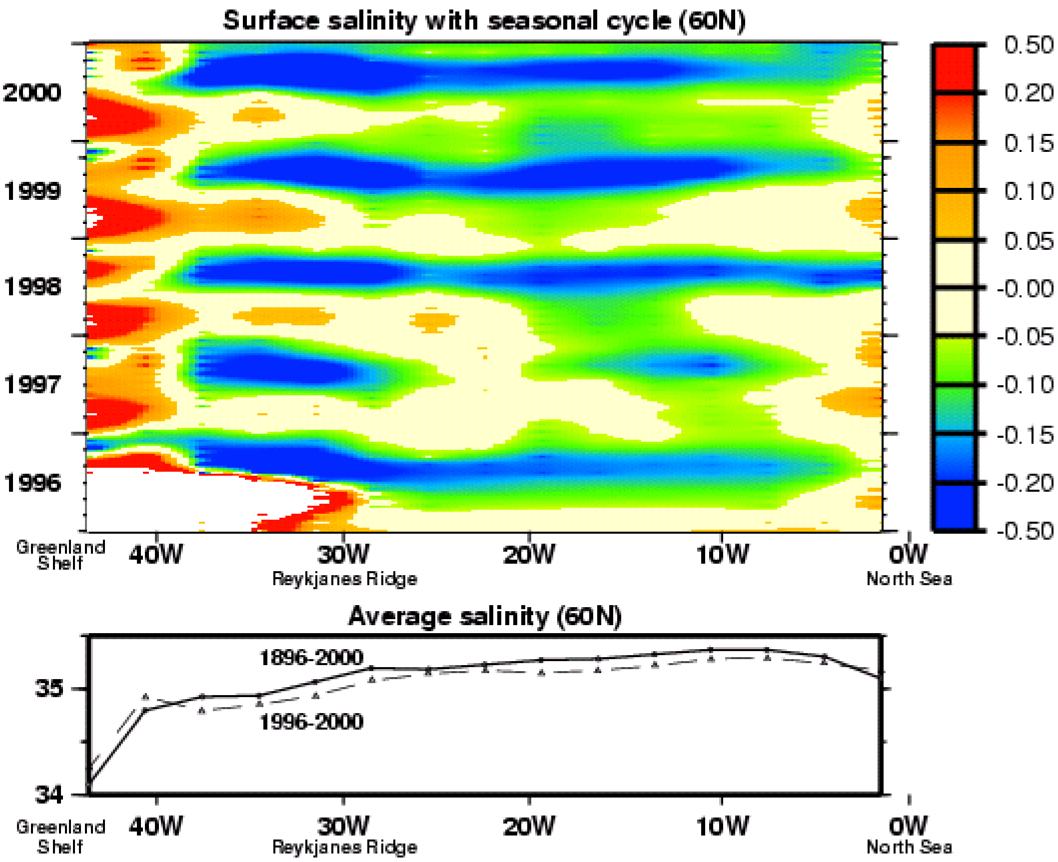

Figure A.E.2. Hovmuller diagram (longitude-time) of surface salinity along 60°N between the Shetland shelf and the Greenland shelf off Cape Farewell. At each longitude, the average salinity from 1896 and 2000 has been removed (the lower panel shows the average difference between this climatology and the data for the period 1996–2000). Data are not common before the autumn 1996 and during January-March of each year. The Nuka Arctica regularly provides data along this latitude band since July 1997.

ANNEX F: THE NAO IN WINTERS 2001 AND 2002: INDICATIONS OF LIMITED RECOVERY TO NAO-POSITIVE CONDITIONS FOLLOWING THE NAO-NEGATIVE WINTER OF 2001

Stephen Dye, Bob Dickson and Jens Meincke

1. Background

The North Atlantic Oscillation (NAO) is the dominant mode of atmospheric variability in the North Atlantic, accounting for 44% of the variance in winter (December-March, DJFM, is defined as the winter season and the year given by January) sea-level pressure (SLP) in the last century (Hurrell, 1995). The classical dipole is shown in the Figure A.F.1 as the first EOF of SLP anomaly (Hurrell, pers. comm.), the next two modes of variability account for 12% and 11% of the variance respectively.

It is conventional to use an index of the winter NAO (NAO_{DJFM}) defined by the pressure difference between the two cells of the dipole, as measured at land stations. Hurrell (1995; 1996) constructs a time-series of the winter NAO_{DJFM} index of Lisbon–Stykkisholmur SLP, whilst Jones *et al.* (1997) use the SLP difference Gibraltar–Reykjavik. These indices have the benefit that they can be extended back to 1864 (Hurrell, 1995) and 1821 (Jones *et al.* 1997). Whilst an NAO_{DJFM} index is normalised to its standard deviation over a base period, it must be remembered that it is simply the measure of SLP difference between two particular land stations. The NAO_{DJFM} index is simply a diagnostic of the NAO_{DJFM} SLP distribution.

The characteristics of the NAO and aspects of the relationship to the ocean were discussed in the prior reports to the WGOH (Dickson & Meincke, 1999, 2000; Dickson *et al.* 2001). The amplification of the NAO_{DJFM} index from the extremes of negative to positive between the 1960s and the late-1980s/early-1990s underwent a sharp decrease in winter 1996. Reports to the WGOH in 1999–2001 described the recovery from the 1996 extreme in the years 1997–2000 and early indications that 2001 was seeing a return to negative value of NAO_{DJFM} index.

Here we briefly report on the full story from the winter of 2001 and early indications for winter 2002. Though March is still in progress the NAO_{DJFM} index for 2002 is likely to show a limited recovery from 2001, in an overall SLP anomaly distribution, which is unlike the classical dipole. Both 2001 and 2002 illustrate the need to use the NAO_{DJFM} index and EOF pattern with reference to the actual SLP anomaly field when trying to understand and explain the physical processes involved in the ocean's response to the NAO_{DJFM}.

2. Winter NAO in 2001

Dickson *et al.* (2001) reported on early indications of a sharp return to NAO_{DJFM} negative conditions, at that time only December 2000 and January 2001 values of the Jones NAO_{DJFM} index (www.cru.uea.ac.uk) were available. In addition SLP anomaly fields from NCEP/NCAR reanalyses for the first 3 months of the 2001 winter (DJF) showed a pattern, which we would associate with a negative NAO_{DJFM} index. Once the full winter data became available the early indications were confirmed. The Jones NAO_{DJFM} index (www.cru.uea.ac.uk) for 2001 was –0.5 whilst the Hurrell NAO_{DJFM} index (www.cgd.ucar.edu/~jhurrell/nao.html) reports a value of –1.89. The NCEP/NCAR reanalysis SLP anomaly composite for the winter 2001 (Figure A.F.2a) shows a clear negative anomaly in the pressure dipole.

In 1996 the NAO_{DJFM} became strongly negative (Jones NAO_{DJFM}=–2.3, Hurrell NAO_{DJFM}=–3.78, SLP anomaly shown in Figure A.F.2b) following a long period of high NAO_{DJFM} positive conditions. A wide range of responses to the 1996 negative NAO_{DJFM} were discussed in Dickson & Meincke (1999), including, northward heat transport in the North Atlantic, a westward shift of the sub-Arctic front in mid-Atlantic, and sea temperatures and cod recruitment in the southern North Sea. Scanfish sections across the northern slope of Dogger Bank in the summer of 1996 found extremely cold water beneath the seasonal thermocline (J. Brown, pers. comm.), leading to enhanced stratification, bottom front and associated flow.

Becker and Pauly (1996) demonstrated the strong correlation between the NAO_{DJFM} index and SST anomaly in the North Sea. To illustrate the different responses of the ocean to negative NAO_{DJFM} forcing, Figure A.F.3 shows the SST anomaly percentile (monthly climatology: 1971–1993, Loewe, 1999) in the North Sea for March 1996 and March 2001 (www.bsh.de/Oceanography/Climate/Actual.htm). March SST is chosen at the end of the winter season so that it has felt the full NAO_{DJFM} of that year, in addition, for both 1996 and 2001 the NAO_{DJFM} index for March itself was strongly negative. Figure A.F.3a shows most of the North Sea in 2001 to be slightly warmer than average. In 1996 (Figure

A.F.3b) the March SST across much of the North Sea was in the coldest 5 percentile, with the SE North Sea colder than we would be expect to find it in 99 years out of 100.

Examination of the SLP anomalies for the two winters (Figure A.F.2) illustrates a possible reason for the markedly different response to negative NAO_{DJFM} forcing. Firstly 1996 was a much stronger negative NAO year. Secondly, the SLP anomaly of 1996 suggests a strong southeasterly wind anomaly bringing cold, dry eastern European air across the southeastern.

North Sea, this is not evident in 2001.

Given the clear response of the North Sea to the 1996 NAO_{DJFM} negative, a similar response to may have been expected in 2001 on receipt of the NAO_{DJFM} index value. This simple example illustrates the need to use the NAO_{DJFM} index only as an initial indicator of possible ecosystem responses and that investigation of the actual physical processes at work in any given year is required to understand any observed response. (We note that full explanation of the differences between 1996 and 2001 would need to consider the conditions preceding the winter, on first inspection (www.bsh.de/Oceanography/Climate/Actual.htm) it appears that autumn 1995 had warmer SST anomaly than autumn 2000, which argues against persistence as the reason for difference between the winter SST responses.

3. Early indications of mixed conditions in the 2002 winter NAO

The Jones NAO index (www.cru.uea.ac.uk) values for December 2001 and January 2002 are −2.25 and +2.31 respectively. A NAO index based on principal component analysis of SLP (provided by the NOAA Climate Prediction Center www.cpc.ncep.noaa.gov/data/teledoc/telecontents.html) gives values of –1.0, 0.4 and 1.6 for December 2001 through January 2002.

Figure A.F.4 shows the SLP anomaly field in the North Atlantic for (a) December 2001, (b-c) January, February 2002 and (d) the composite of those 3 months (NCEP/NCAR Reanalysis data from NOAA-CIRES Climate Diagnostics Center: www.cdc.noaa.gov/Composites). In marked contrast to 2001 (Dickson *et al.,* 2001) each month has distinct differences from one another, and from the classical EOF-1 winter SLP anomaly distribution (Figure A.F.1). December has some of the zonality of EOF-1 (as a negative NAO) but is reminiscent of the third EOF (Figure A.F.1) -an anticyclonic anomaly south of Iceland. We note that by definition the first and 3rd EOF of SLP are independent of each other however both would have a strong effect on the instrumental NAO index. January shows a dipole E-W. February suggests positive NAO but limited in the west with weak northerly wind anomalies across the Labrador Sea. The individual months exhibit strong, if unusual, patterns of SLP anomaly, however the composite of the three months suggests that the influence of the overall NAO_{DJFM} will have been weak.

Strong positive and negative monthly NAO anomalies in winter 2002 appear from this early indication to be adding to a weak overall NAO_{DJFM}. The ecosystem response is unlikely to be linear; our experience of the 1960s-1990s may not provide the background for such a mixed NAO_{DJFM}. Depending on the timing and location of specific processes, we may observe responses in the ocean, which we would normally associate with either extreme NAO_{DJFM}.

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Figure Captions

Figure A.F.1: The first three EOFs of winter SLP anomalies over the Atlantic sector describe almost 70% of the variance. Figure courtesy of J. Hurrell, NCAR.

Figure A.F.2: Winter (December-March) SLP anomaly in the North Atlantic in the NAO_{DJFM} index negative years a) 2001 and b) 1996. (NCEP/NCAR Reanalysis data from the NOAA-CIRES Climate Diagnostics Center: www.cdc.noaa.gov/Composites).

Figure A.F.3: March North Sea SST percentile for the years a) 2001 and b) 1996. Figures from the Bundesamt für Seeschiffahrt und Hydrographie (www.bsh.de).

Figure A.F.4: The Atlantic distribution of SLP anomaly in the North Atlantic for (a) December 2001, (b) January, (c) February 2002 and (d) the composite of those 3 months (NCEP/NCAR Reanalysis data from NOAA-CIRES Climate Diagnostics Center: www.cdc.noaa.gov/Composites).

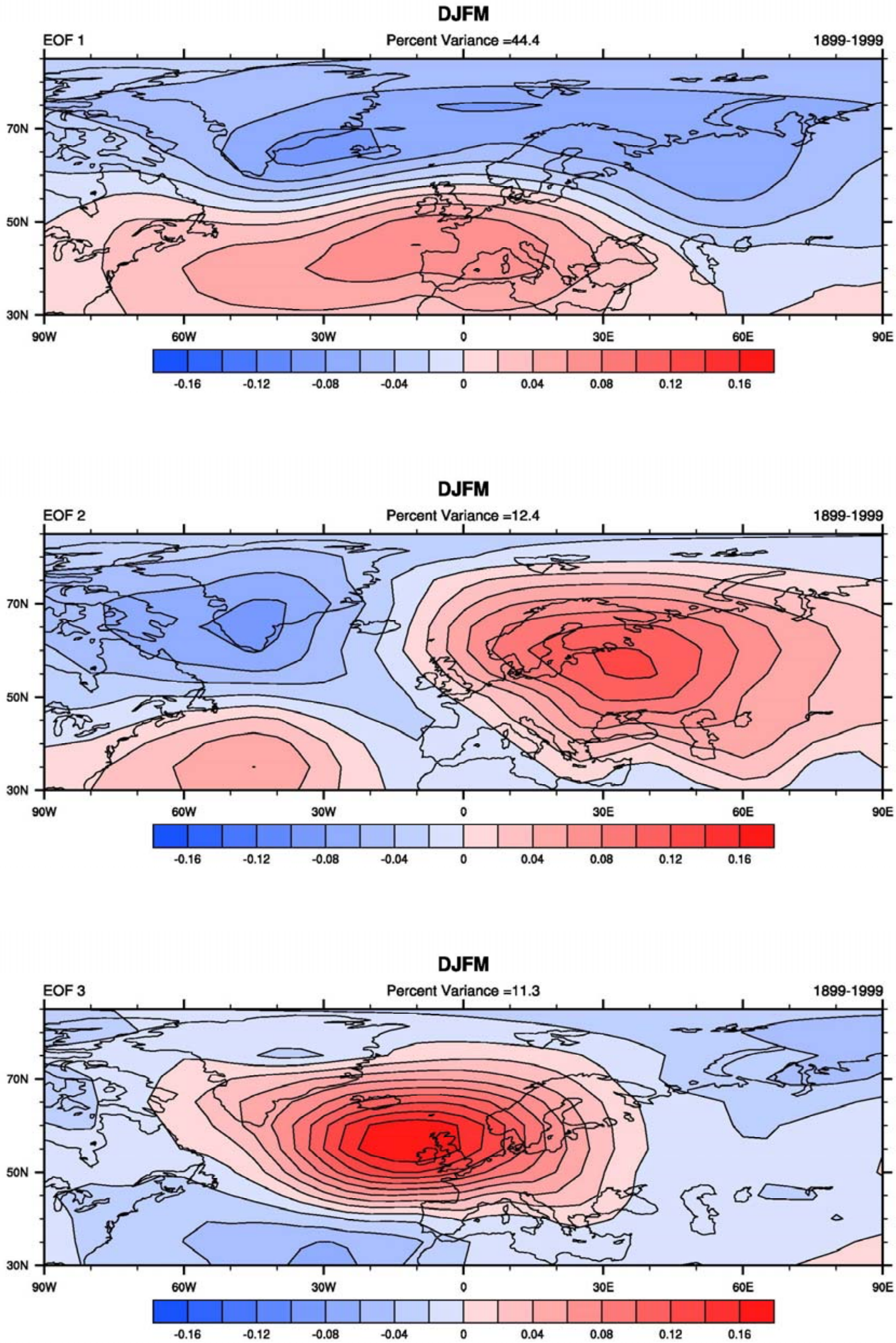

Figure A.F.1. The first three EOFs of winter SLP anomalies over the Atlantic sector describe almost 70% of the variance. Figure courtesy of J. Hurrell, NCAR.

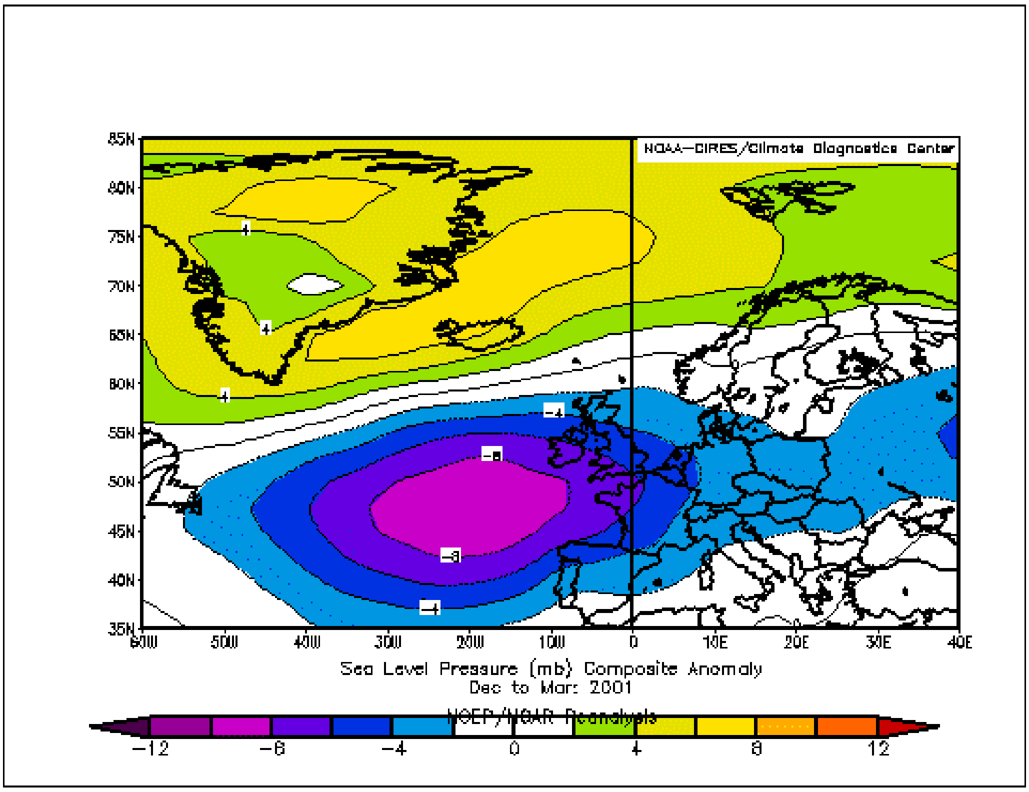

Figure A.F.2a) 2001.

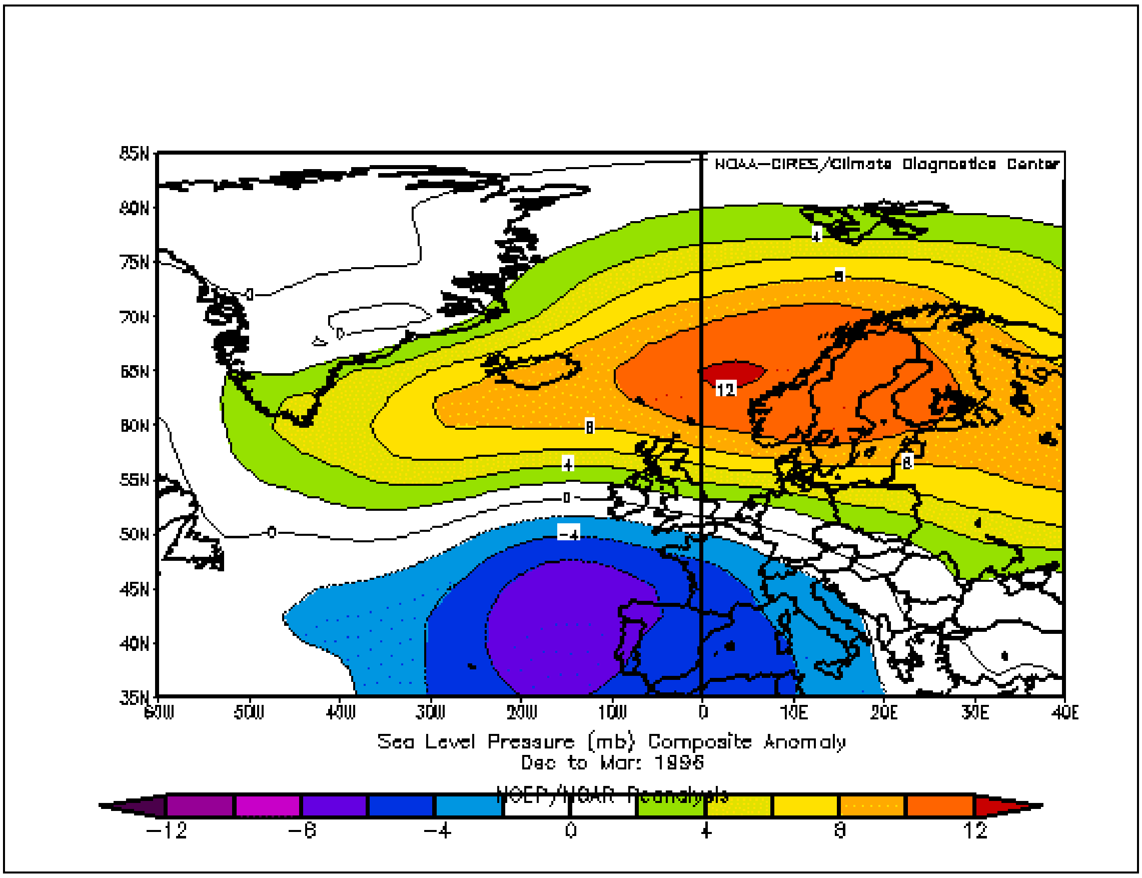

Figure A.F.2b) 1996.

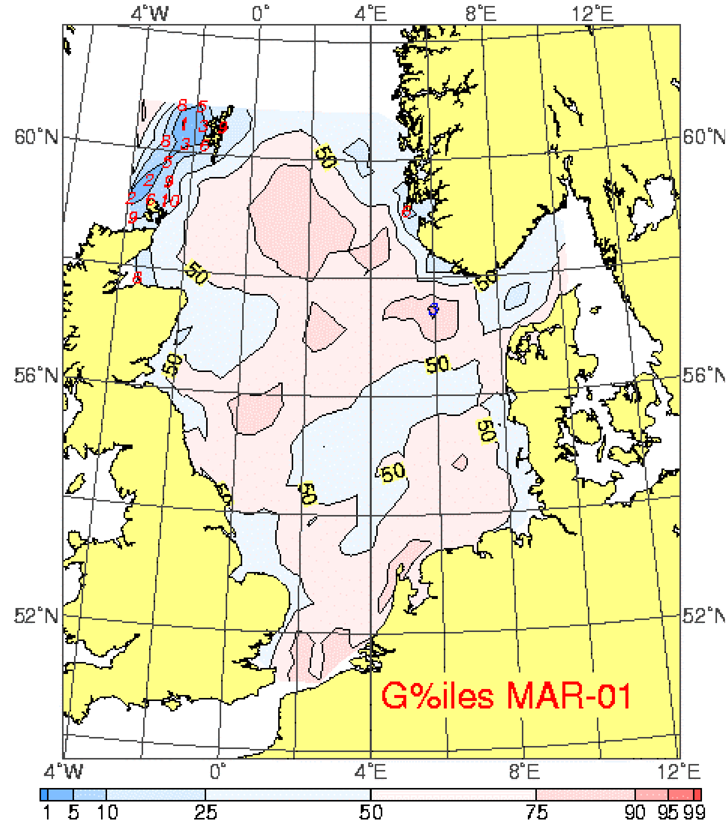

Figure A. F.3a) 2001.

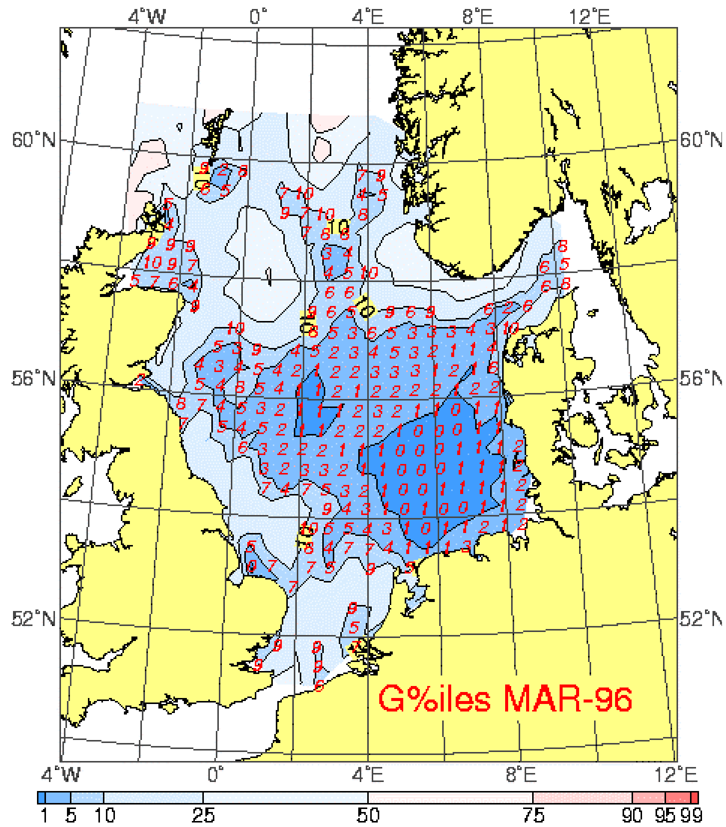

Figure A.F.3b) 1996.

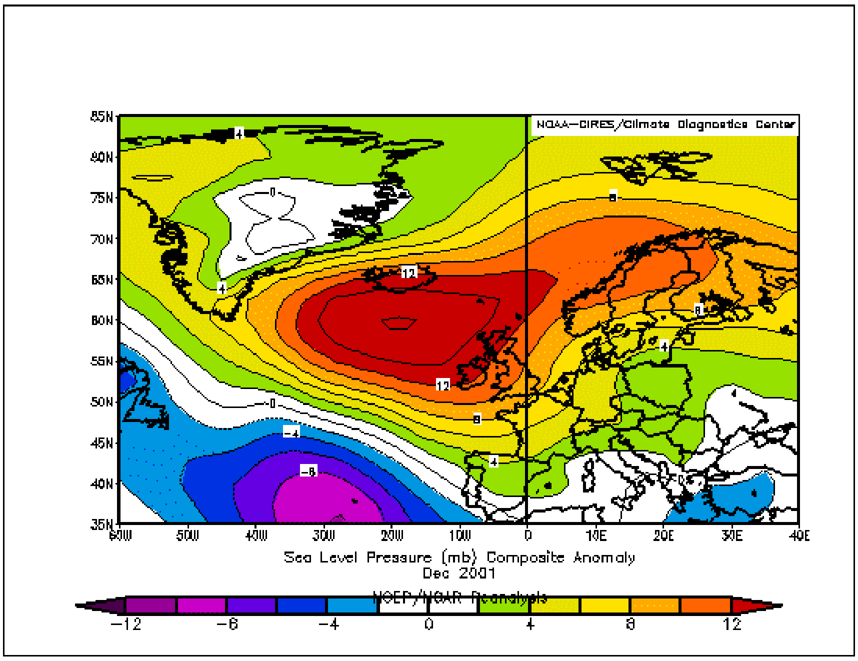

Figure A.F.4a) December 2001.

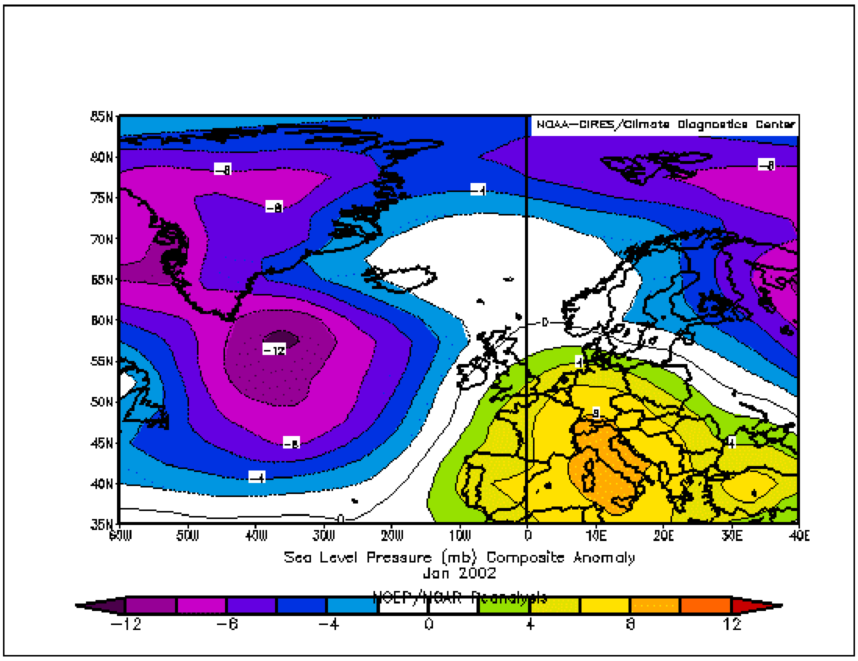

Figure A.F.4b) January 2002.

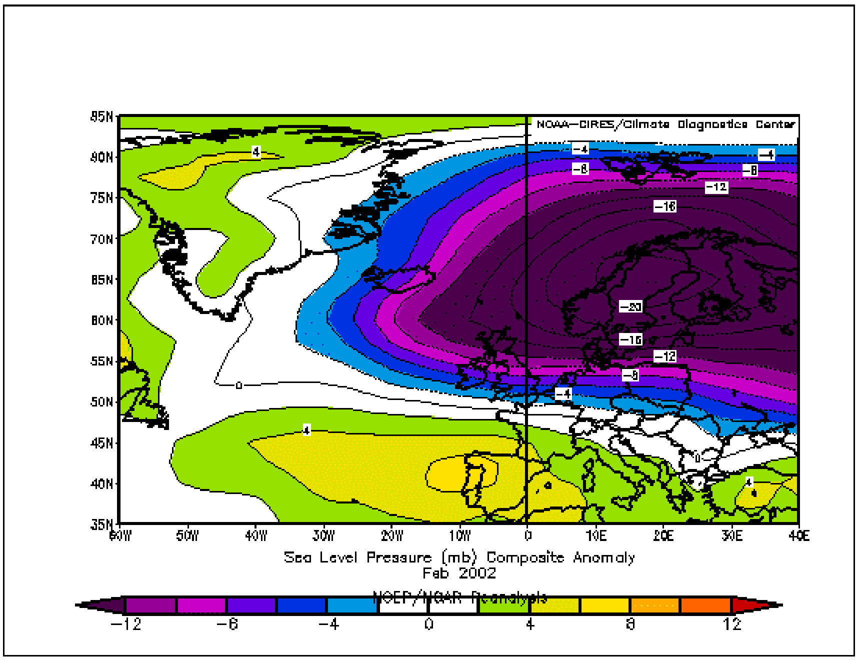

Figure A.F.4c) February 2002.

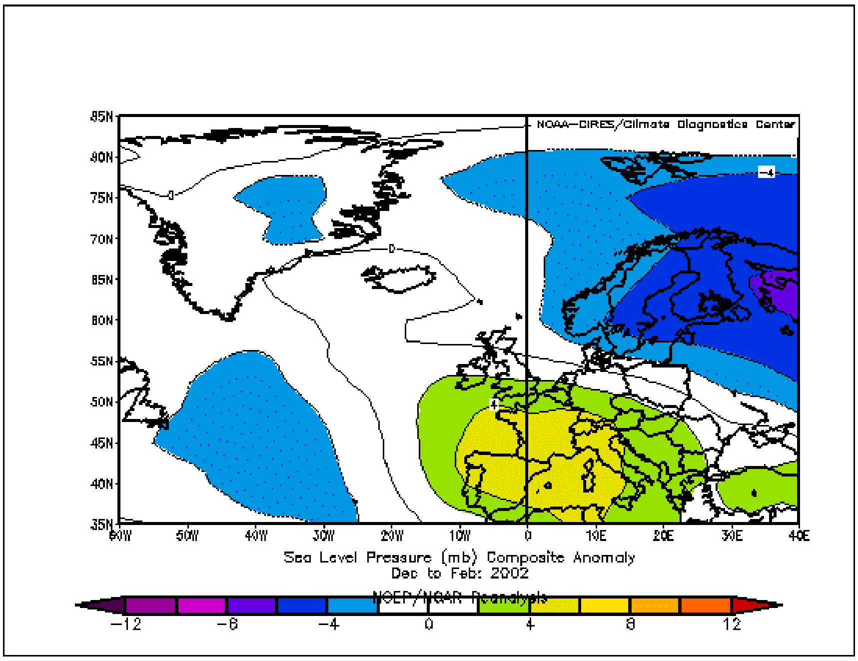

Figure A.F.4d) DJF 2001–2002.

ANNEX G: CLIMATIC CONDITIONS OFF WEST GREENLAND (ICES AREA 1)

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Overview Summary

Ocean temperatures off West Greenland showed considerable warming during *summer* and autumn 2001. This warming is similar as observed during the 1960s. Anomalous high salinities were observed in the off-slope surface waters during autumn.

Area 1 - West Greenland

West Greenland lies within the area, which normally experiences warm conditions when the NAO index is negative. The 2001 NAO index was –1.89. Accordingly the climatic conditions at West Greenland were anomalous warm. 2001 annual air temperature at Nuuk was –0.1°C, which is about 1.3°C above normal (Figure A.G.1). Changes in the ocean climate in the waters off West Greenland generally follow those of the air temperatures. The relative mild atmospheric conditions were reflected in the mean temperature at Fyllas Bank during autumn (Figure A.G.2), with the 2001 temperature value (T_{anom} = 1.78°C) for the upper 200m being the second highest temperature anomaly observed since 1963.

In summary, oceanographic conditions off West Greenland during autumn of 2001 were warmer and more saline (Figure A.G.3) due to mild atmospheric conditions and inflow of Irminger Water which was found as far north as 62°N (Frederikshaab Bank, Figure A.G. 4).

Figures and Captions

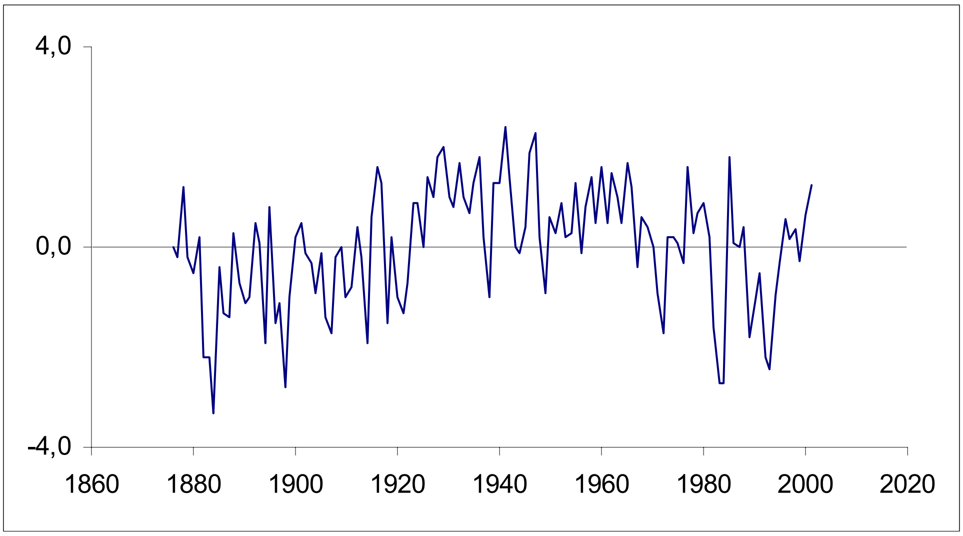

Figure A.G.1. Nuuk mean annual air temperature anomaly (rel. 1961–1990 climatic mean).

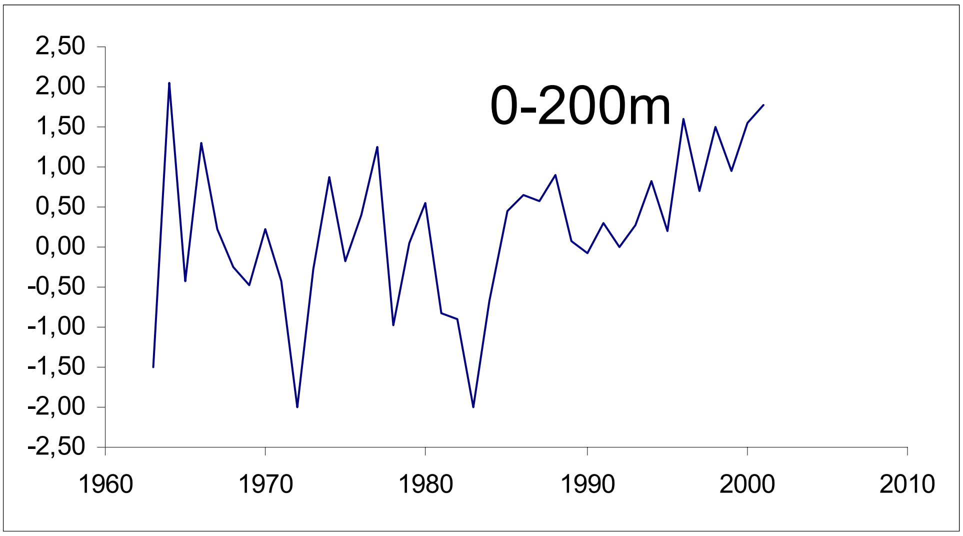

Figure A.G.2. Fyllas Bank Station 4 temperature anomaly autumn, 0–200m.

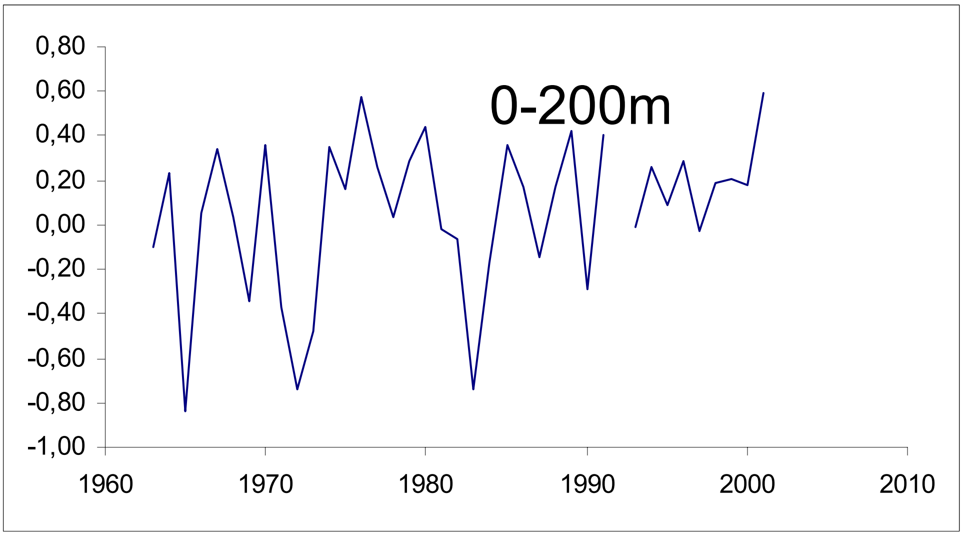

Figure A.G.3. Fyllas Bank Station 4 salinity anomaly autumn, 0–200m.

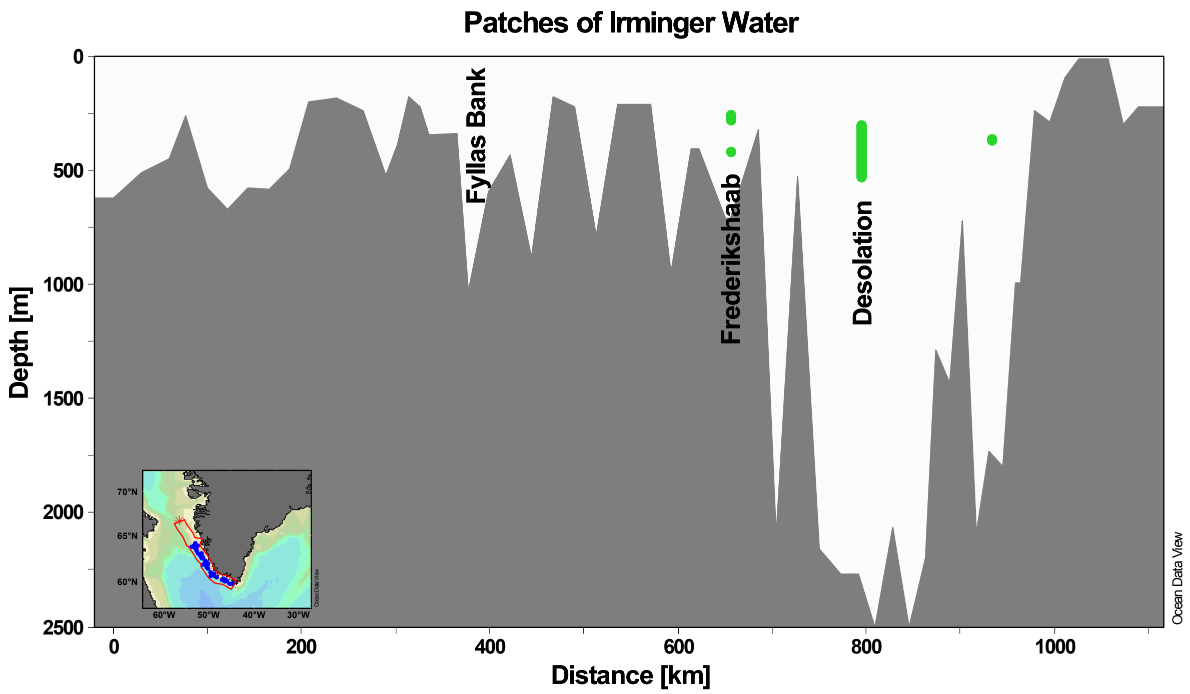

Figure A.G.4. Patches of Irminger Water along the West Greenland shelf slope during October/November 2001.

ANNEX H: OCEANOGRAPHIC INVESTIGATIONS OFF WEST GREENLAND 2001 (ICES AREA 1)

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April 2002.

Abstract

Results of the 2001 summer cruise to the standard sections along the west coast of Greenland are presented together with CTD data gathered during trawl surveys.

The time series of mid-June temperatures and salinities on top of Fylla Bank revealed 2001 to be a year close to average conditions. Pure Irminger Water was observed only at the Cape Farewell Section, while Modified Irminger Water could be traced all the way from Cape Farewell to Holsteinsborg in June 2001.

1. Introduction

The North Atlantic marine climate is largely controlled by the so-called North Atlantic Oscillation (NAO), which is driven by the pressure difference between the Azores High and the Iceland Low pressure cells. The NAO index during the 2001 winter did after 4 years of positive values again assume a negative value, however only slightly negative, Figure A.H.1.

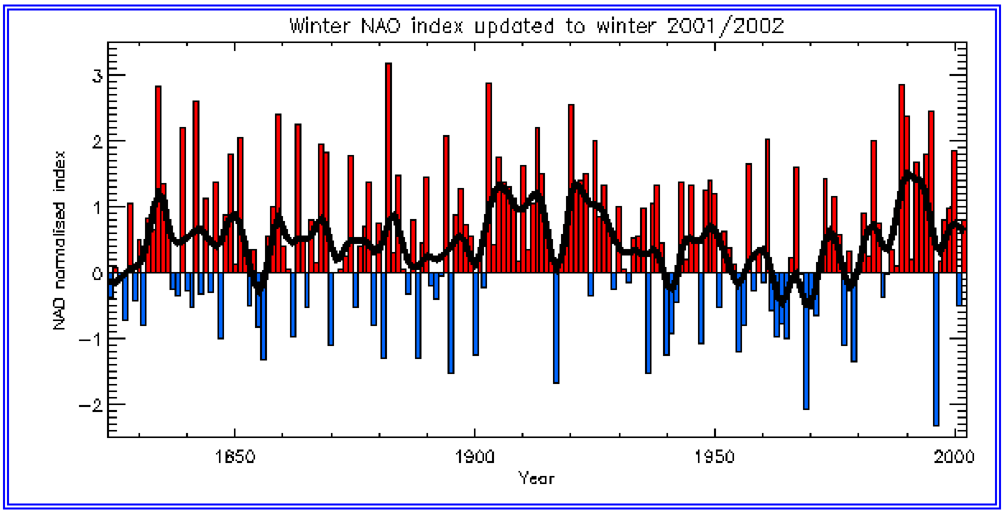

Figure A.H.1. Time series of the winter NAO (December to March average). After Jones *et al*. (1997) updated to the winter 2001–2002.

West Greenland lies within the area, which normally experiences warm conditions when the NAO index is negative. As can be seen from Figure A.H.2 the annual mean air temperature anomaly in Nuuk was 1.43°C, which is slightly higher than the previous year.

Changes in the ocean climate in the waters off West Greenland generally follow those of the air temperatures. In 2001 however, the mean temperature on top of Fylla Bank in the middle of June (Fig. 3) was well below the values of the previous 3 years. These 3 years did however show anomalously high values due to an eastward displacement of the NAO Pattern (ICES, 2000, Buch and Nielsen, 2001). The 2001 temperature value (T = 1.74°C) is slightly above the average value of 1.67°C for the whole 50-year period, which correlates well with the slightly negative value of NAO. The 2001 conditions therefore most likely reflect a return to normal conditions.

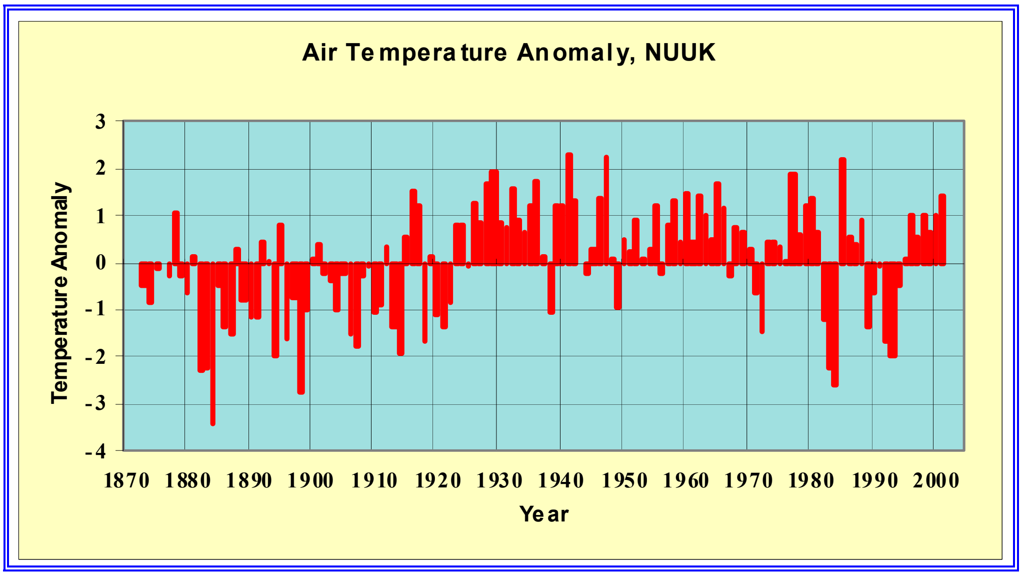

Figure A.H.2. Anomaly in the annual mean air temperature observed at NUUK for the period 1873 to 2001. (The anomaly is taken relative to the mean temperature for the whole period).

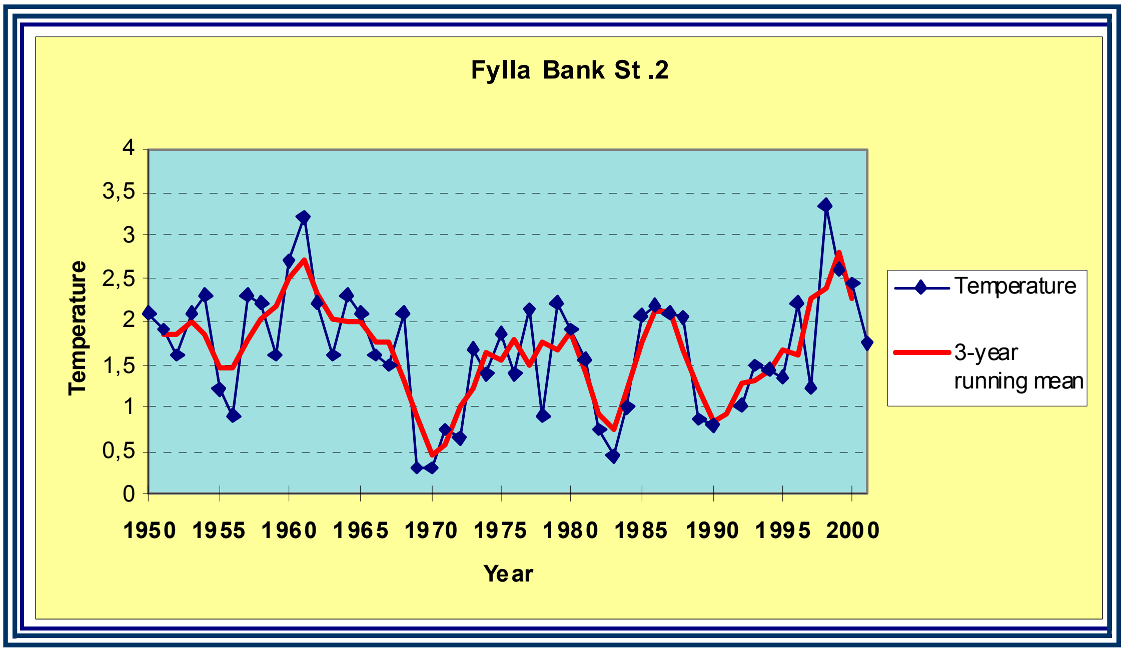

Figure A.H.3. Time series of mean temperature (observations and 3 year running mean) on top of Fylla Bank (0–40 m) in the middle of June.

2. Measurements

The 2001 cruise was carried out according to the agreement between the Greenland Institute of Natural Resources and Danish Meteorological Institute during the period June 6–June 11, 2001 onboard the Danish naval ship **"TULUGAQ".** Observations were performed on the following stations (see also Figure A.H.4):

- Cape Farewell St. 1–5
- Cape Desolation St. 1–5
- Frederikshaab St. 1–5
- Fylla Bank St. 1–5
- Sukkertoppen St. 1–5
- Holsteinsborg St. 1–5

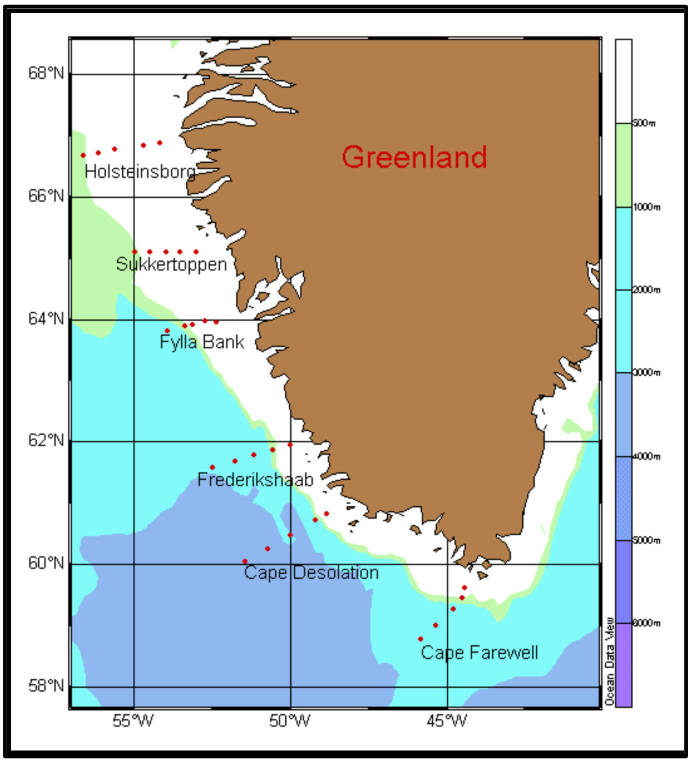

Figure A.H.4. Position of the standard sections off West Greenland.

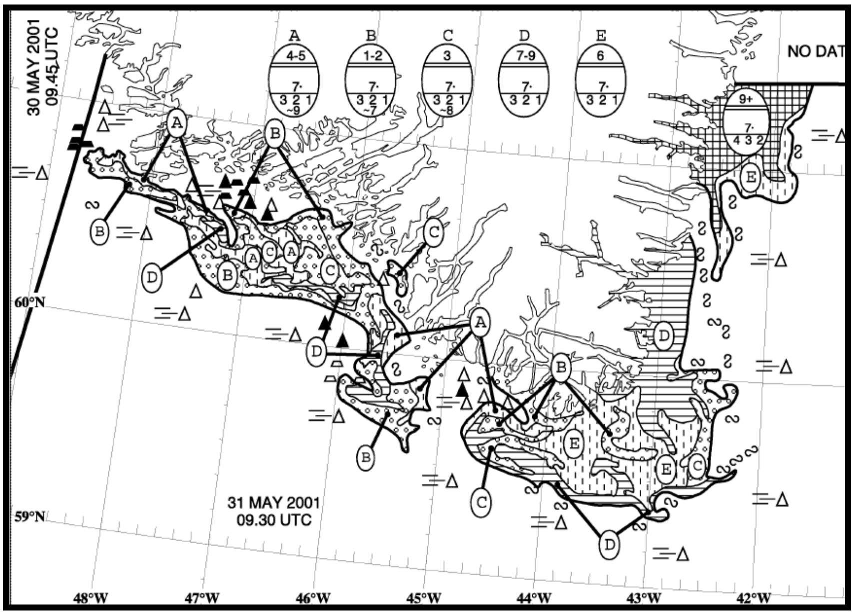

Figure A.H.5. Distribution of sea ice in the Cape Farewell region 31 May 2001.

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, Figure A.H.5, but fortunately not in quantities preventing the measuring program being carried out.

3. Data handling

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

The CTD data were analysed using SEASOFT 4.225 software provided by SEABIRD.

CTD data collected by the Greenland Institute of Natural Resources during 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.

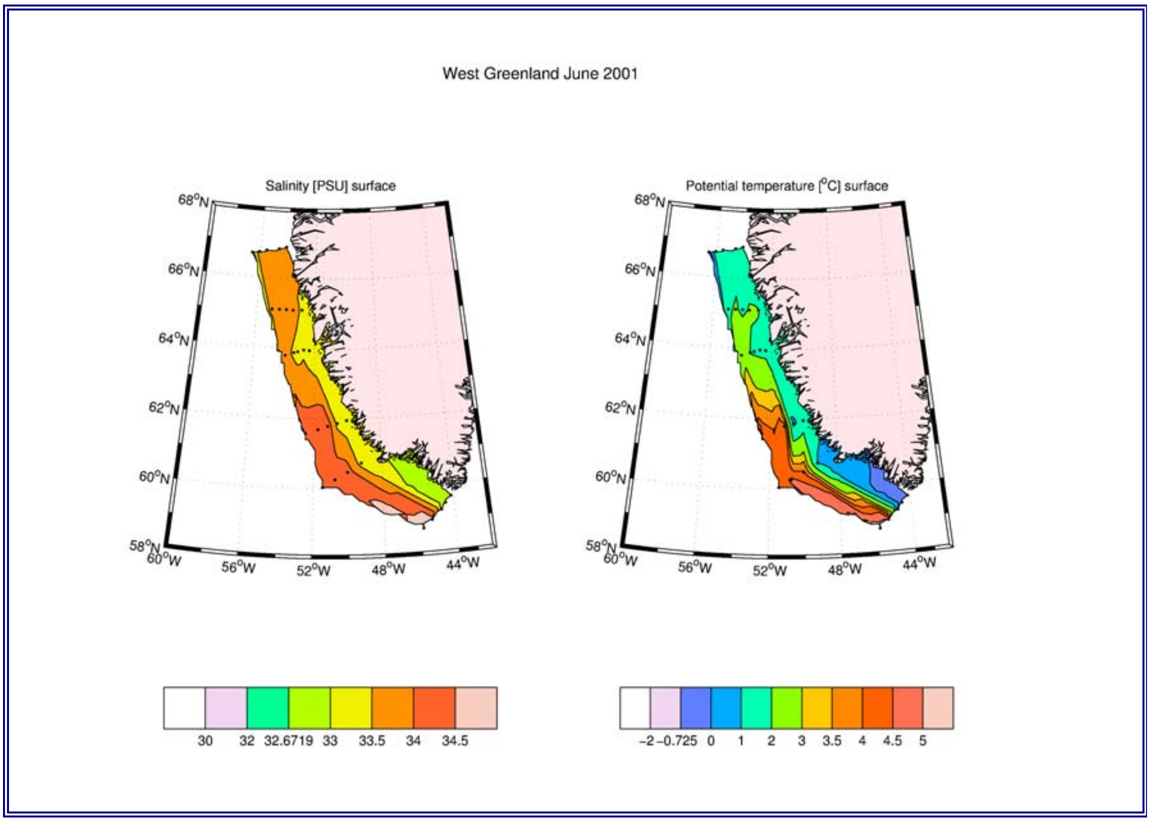

Figure A.H.6. Surface temperature and salinity, June 2001.

4. Oceanographic conditions off West Greenland in 2001

The surface temperatures and salinities observed during the 2001 cruise are shown in Figure A.H.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) is found at the surface only at the outermost stations on the Cape Farewell Section.

The 2001 mean salinity value (33.40) on top of Fylla Bank (Figure A.H.7) was slightly higher than in 2000, and equal to the average value for the entire period.

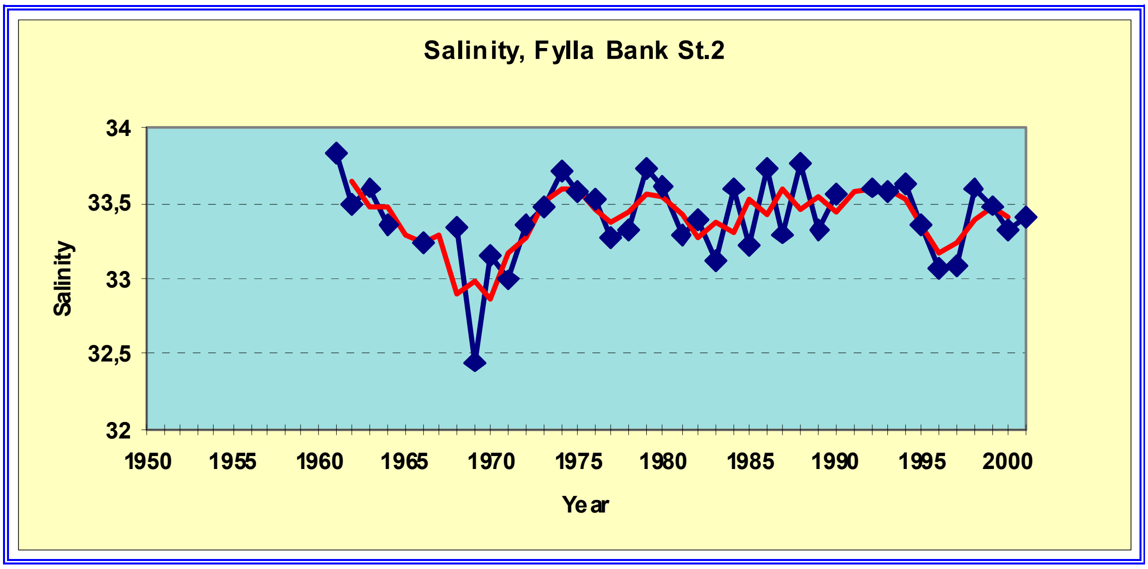

Figure A.H.7. Time-series of the mean salinity (observations and 3 year running mean) on top Fylla Bank (0–40m) in the middle of June.

The vertical distribution of temperature, salinity and density as well as TS-relations at sections along the West Greenland coastline is given in Figures A.H.8–18. In addition to data from the six standard sections obtained during the TULUGAQ cruise in early June, data from the Disko Bay and further north obtained during the R/V PAAMIUT cruise in August are shown.

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, the gradient however, being weaker at the Cape Desolation section than on the other two. At Fylla Bank the core of Polar Water was observed across the bank a depth of 50–100 m. (see also Figure A.H.8), while further north this cold core of Polar water could not be traced.

At Egedesminde and northwards a cold layer is found between approximately 40 and 150m with extreme low temperatures at around 75m. 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 ($T \sim 4.5^oC$, $S > 34.95$ psu) was clearly present at the Cape Farewell section, but has not advected beyond this point. Modified Irminger Water ($34.88 < S < 34.95$) was present in great quantities at all sections up to the Holsteinsborg section, however most clearly at the southernmost sections.

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

6. Conclusions

The oceanographic conditions off West Greenland during the summer 2001 was characterised by:

- Climatic conditions – NAO, Nuuk Air Temperatures, medio June temperature and salinities on top of Fylla Bank – were close to average conditions
- Pure Irminger Water was only observed at the Cape Farewell region
- Modified Irminger Water was in June observed all the way from Cape Farewell to Holsteinsborg

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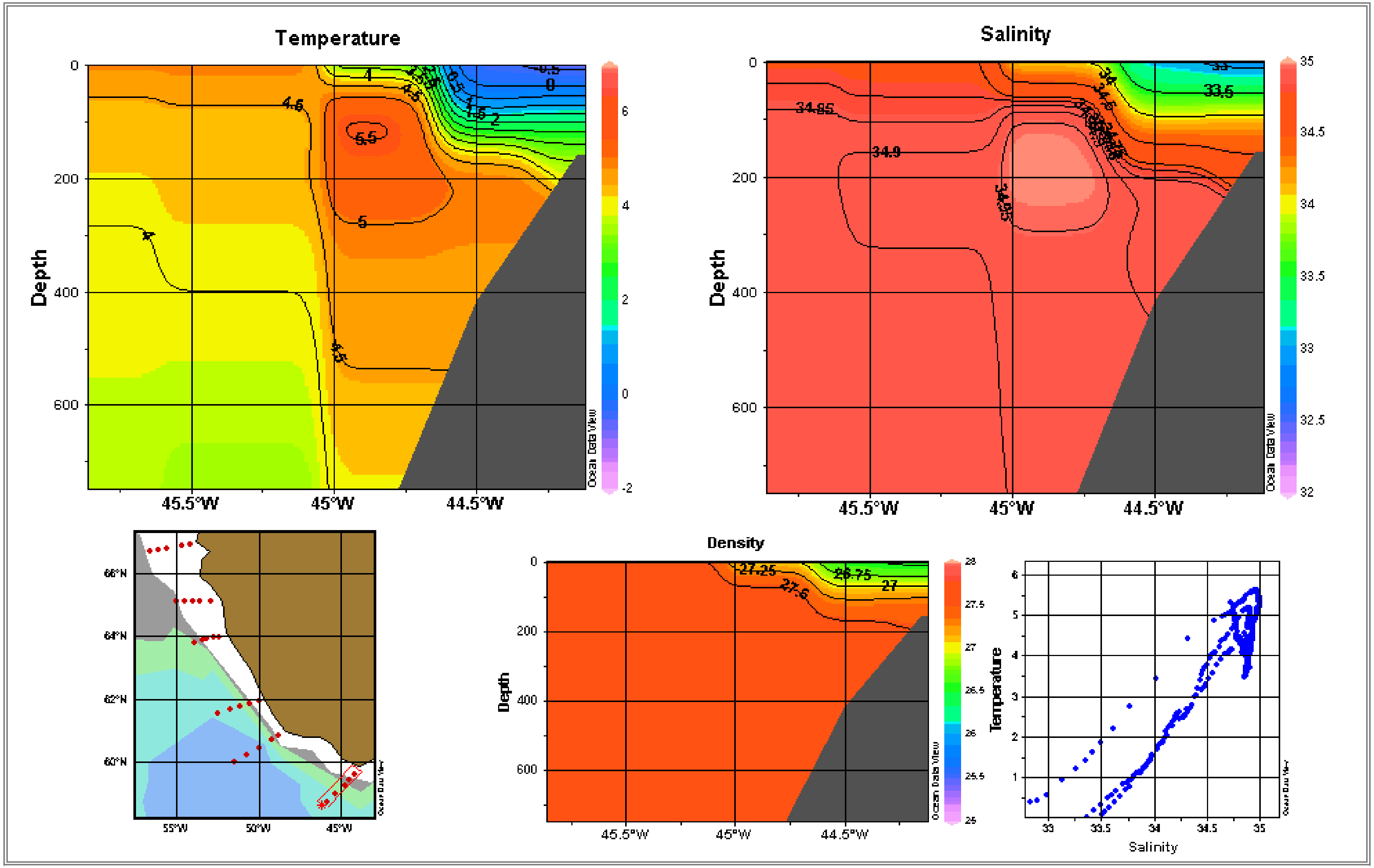

Figure A.H.8. Vertical distribution of temperature, salinity and density at the Cape Farewell section, 6 June 2001.

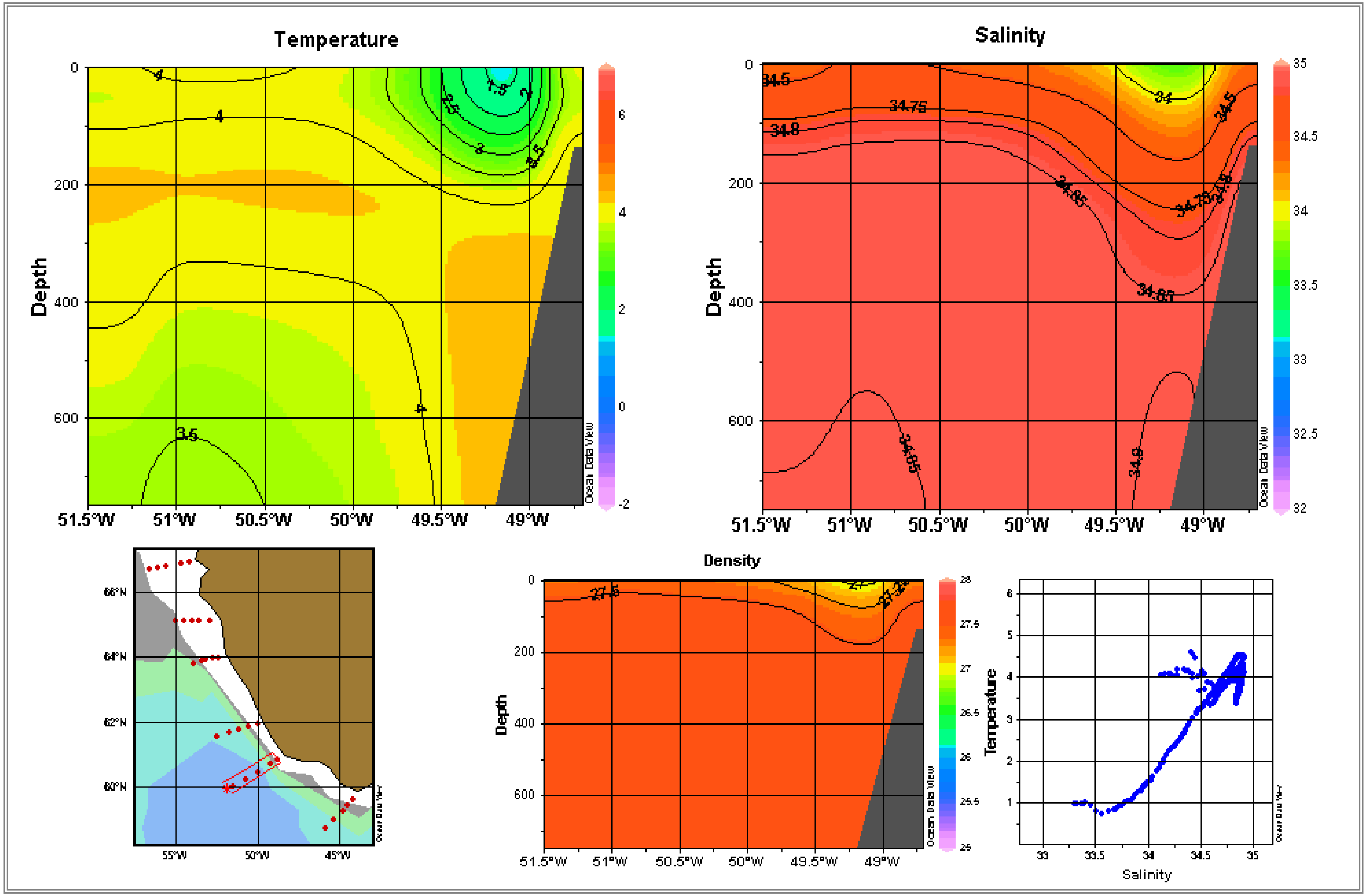

Figure A.H.9. Vertical distribution of temperature, salinity and density at the Cape Desolation Section, 7 June 2001.

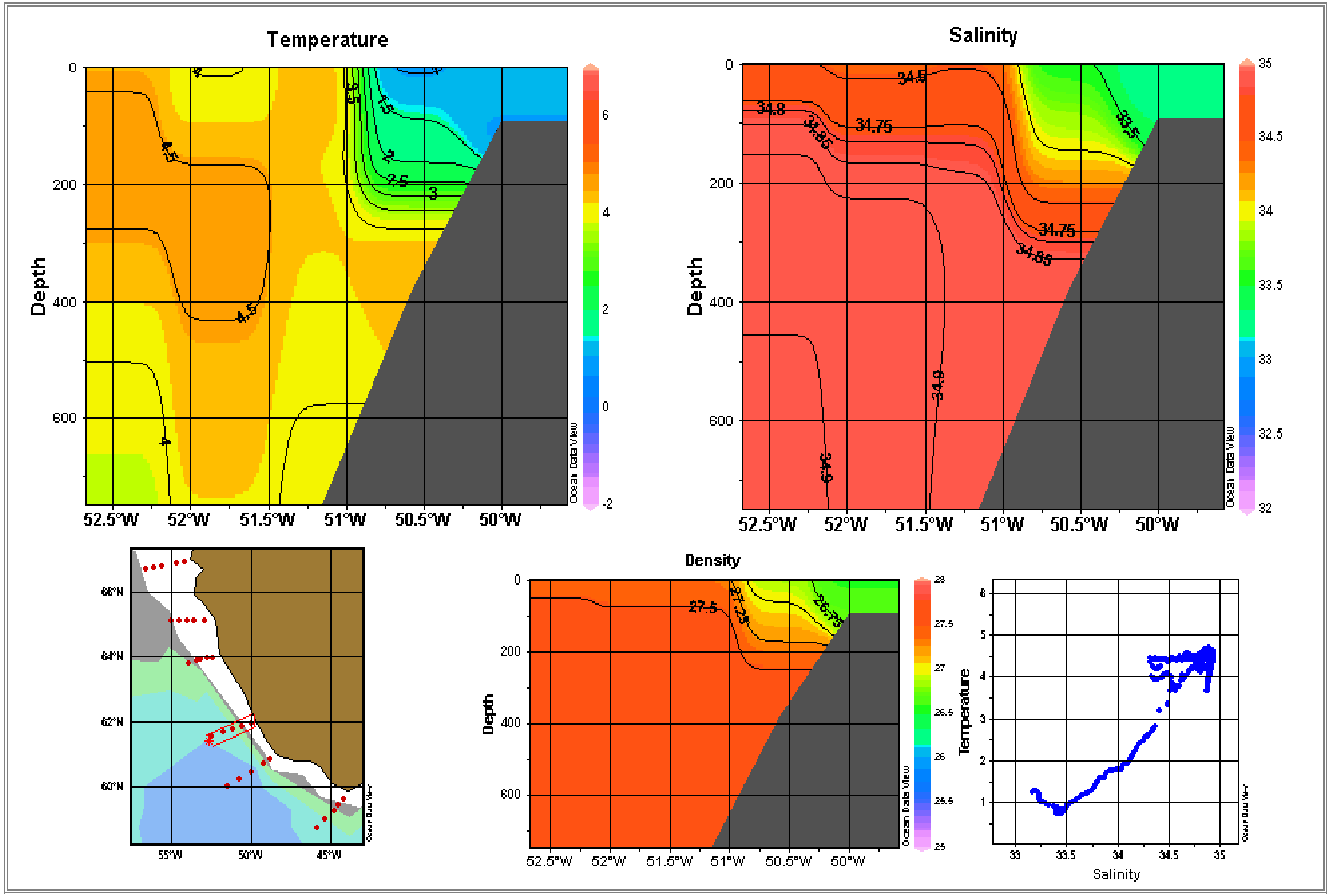

Figure A.H.10. Vertical distribution of temperature, salinity and density at the Frederikshaab Section, 8 June 2001.

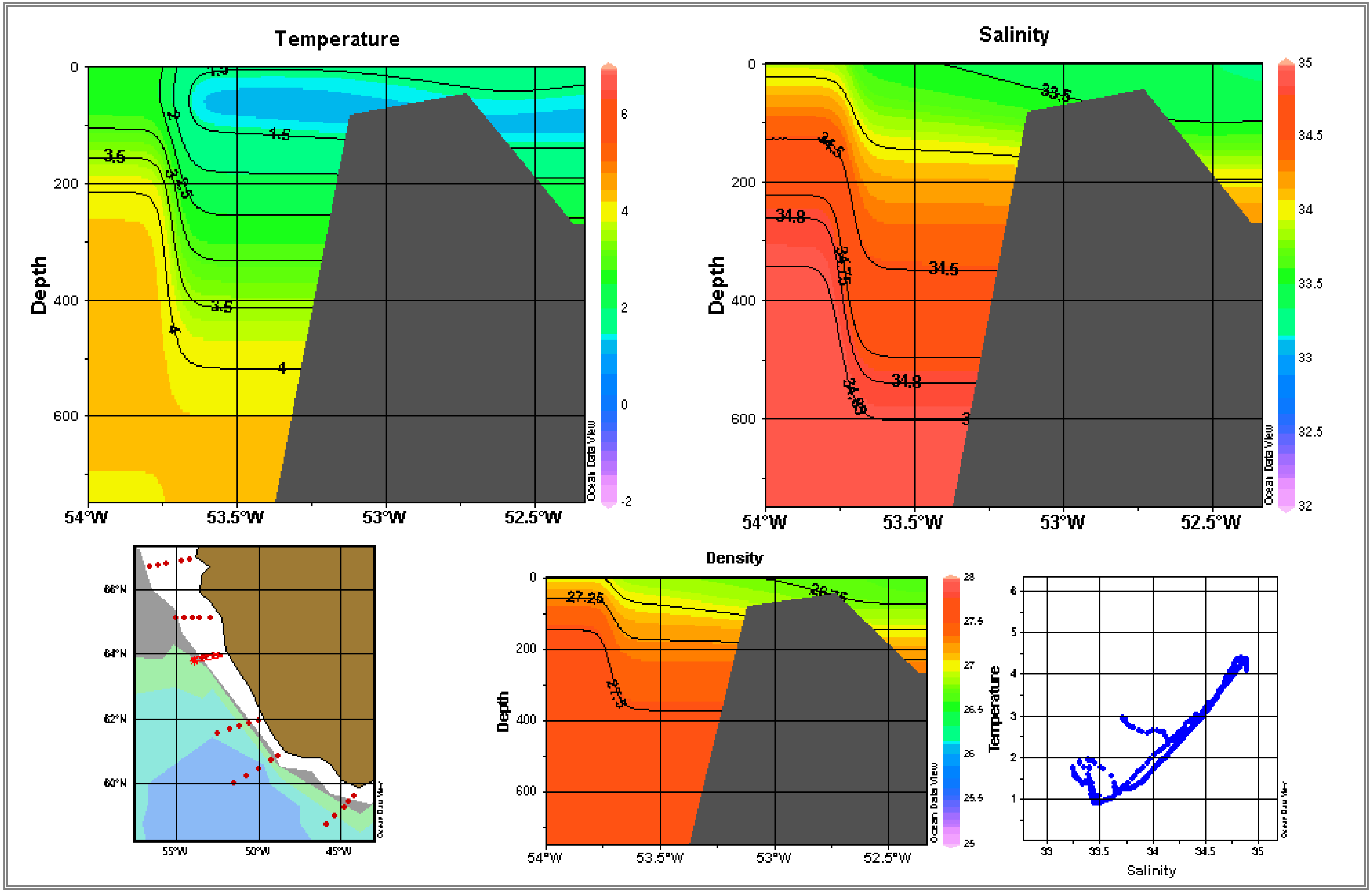

Figure A.H.11. Vertical distribution of temperature, salinity and density at the Fylla Bank Section, 9 June 2001.

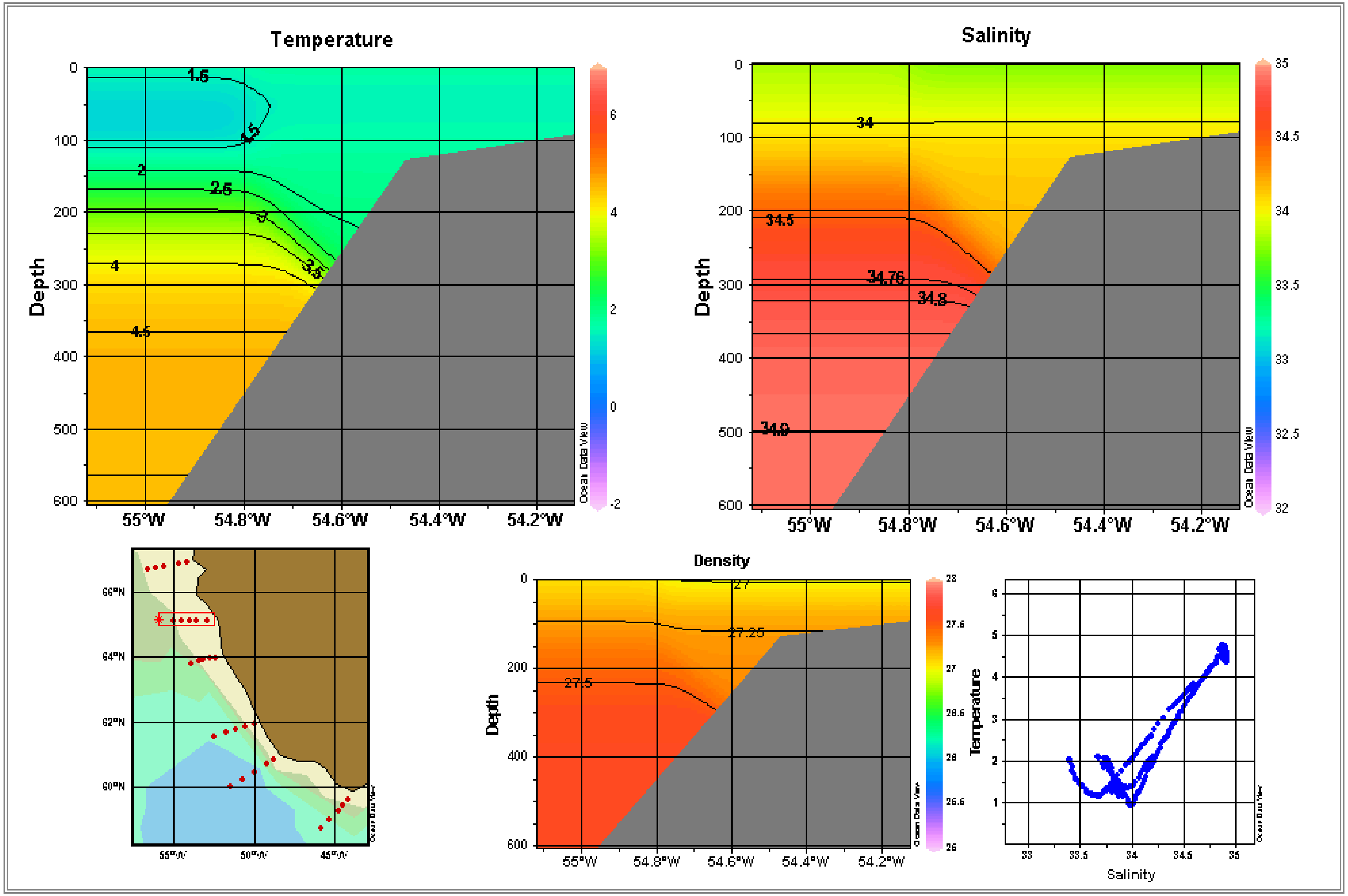

Figure A.H.12. Vertical distribution of temperature, salinity and density at the Lille Hellefiske Bank Section, 10 June 2001.

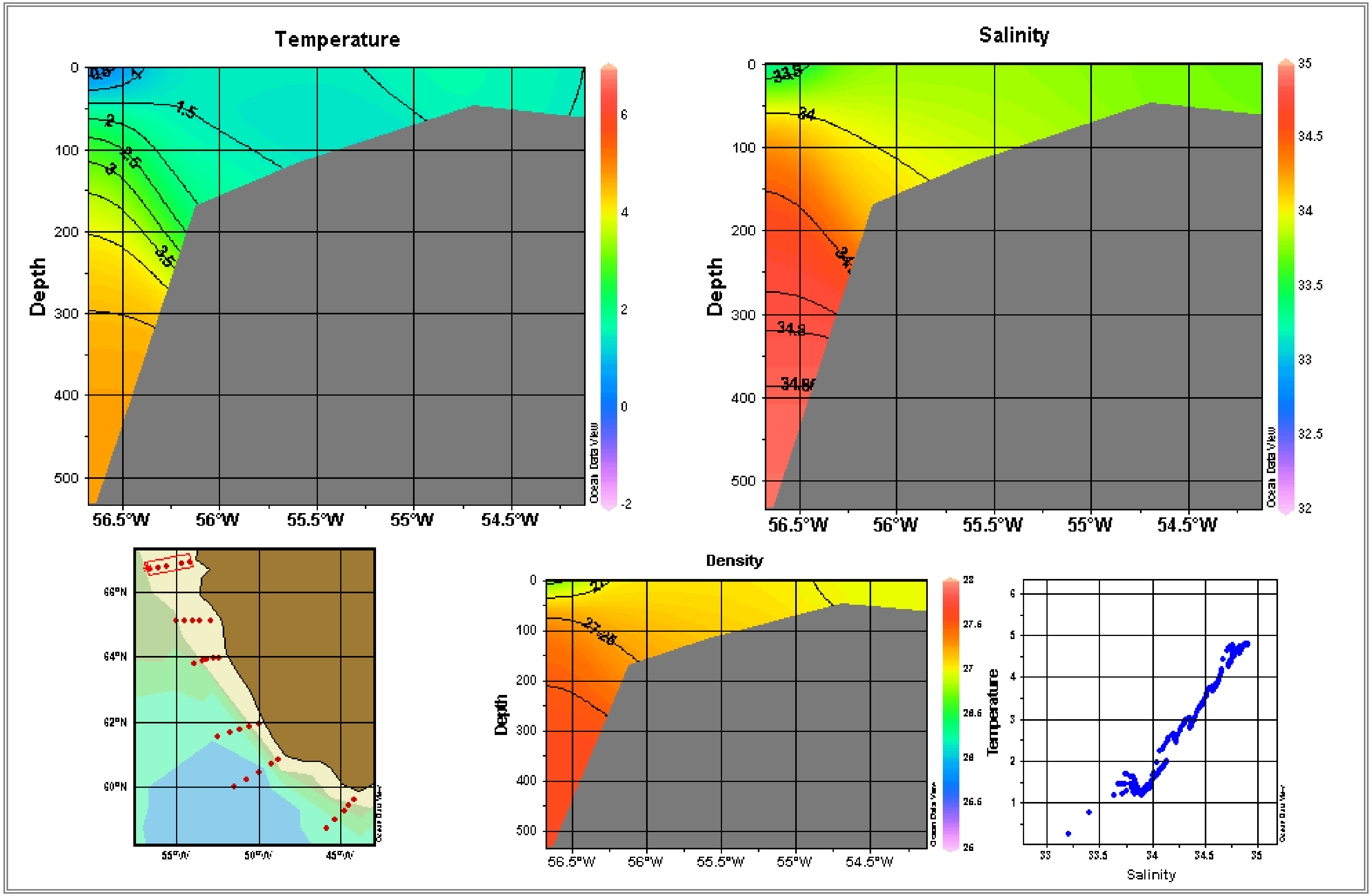

Figure A.H.13. Vertical distribution of temperature, salinity and density at the Holsteinsborg Section, 10–11 June, 2001.

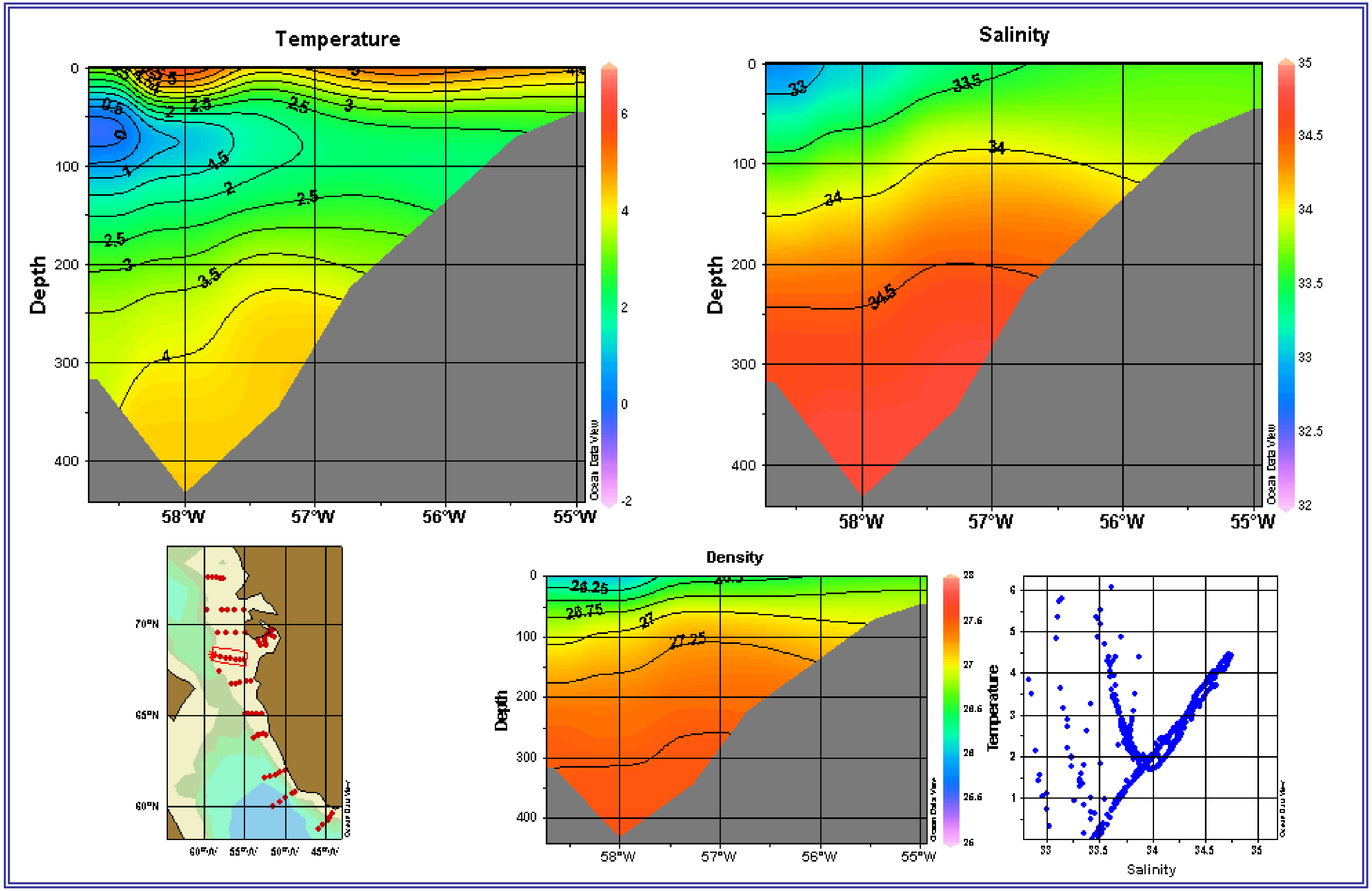

Figure A.H.14. Vertical distribution of temperature, salinity and density at the Egedesminde Section, 6 August 2001.

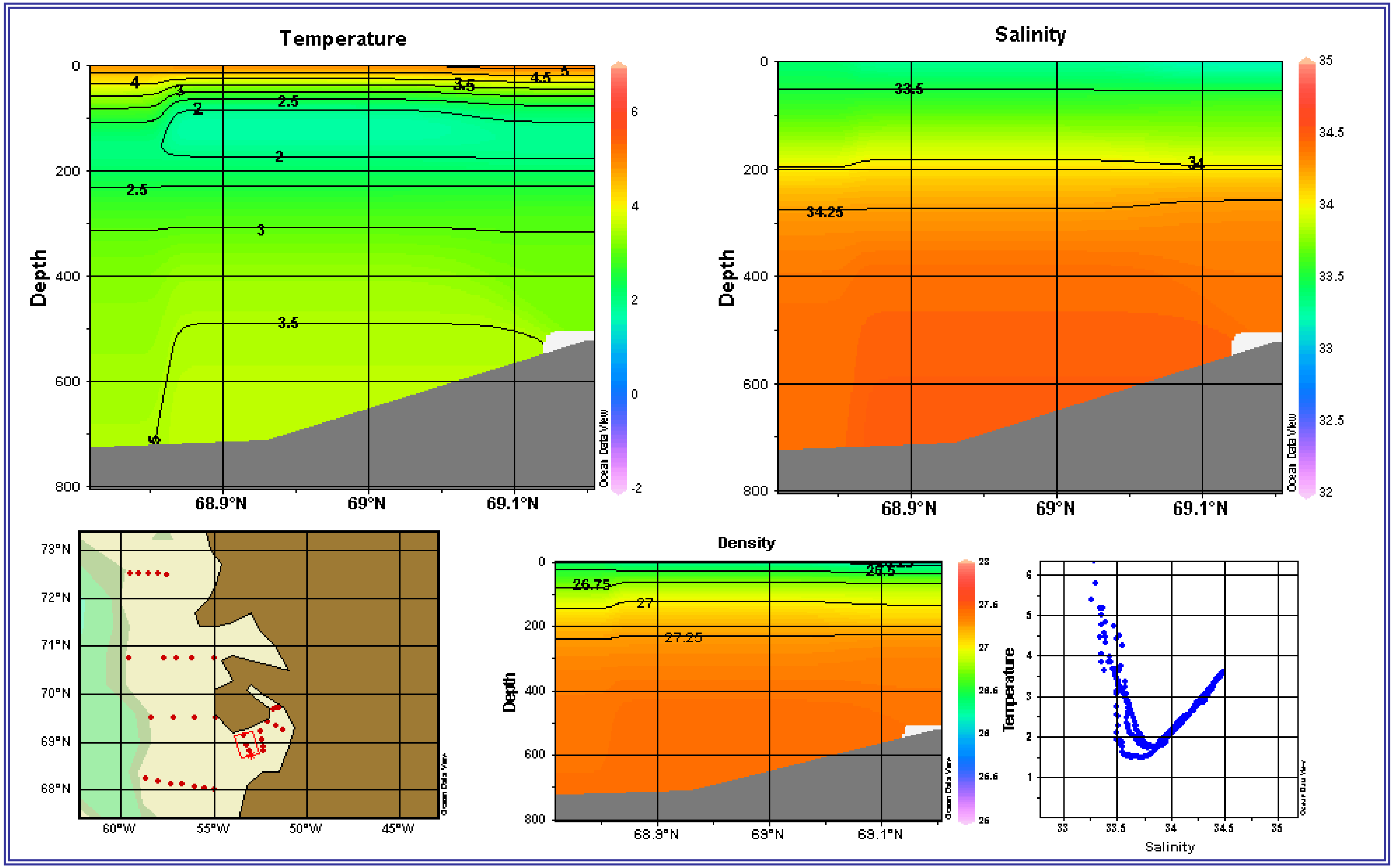

Figure A.H.15. Vertical distribution of temperature, salinity and density at the Godhavn-Egedesminde Section, 14 August 2001.

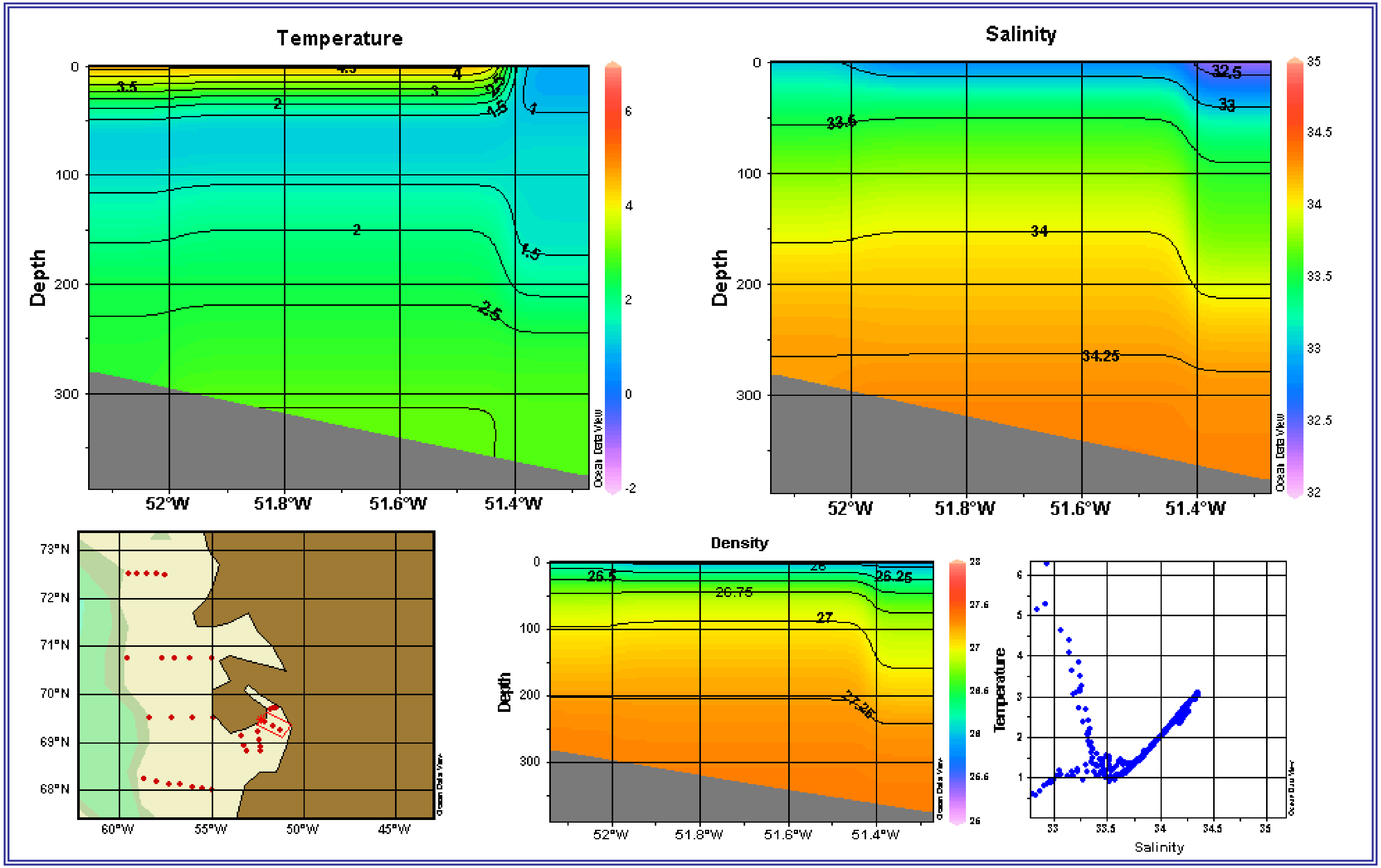

Figure A.H.16. Vertical distribution of temperature, salinity and density at the Jakobshavn Section, 24 August 24, 2001

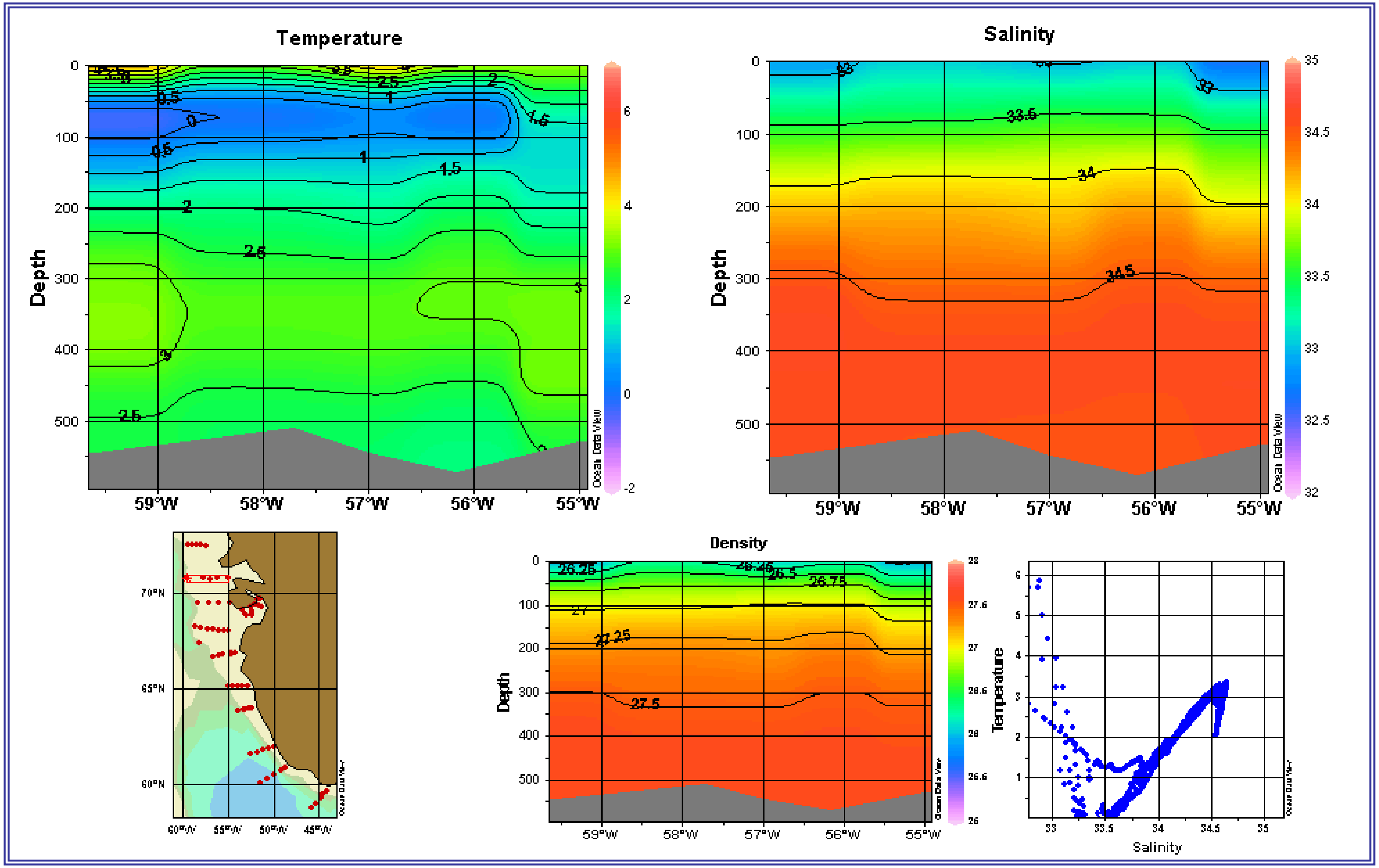

Figure A.H.17. Vertical distribution of temperature, salinity and density at the Nugssuaq Section, 20 August 2001.

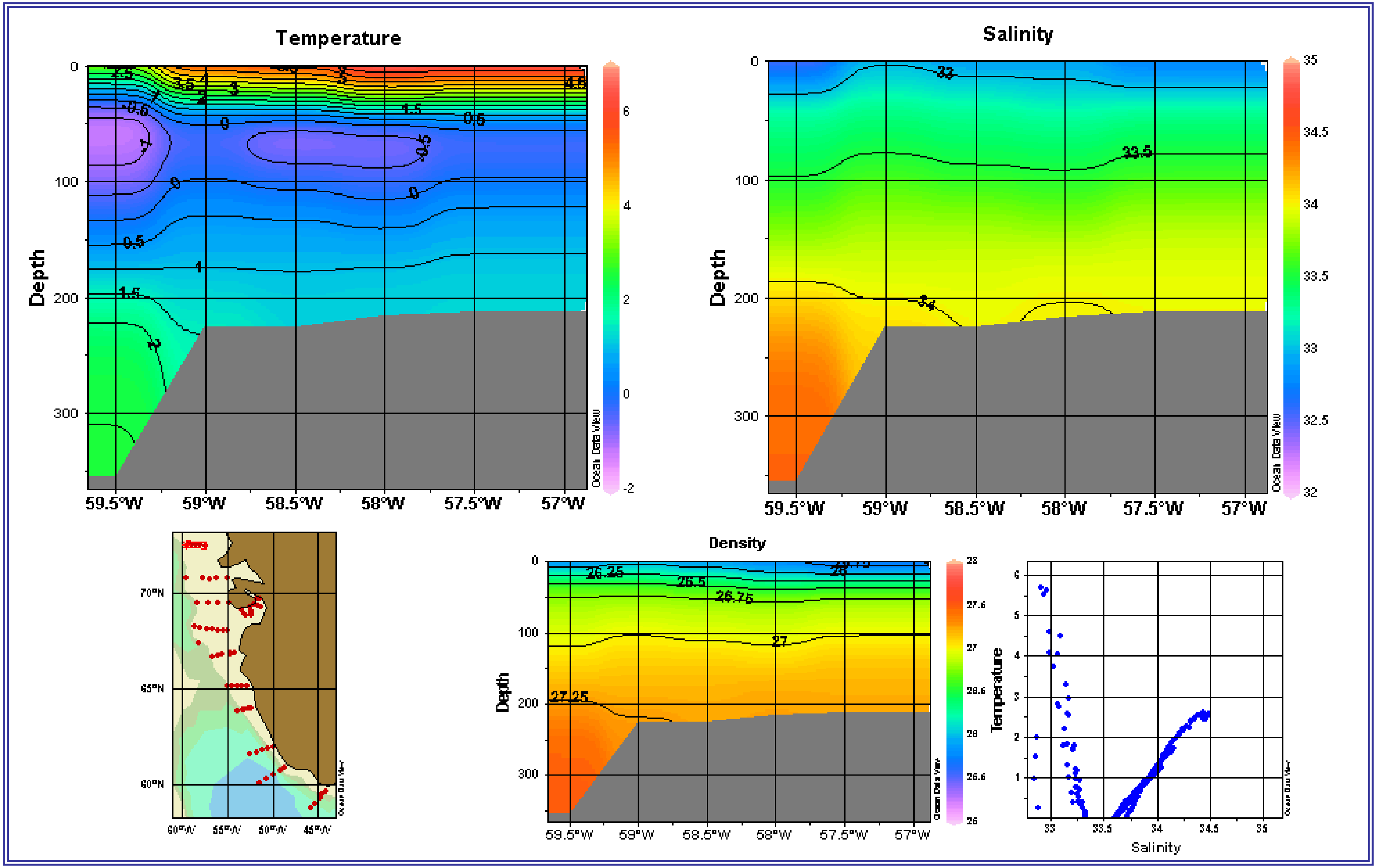

Figure A.H.18. Vertical distribution of temperature, salinity and density at the Upernavik Section, 19 August 2001.

ANNEX I: ENVIRONMENTAL CONDITIONS IN THE NORTHWEST ATLANTIC DURING 2001 (ICES AREA 2)

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1. Introduction

Meteorological and oceanographic conditions during 2001 are presented referenced to a standardised base period from 1971–2000 in accordance with the convention of the World Meteorological Organisation. The data were collected by a number of researchers in Canada and Europe and compiled into time series for the standard sections and stations (Figures A.I.1 and A.I.2). The meteorological and sea ice data and analysis were provided by K. Drinkwater and I. Peterson at the Bedford Institute of Oceanography in Dartmouth Nova Scotia, Canada.

One of the most widely used and longest oceanographic time series in the Northwest Atlantic is from Station 27 located at latitude 47° 32.8′ N and longitude -52° 35.2′ W. This monitoring station was first occupied 1946, it is located in the inshore region of the eastern Canadian continental shelf about 8 km off St. John's Harbour Newfoundland (Figure A.I.2), 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 57 occupations during 2001.

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 sections 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 from Cape Cod (USA) to Egedesminde (West Greenland) (Anon. 1978). Several of these transects are occupied annually during mid-summer on an oceanographic survey conducted by the Canadian Department of Fisheries and Oceans (Figure A.I.2). In this report the results for the Seal Island section on the Southern Labrador Shelf, the Bonavista section off the east coast of Newfoundland and the Flemish Cap section, which crosses the Grand Bank at 47°N, are presented for the summer 2001 survey.

2. Meteorological and sea-ice conditions

Monthly and annual air temperature anomalies for 2001 relative to their 1971–2000 means at four sites in the northwest Atlantic from Nuuk (Godthaab) in Greenland to St. John's Newfoundland are shown in Figure 3. The predominance of warmer-than-normal annual air temperatures at all four sites during 2001 is clearly evident with annual anomalies ranging from a maximum of +1.6°C at Nuuk Greenland to +0.6°C at St. John's Newfoundland. Monthly air temperatures were above normal in 8–11 out of 12 months of 2001 at these sites. Except for St. John's where the annual air temperature decreased significantly over 2000, most sites experienced an increase over values recorded during 2000. Note that the interannual variability in air temperatures since 1960 at Nuuk, 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. Also note that all sites where data are available, cold conditions (relative to the 1971–2000 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 (Drinkwater *et al.* 2000).

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 (approximately +14 mb) however the colder-than-normal winter conditions usually associated with high NAO index did not extend into this region during these years due to shifting pressure patterns. The NAO index for 2001 was below normal (by 8 mb) indicating a reduced Arctic outflow to the Northwest Atlantic during the winter months (Figure A.I.4). The spatial extent of the NAO atmospheric sea-level pressure fields during the winter months of 2001 returned to normal, ending the anomalous eastward shift that occurred during 1999 and 2000. These changes in the NAO index fit the pattern of quasi-decadal variability that has persisted since the 1960s.

Information on the location and concentration of sea ice is available from the daily ice charts published by Ice Central of Environment Canada in Ottawa. The time series of the areal extent of ice on the Newfoundland and southern Labrador shelves (between 45-55°N) show that the peak extent during 2001 decreased slightly over 2000 remaining below average for the fourth consecutive year (Figure A.I.4). The average ice area during both the period of southward advancement (January to March) and northward retreat (April to June) also decreased slightly relative to 2000, remaining much less than the heavy ice years of the early 1990s (Figure A.I.4). In general, sea ice coverage was lighter-than-average and of a shorter duration than normal during 2001 on the Newfoundland and Labrador Shelves.

3. Time Trends in Temperature and Salinity at Station 27

The water mass on the eastern Newfoundland Shelf is near isothermal during the winter months with temperatures ranging from 0° to –1°C. These cold temperatures generally persist throughout the year in the bottom layers. Surface layer temperatures ranged from about –1° to 0°C from January to late April, after which the annual warming commenced. By mid-May upper layer temperatures had warmed to 1°C and to >13°C by August at the surface, after which the fall cooling commenced. Except for a near surface cold anomaly during the spring, these values were about a 1/4° above normal for the winter months over most of the water column, but increased to 0.5°–1.0°C above normal in the upper water column by late May and into July. This warm anomaly continued during late summer and fall months with values reaching 1.5°C above normal in October. Temperatures at mid-depths (centred at 75–100 m) were below normal from August to December with values reaching 0.5°C below normal in November. Bottom temperatures ranged from 0° to 1/4°C above normal from January to December (Figure A.I.5).

Surface water salinities on the inner Newfoundland Shelf reached a maximum of >32.2 by mid-February and decreased to a minimum of <30.8 by September with the arrival of fresher ice melt water from Labrador. These values were about normal during the winter months but decreased to below normal values during the spring to late fall in the upper water column. In the depth range from 50–100-m, salinities generally ranged from 32.2 to 32.7 and near bottom they varied throughout the year between 32.8 and 33. Except for the near-normal values during the winter months, salinities recorded at Station 27 were generally below normal (by >0.2) during most of 2001 (Figure A.I.5).

The annual time series of temperature and salinity anomalies generally show three significant colder and fresher-than-normal periods at near decadal time scales since the early 1970s (Figures A.I.6 and A.I.7). At the surface the negative temperature anomaly that reached a minimum in the early 1990s began to moderate to near-normal conditions by the summer of 1994 and have continued above normal up to 2001. 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 started to warm and by 1996 were above the long-term mean. Bottom temperatures from 1998 to 2001 have remained above the long-term mean. Annually, surface temperatures were above normal 9/12 months and near-bottom they were above normal during all 12 months of 2001 (Figure A.I.6 right panels).

Near-surface salinity anomalies (Figure A.I.7) shows the large fresher-than-normal anomaly that began in early 1991 had moderated to near normal conditions by early 1993 but returned to fresher conditions by the summer of 1995. Salinities approached near normal values during 1996 but decreased to mostly below normal values from 1997 to 2001. 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 (Colbourne *et al.* 1994, Drinkwater 1996). Annually, surface salinities were below normal for 10/12 months and near-bottom they were above normal during winter and fall months but below normal from April to September of 2001 (Figure A.I.7, right panels).

The vertically averaged (0–175 m) annual temperature and summer salinity anomaly time series at Station 27 are displayed in Figure A.I.8. The temperature time series 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 to 2001. During 2001 the vertically averaged temperature at Station 27 was very similar to the 2000 value (Figure A.I.8).

The salinity time series (Figure A.I.8), which are averages of the July-September values show similar response as the heat content time series with fresher-than-normal periods generally corresponding to the colder-than-normal conditions up to at least the early 1990s. 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), however, the spatial extent of the anomaly was mainly restricted to the inner Newfoundland Shelf. From 1996 to 2000 summer salinities at Station 27 varied about the mean but during 2001 they decreased over 2000 to below normal conditions.

4. Standard Sections

Flemish Cap (47^{o}N)

Near surface temperatures along the Flemish Cap section during the summer of 2001 ranged from 8–9^{o}C while sub-zero (^{o}C) temperatures were generally found below 60-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 (Figure A.I.9). Temperatures were generally above normal over most areas along this section during the summer except for isolated areas near the surface and in the offshore regions. Bottom temperatures over most of the Grand Bank were also above normal during the summer of 2001. Salinities along the section on the Grand Bank are characterised by generally fresh conditions on the Grand Bank (<33), a strong horizontal gradient at the shelf break separating the saltier (>35.25) slope water offshore in the Flemish Pass (Figure A.I.10). Salinity anomalies during 2001 were quite variable along this section, but overall were slightly higher than average in the upper layers and below normal in areas generally corresponding to regions of the Labrador Current.

Bonavista

The dominant water mass feature along this section during the summer months is the cold intermediate layer of <0^{o}C water (CIL) which develops during early spring after intense winter cooling. Temperatures along the Bonavista section during the summer of 2001 in the upper water column ranged from 7–8^{o}C. These values were generally above normal (up to 2^{o}C) over most of the shelf regions. The main except was the colder-than-normal anomaly in the near-shore region and in the offshore area of the Labrador Current located at the edge of the continental shelf (Figure A.I. 9). In general however temperatures on the eastern Newfoundland Shelf were above normal at intermediate depths and near bottom depths during 2001. Salinities along the Bonavista section generally range from <32 near the surface in the inshore region to >34 in the offshore region (Figure A.I. 10). Bottom salinities ranged from 32.5 in the inshore regions, to 34.75 at about 325-m depth near the shelf edge. In areas generally associated with the inshore and offshore Labrador Current sub-surface salinities were fresher-than-normal (up to 0.5). In the surface waters and at all depths over the central shelf region salinities were predominantly saltier-than-normal during 2001.

Seal Island

The Seal Island section, which crosses Hamilton Bank on the southern Labrador Shelf, was also sampled in July of 2001 (Figures A.I.9 and A.I.10 bottom panels). Upper layer temperatures across this region ranged from 0^{o}C at approximately 50-m depth to between 3–4^{o}C at the surface. Temperatures below 50-m depth were generally sub-zero ^{o}C over most of the shelf, corresponding to CIL waters, except near bottom where they ranged from 0.5^o-1^{o}C. Near the shelf break temperatures increase to 2^o to 3^{o}C. Temperature anomalies in the surface layer were up to 1^{o}C below normal over most of the shelf, but were up to 2^{o}C above normal offshore of the shelf break. In water generally associated with the CIL, temperatures were above normal by up to 1^{o}C in the inshore regions. Surface salinities along this section ranged from <31 inshore of Hamilton Bank to >34 in the offshore region. Bottom salinities ranged from 32.5 near shore to 34.75 at the edge of the shelf in water depths >400-m. Again similar to conditions along sections further south, intermediate water salinities were fresher-than-normal in areas corresponding to the locations of the inshore and offshore Labrador Current and generally above normal elsewhere, particularly at the surface. Offshore of the shelf break salinities were near normal at depth and above normal in the upper water column.

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 to the fall is dominated by a layer of cold sub-zero ^{o}C water trapped between the seasonally heated upper layer and warmer slope water near the bottom. This water mass is commonly referred to as the cold intermediate layer or CIL (Petrie *et al.* 1988). The cold, relatively fresh, shelf water is separated from the warmer saltier water of the continental slope by a frontal region denoted by a strong horizontal temperature and salinity gradient near the edge of the continental shelf. The spatial extend of this winter chilled water mass is evident in the section plots of the temperature contours, for example along the Seal Island section (Figure A.I.9) the CIL extends offshore to over 200 km, with a maximum vertical extent of approximately 150 m. This corresponds to a cross-sectional area of around 25 km^2. Figure A.I.11 shows the annual summer CIL cross-sectional area anomalies defined by the 0^{o}C contour for the Flemish Cap, Bonavista and Seal Island sections.

Along the Flemish Cap section the CIL was below the 1971–2000 normal, similar to conditions observed during the past 3-years but a slight increase over 2000. Off Bonavista the CIL area decreased to the lowest value observed since 1978 continuing the trend of below normal values observed since 1994. Similarly, along the Seal Island section the area of sub-zero ^{o}C water decreased over 2000 values continuing the recent below normal trend. This is in contrast to the near record high values measured during the early 1990s, which was a very cold period on the Newfoundland Shelf. Minimum temperatures (expressed as anomalies) measured in the core of the CIL for all three sections during the summer from 1951 to 2001 are also shown in Figure A.I.11. The minimum temperature observed along the Flemish Cap, Bonavista and Seal Island sections during 2001 were -1.26°, -1.51°, –1.61°, and -1.34°C, respectively. These were all above normal and represent an increase over the 2000 values.

Geostrophic Circulation and Transport

The temperature and salinity data from the summer 2001 survey were used to compute geostrophic currents relative to 300 m along all sections sampled during the summer of 2001 (Figure A.I.12). The geostrophic component of the speed of the southward flowing Labrador Current along these sections generally show distinct inshore and offshore branches. The inshore branch is generally weaker than the shelf-slope branch and is usually restricted to the inshore troughs within approximately 50–100 km of the coast. Typical current speeds in these regions range from 0.05–0.10 m/s, although some estimates were up to 0.2 m/s along the Bonavista and Seal Island sections during 2001. The offshore branch is located at the shelf break in water depths generally greater than 400 m. The offshore distance and the width of the current vary according to the underlying topography. Along the Seal Island section, for example, the core of the offshore branch is about 100 km wide, centred at about 200 km offshore over the 400-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, typical speeds range from 0.05 m/s at 175-m depth to >0.2 m/s in the upper water column. At mid-shelf currents sometimes reverse direction, with clockwise circulation on Hamilton Bank, for example. These currents are generally weak however, with speeds generally less that 0.05 m/s. In general, geostrophic currents along the Labrador Shelf (Seal Island, Makkovik Bank and Nain Bank) appear stronger than those on the eastern Newfoundland Shelf with speeds over 0.40 m/s offshore from Nain Bank for example (Figure A.I.12).

The historical (1951–2001) summer (July-August) temperature and salinity data along the Seal Island, Bonavista and Flemish Cap sections were used to compute a time series of geostrophic transports. The volume transport was calculated by integrating the speed both vertically through the water column and horizontally through the offshore branch of the current. 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 sections (Figure A.I.13) 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 2001 increased slightly over the 2000 values.

5. Summary

The annual water column averaged temperature at Station 27 for 2001 warmed slightly compared to 2000 remaining above the long-term mean. Surface temperatures were above normal for 9 out of 12 months with anomalies reaching a maximum of near 1.6°C in October. Spring (April to May) values were below normal. Bottom temperatures at Station 27 were above normal (by □0.5°C) during all 12 months of the year. Water column averaged summer salinities at Station 27 decreased to below normal values over the near-normal conditions of 2000.

The cross-sectional area of sub-zero °C (CIL) water on the Newfoundland and Labrador Shelves during the summer of 2001 decreased over 2000 values, except on the Grand Bank where there was a slight increase. The CIL areas were below normal along all sections from the Grand Bank (Flemish Cap section), to the Seal Island section off southern Labrador. Off Bonavista the CIL area decreased to the lowest value observed since 1978.

In summary, the below normal trends in temperature and salinity, established in the late 1980s reached minima 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 and 2001 ocean temperatures were cooler than 1999 values, but remained above normal over most areas continuing the warm trend established in 1996. Salinities during

2001 were generally fresher than normal in the inshore regions, which is a continuation of the trend observed during most of the 1990s.

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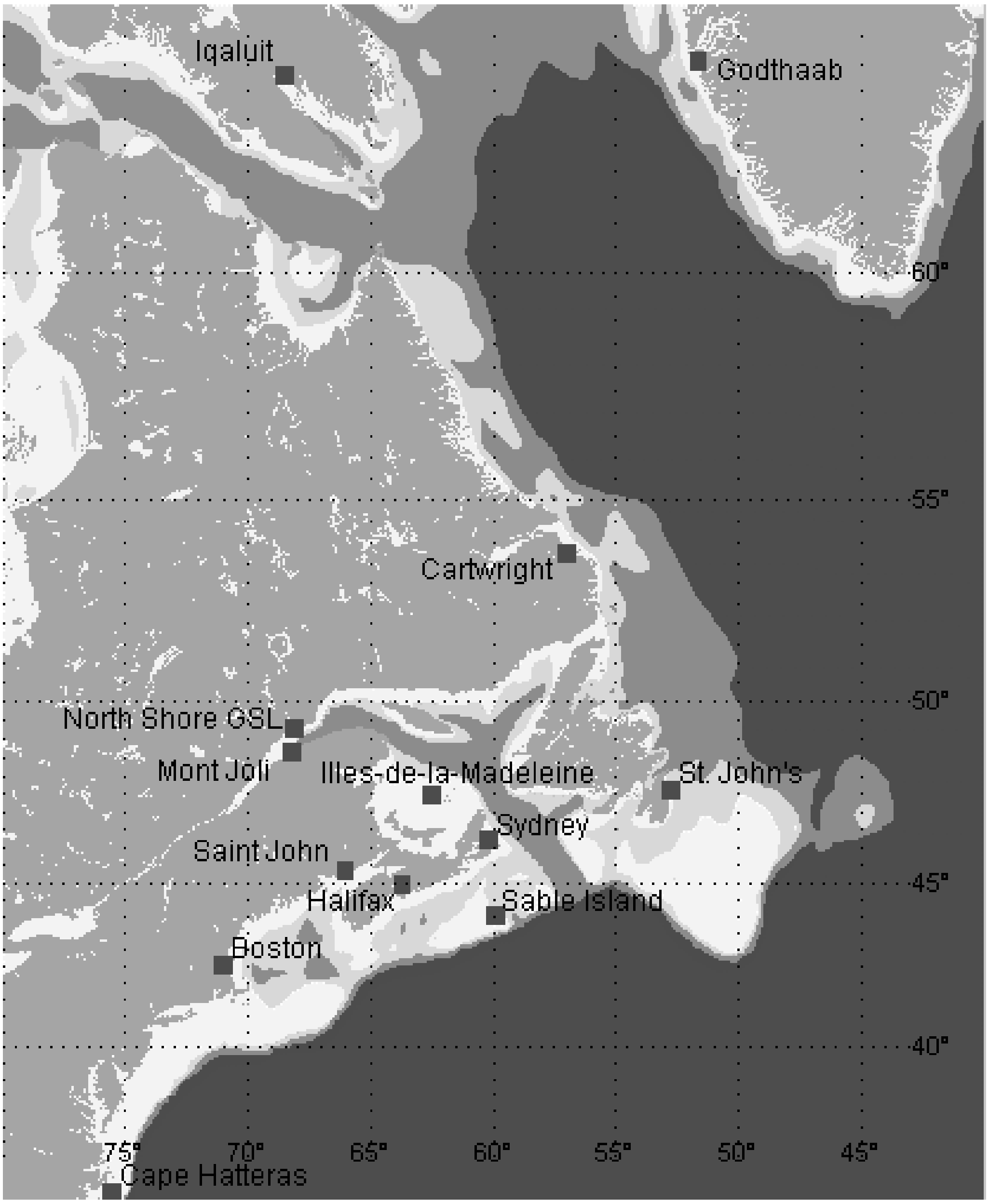

Figure A.I.1. Northwest Atlantic showing coastal air temperature-monitoring stations.

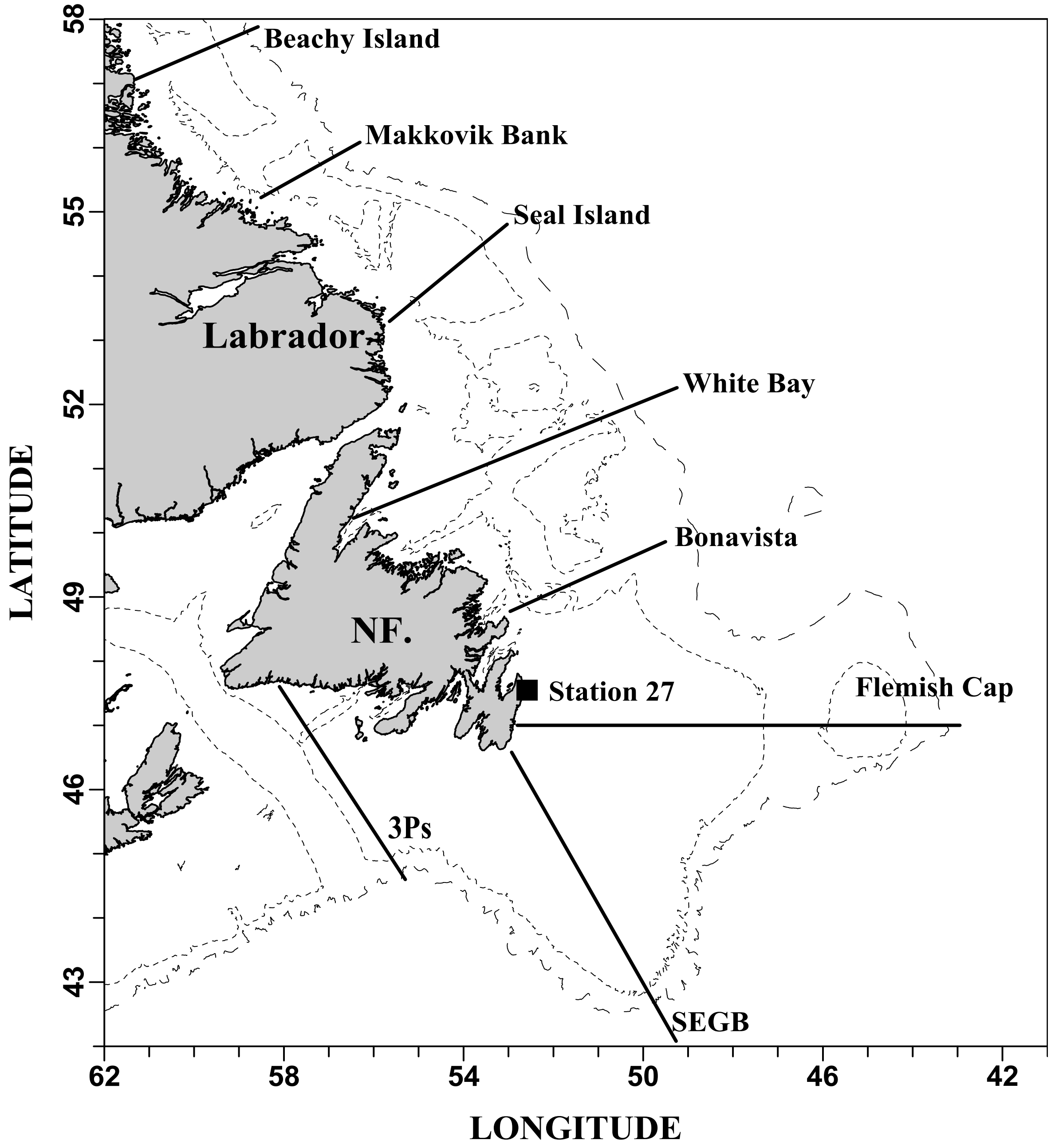

Figure A.I.2. Location map showing the positions of standard monitoring sections on the Newfoundland and Labrador Shelves. The location of Station 27 is also shown. Bathymetry contours are 300 and 1000 m.

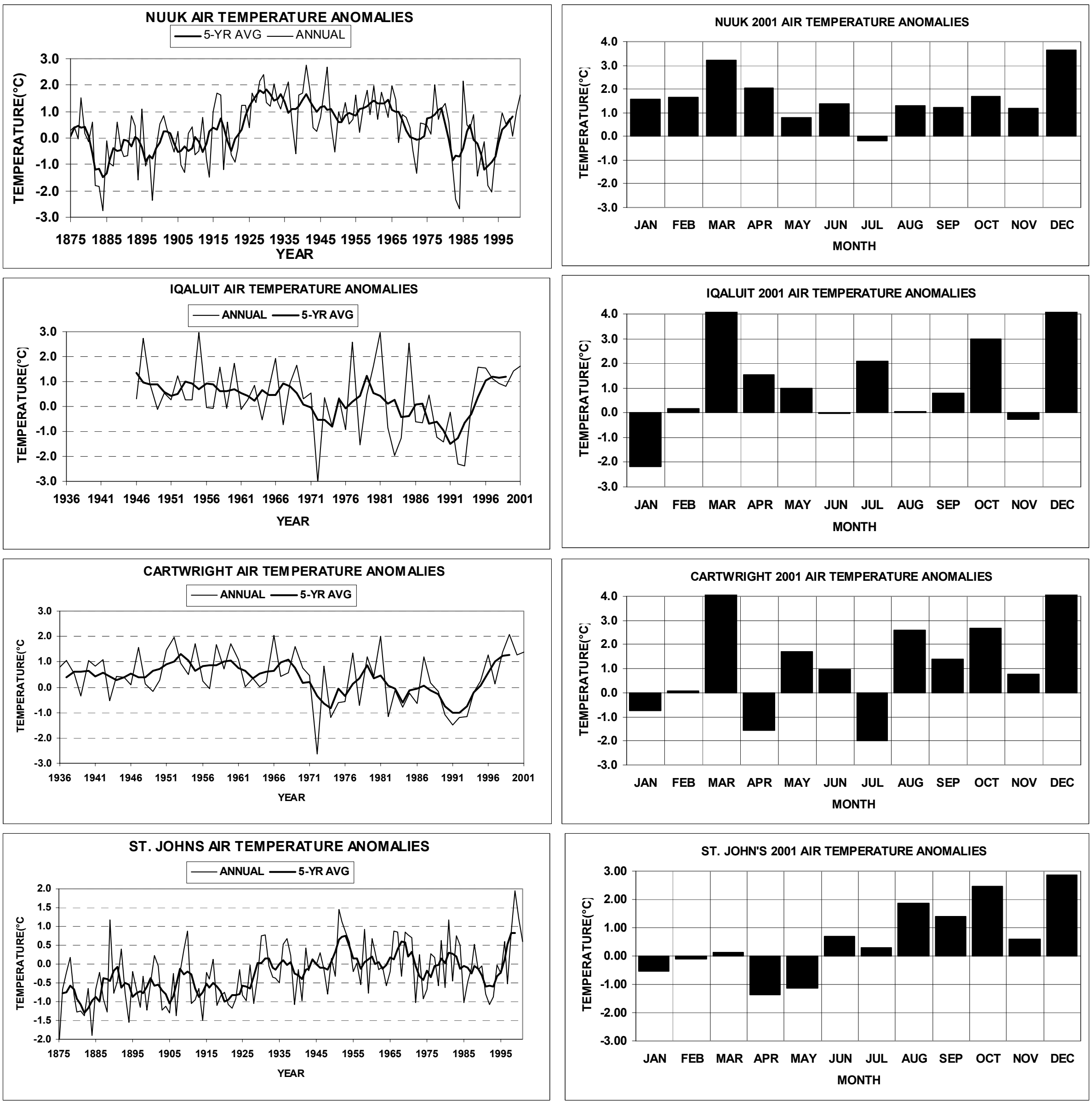

Figure A.I.3. Annual and monthly air temperature anomalies in 2001 at selected coastal sites (see Figure A.I.1 for locations). The anomalies are referenced to their 1971–2000 means.

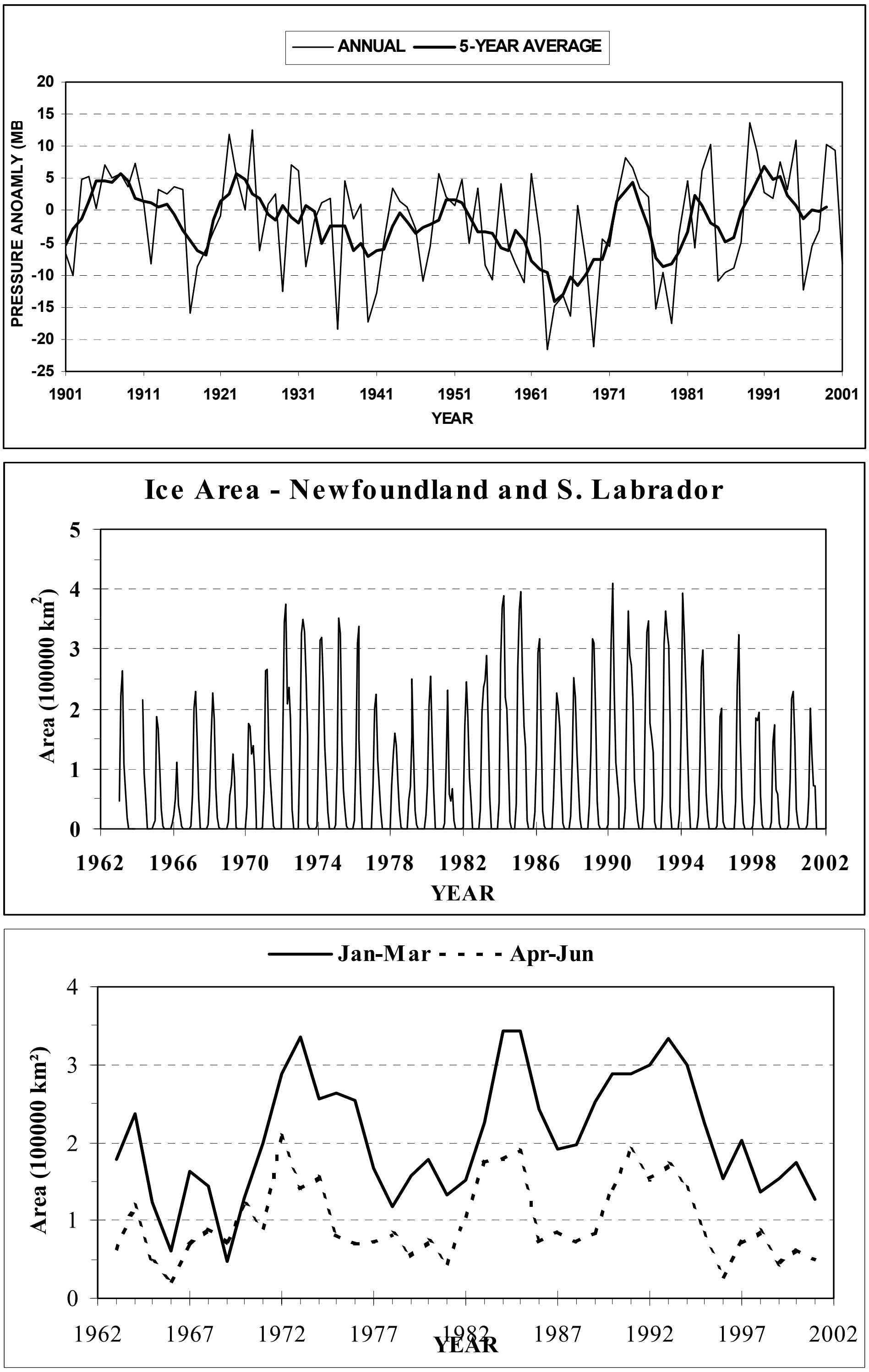

Figure A.I.4. Anomalies of the North Atlantic Oscillation Index relative to the 1971–2000 mean (top panel), monthly mean ice areas off Newfoundland and Labrador between 45°N – 55°N (centre panel) and the average ice area during the normal periods of advancement (January-March) and retreat (April-June) (bottom panel).

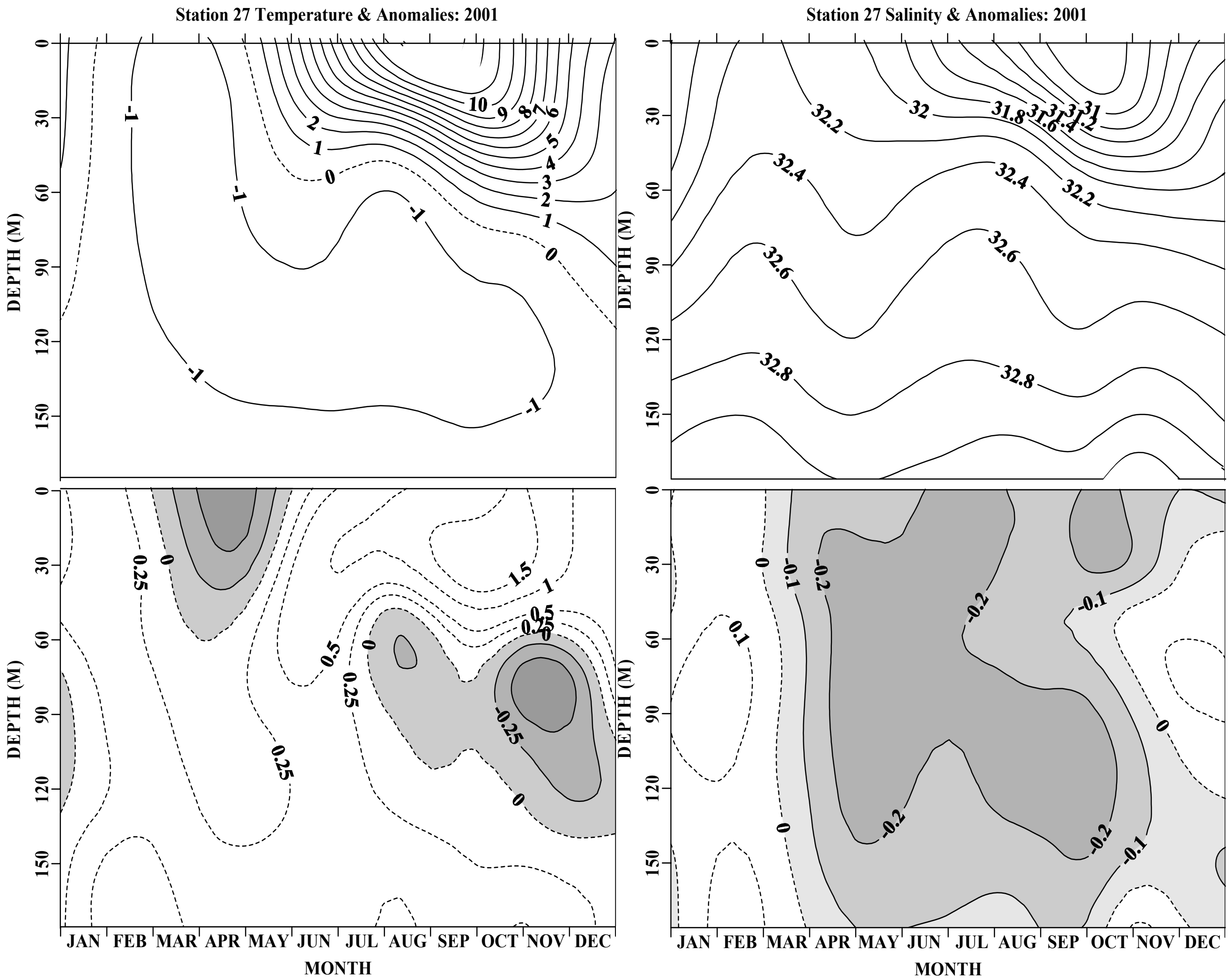

Figure A.I.5. Contours of the annual cycle of temperature and temperature anomalies (in °C) (left panels) and salinity and salinity anomalies (right panels) as a function of depth at Station 27 for 2001. Negative anomalies are shaded.

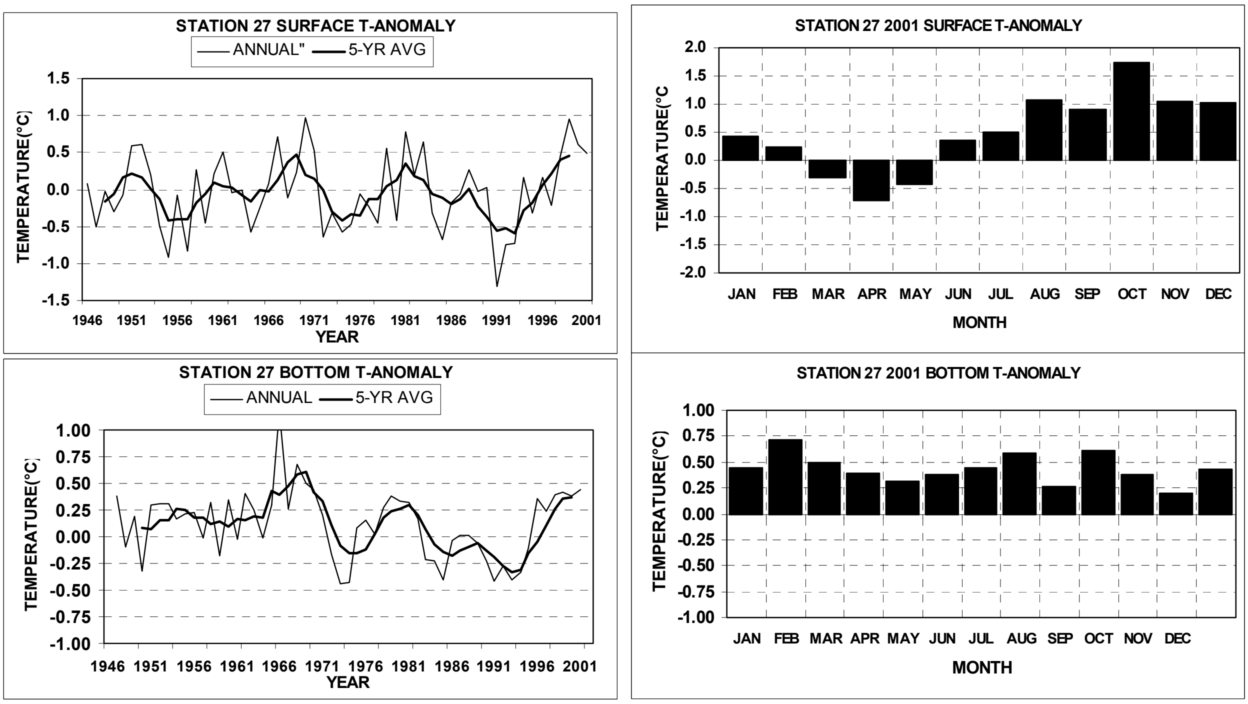

Figure A.I.6. Monthly surface and bottom temperature anomalies at Station 27 during 2001 (right panels) and their annual anomalies with 5-year running means (left panels).

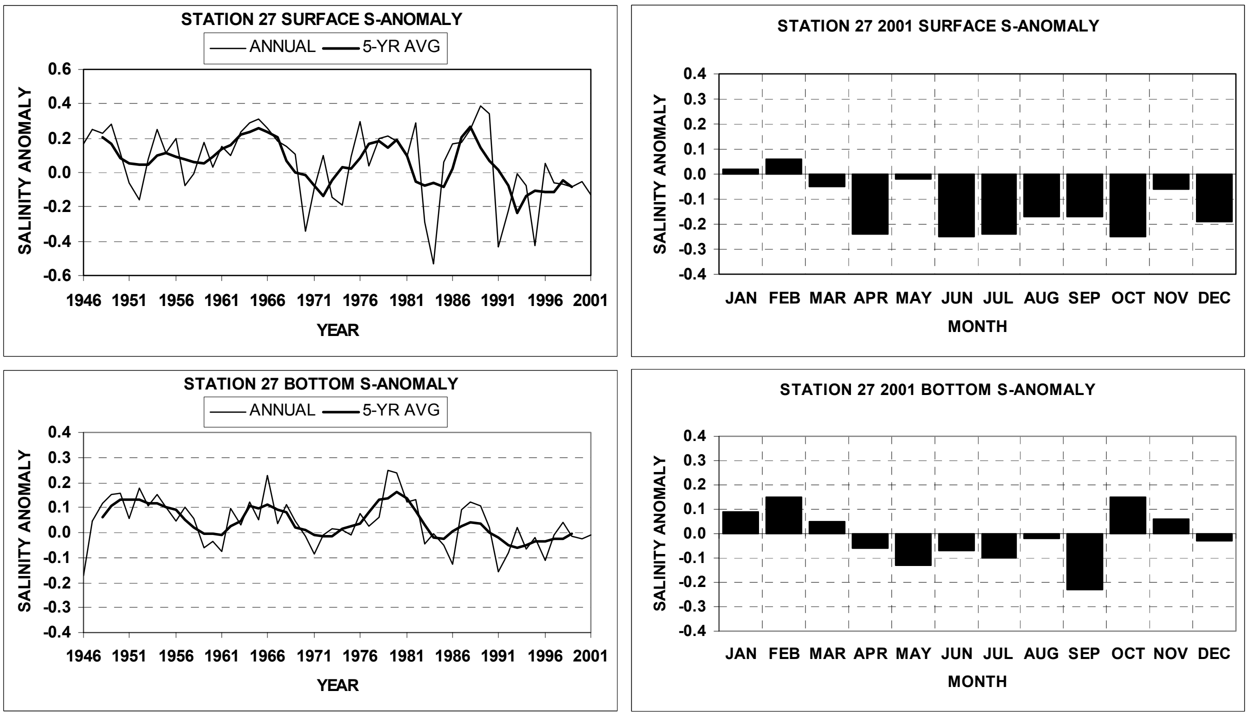

Figure A.I.7. Monthly surface and bottom salinity anomalies at Station 27 during 2001 (right panels) and their annual anomalies with 5-year running means (left panels).

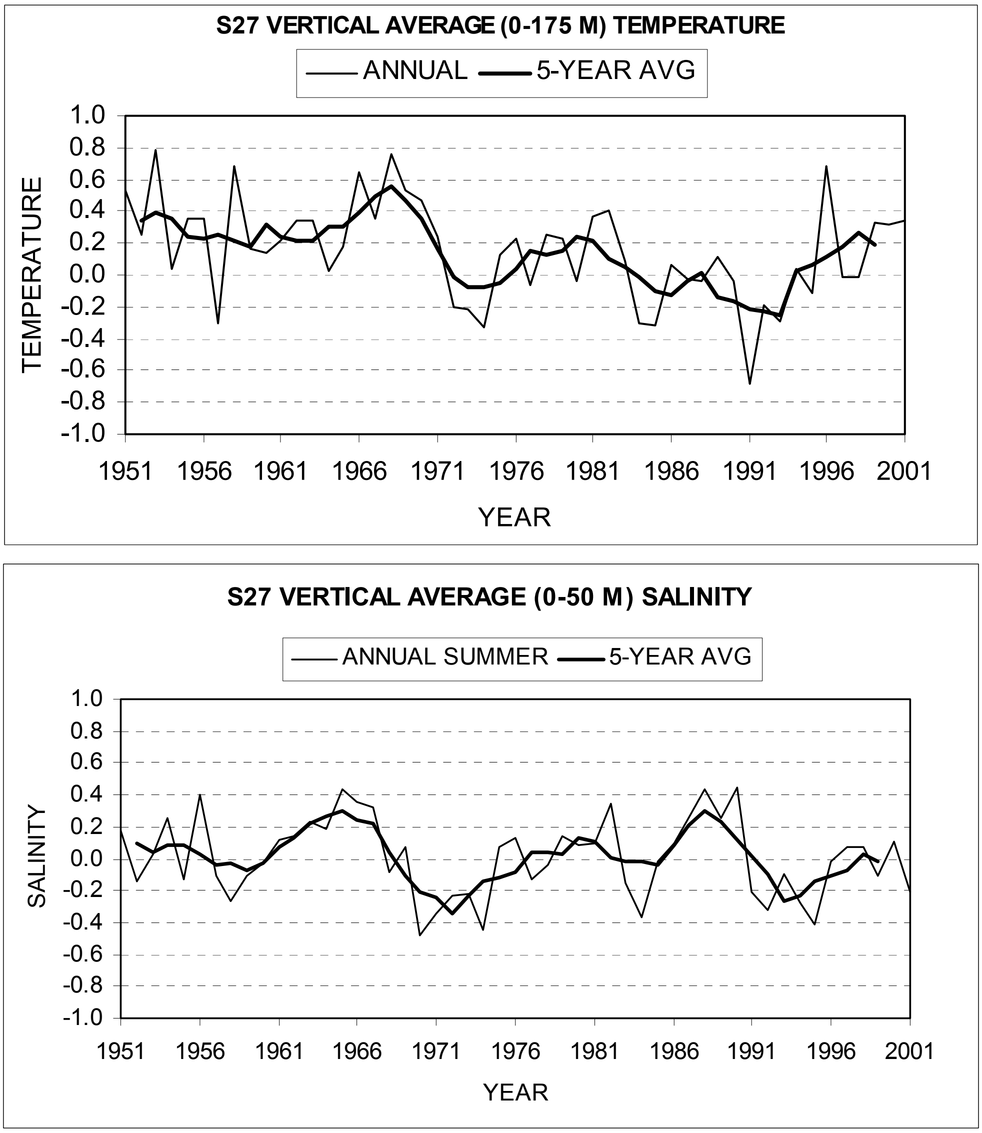

Figure A.I.8. The annual vertically averaged (0–176 m) Station 27 temperature anomalies and the vertically averaged (0–50 m) summer (July-Sept.) salinity anomalies. The heavy lines are the 5-year running means.

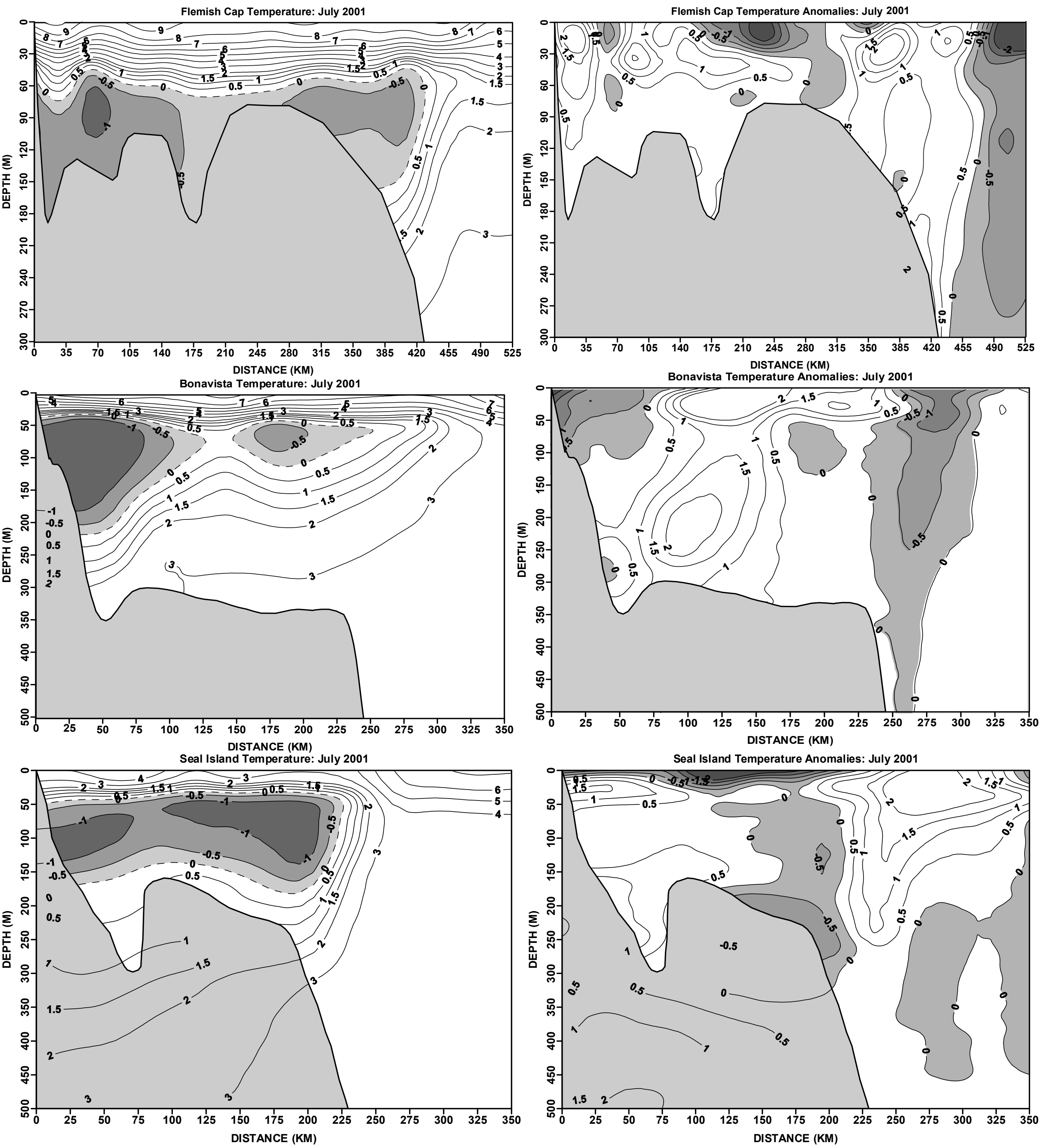

Figure A.I.9. Contours of temperature and temperature anomalies (in ºC) along the Flemish Cap, Bonavista and Seal Island sections (Figure A.I.2) during the summer of 2001.

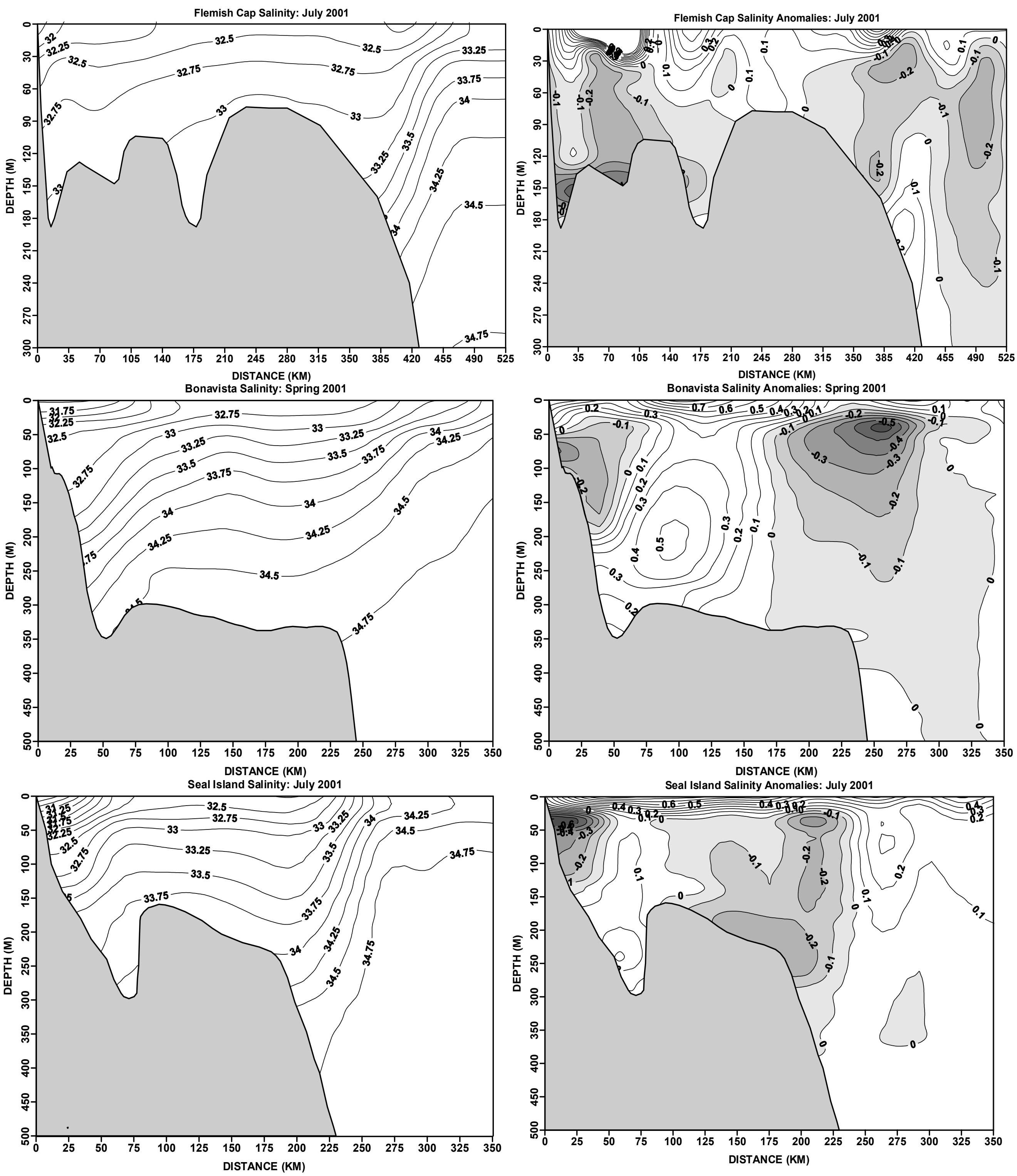

Figure A.I.10. Contours of salinity and salinity anomalies along the Flemish Cap, Bonavista and Seal Island sections during the summer of 2001.

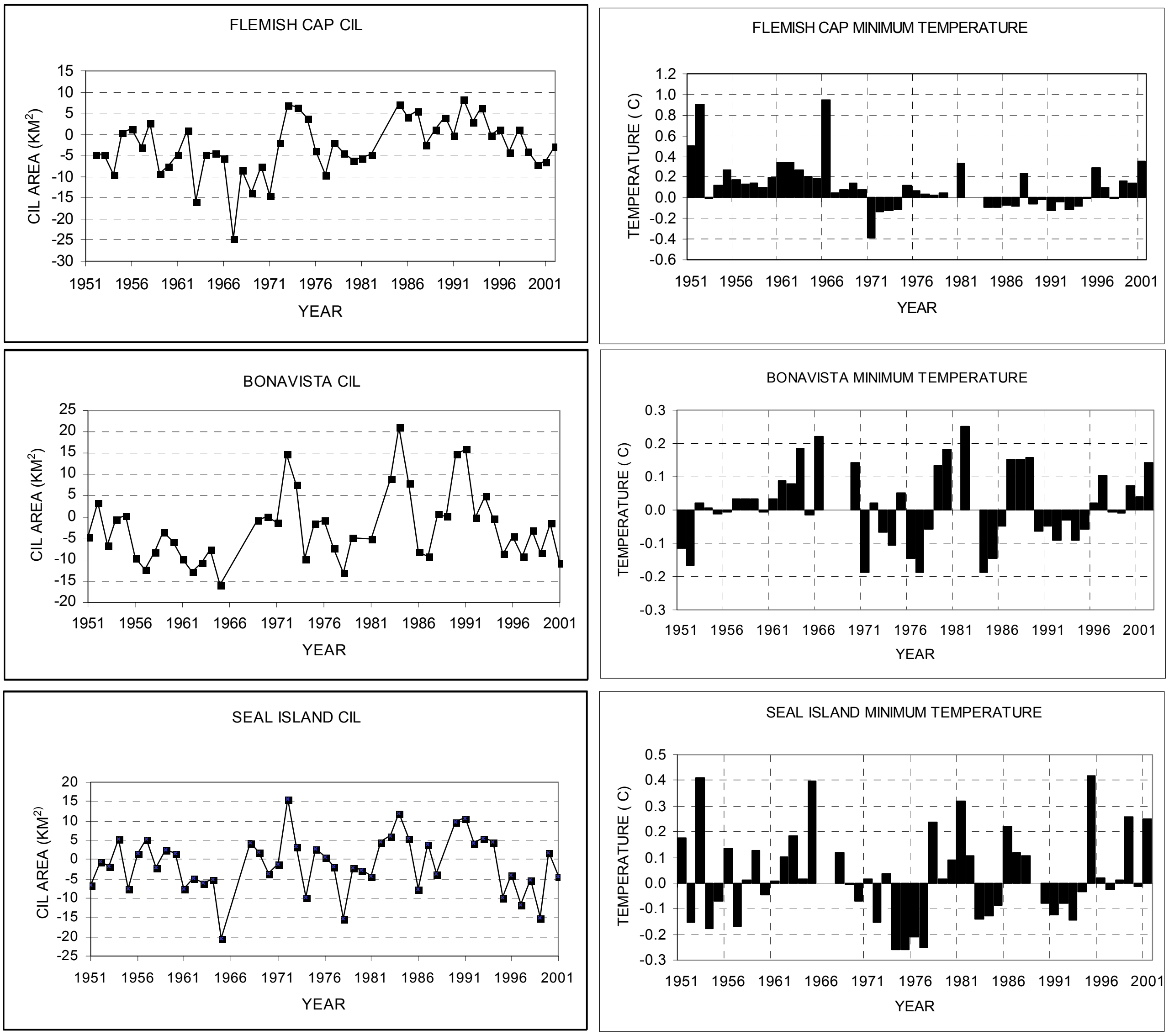

Figure A.I.11. Annual summer CIL cross-sectional area (left panels) and minimum temperature (right panels) anomalies along the Flemish Cap, Bonavista and and Seal Island sections. The anomalies are references to the 1971–2000 means.

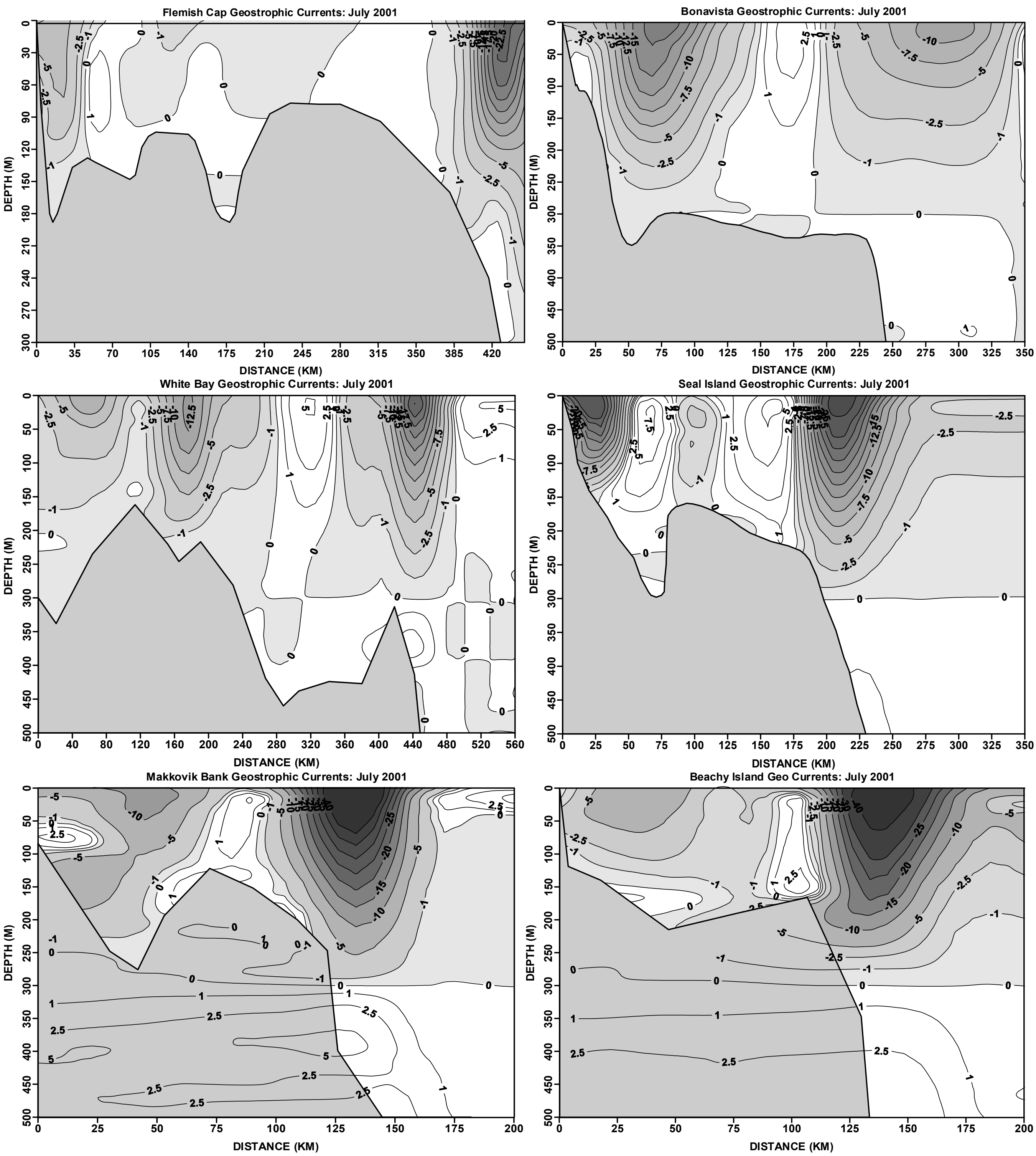

Figure A.I.12. Contours of geostrophic currents (in cm/s) along sections on the Newfoundland and Labrador Shelf (Figure A.I.2) during the summer of 2001. Negative shaded values are southward.

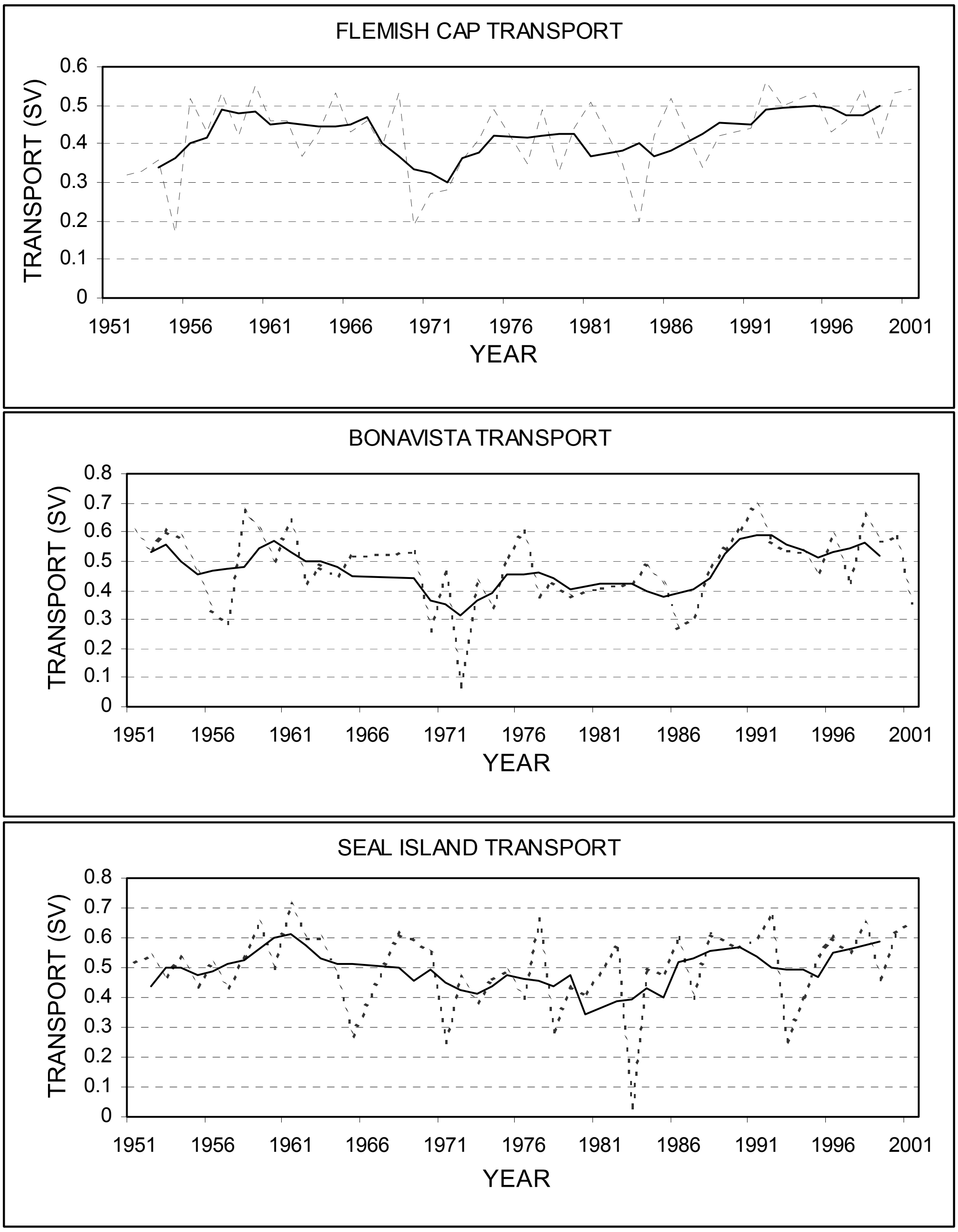

Figure A.I.13. Time series of geostrophic transport (10^6 m^3/s) relative to 130-m depth of the offshore branch of the Labrador Current through the Flemish Cap, Bonavista and Seal Island sections. The heavy line is the 5-year running mean.

ANNEX J: LABRADOR SEA CONDITIONS IN SPRING 2001 (ICES AREA 2B)

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

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Summary

The upper layers of the Labrador Sea were observed to be warmer, saltier, and less dense in the summer of 2001 compared with conditions in 2000. These changes seem to be due largely to advection: there is no evidence for convective overturning during the winter of 2000–2001 to depths greater than 500 m.

Introduction

The most recent transect of WOCE Line AR7W by Ocean Sciences Division (Fisheries and Oceans Canada at the Bedford Institute of Oceanography) was made during 30 May - 15 June 2001 on board CCGS Hudson. Chief scientist for Expedition Hudson 2001022 was R. Allyn Clarke of Ocean Sciences Division. There were no major problems and all expedition goals were achieved.

Figure A.J.1 shows a map of the Labrador Sea with station positions for the 2001 Hudson expedition, including 31 full-depth AR7W stations with water samples for a suite of chemical measurements. The Bravo mooring site in the central Labrador Sea near the historical location of Ocean Weather Ship Bravo is marked. TOPEX/POSEIDON ground tracks are also shown.

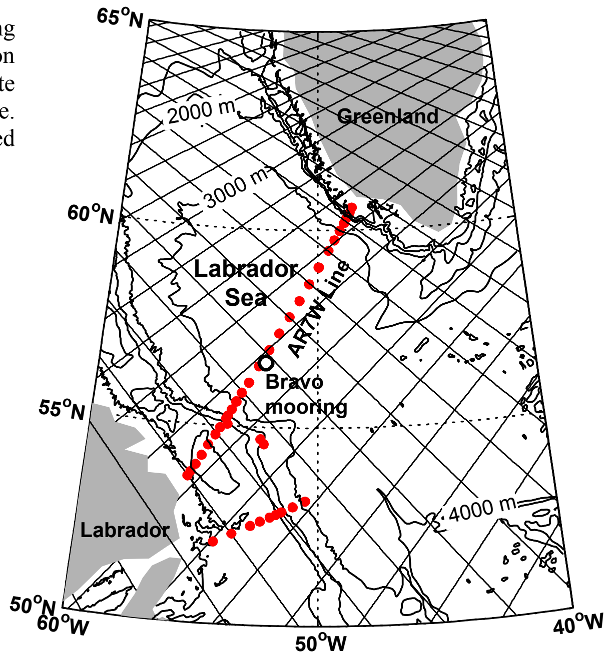

Figure A.J.1. Map of the Labrador Sea showing CTD station positions for Hudson Expedition 2001022 (solid circles). The Bravo mooring site is marked with an open circle. TOPEX/POSEIDON ground tracks and selected bathymetric contours are also shown.

Vertical sections

Contoured sections of potential temperature, salinity, and potential density anomaly for the 2001 AR7W section are shown in Figures A.J.2a, b, and c.

The most noticeable features of the upper layers are the warm, saline waters of the West Greenland Current at the eastern boundary of the Labrador Sea and the cold, fresh waters of the Labrador Current on the western boundary. A seasonal thermocline with a maximum surface temperature of about 6.1^{o}C had developed at the time of the survey. Its effects are limited to the upper 100 m. Below the seasonal layer, the upper 2000 m of the water column show considerable horizontal and vertical structure in all fields. Centered near distance 450 km there is a prominent pool of cool, fresh water. This feature has a horizontal extent of 100–200 km and extends to 400–500m depths. Potential density contours are somewhat depressed in and below the feature relative to the adjacent waters. The origin of this feature is unclear.

Figure A.J.2a shows a widespread temperature minimum in the vertical (values near 3.1^{o}C) that deepens from 700–900 m to 900–1100 m depths from west to east. This is a remnant of the convection that took place during the winter of 1999–2000 and was observed in Spring 2000. The persistence of this layer through the winter of 2000–2001 shows that convection did not reach these depths during this past winter.

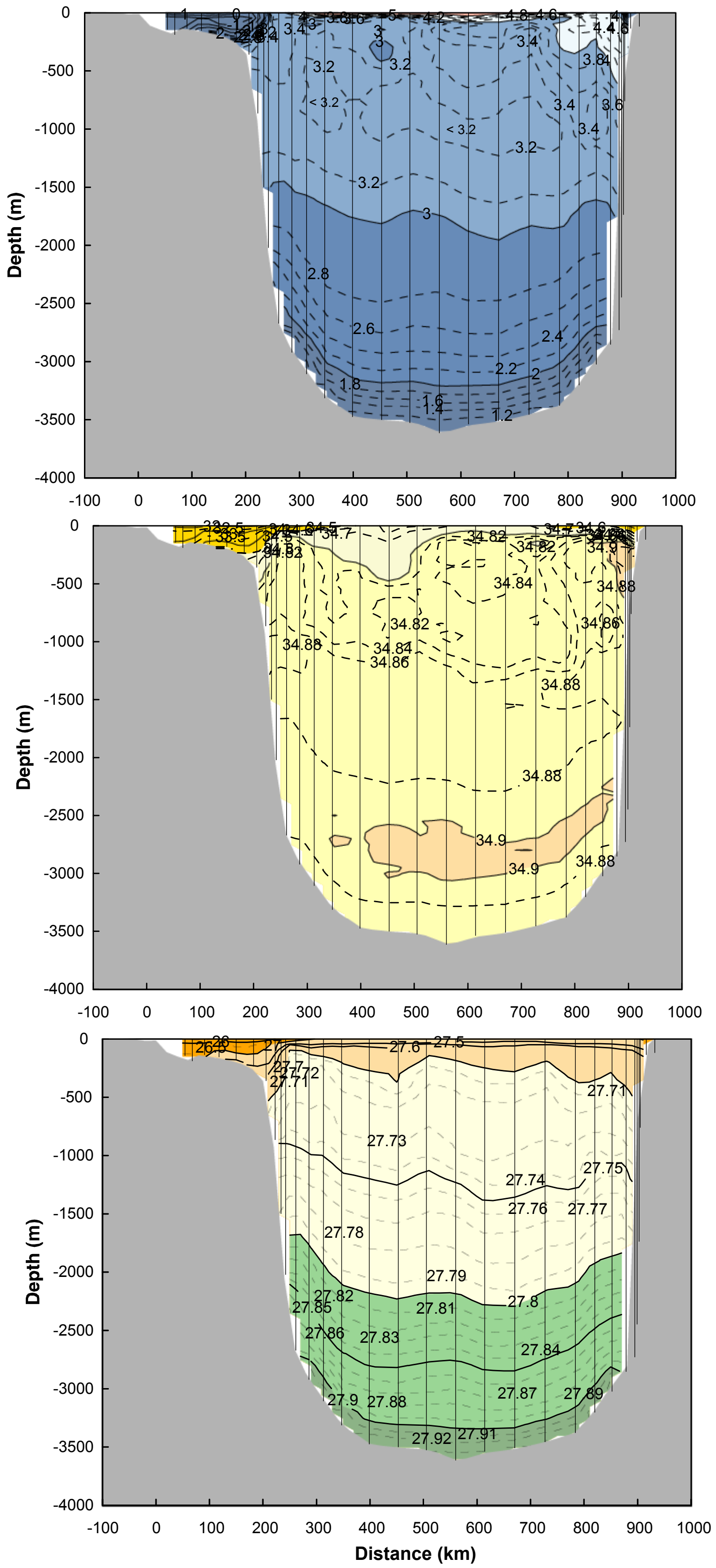

Figure A.J.2a (upper) AR7W potential temperature (°C) section for Hudson 2001022, 30 May - 15 June 2001.
Figure A.J.2b (middle) Salinity section as in Figure A.J.2a.
Figure A.J.2c (lower) Potential density anomaly (kg m^{-3}) section as in Figure A.J.2a.

The vertical structure in potential temperature and salinity may be seen more clearly in Figure A.J.3 which shows the average potential temperature - salinity curve derived from the four Year 2001 stations in the distance range 320–520 km. Depth annotations are added at 500 m intervals. A similar average for the Year 2000 AR7W occupation is included for comparison. The shape of the 2001 curve is similar to the 2000 curve in the 500–2000 m depth range. The similarity suggests that any convection that may have occurred during the winter of 2000–2001 was limited to depths less than 500 m.

Deeper Labrador Sea Water (LSW) formed by deep convection in a series of severe winters between 1988 and 1993 is still present in 2001. This is shown in Figure A.J.3 by the cold, fresh salient in the potential temperature - salinity curve at depths near 2000 m. Since 1994, the core of this water has steadily become warmer and saltier. This trend continued in 2001: the 2001 values are 0.02 to 0.03°C warmer and 0.002 to 0.003 saltier on density surfaces than the 2000 values in this depth range.

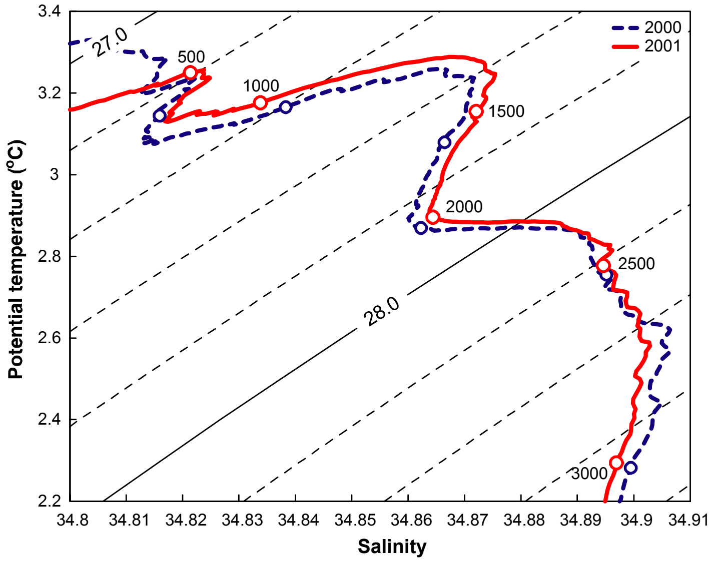

Figure A.J.3 Potential temperature - salinity curve for the western Labrador Sea from Hudson 2001022 (solid curve). The curve is average over four stations in the distance range 320 to 520 km. Depths are indicated at 500 m intervals. A similar curve for the Spring 2000 occupation of AR7W is also shown (dashed curve). Selected potential density anomaly curves at 0.2 kg m^{-3} intervals are shown.

Contoured sections of the changes in potential temperature, salinity, and potential density relative to the previous year's occupation (Expedition HUDSON 2000009, 20 May - 8 June 2000) are shown in Figures A.J.4a, b, and c.

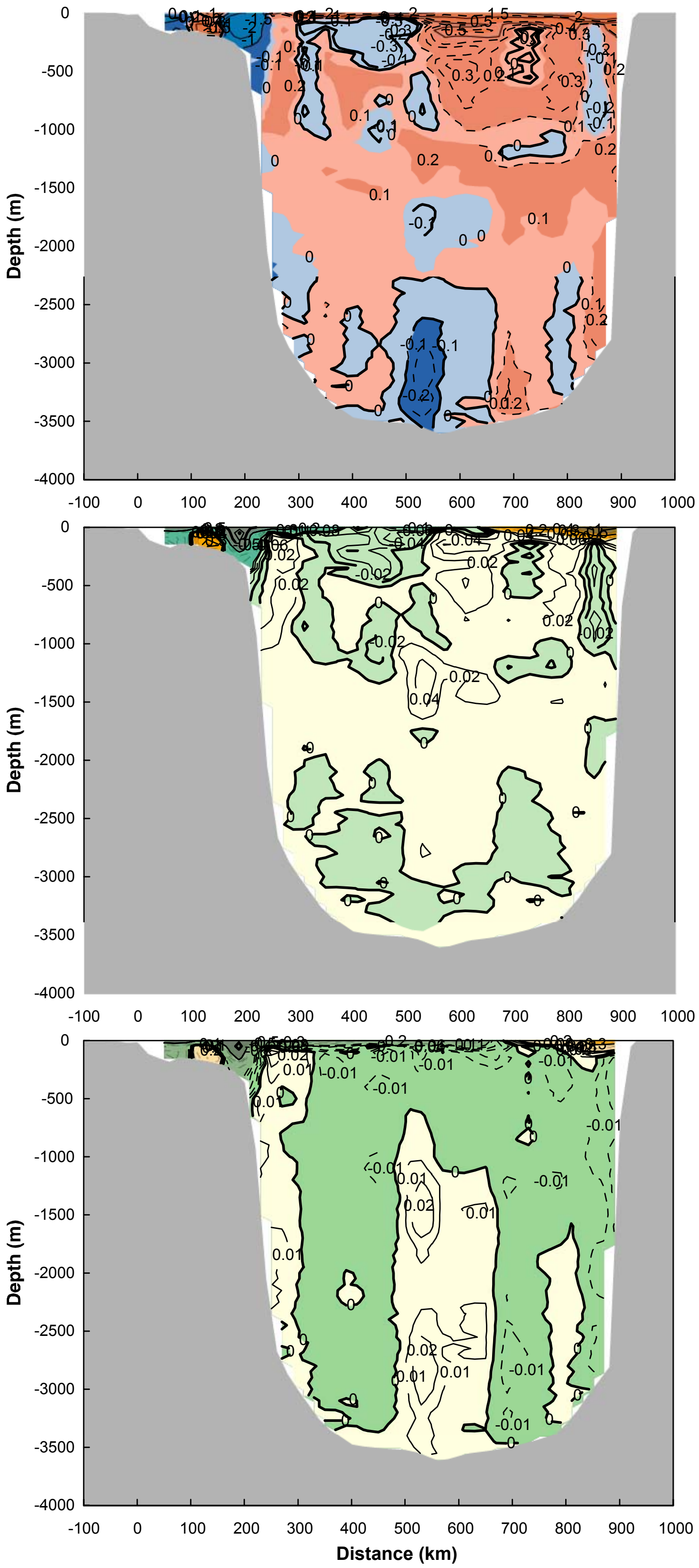

Figure A.J.4a (upper) Contoured change in potential temperature (^{o}C) from Spring 2000 to Spring 2001.
Figure A.J.4b (middle) Contoured change in salinity as in Figure A.J.4a.
Figure A.J.4c (lower) Contoured change in potential density (kg m^{-3}) as in Figure A.J.4a.

The cool and fresh pool near 450 km distance noted above is prominent in the difference plots for potential temperature and salinity, but less so for potential density. The general trend to warmer, more saline, and less-dense properties shown in Figure A.J.3 for the western side of the Labrador Sea is widespread in the upper 1000 m. The likely source is an increased warm water input from the West Greenland Current: the effects are more pronounced closest to the presumed source on the eastern side of the Labrador Sea. We should note that the gridded differences depend on interpolating the 2000 results across a gap in coverage in the distance range 615 to 730 km.

The 2000 survey observed an energetic eddy centred at 530 km. At depths greater than 500 m, density surfaces in the eddy were displaced downwards. The effects penetrated all the way to the bottom. This transient feature in the 2000 fields increased the potential temperature and decreased the potential density on pressure surfaces. It is responsible for the apparent cooling and increase in density of the deeper waters near the 530-km distance mark in the contoured difference fields.

The Northeast Atlantic Deep Water (NEADW, underlying the deep LSW) appears to have freshened by 0.002 to 0.003 and become correspondingly colder on density surfaces. The deepest waters, originating in the Denmark Strait Overflow Water (DSOW), do not appear to have changed appreciable since the previous year.

Sea level changes from TOPEX/POSEIDON altimetry and hydrography

Time series of sea level at the site of the central mooring were extracted from the Maps of Sea Level Anomaly TOPEX/POSEIDON (T/P) 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 22 October 1992 through 5 September 2001. The mean for the entire measurement period was removed, and a seasonal signal was estimated by a least-squares fit to annual and semi-annual harmonics. After the seasonal signal was removed, a low-pass filtered times series was produced using a squared second-order Butterworth filter with a 1.5-year cut off period.

Figure A.J.5 shows the time series of the original 10-day MSLA samples and the low-pass filtered series with and without the seasonal signal. Also shown are the time changes in geopotential height relative to 2000 dbar calculated from AR7W measurements since 1900 relative to the mean of spring values during the T/P measurement period. Each value is an average of approximately 4 stations in the 320–520 km distance range. Sample standard deviations for each cruise are also shown. The seasonal signal has a range of just less than 9 cm. There is reasonable agreement between the changes in geopotential height relative to 2000 dbar and the changes measured by the altimeter when seasonal effects are included. The low-frequency sea level time series shows an increase of 1–2 cm between the 2000 and 2001 AR7W occupations.

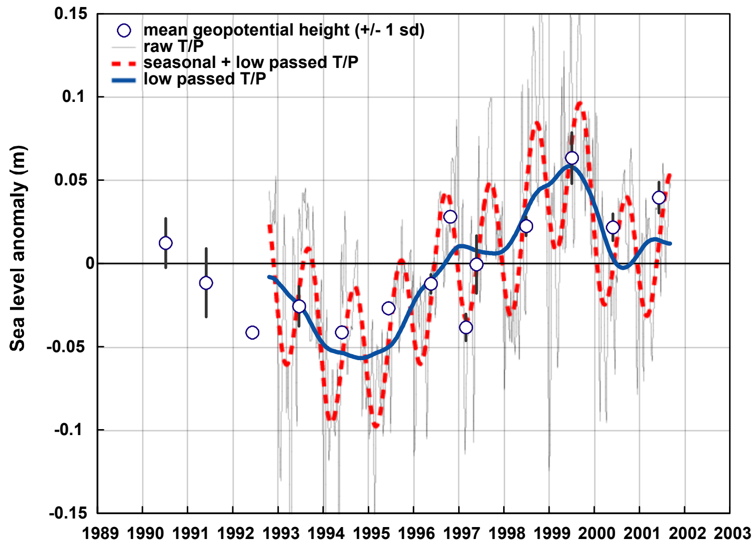

Figure A.J.5. TOPEX/POSEIDON sea level anomaly at the central Labrador Sea mooring site. Shown are 10-day MSLA values relative to their overall mean (thin line), seasonal cycle plus low-passed sea level (dashed line), and low-passed sea level (thick line). Also shown are changes in geopotential height relative to 2000 dbar from AR7W occupations since 1990 relative to the mean spring values during the T/P measurement period (open circles are means over distance range 320 to 520 km; error bars are sample standard deviations).

Figure A.J.6 shows a map of the change in low-passed T/P sea level in the Labrador Sea between Spring 2000 (central date 2 June 2000) and Spring 2001 (central date 7 June 2001). There is a widespread increase in sea level over much of the region, with typical values of 1–3 cm. The changes at the Bravo mooring site appear to be representative of this broader region. There is a contrasting decrease in sea level shoreward of the 3000-m depth contour on the western side of the Labrador Sea.

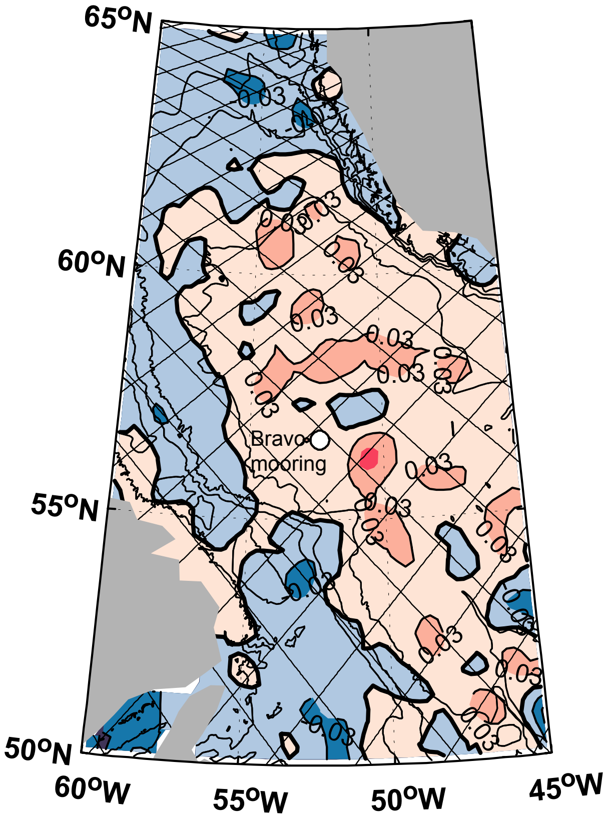

Figure A.J.6. Spatial map of the change in low-passed T/P sea level in the Labrador Sea between Spring 2000 (central date 2 June 2000) and Spring 2001 (central date 7 June 2001). The contour interval is 0.03 m.

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.

The cruise report for the 2001 Labrador Sea AR7W transect can be found at http://www.mar.dfo-mpo.gc.ca/science/ocean/woce/reports/CHUD2001022a.pdf

ANNEX K: HYDROGRAPHIC STATUS REPORT 2001: ICELAND SECTION (ICES AREA 3)

Svend-Aage Malmberg and Héðinn Valdimarsson

Marine Research Institute, Reykjavík

Iceland is situated at the meeting place of warm and cold currents (Figure A.K.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.

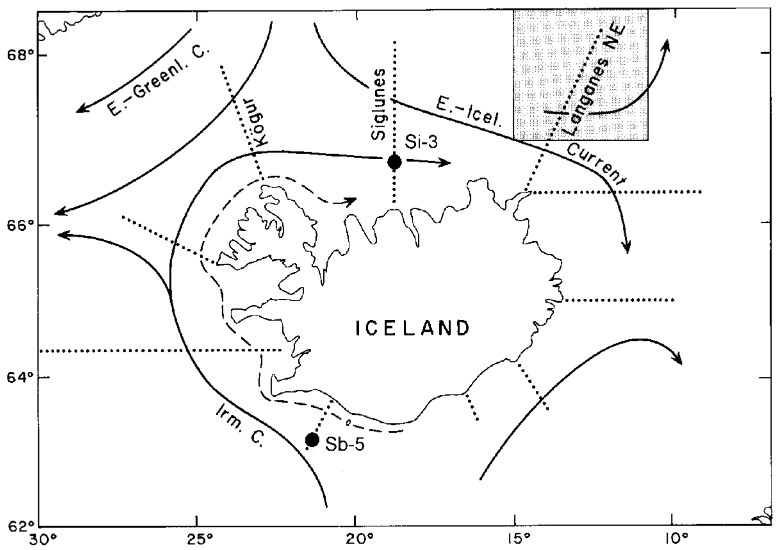

Figure A.K.1. Main currents and location of standard hydro-biological sections in Icelandic waters. Selected areas and stations dealt with in this report are indicated.

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 (Figure A.K.2). 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 2001 revealed in general relatively high temperatures and salinities as in the 3–4 previous years. The salinity in the warm water from the south was as since November 1997 higher than was observed over the last decades (Figure A.K.3) but though slightly lover than in 1998–2000. 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 (Figures A.K.2 and A.K.4).

In 1999–2001 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 (Figure A.K.4).

The cold-water north, northeast and east of Iceland in the East Icelandic Current was in 2001 as in both 1999 and 2000 relatively far offshore. The temperature and salinity in the East Icelandic Current was in 2001 slightly lower than in 2000 but still with salinities well above the critical value which prevents convection (>34.7; Figure A.K.3 and A.K.5). These mild conditions in Icelandic waters in 1999–2001 (Figure A.K.6) 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 2002 still revealed relatively high temperatures and salinities in the warm water south of Iceland (S > 35.15), while values in the north- and northeastern area were lower and similar to what was observed in 1997 and salinities of the surface layers were under the critical 34.7.

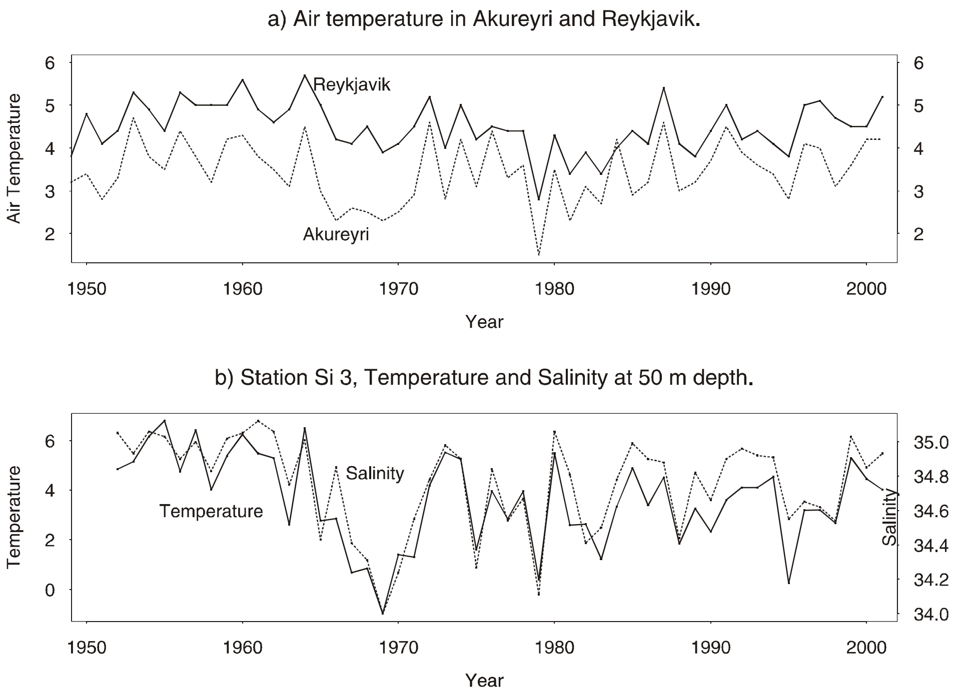

Figure A.K.2a. Mean annual air-temperatures in Reykjavík and Akureyri 1950–2001.
Figure A.K.2b. Temperature and salinity at 50 m depth in spring at Station Si-3 in North Icelandic waters 1952–2001.

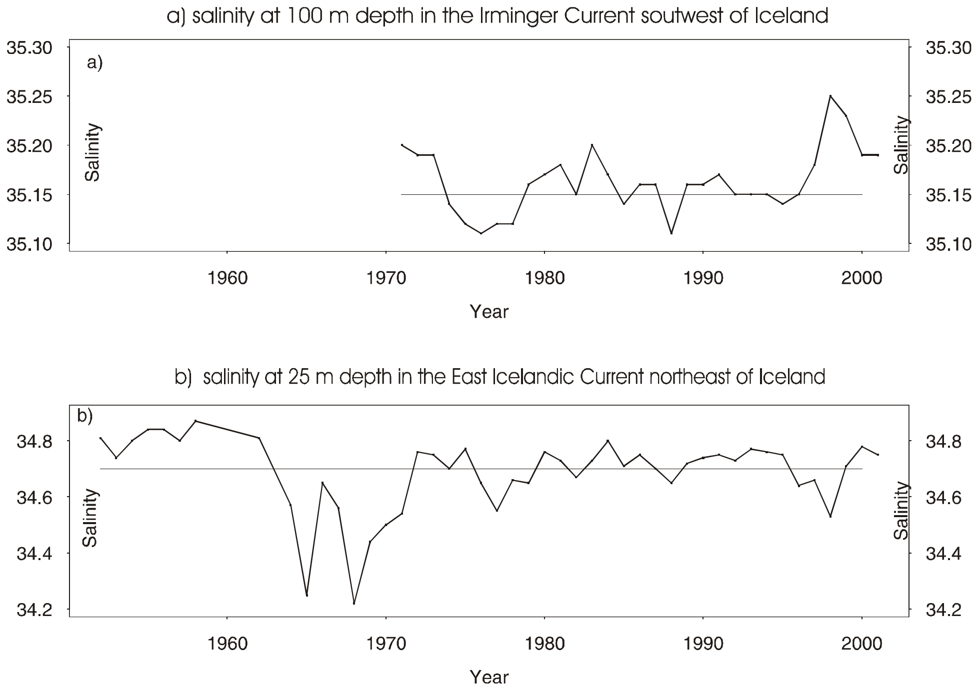

Figure A.K.3. Salinity deviations in spring at:
a. 100 m depth in the Irminger Current south of Iceland (Sb-5) 1971–2001.
b. 25 m depth in the East Icelandic Current north-east of Iceland 1952–2001.

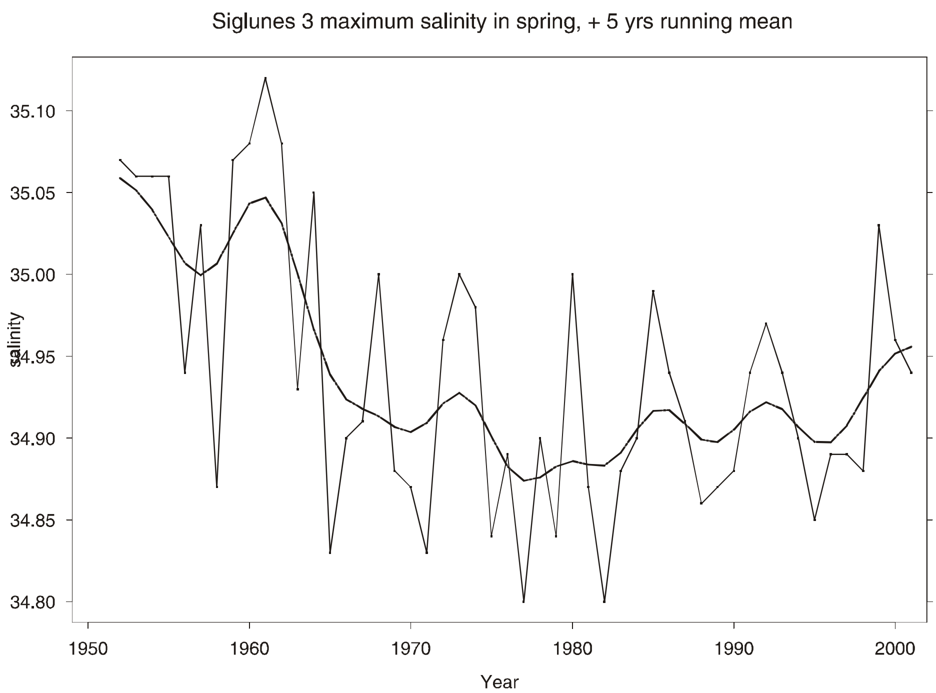

Figure A.K.4. Maximum salinity in the upper 300 m in spring at station Si-3 in North Icelandic waters 1952–2001 and five years running mean.

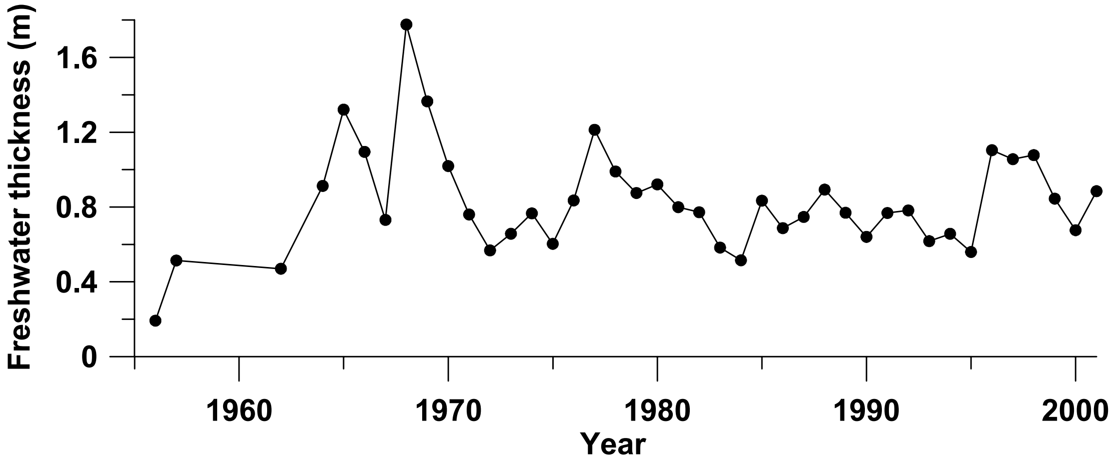

Figure A.K.5. The fresh water thickness at Langanes NE 4 above 150 m, relative to salinity of 34.93 in May/June 1956–2001.

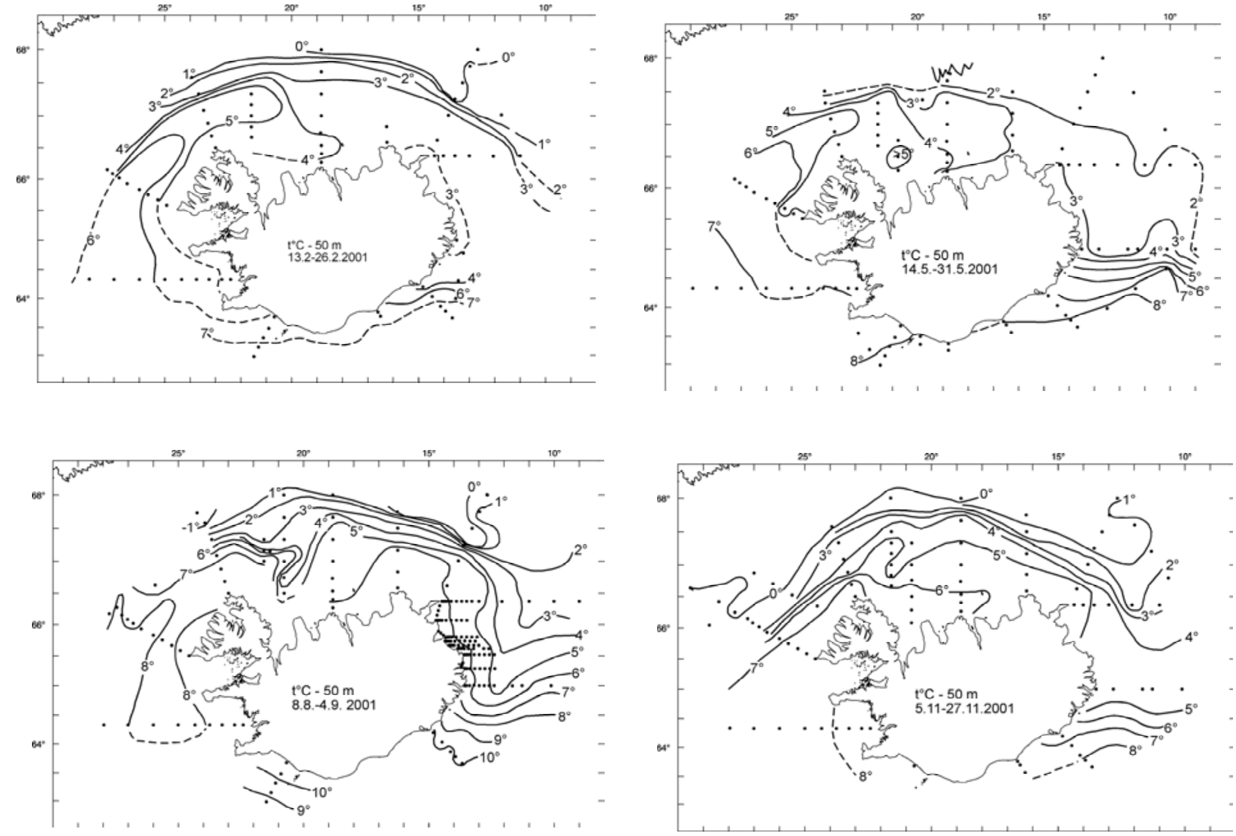

Figure A.K.6. Temperature at 50 m depth in Icelandic waters in February, May, August and November/December 2001.

ANNEX L: HYDROGRAPHIC STATUS REPORT 2002: SPANISH STANDARD SECTIONS (ICES AREA 4)

C. Lavín[1], González-Pola[2] and J. M. Cabanas[3]

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The Spanish Standard Sections cover the area of the shelf and shelf-break of the Eastern Atlantic and North Iberian Peninsula. Five sections are sampled monthly by the Instituto Español de Oceanografía situated in Santander (43.5ºN, 3.8ºW), which is the larger, two in Asturias (43.6ºN, 6.2ºW) and from year 2001 (43.6ºN, 5.6ºW), La Coruña (43.40ºN, 8.3ºW) and Vigo (42.1ºN, 9.0ºW). (Figure A.L.1).

The Bay of Biscay is almost an adjacent sea of the Atlantic, located between the eastern part of the subpolar and subtropical gyres. The region is affected by both gyres depending on latitude but the general circulation in the area mainly follows the subtropical anticyclonic gyre in a relatively weak manner (1–2 cm/s). At the southern part of the Bay of Biscay east flowing shelf and slope currents are common in autumn and winter due to westerly winds whereas in spring and summer eastern winds are predominant and coastal upwelling events are frequent.

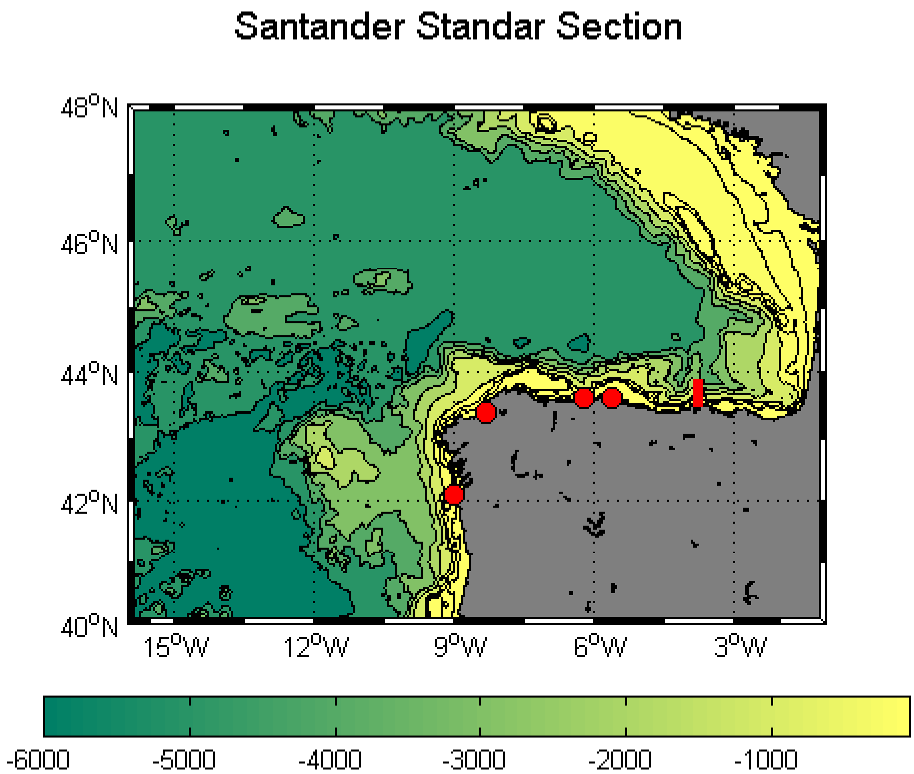


Figure A.L.1. Spanish Standard Sections from the Instituto Español de Oceanografía.

Meteorological Conditions

Meteorological conditions in the north of the Iberian Peninsula in 2000 are similar to those of 1998 to 2000. The annual mean air temperature over the southern Bay of Biscay during 2001 has remained at nearly the same value as during the two preceding years, at 14.8°C, 0.4ºC over the 1961–2001 average. In Figure A.L.2 we have plotted the de-seasoned running mean temperature within annual means and total average.

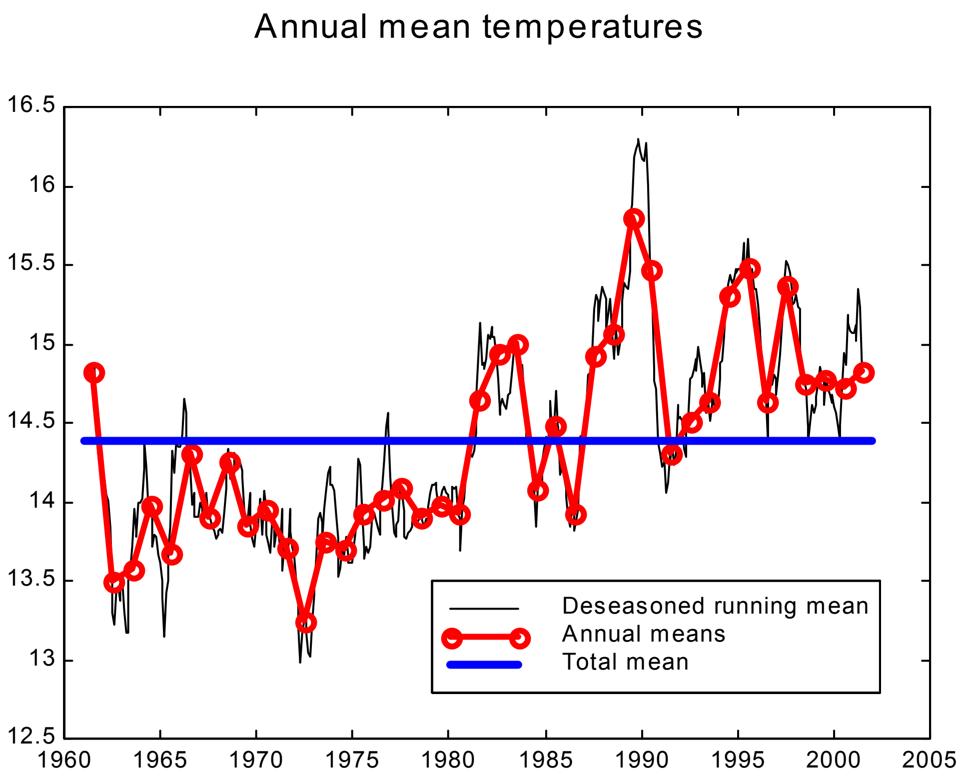


Figure A.L.2. Annual mean temperatures in Santander (43.5ºN, 3.8ºW). Courtesy of the Instituto Nacional de Meteorología.

However, positive anomalies in the annual cycle appear in the winter (January to March), and October and negatives in late Autumn (Nov-Dec). During March and October this anomalous behaviour is really marked. 2001 was the driest year on the historical series. In Figure A.L.3 we show the monthly mean air temperatures superimposed to the annual cycle in the Santander (Instituto Nacional de Meteorología), this annual cycle was constructed supposing a linear trend plus two harmonics functional form, we represent both signals with trend (3.5ºC per century since 1961) and without it.

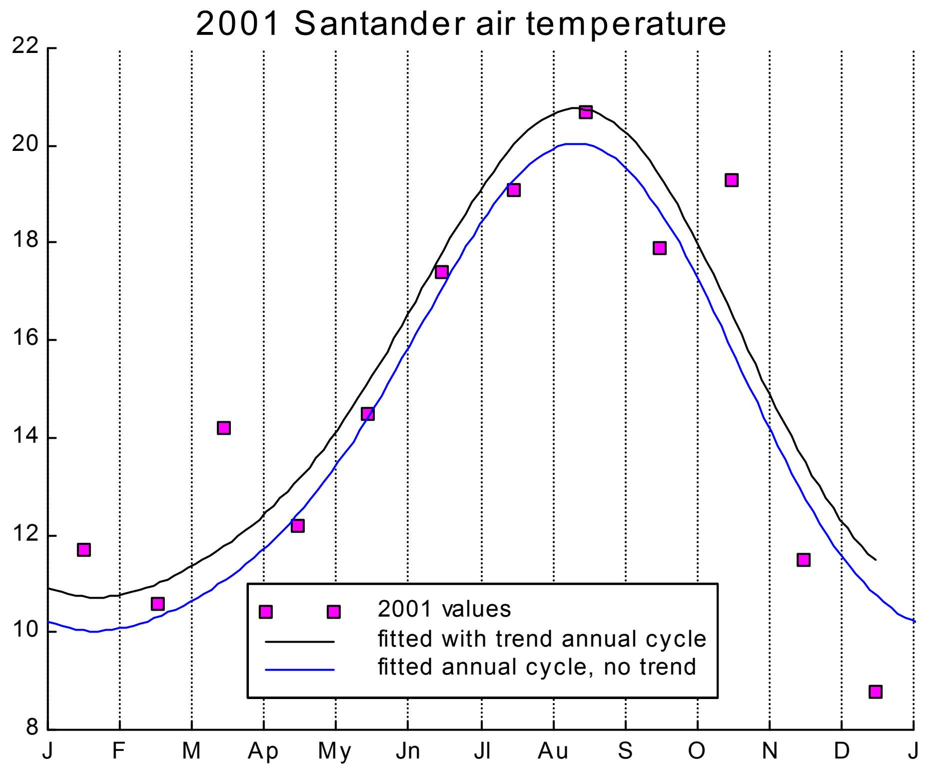


Figure A.L.3. Air temperatures in 2001 in Santander (43.5ºN, 3.8ºW). Courtesy of the Instituto Nacional de Meteorología.

Hydrography

In order to get a first approximation to the data, contours of temperature, salinity and nitrates (over the shelf (100 m depth) in the Santander section are presented in Figure A.L.4. The seasonal cycle in temperature is clearly marked in the upper layers. Stratification develops between April-May and October-November, during the rest of the period the water column is mixed. Summer stratification on 2001 present a shallow picture, temperature was high but termocline reach as much as 25 m depth thus presenting a opposite picture to 2000 when termocline reach deeper. 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. This advection has strong influence during summer and Autumn 2001, the largest and deepest of the decade, only comparable to 1995 values. Salinity high values over most of the shelf that appear from the strong incursion of saltier and ward water in 1997 reduce since January 2000 to values of the same order than in 1995. With regard to nitrate distributions, high values appear in the mixed period and due to upwelling events in the stratified part of the year. 2000 and 2001 have a very low influence of upwelling, and only after June do 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, but caution must be taken with the abnormally high values found in March 2001.

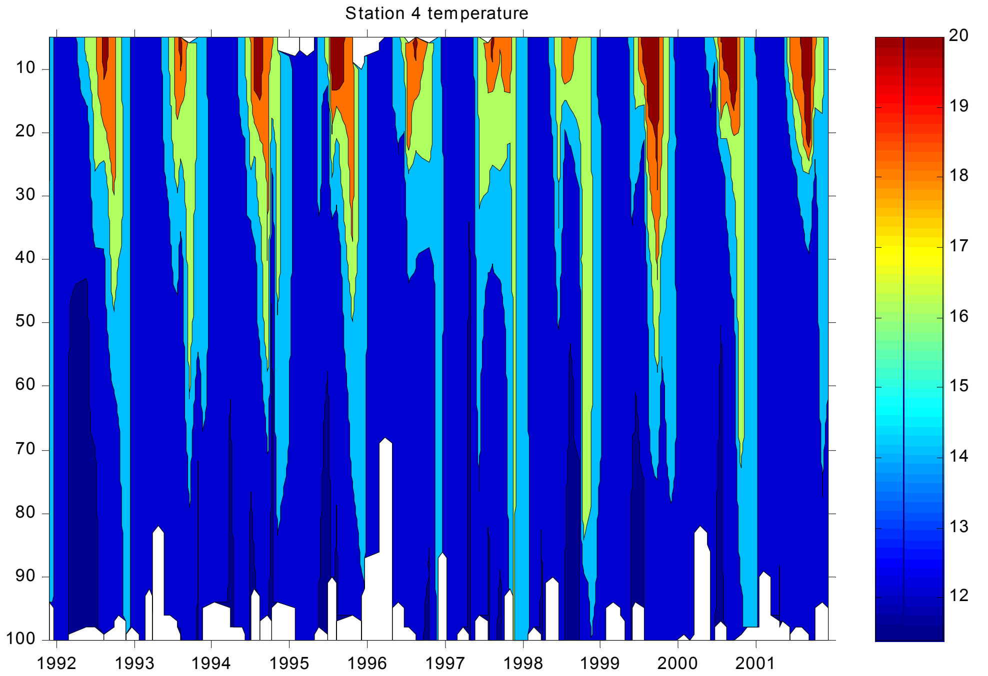


Figure A.L.4a. Temperature evolution at Santander station 4 (shelf).

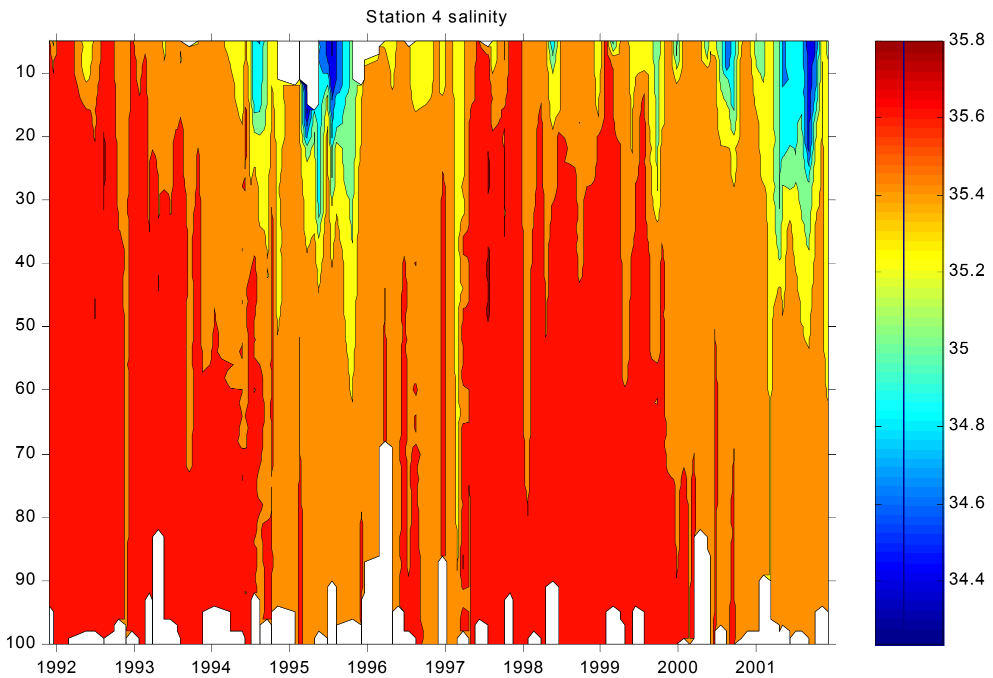


Figure A.L.4b. Salinity evolution at Santander station 4 (shelf).

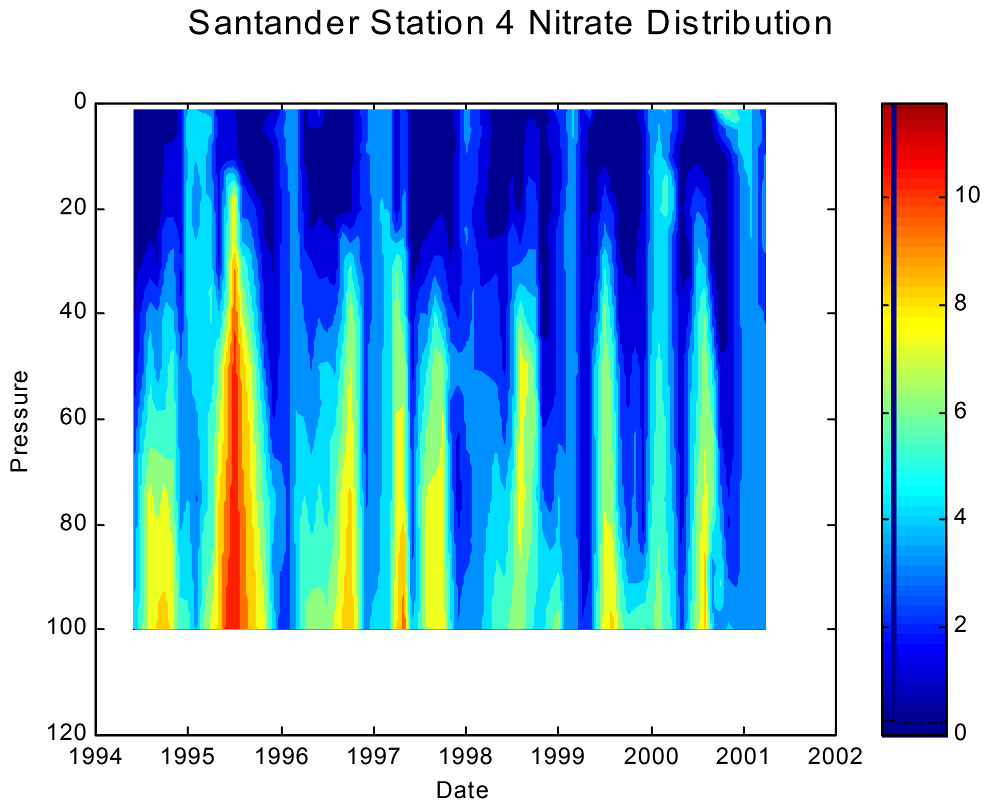
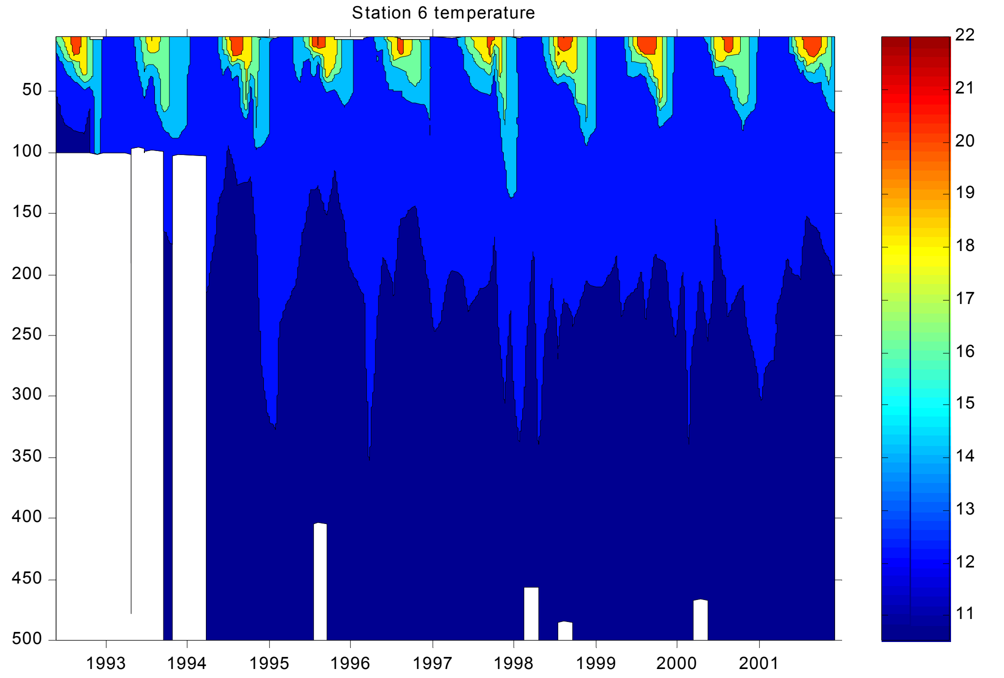
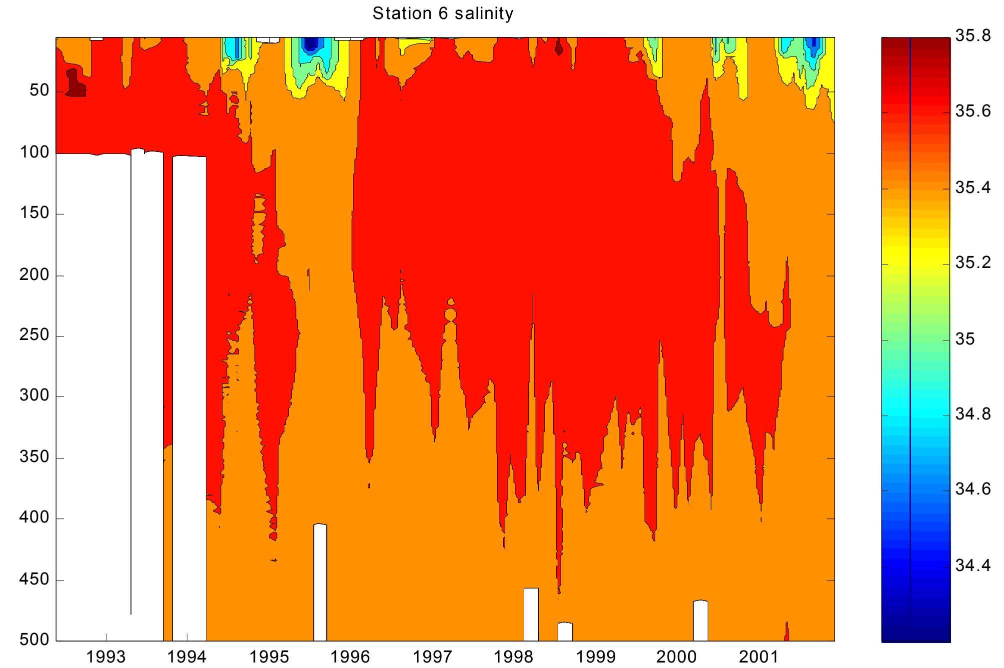


Figure A.L.4c. Nitrate evolution at Santander station 4 (shelf).

Contours of temperature, salinity and nitrates over the shelf-break (600 m depth) in the Santander section are presented in Figure A.L.5. During the first period (1992–1994) only upper layers were sampled. As happens over the shelf the period of low salinity in the upper waters (1994–1995) occurs again in 2001, also after a fresher summer. Below the mixed layer, salinity falls from 1992 to 1995 and increases again to 1997/1998 before falling once more until 2001. 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, the autumn mixing is marked even until 350 m depth.

Salinity contours show high values after the end of the mixing period at the beginning of the winter, extending sometimes 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 break 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.





Figures A.L.5a,b. Temperature and Salinity evolution at Santander station 6 (shelf-break).

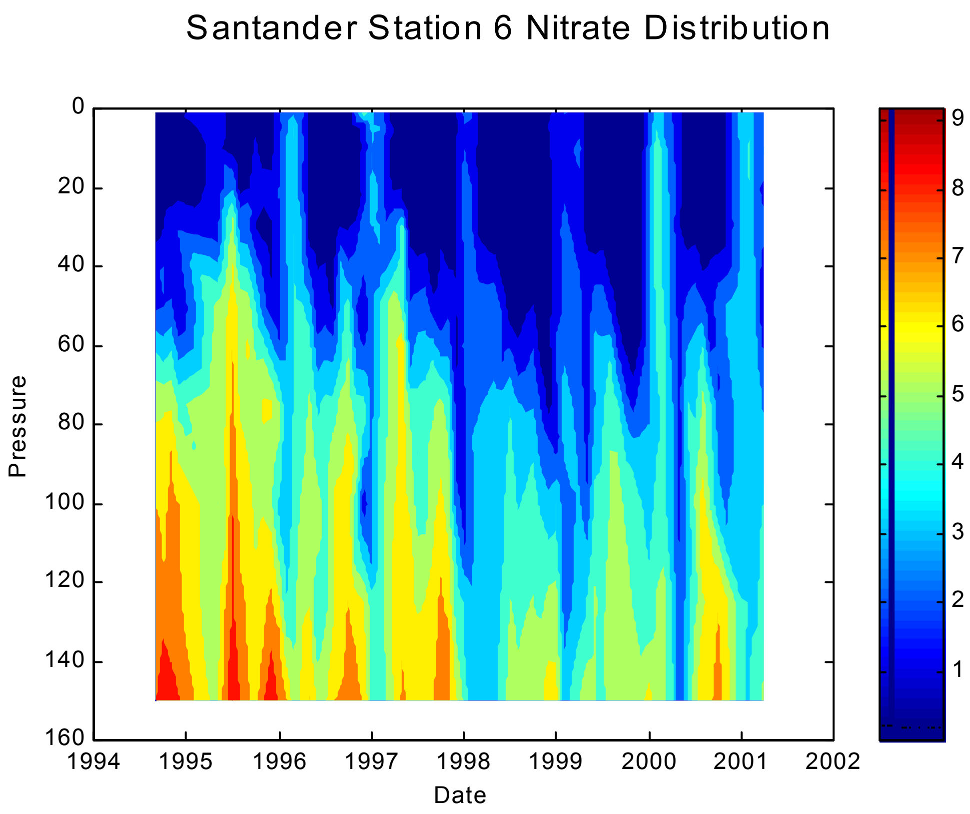


Figure A.L.5c. Nitrate evolution at Santander station 6 (shelf-break).

A similar way to visualize the behaviour of the hydrography compared with the historical data is superimposing several time series at different depths, in figure 6 we perform such representation for station 6. We can see how years with low salinity values in surface waters (NE regimes) enhance a shallow sharp thermocline.

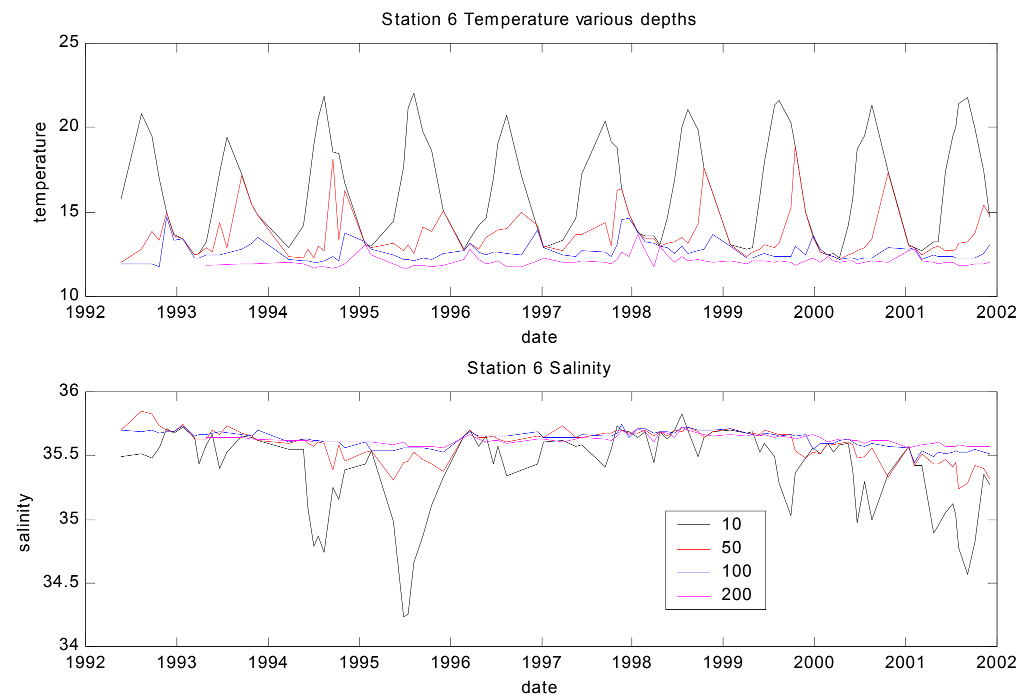


Figure A.L.6. Temperature and Salinity at various depths, Santander station 6 (shelf-break).

Looking at thin layer superficial waters we expect to find out an approximate mirror of atmospheric forcing. Due to the thermal inertia of seawater surface, temperature seasonal cycle do not follow a sinusoidal cycle but presents a rapid warming period in late spring whereas the autumn cooling is less abrupt. As said before, superficial salinity present a seasonally decrease produced by the advection of fresher water from the eastern of the Bay of Biscay, usually in spring-summer time, when the wind regime is from the first quadrant and outflow from rivers is maximum.

As it has been done for air temperature, fitting the temperature signal by two harmonic terms plus a linear trend we can approximately reproduce the signal. Taking it into account we can compare year 2001 with the climatological mean for surface waters finding a slightly cool winter followed by a hot and persistent summer for the first water layer (Figure A.L.7). Winter seems to be longer in 2001 than in other years but this impression can be caused by an extremely early sampling in May for this year (Figure A.L.8).

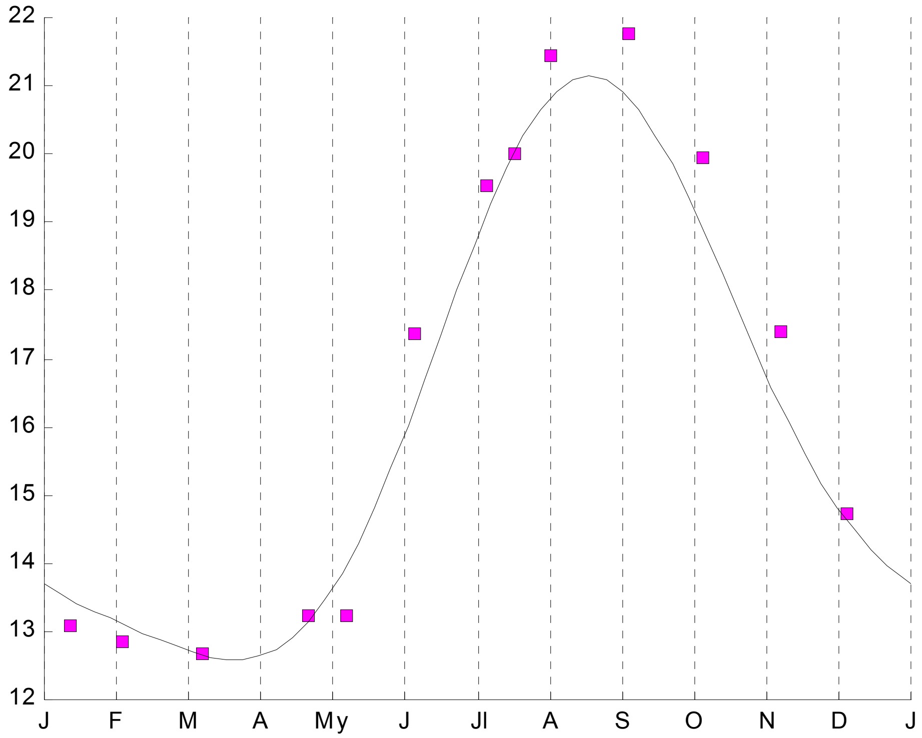


Figure 7a,b. Seawater Surface Temperature at Santander station 6 (shelf-break).

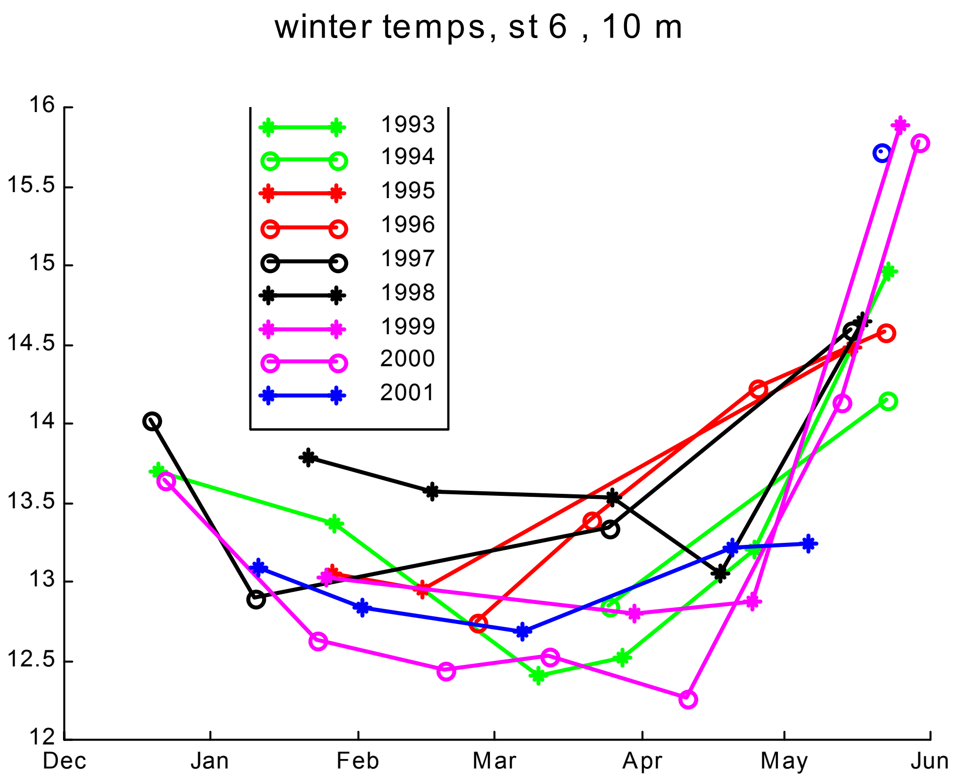


Figure A.L.8. Winter-Spring surface temperatures at Santander station 6.

The salinity decrease signal is found down to 300 meters depth, an average of this layer is shown in Figure A.L.9 for station 6. Same behaviour is found for shelf stations. Down to this depth salinity evolution does not have clear cycles (positive trends seems to appear at lower levels), but heat content have slightly increased during the previous decade, mainly biased by the anomalous 1998, and seem to be almost steady in 2000 and 2001. In Figure A.L.10 we can see evolution in both mixing layer and NAECW. Total heat content for the whole 500 first layer followed last three years a repetitive annual cycle.

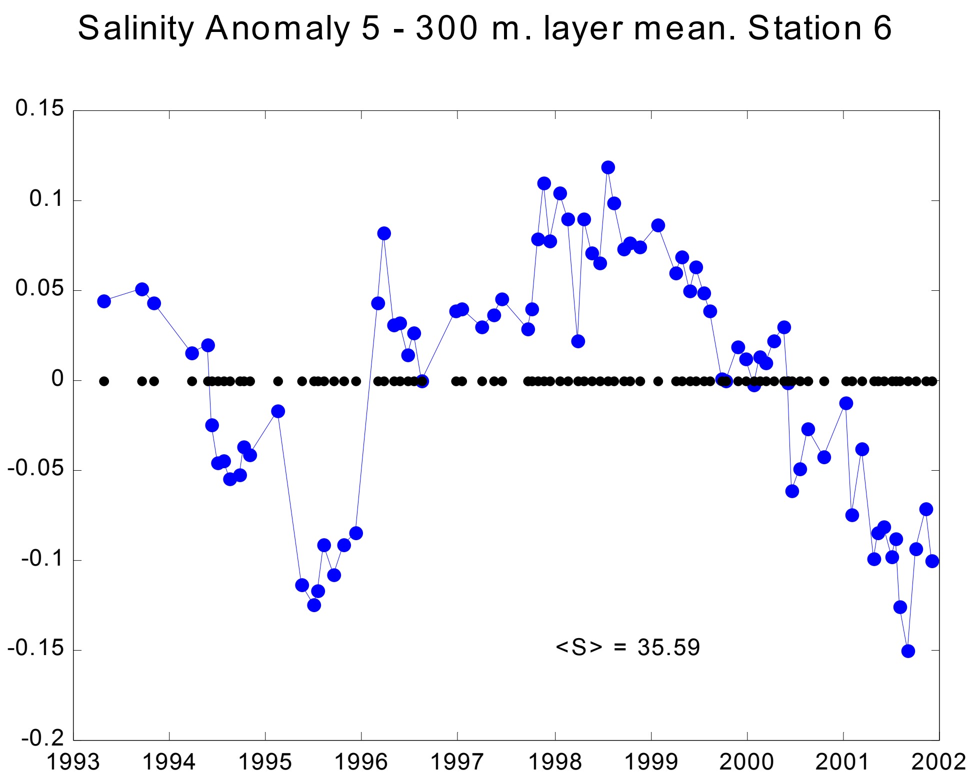


Figure A.L.9. Salinity anomaly evolution at Santander station 6.

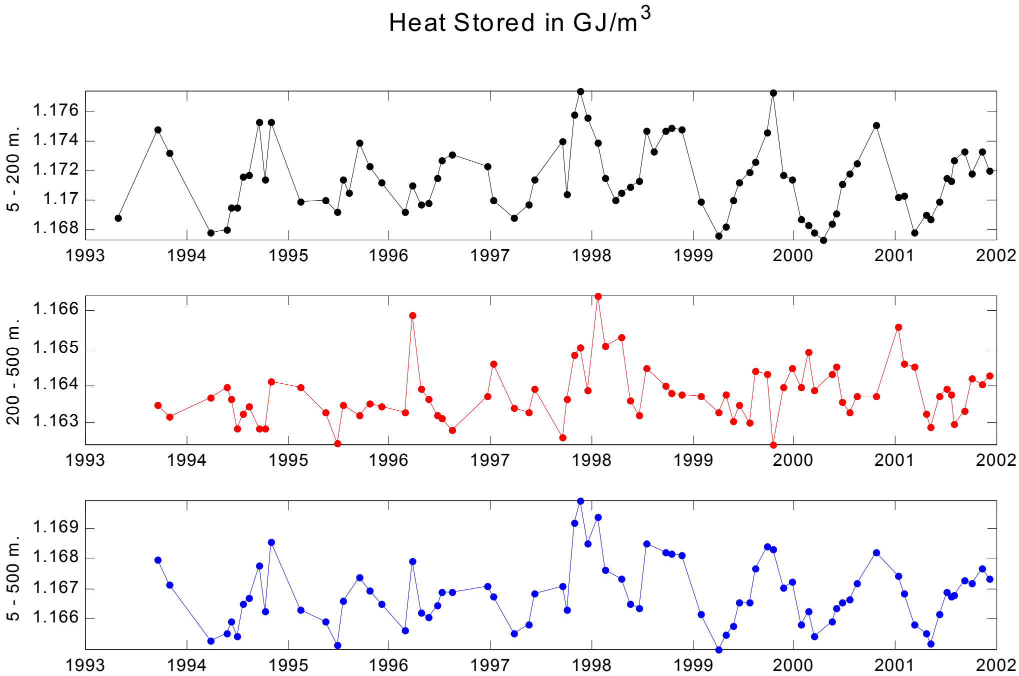


Figure A.L.10. Heat stored in the water column at Santander station 6.

An analysis on heat stored trends distinguishing for 100 metres layers below 200 meters depth is shown in Figure A.L.11 for station 7 and also the linear fit coefficients converted to equivalent degrees.

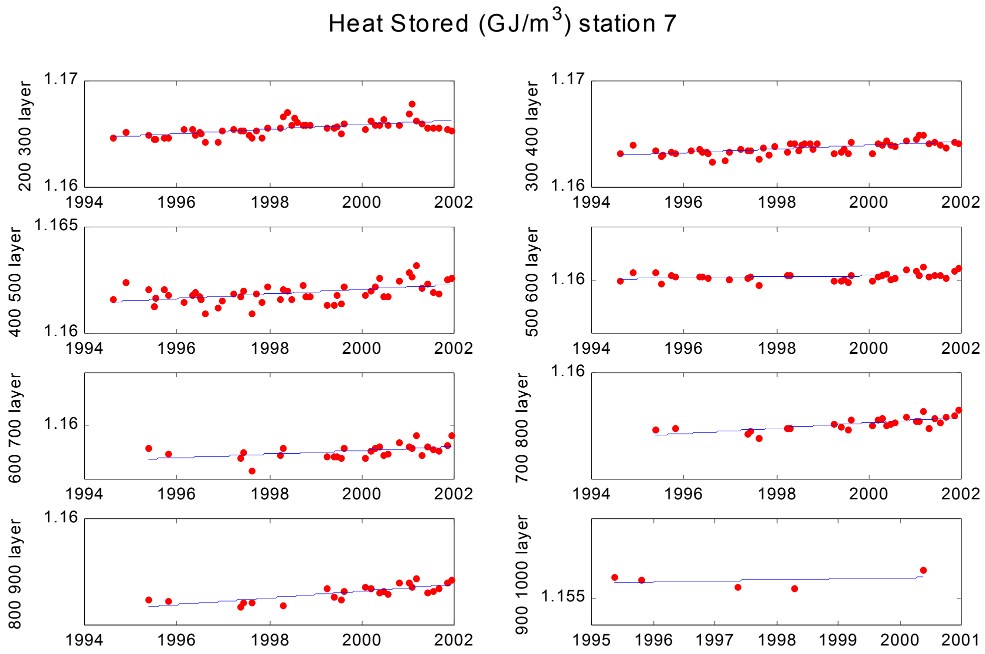


Figure A.L.11a. Heat stored in the water column at Santander station 7.

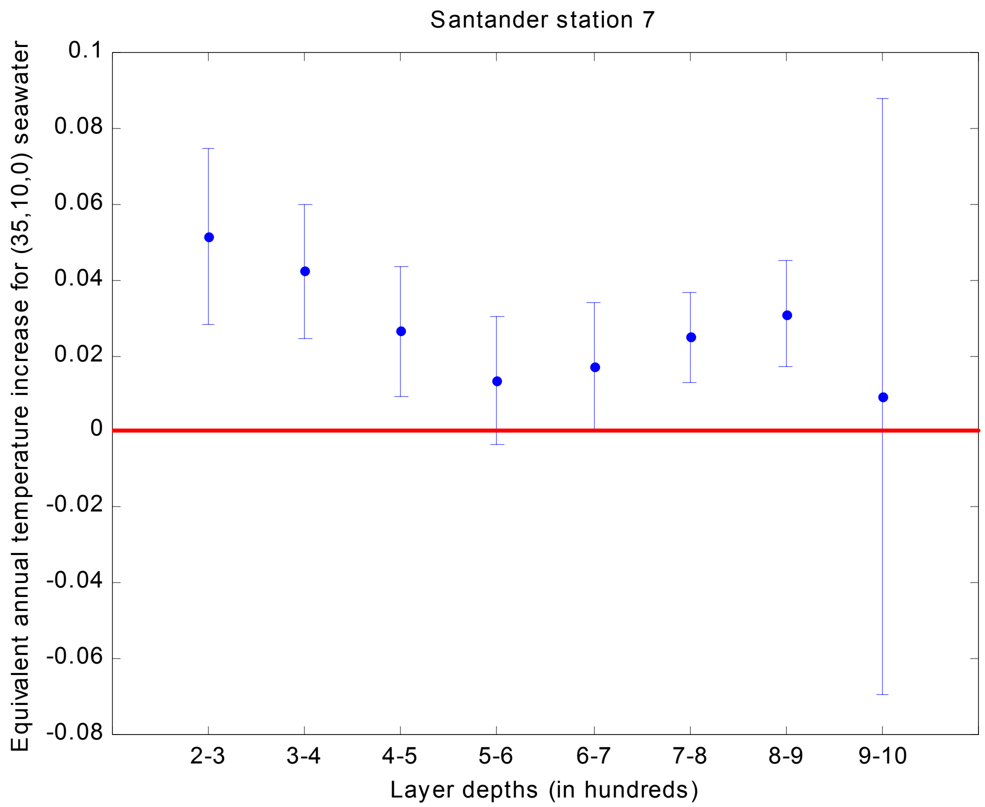


Figure A.L.11b. Heat stored linear trends coefficients at water column. Santander station 7.

Vigo Standard Section

Contours of temperature, salinity over the shelf (94 m depth) in the Vigo section from 1994 to 2001 are presented in Figure A.L.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 and 2001.

Nitrate levels are in accordance with the upwelling intensity, 1995 show the highest levels and 1997 the poorest.

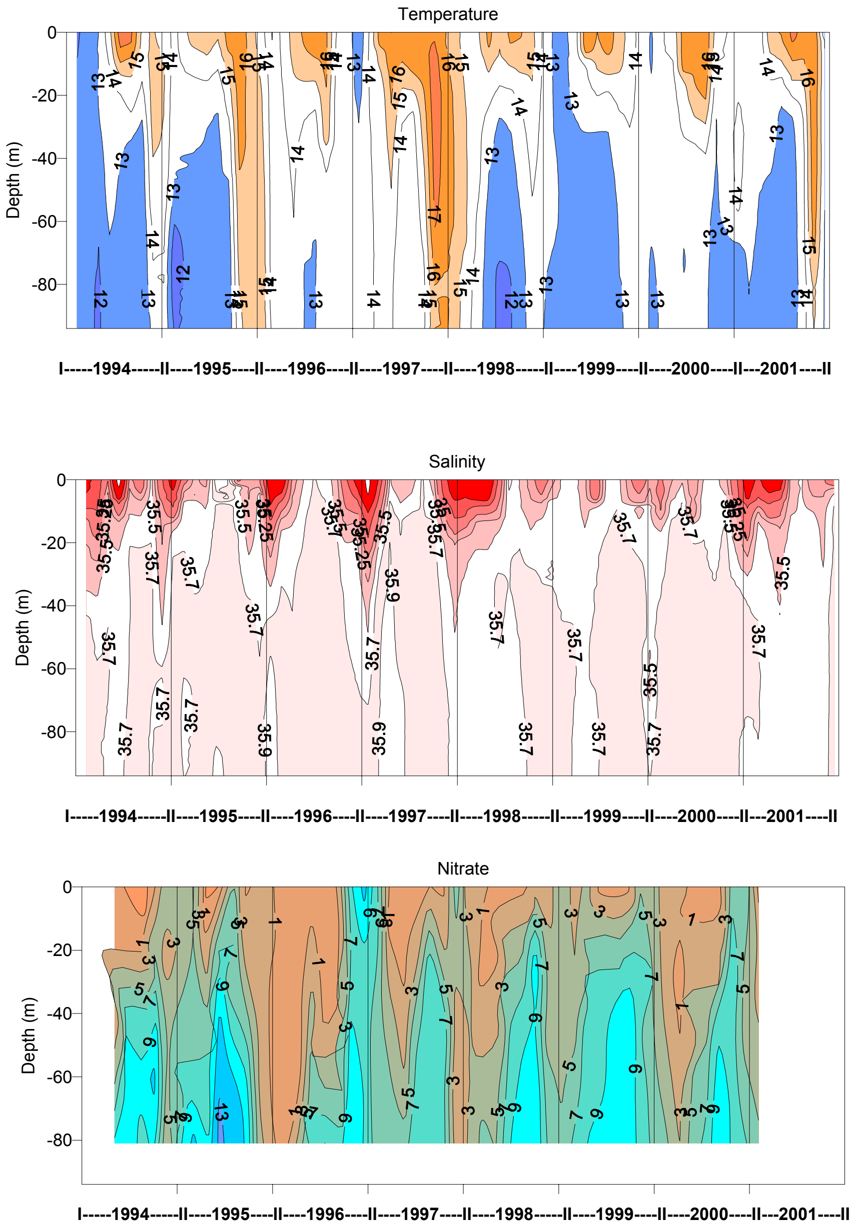


Figure A.L.12a,b,c. Seawater evolution at Vigo (42.1ºN, 9.0ºW) station.

ANNEX M: THE ROCKALL TROUGH TIME SERIES: HYDROGRAPHIC SECTIONS AND PROFILING FLOATS (ICES AREA 5)

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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 May-June 2001 the Scotland to Iceland section was occupied once by SOC as part of a large-scale physical and biological survey of the northeast Atlantic. A complete CTD section of the Ellett line was obtained and is presented here. In addition two profiling floats were deployed in the Rockall Trough, providing temperature and salinity profiles every 10 days since then. In September 2001 the Ellett line was visited by Dunstaffnage Marine Laboratory, but foul weather prevented all but 2 deep CTDs. They were able to deploy current meter moorings at stations F and M (Figure A.M.1).

The May 2001 Hydrographic Section

The potential temperature, salinity, density (sigma0) and θ-S of the section are shown in Figure A.M.1. The sections show the seasonal thermocline has developed and the homogeneous winter mixed layer has already been replaced by more stratified ENAW (Eastern North Atlantic Water). There are some indications of 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 1900 dbar with the freshest water east of the seamount.

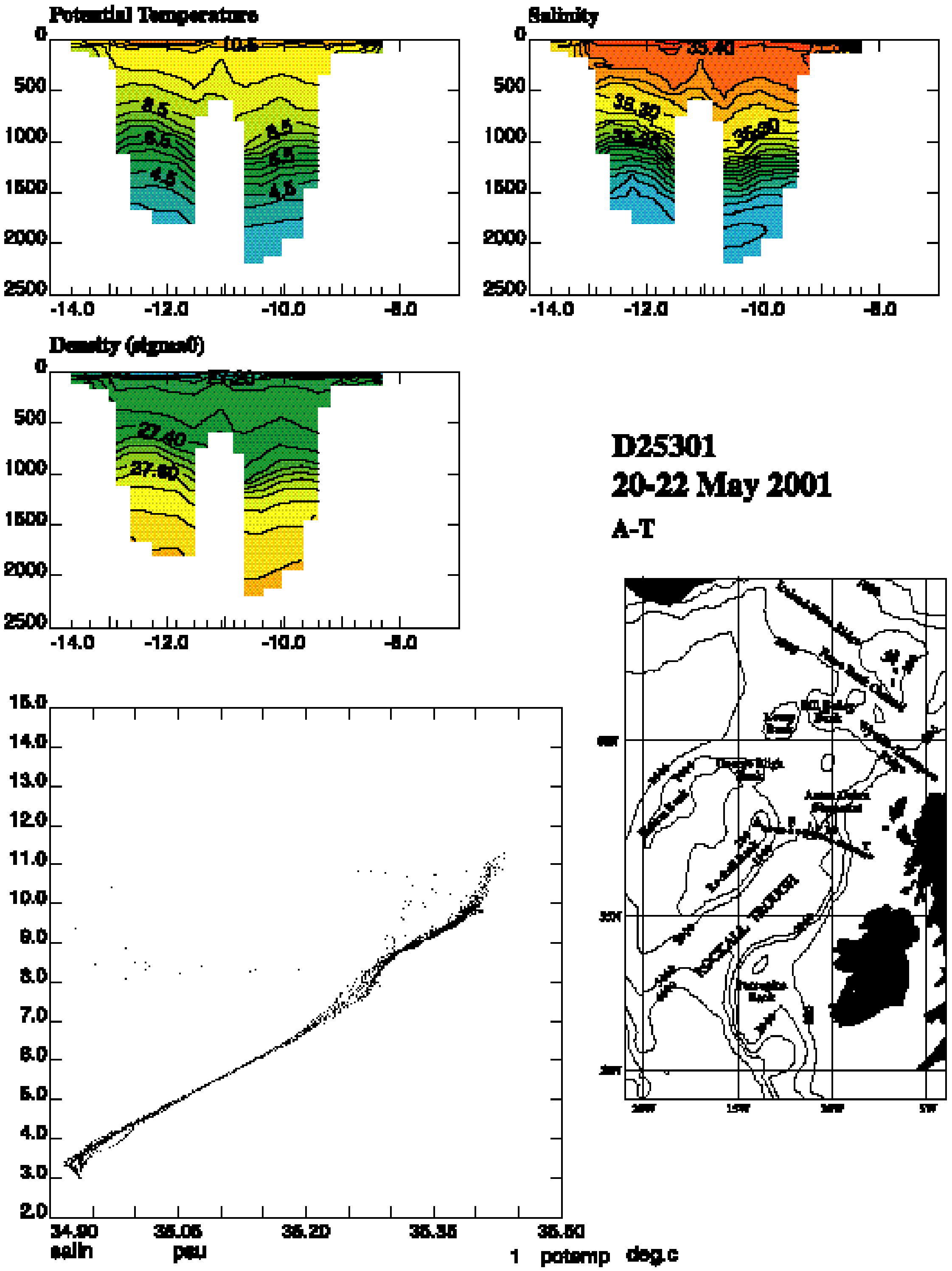

Figure A.M.1. Properties of the May 2001 occupation of the Ellett line. Potential temperature contour intervals of 0.5°C; salinity contour intervals of 0.025; density contour intervals of 0.05.

The Updated Time Series of Rockall Trough Properties

The May 2001 occupation shows little difference from the previous occupation in May 2000. Both years show a small downturn from the salinity and temperature maxima in 1998/1999, though they remain high compared to the rest of the time series (Figure A.M.2).

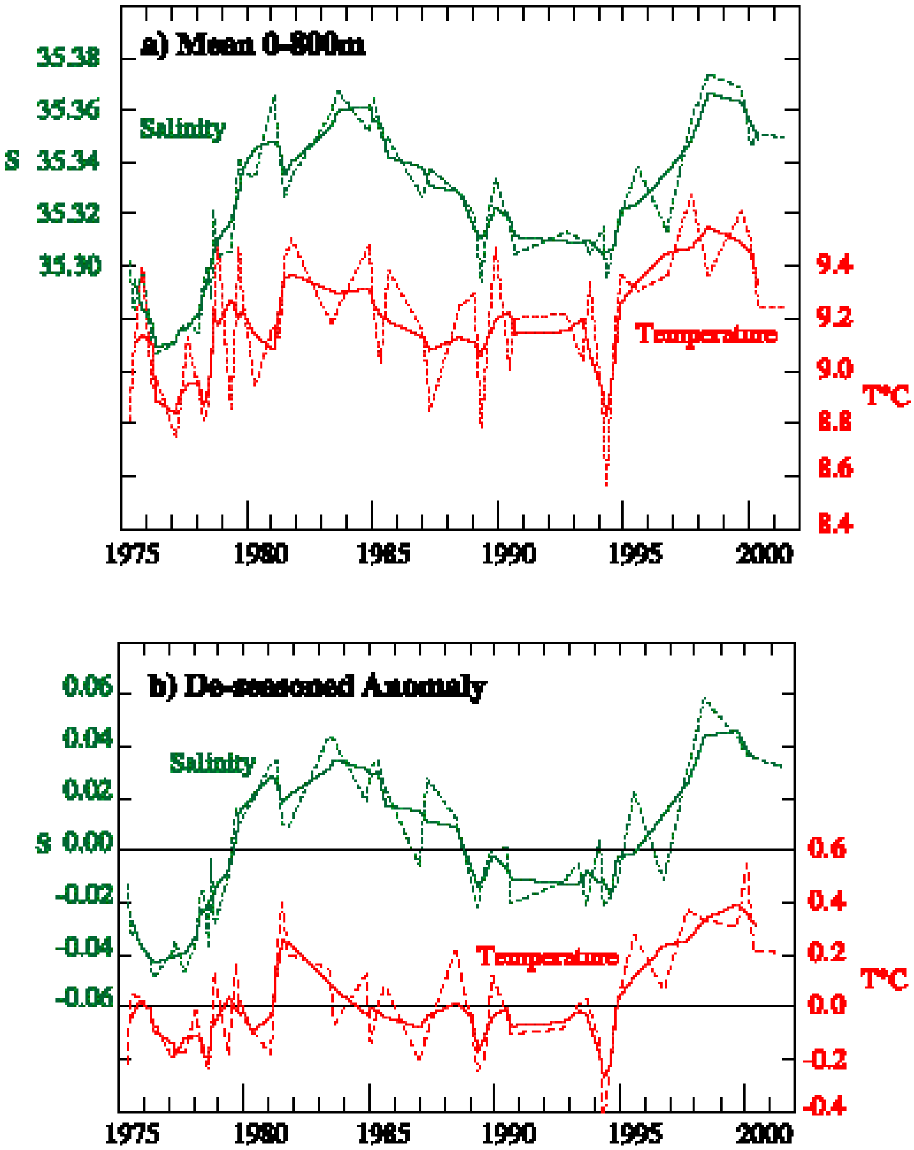

Figure A.M.2. Time series of the ENAW a) the mean temperature and salinity 0–800 dbar; b) the temperature and salinity anomalies from seasonal means. Dashed lines are original time series; solid lines are 3-point running means.

Profiling Floats in the Rockall Trough

With fewer opportunities to sample the Ellett line with ships and CTDs, means are being sought to instrument the area with alternative sampling platforms. As part of the UK Argo programme, two profiling floats were deployed in the Rockall Trough in May 2001. The floats are ballasted to be neutrally buoyant at 1750 dbar ("park" depth) where they float for a period of 10 days. At the end of the 10-day period they sink to 2000 dbar (to sample the deep water for calibration purposes) before rising to the surface, measuring temperature and salinity on the ascent. At the surface they transmit their location and profile data to an Argos satellite from where it is sent to SOC in real-time. The float remains at the surface for a few hours before sinking to their park depth.

Both floats have remained in the Rockall Trough continuing to provide profiles every 10 days (Figure A.M.3). One float (13354) is currently recirculating northwest of the Anton Dohrn Seamount, while the other (13353) is "grounded" slight further north (where the water depth is shallower than the park depth).

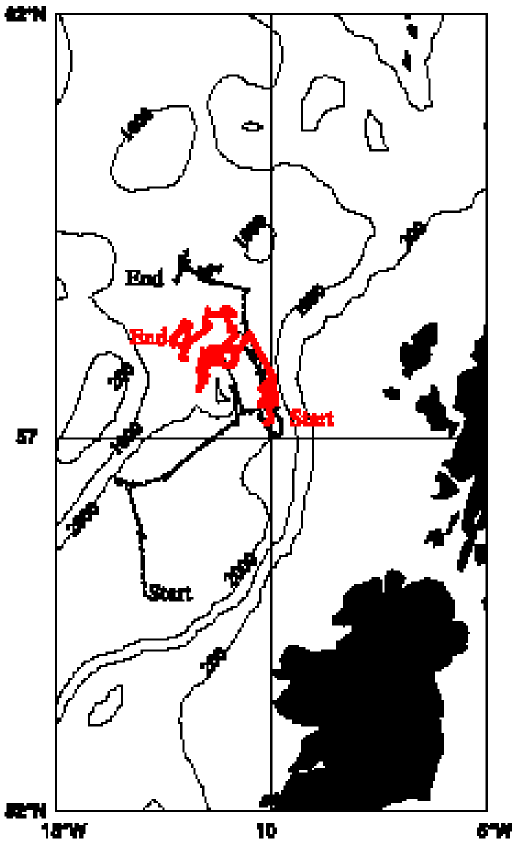

Figure A.M.3. Locations of two profiling floats in the Rockall Trough, May 2001-March 2002. Float 13353 is black dashed line; float 13354 is red solid line.

The time series of temperature and salinity profiles is shown in Figure A.M.4. Salinity is shown as uncalibrated, though deep CTDs taken at the time of deployment will be used to calibrate the profiles, and with luck future CTDs in the region will be used as a continuing check on calibrations. The figure shows the development of the summer warm, fresh surface layer during June to September, followed by the breakdown of the seasonal thermocline during October/November, and the establishment of the winter mixed layer starting in December. The floats are of course affected by mesoscale features typical of this region, and several profiles show elevation of isotherms, which may suggest the passing of an eddy. The gradual shallowing of deep isohalines suggests a freshening of the upper ocean, and this is reflected in the time series of mean temperature and salinity shown in Figure A.M.5.

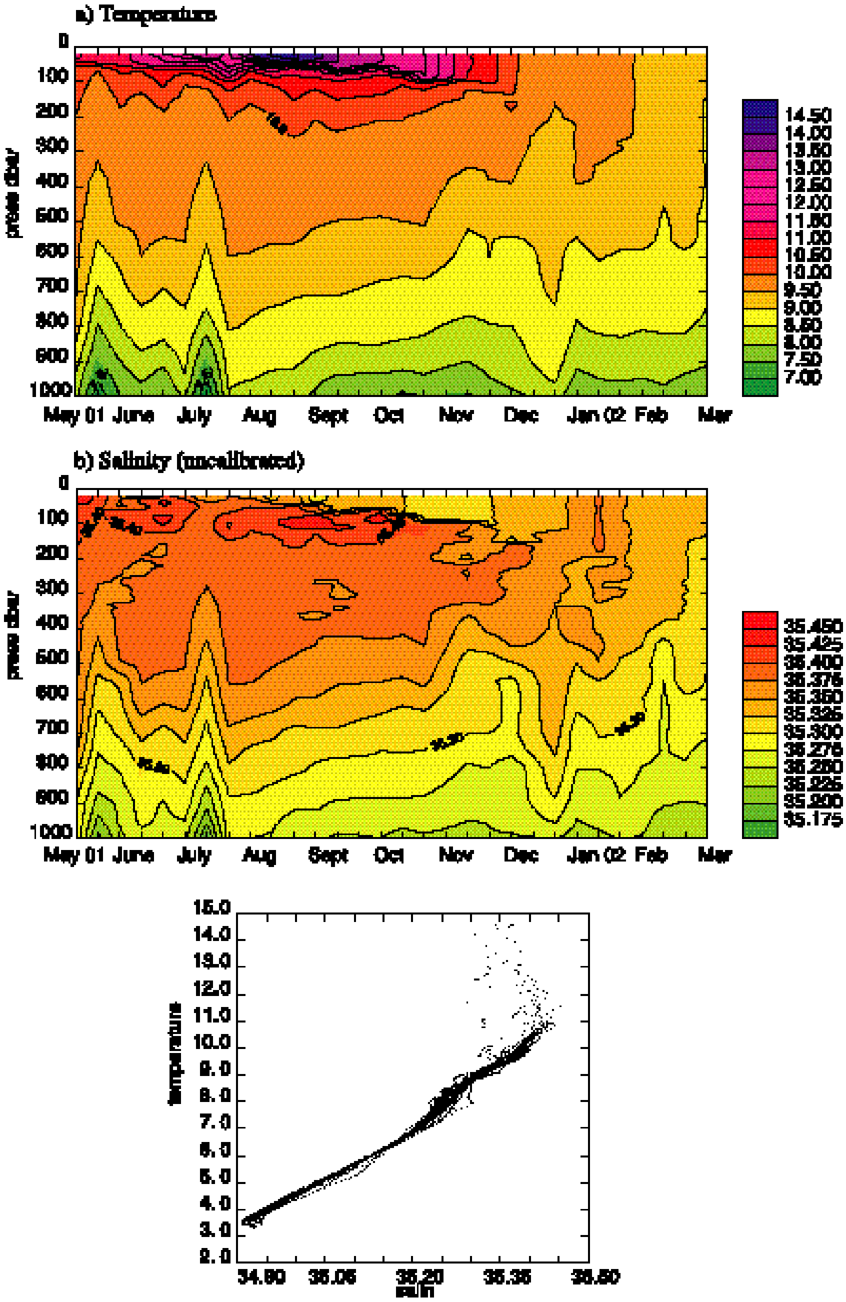

Figure A.M.4. Time series of a) temperature and b) salinity (uncalibrated) from profiling float 13353.

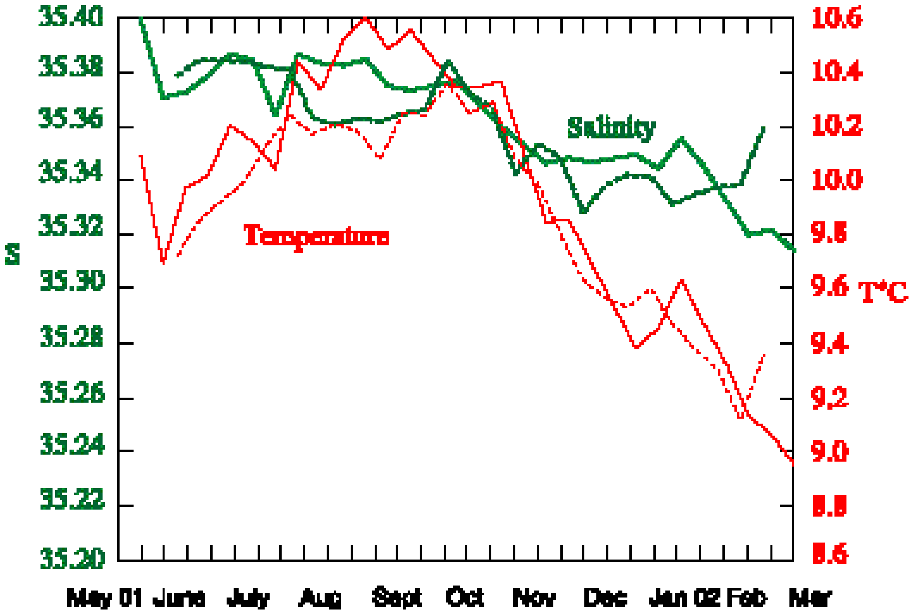

Figure A.M.5. Mean temperature and salinity of 0–800 dbar from floats 13353 (solid line) and 13354 (dashed line).

The mean temperature and salinity of the top 800m as shown by the float profiles has some interesting features. The salinity shows the gradual decline indicated by the general shallowing of deep isohalines in Figure A.M.4. This suggests that the Rockall Trough as a whole may be continuing the freshening observed since May 2000, possibly to a level around the “mean” conditions of the 27 year time series. The average salinity recorded by the floats is higher than that from the hydrographic section in Figure A.M.2; this may in part be a calibration issue, but also reflects the fact that the floats are sampling only the interior higher salinity waters, whereas the hydrographic section mean encompasses the range of salinities across the section (Figure A.M.1). The temperature curve shows the summer warming very nicely, but the cooling since September 2001 is greater than would be expected from simply the seasonal cycle, indicating a general cooling of the upper ocean associated with the freshening.

In conclusion, the profiling floats have the potential to expand the temporal resolution of the time series by proving information between hydrographic sections. However there are calibration issues to be resolved, and careful attention needs to be paid to the influence of passing eddies on the results from the single point time series. The floats deployed so far such that the Rockall Trough has significantly cooled and freshened between summer 2001 and March 2002 (over that expected due to the seasonal cycles).

ANNEX N: NORWEGIAN WATERS (ICES AREAS 8, 9, 10, 11)

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Summary

The Barents Sea temperature was higher than average during 2001, and with highest anomalies in the first half of the year. At the end of 2001, the temperature was just above the long-term mean. In 2001 there was, in the upper layer, an increased temperature in central part of the Norwegian Sea. In the North Sea, the temperature was close to the long-term mean in 2001.

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

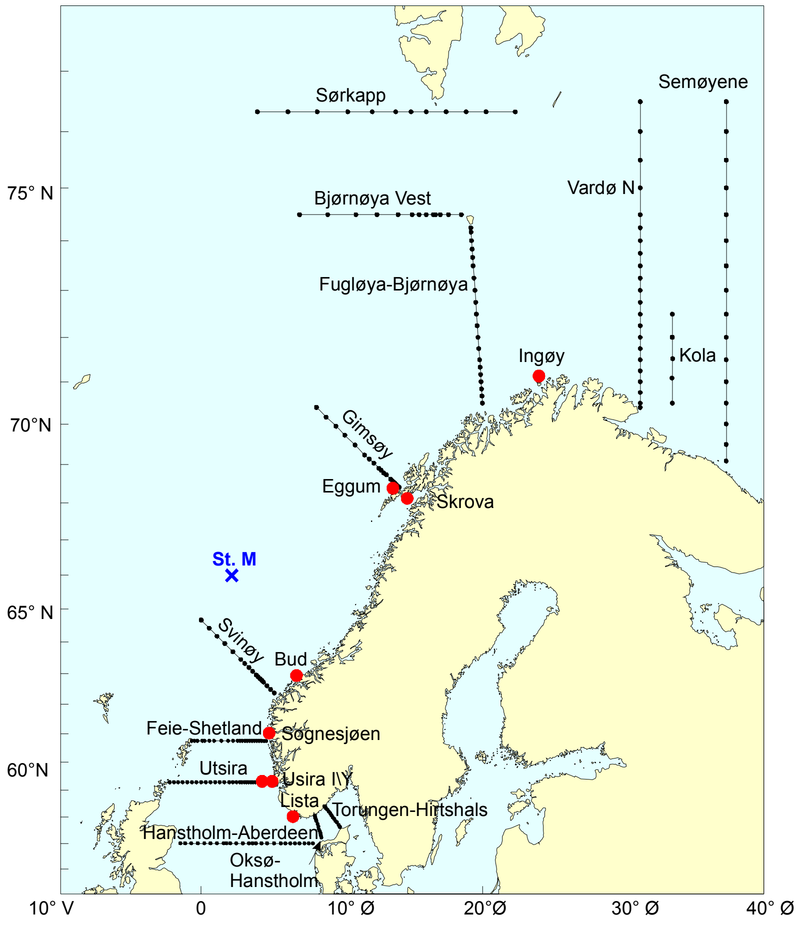

Figure A.N.1. Standard sections and fixed oceanographic station worked by Institute of Marine Research, Bergen. The University of Bergen is responsible for station M, while the Kola section is operated by PINRO, Murmansk (Anon. 2002).

The Norwegian Sea

The inflow of warm Atlantic water to the eastern part of the Norwegian Sea was in 2001 at about same level as in 2000. It is expected that the temperature in eastern part of the Norwegian Sea will be about the average in 2002. 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 and northern parts of the Norwegian Sea.

Figure A.N.2 shows the development in temperature and salinity in three different sections from south to north in the Norwegian Sea (Figure A.N.1). Since 1981, distinct trends in the temperature and salinity are only seen in the Sørkapp section. There, the temperature shows a slight increase while the salinity has a decreasing trend. Compared with 2000, the temperature decreased in the Svinøy-section while it increased both in the Gimsøy and Sørkapp sections. Compared with the long-term average, the southernmost section had temperature close to the long-term average, while the temperatures in the two other sections were about 0.2°C above the long term mean. The salinity showed the same trend as the temperature in 2001.

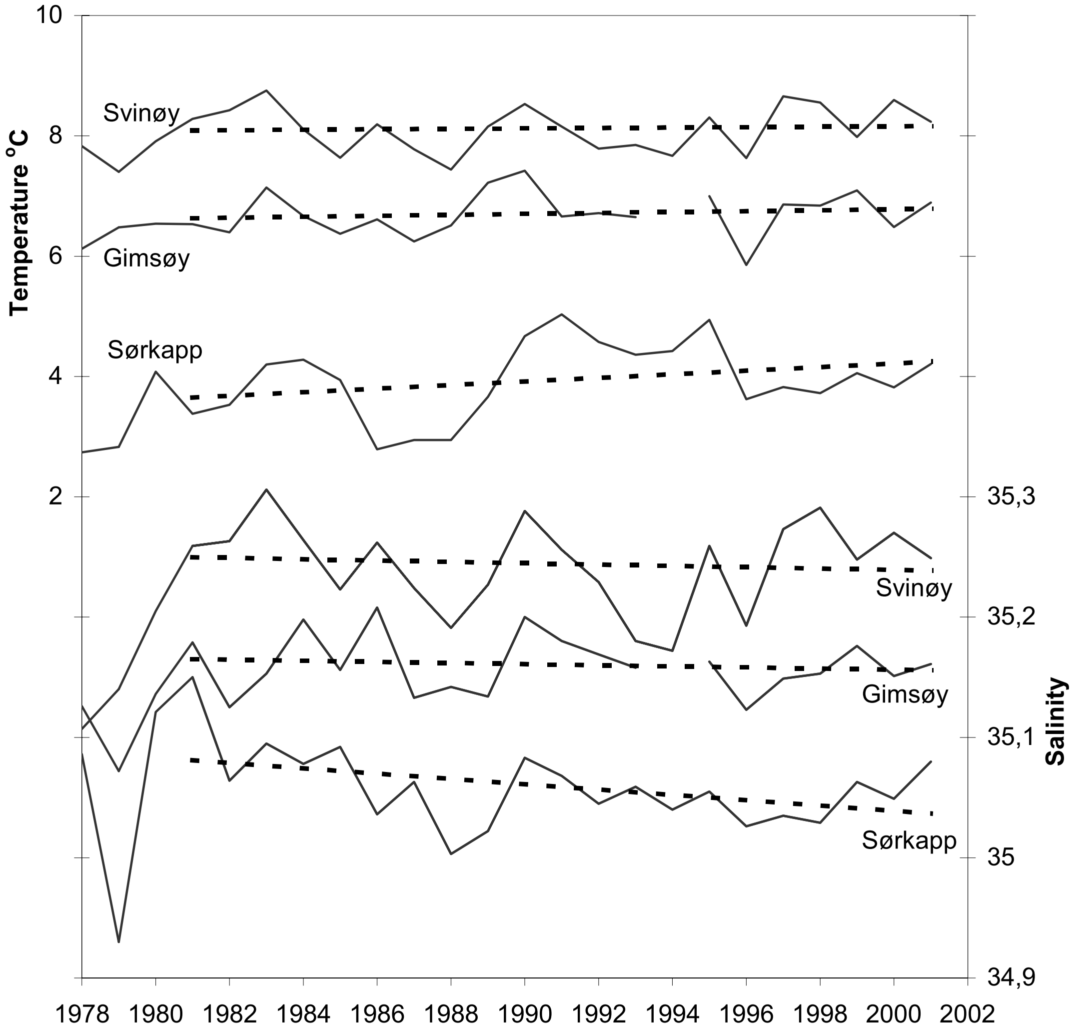

Figure A.N.2. Temperature and salinity, observed in July/August in the core of Atlantic water in the sections Svinøy-NW, Gimsøy-NW and Sørkapp-W, averaged between 50 and 200 m depth. (Anon. 2002).

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 Figure A.N.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 followed by approximately same value in 2001. The area increased in 2001 and had the highest value since 1991. The temperature has increased with approximately 0.3°C since early 1980s.

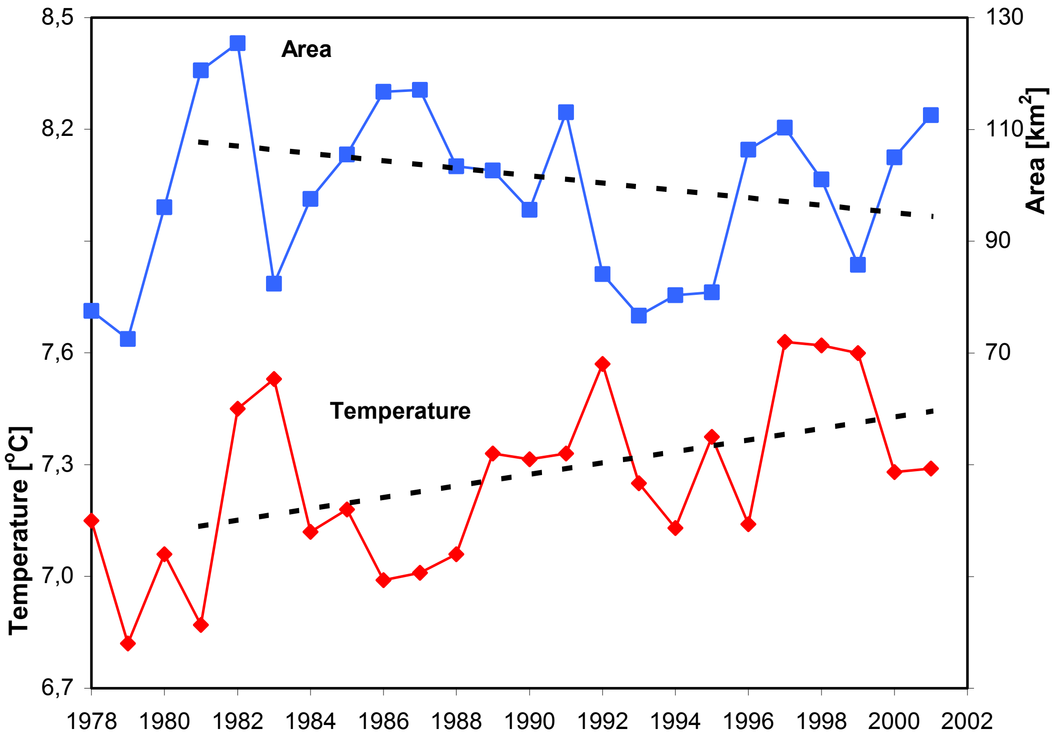

Figure A.N.3. Time series of area (in km^2) and averaged temperature (red) of Atlantic water in the Svinøy section, observed in July/August 1978–2001 (Anon. 2002).

During research cruises in May and July/August with the aim of estimating the pelagic stock hydrographic observations are also taken, covering most of the Norwegian Sea. Compared with 2000, the temperature at 100 m depth increased in 2001 in southern and central areas (not shown). In July/August the temperature decreased northeast in the Lofoten Basin, south of Spitsbergen.

The Barents Sea

The Barents Sea is a shelf area, receiving inflow of Atlantic water from the west. The inflowing water demonstrates considerable interannual fluctuations in water mass properties, particularly in heat content, which again influence on winter ice conditions. The variability in the physical conditions is monitored in two 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. In both sections there are regular hydrographic observation, and in addition, current measurements are carried out in the Fugløya- Bear Island section.

Figure A.N.4 shows the temperature and salinity anomalies in the Fugløya-Bear Island section in the period from 1977 to January 2002. 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 before it turned warm again at the end of the decade. Even the whole decade was warm; it was only the third warmest decade in the 20th century (Ingvaldsen *et al.* 2002).

In the first half of 2001, the temperature in the Atlantic water in the western and central areas of the Barents Sea was 0.6–0.8°C higher than the long-term average. This was also somewhat higher than the year before. The temperature decreased during summer, and in late August the temperature was only 0.1°C higher than the long-term mean. In January 2002, the conditions were exactly the same, which means that we had the lowest January temperature since 1997.

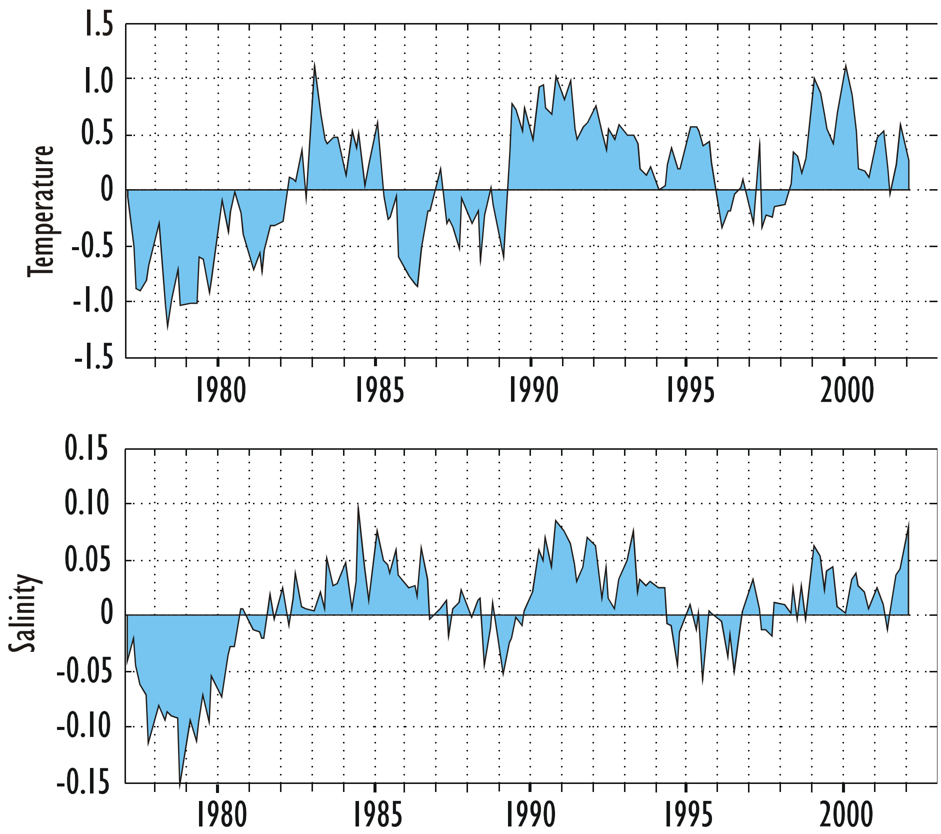

Figure A.N.4. Temperature anomalies (upper panel) and salinity anomalies (lower panel) in the section Fugløya – Bear Island (Anon. 2002).

Figure A.N.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. 2002 had highest ice index recorded since 1970, which means very little ice. During the winter of 2001 there was slightly more ice than the year before, but the ice melt during summer was extremely high and beat the record from 1984.

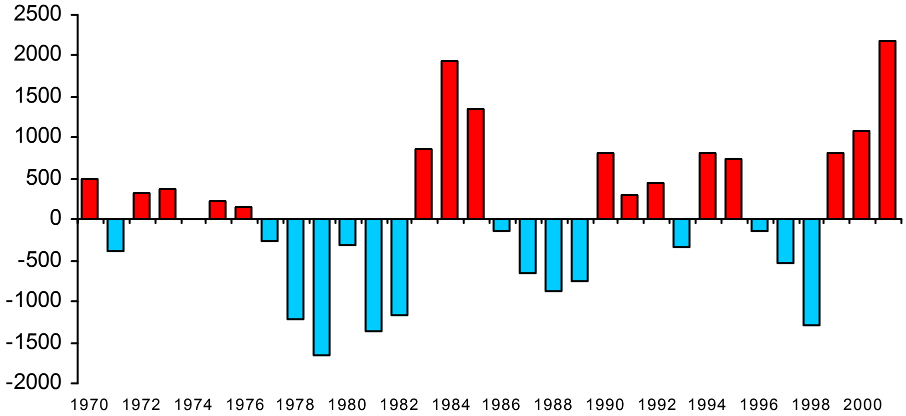

Figure A.N.5. Ice index for the period 1970–2001. Positive values means less ice than average, while negative values show more severe ice conditions (Anon. 2002).

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.

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 (Figure A.N.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 and in 2000 there were two periods with strong outflow, one in January and a second one in June. In spring 2001, the net inflow was much lower than earlier years. Results from a wind driven model shows similar results (Figure A.N.7). The inflow during the first 4 months were stronger than average, while the model gave reduced inflow during late spring and summer. These show that the inflow of Atlantic water to a large extend is 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).

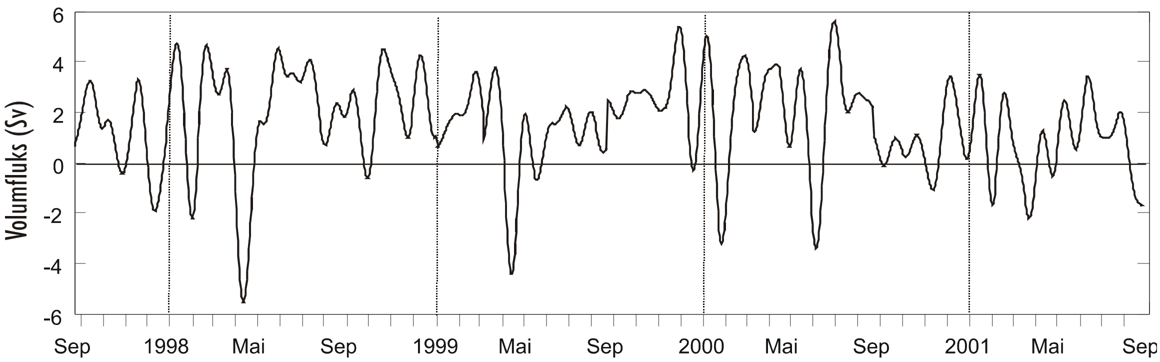

Figure A.N.6. Total volume flux across the section Norway-Bear Island. All data have been low pass filtered over 30 days (Anon. 2002.).

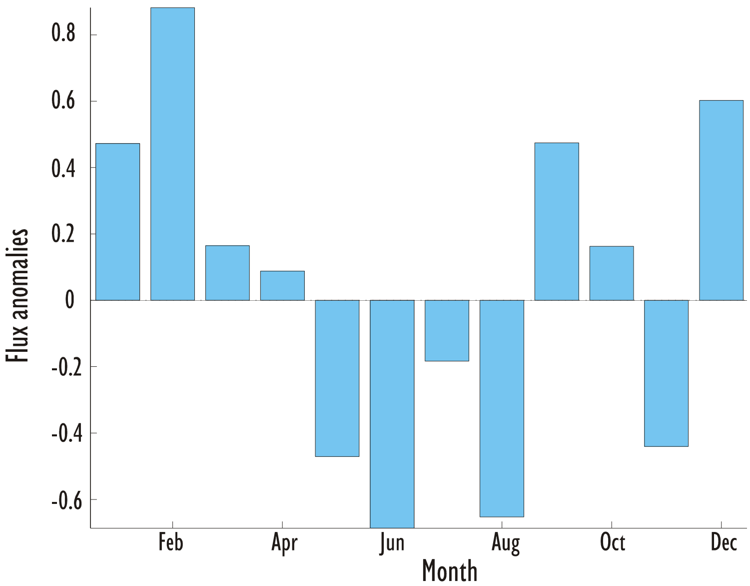

Figure A.N.7. Modelled flux anomalies in 2001 through the section between Norway and Bear Island (Anon. 2002).

The North Sea

The temperature of the upper layer of most of the North Sea was close to normal in 2001. Figure A.N.8 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 than in the core of the inflowing Atlantic water (Figure A.N.8). 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 and 2001 were rather close to the long-term average.

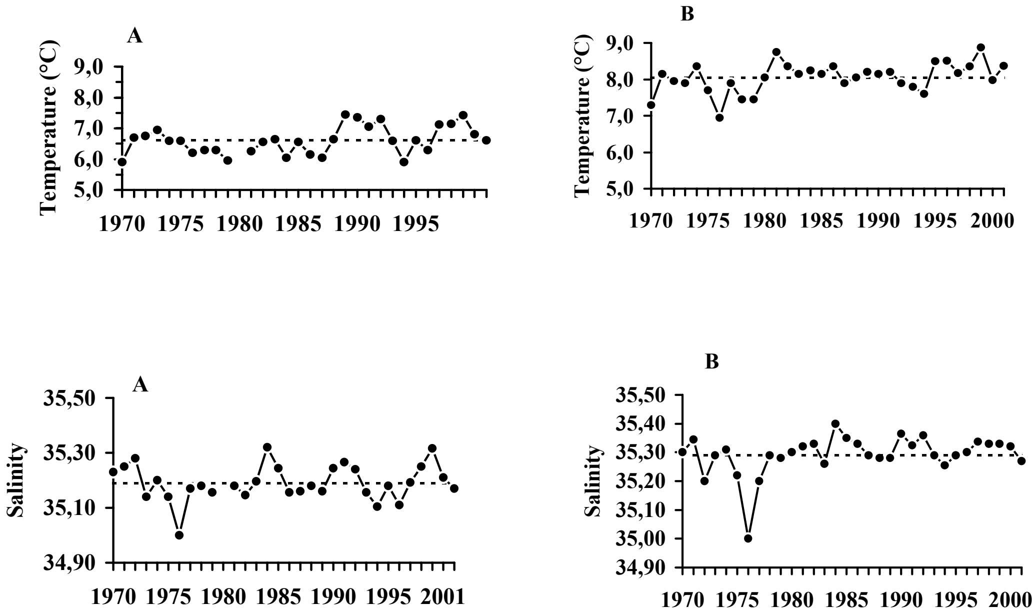

Figure A.N.8. Temperature and salinity near bottom in the northwestern part of the North Sea (A) and in the core of Atlantic water at the western shelf edge of the Norwegian Trench (B) during the summers of 1970–2001 (Anon. 2002).

Estimates from a numerical ocean circulation model showed that the circulation in the North Sea was somewhat weaker than normal. Especially the inflow of Atlantic water in the north was very weak in the first half of the year (Figure A.N.9). This weak inflow lead to a weaker (model based) annual primary production in large areas of the North Sea and small catches of horse mackerel. In the English Channel there was a weak net outflow during the second half of the year, usually having a net inflow.

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, the thickness of the Skagerrak coastal water was most of the year about 20–25 m. The brackish water was found in the upper 5 m from April to June. The transition between Skagerrak water (with salinity between 32–35) and the Atlantic water was found generally deeper than 75 m. The winter of 2001 was somewhat colder than the year before, resulting in a cooling of the surface water masses. A warm summer resulted in surface temperatures significantly above average, but with a rapid cooling at the end of the year. As expected in 2000, a deep inflow to the deepest part of the Skagerrak basin occurred in 2001. This happened in April-May with cold and relatively fresh water masses from the North Sea plateau, which had somewhat higher oxygen concentration, but approximately the same density as before.

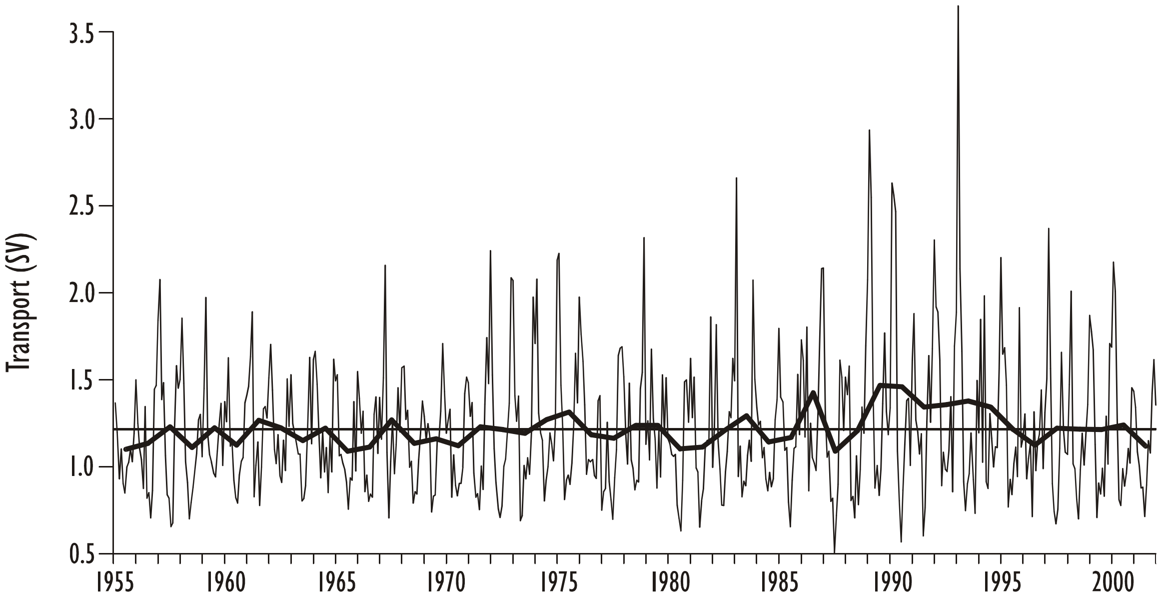

Figure A.N.9. Time series (1955–2001) of modelled annual mean (bold) and monthly mean volume transport of Atlantic water into the northern and central North Sea southward between the Orkney Islands and Utsira Norway. 1 Sv = $10^6 m^3 s^{-1}$. (Anon. 2002).

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ANNEX O: INITIAL EVIDENCE OF EXTREME FRESHENING IN THE SOUTHERN BIGHT DURING 2001 (ICES AREA 9)

Bob Dickson, Ken Medler, Sue Norris, and Jon Rees

CEFAS, Lowestoft, UK

1) The event: In waters off England and Wales routine sampling of near surface hydrography by ship-of-opportunity is now restricted to a single route across the Southern Bight of the North Sea from Felixstowe to Rotterdam. Along that route, salinity samples are collected weekly at 9 stations along 52°N by the *European Freeway*, maintaining time-series that are now 30 years in duration. In 2001, this sampling programme revealed evidence of a freshening that was often more extreme than at any other time in this record.

Although sampling along this zonal route can vary by up to 0.7 degrees of latitude (Figure A.O.1), in practice 95% of stations fall within one third of that range (solid lines, Figure A.O.1) and it is for this narrower latitude band that the station means described below are calculated. In the following analysis, we will also rely less on stations 1, 8 and 9 from the more-coastal and thus more-variable western and eastern ends of the section. Figure A.O.2 a, b, c, d shows the time-dependence of salinity in 2001 for stations 2, 4, 6 and 7 in the middle reaches of the section compared with the 30-year mean, with the decadal mean for the 1990s and with conditions in the two preceding years 1999 and 2000.

Two main features are evident. First, at one time or another in 2001, freshening develops that is more extreme than any of the comparison series. Second, that extreme freshening appears to set in earlier in the west, being already well developed by February at station 2 (1.7° E), but not until June or July in the east (3–3.3° E).

Figure A.O.3 attempts to provide a better measure of the extreme nature of the event and its timing in 2001. The upper panel lists and contours the anomalies of sea surface salinity compared with the 30-year means for each station and month. The lower panel ranks the degree of freshening in terms of the whole 30-year period, with 1 signifying the freshest in the 30-year series in that month and station, and no ranking given when greater than 10th freshest in the series. Two episodes of freshening are apparent during the year-----in March-June in the western stations of the section when the largest departures from the mean are found (anomalies >-0.5, stations 2–5), and later in the year (September-December) when the most extreme rankings in the 30-year record (1st or 2nd ranking extrema) tended to prevail across most of the section.

2. Confirmation: It is clearly unsafe to base accounts of extreme conditions on the results from a single route and vessel, but while records are being compiled we have little yet available for comparison. Extreme low salinity conditions reported by the *Nuka Arctica* on a westward leg following a port call in Rotterdam in late February appear to offer confirmation and are entered on the GTS, but are almost certainly wrong (due to plastic debris from a broken fire-pump impeller lodging in the TSG sensor housing). We do however have some reliable and independent data to confirm the extreme nature of the fresh conditions along the Felixstowe-Rotterdam route in 2001. Figure A.O.4 compares the route data with the semi-continuous salinity record from 11 successive deployments of the CEFAS "Gabbard Buoy" between December 2000 and January 2002. This buoy is located in 45m water-depth at 52N, 02 20E, close to the position of Station 4, and carries an FSI conductivity sensor located at 0.8m depth immediately beneath a surface toroidal buoy [for further details see www.cefas.co.uk/monitoring]. As shown, the two curves are virtually identical over the period December 2000-August 2001 at this site, and R/V CTD data collected close by (dots and squares, Figure A.O.4) provide further confirmation of their validity.

3. Cause: Though the last two SSS minima on the route in winters of 1996 and 2001 have coincided with NAO-negative conditions (Figure A.O.5), overall there seems to be little or no correlation with the winter NAO index over the past 3 decades. Neither is there any clear link with the trend of SSTs on the section, which continue, generally warm as they have done throughout much of the NAO-positive 1990s (Figure A.O.5). Instead the cause is attributed directly to the extreme rainfall that prevailed over England and Wales and parts of NW Europe in these and antecedent months.

Autumn (S, O, N) 2000 over England and Wales was the wettest autumn since records began in 1766. Moreover, in their Statement on the Status of the Global Climate in 2000, [http://www.wmo.ch/web/Press/Press670.html] the WMO extend the "wettest ever" description to include SE Norway, and describe 400–2000 mm surpluses in the SW Alps, along the headwaters and much of the catchment of the Rhine system (their Figure A.O.3). Though rainfall records for

2001 are not fully available, the record precipitation for Autumn 2000 was apparently followed by extreme rainfall also in January to April 2001 and to a lesser extent in July – October. The following figures are kindly provided by Dr Tim Osborn of the Climatic Research Unit of UEA for monthly rainfall excess over East Anglia and SE England (100%=normal, >100%=wetter than normal):

	East Anglia	**SE England**
2001		
Jan	**104%**	**128%**
Feb	**221%**	**186%**
Mar	**191%**	**195%**
Apr	**159%**	**150%**
May	85%	56%
June	74%	42%
July	**164%**	**108%**
Aug	**139%**	**136%**
Sep	**164%**	**107%**
Oct	**163%**	**179%**
Nov	90%	52%
Dec	48%	34%

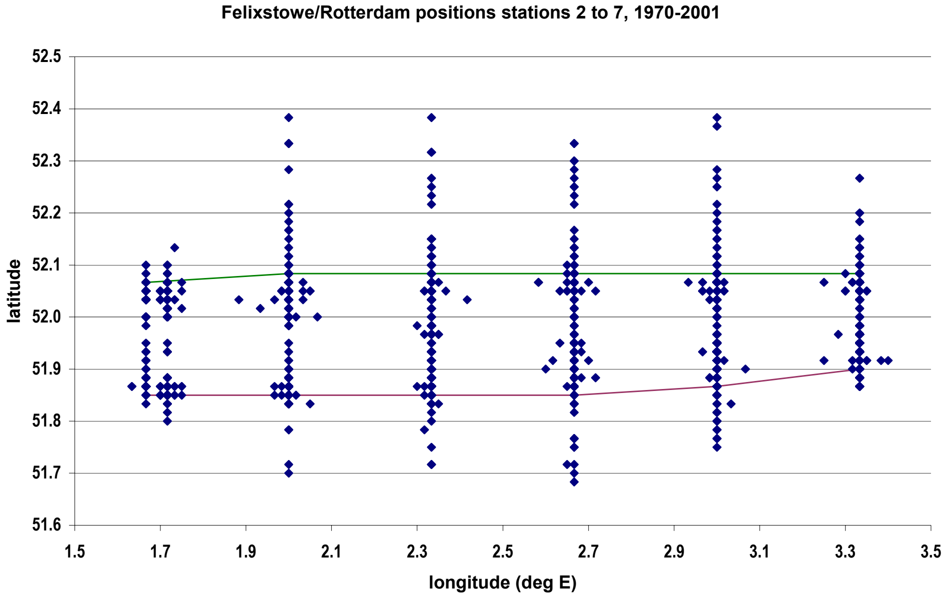
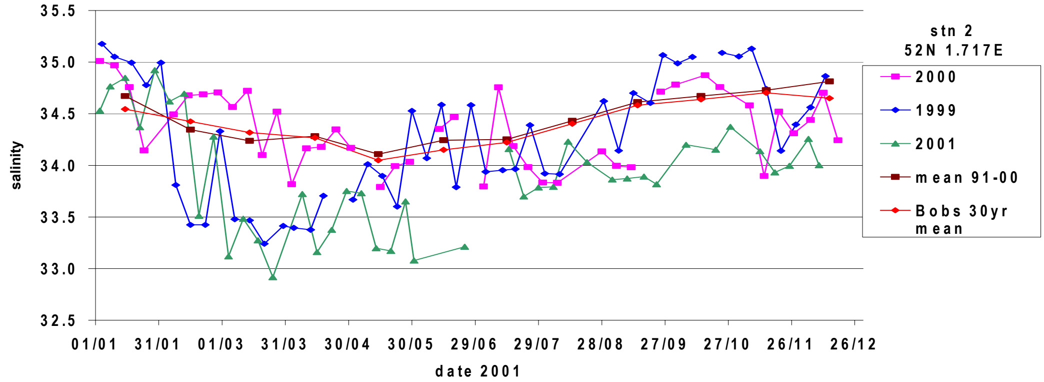
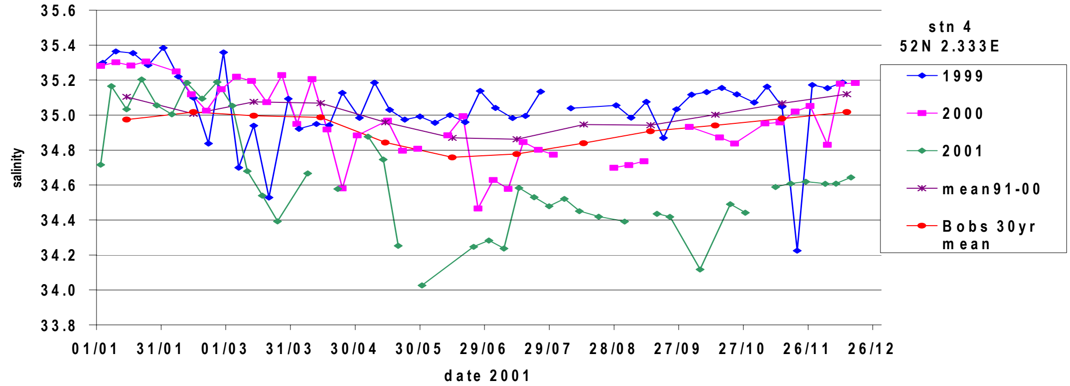


Figure A.O.1. Latitudinal spread of the station positions on the Felixstowe-Rotterdam Route, 1971-2001. The thin solid lines enclose 95% of the dataset.





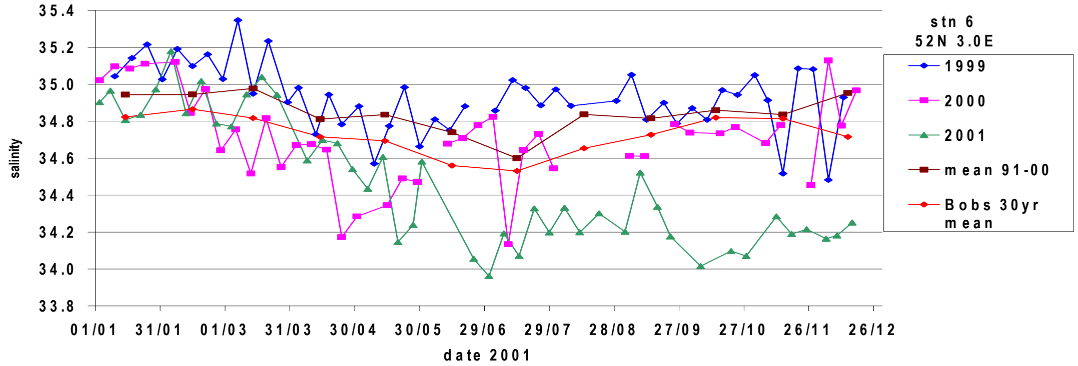


Figure A.O.2. Salinity series at stations 2,4,6, and 7 on the mid-section of the Felixstowe-Rotterdam route during 2001 (green line) compared with the 30 year mean, and the two preceding years (see key). Low salinities were encountered at all the stations during 2001 but with differences in timing between sites. Extreme freshening appears to set in earlier in the west, being already developed by February at station 2 (1.7° E), but not until June.

Month 2001	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7
Jan	0.14	0.18	0.06	0.04	0.07	0.15
Feb			0.10	0.06	0.09	
Mar					0.11	
Apr						
May						
June						0.21
July						
Aug						
Sep						
Oct						
Nov						
Dec						

Month 2001	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7
Jan						
Feb	10	9				9
Mar	1	3	3	6	10	10
Apr	4	5	2	6	10	10
May	4	4	6	4	5	8
June	1	1	1	2	10	
July	7	5	4	4	6	7
Aug	7	6	4	4	6	10
Sep	1	2	3	2	6	
Oct	2	1	1	1	1	2
Nov	1	1	2	2	1	4
Dec	3	5	2	2	2	6

Figure A.O.3. Estimating the extreme nature of the freshening event and its timing in 2001 along the Felixstowe-Rotterdam Route. The upper panel lists and highlights (0,-0.25,-0.5,<-0.75) SSS anomalies from the 30 year means for each station and month. The lower panel ranks the degree of freshening in terms of the whole 30 year period, with 1 signifying the freshest in the 30 year series in that month and station, and no ranking given when greater than the 10th freshest in the series. Two episodes of freshening are apparent---in March-June in the western stations of the section when the largest anomalies are found (anomalies <-0.5, stations 2-5), and later in the year (Sept-Dec) when the most extreme rankings in the 30-year tended to prevail across most of the section.

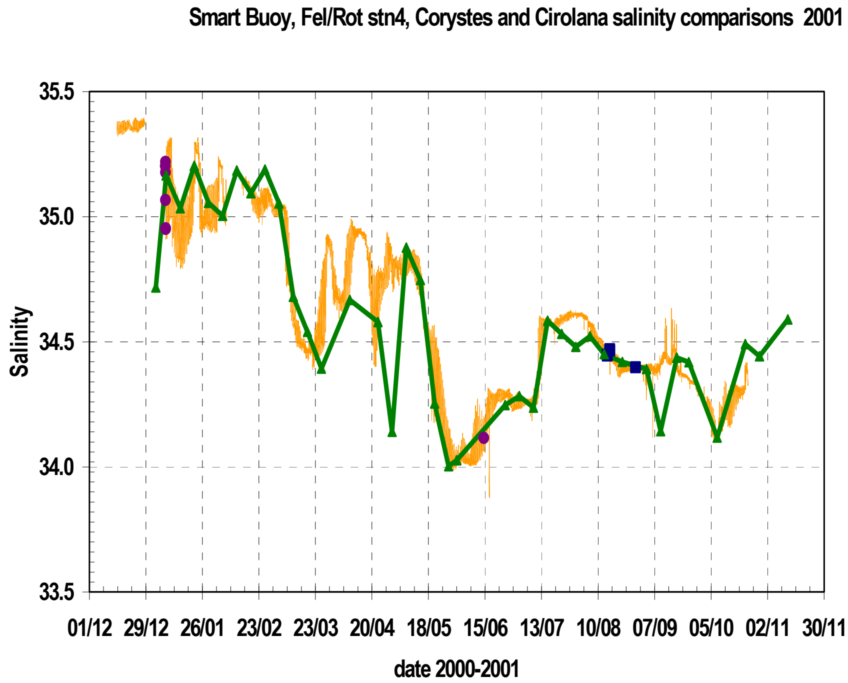


Figure A.O.4. Comparison of salinity data from Station 4 of the Felixstowe-Rotterdam Route in 2001 with the semi- continuous salinity record from 11 successive deployments of the CEFAS "Gabbard Buoy" and with R/V CTD data collected between December 2000 and January 2002. The two curves show a close correspondence, confirming the validity of the extreme low-salinity observations.

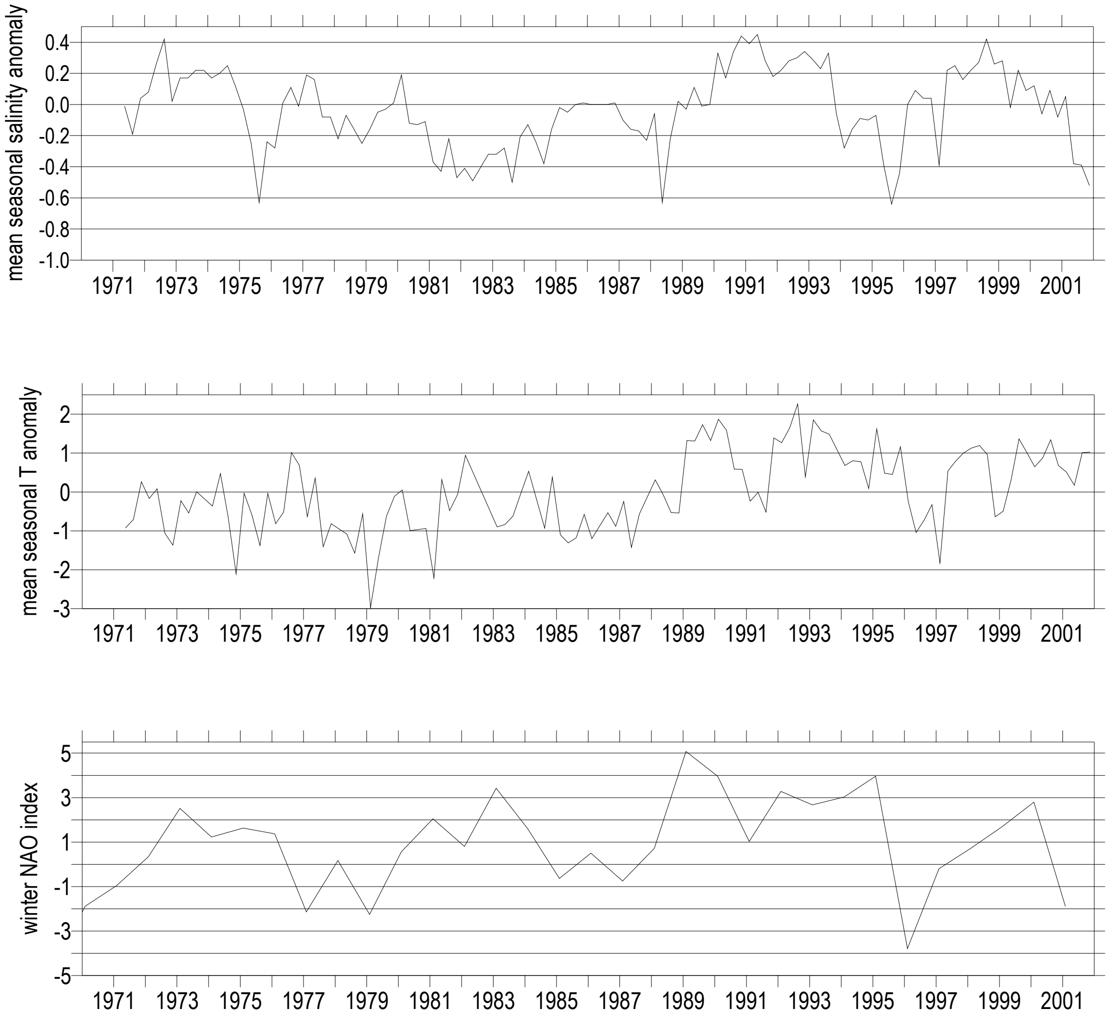


Figure A.O.5 Comparison of the mean annual SSS and SST anomalies on the Felixstowe-Rotterdam Route with the NAO Index over the period 1971-2001. (Surfer plot)

ANNEX P: SKAGERRAK, KATTEGAT AND THE BALTIC (ICES AREA 9B)

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The seas around Sweden are characterized by large salinity variations. In the Skagerrak, water masses from different parts of the North Sea are present. The Kattegat is a transition area between the Baltic and the Skagerrak. The water is strongly stratified with a permanent halocline. The deep water in the Baltic Proper, which enters through the Belts and the Sound, can in the inner basins be stagnant for long periods. In the relatively shallow area south of Sweden smaller inflows passes relatively quickly and the conditions in the deep water are here highly variable. The surface salinity is very low in the Baltic Proper and the Gulf of Bothnia. The latter area is ice covered during winter.

The effect of the high freshwater discharge to the Gulf of Bothnia in 2000 was reflected in the lower than normal values of the surface salinity in the Baltic this year. This feature is illustrated in Figure A.P.1, which shows the surface salinity at a station east of Gotland. The trend of decreasing values of the surface salinity in this area, which has been seen since the late 1970s, thus continued (Figure A.P.2).

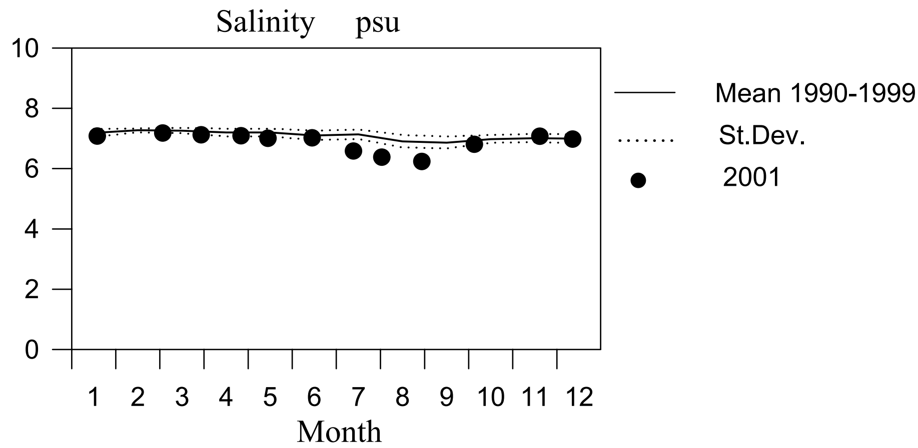


Figure A.P.1. The surface salinity at station BY15 (east of Gotland) in the Baltic proper. The data were collected by R/V Argos within the Swedish National Monitoring Programmes.

During the first half of the year the river runoff to the West Coast of Sweden was unusually large as a result of periods with very high precipitation. The changes in surface salinity were in evidence mainly at the coastal stations. In the late autumn of 2001 deep-water inflows of comparatively high salinity took place through the Sound and the Belts.

In the Baltic high values of the surface temperature were found in the beginning of the year continuing the warm period that occurred at the end of 2000. The freeze-up was fairly late in 2001 with maximum ice coverage on March 27 (see Figure A.P.3). The surface temperatures were generally higher than normal during the first part of the summer in the Baltic as well as in Kattegat and Skagerrak. At several stations in Skagerrak the temperature was 4–5° C above the mean value, as demonstrated in Figure A.P.4.

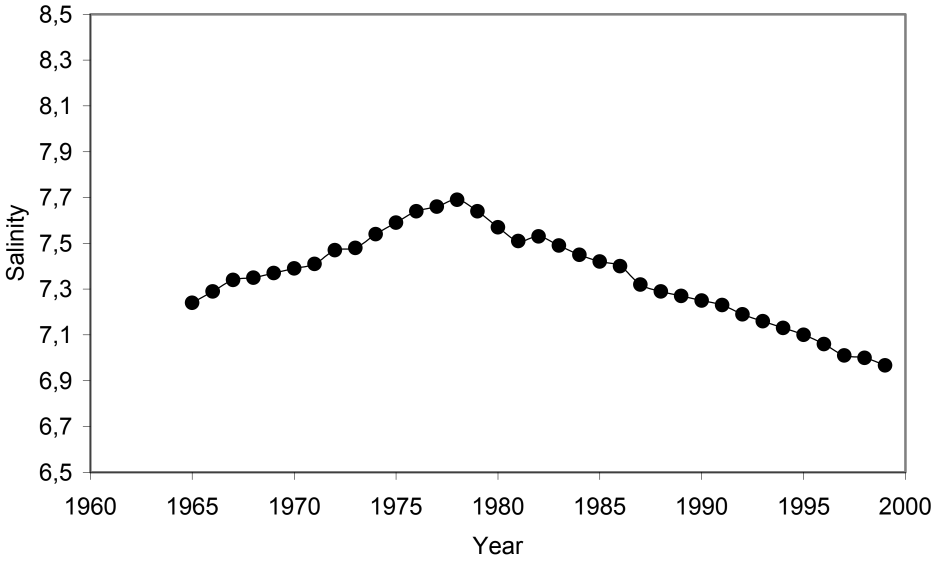


Figure A.P.2. The surface salinity at station BY15 (east of Gotland) in the Baltic proper (5-year running mean). Data have been obtained from the Swedish Ocean Archive (administrated by SMHI), which contains Swedish as well, as foreign observations.

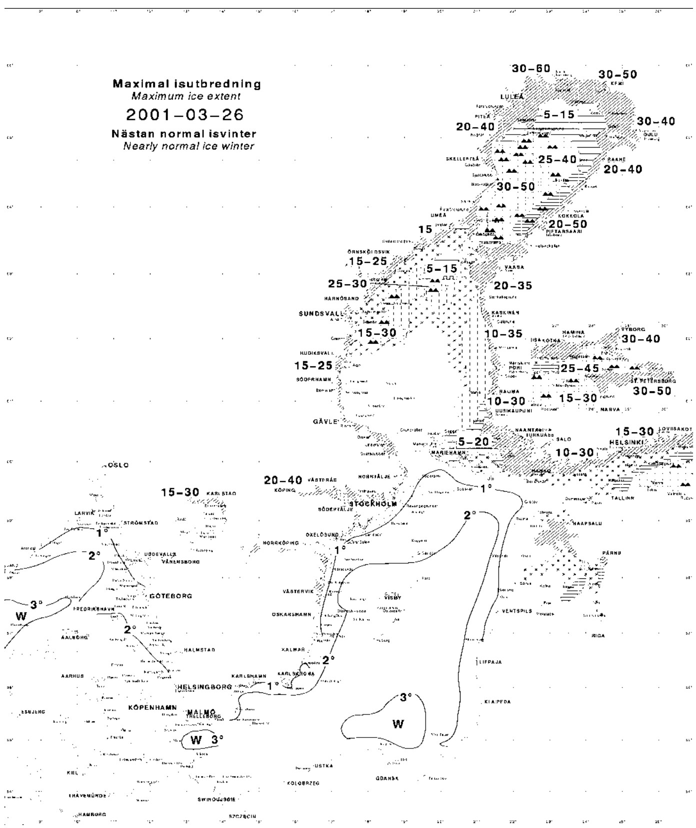


Figure A.P.3. The maximum ice extent in the Baltic during 2001. The map was constructed by SMHI.

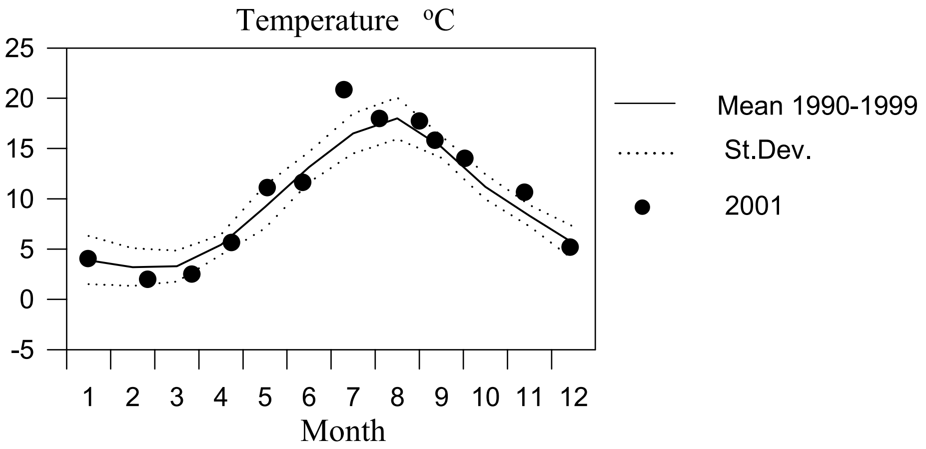
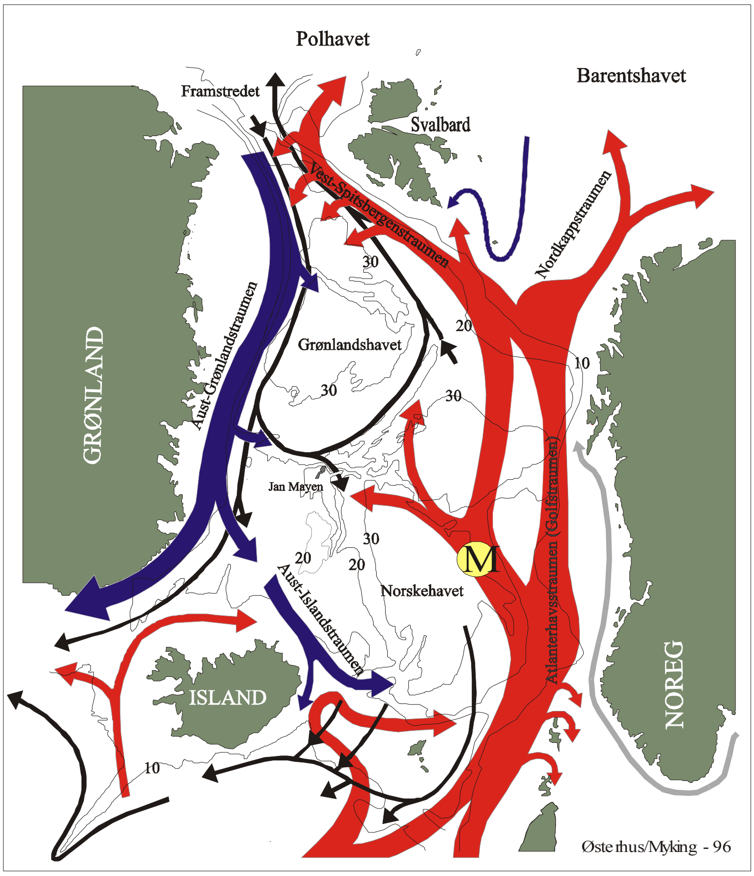
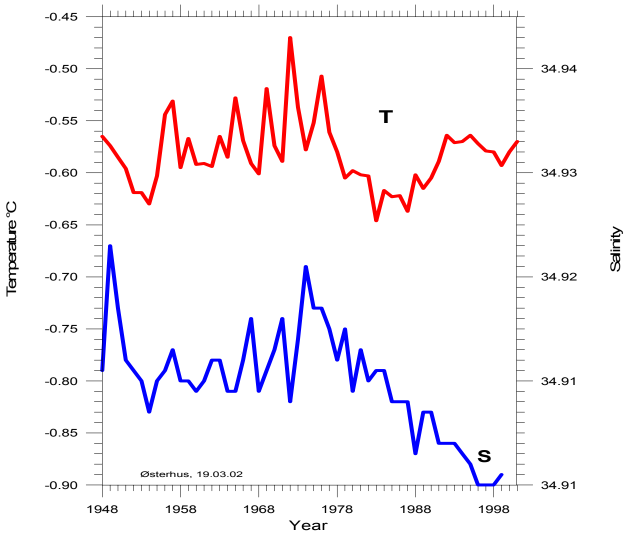
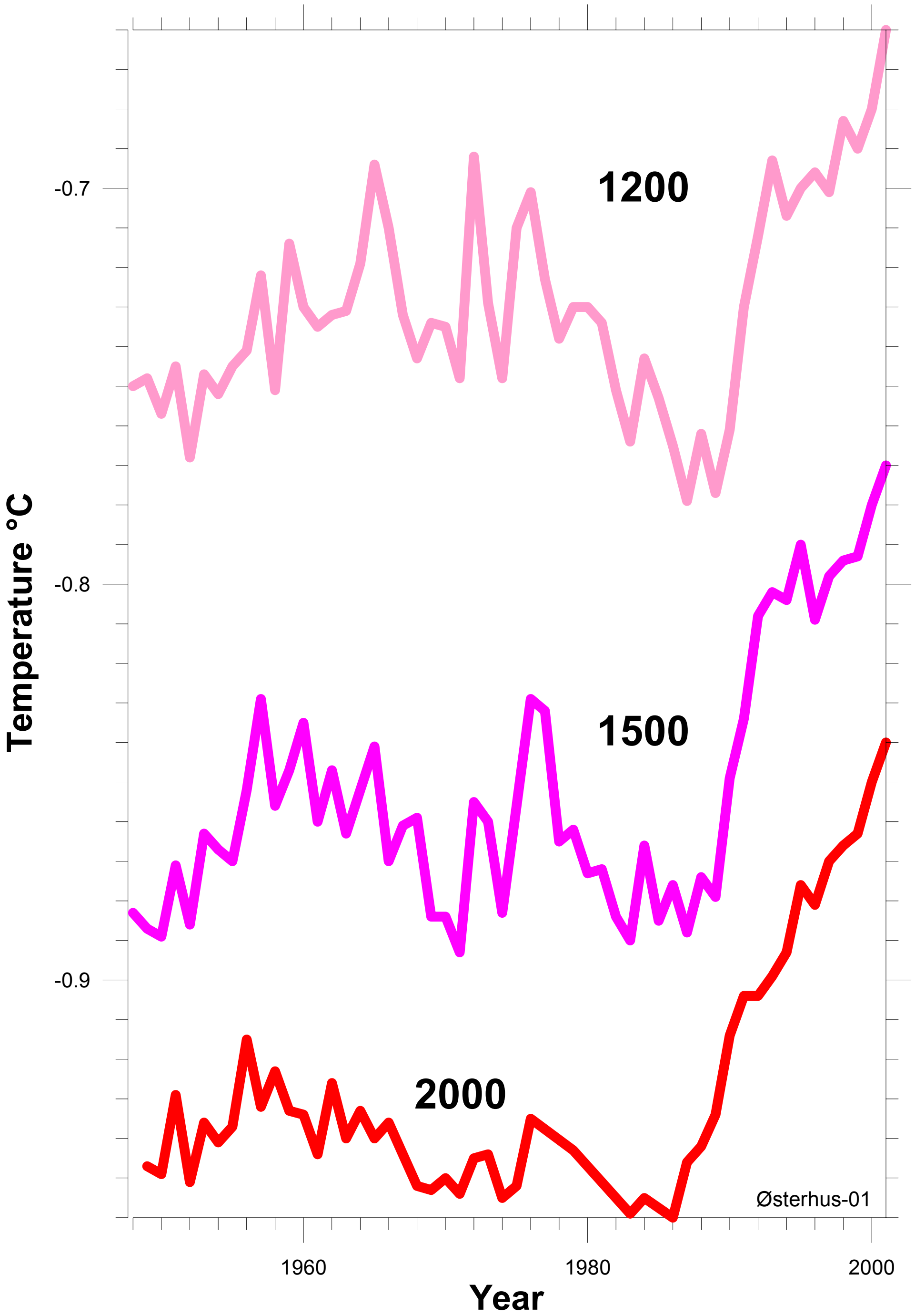


Figure A.P.4. The surface salinity at station P2 in the southern part og Skagerrak. The data were collected by R/V Argos within the Swedish National Monitoring Programmes.

ANNEX Q: RESULTS FROM OWS MIKE (ICES AREA 10)







-0.7
-0.8
-0.9
Temperature °C
1200
1500
2000
Østerhus-01
1960
1980
2000
Year

ANNEX R: RUSSIAN STANDARD SECTIONS IN THE BARENTS AND NORWEGIAN SEAS (ICES AREAS 10, 11)

V.Ozhigin

PINRO, Murmansk, Russia

The Barents Sea

Position of the main Russian standard sections in the Barents Sea is shown in Figure A.R.1. The Kola Section (along 33°30´E) is the one occupied on a most regular basis. It was occupied 10 times in 2001. Measurements along other sections were made 2–4 times during the year.

The following features characterized meteorological and oceanographic conditions in the Barents Sea and adjacent areas of the Norwegian and Greenland Seas during 2001.

Large-scale atmospheric circulation caused the predominance of warm air over the Barents Sea. Air temperatures at the beginning of the year were 2–4°C above normal. In February-March, an increased airflow from the Arctic caused cooling of the air with the minima in the western Barents Sea, where negative anomalies in March-April reached 1–2°C. From May to the end of the year air temperatures over the entire sea were slightly above the long-term mean.

Ice conditions in the Barents Sea during 2001 were very favourable. Ice coverage early in the year was far below normal. In March it reached the long-term mean, which was probably caused by the predominance of northerly winds. In April, ice coverage significantly reduced and during summer (July-September) there was virtually no ice in the sea. Similar ice conditions were observed in 2000.

Sea surface temperatures (SST) in January were warmer than normal. In February-May the positive anomalies persisted in the southern Barents Sea, but somewhat decreased in the northwest and southeast. In June-September, high positive SST anomalies were observed over the entire sea. In the succeeding months positive SST anomalies began to decrease in the south and southeast owing to seasonal cooling, but remained high in the Bear Island - Spitsbergen area.

Oceanographic conditions in the Barents Sea were characterised, as in 2000, by an increased advection of heat during winter and spring. The high positive anomalies were recorded during that period in all layers of the Main and Coastal branches of the Murman current (Figure A.R.2). In the summer and autumn, temperatures in the Murman current gradually fell to the level slightly above the long-term mean. The anomalies in the 0–200 m layer of the Main and Coastal branches of the Murman current reduced from 1.2°C and 0.9°C in January-February to respectively 0.0°C and 0.4°C at the end of the year. Temperature of the Norwegian current (0–200 m) west of the Bear Island grew from the long-term mean in spring to warmer-than-normal by 0.4°C in August-September (Figure A.R.3). Salinities along that section were by 0.02–0.03 higher than normal.

In the near-bottom layer positive temperature anomalies prevailed virtually over the entire sea.

Generally, water temperatures in the southern Barents Sea were warm in 2001. Annual mean anomaly in the 0–200 m layer of the Kola section (St. 3–7) was 0.6°C (Figure A.R.4). The cooling in the southern Barents Sea in the second half of 2001 is expected to extend into 2002. However, annual mean temperature in the Murman current is expected to be close to the long-term mean.

The Norwegian Sea

Standard sections occupied by PINRO in June-July 2001 are displayed in Figure A.R.5.

Atmospheric processes over the Norwegian Sea during 2001 were characterised by a reduced cyclonic activity. Air temperatures and SST were generally above normal throughout the year with the maxima (positive anomalies of >1°C) in September-October.

The main feature of oceanographic conditions in the Norwegian Sea was an increased inflow of Atlantic waters along the Eastern and Western branches of the Norwegian current (Figure A.R.6). Warm waters hindered the penetration of Arctic waters to the areas south of 62–63°N. Cold waters of eastern Icelandic origin occupied a large area in the central Norwegian Sea between 64° and 66°N. Water temperatures of the Eastern Icelandic Current were, for the first time in the recent 5 years, close to normal. The intermediate layer (200–500 m) was by 0.6–1.0°C colder than normal over most of the sea (south of 68°N), which was probably related to the rise of deep waters. Depth of the 0°C isotherm in the centre and in the east of the sea rose by 100–150 m as compared to previous years. In the north, temperature of the Norwegian current was by 0.4–0.7°C above normal both in the upper 200 m layer and at greater depths.

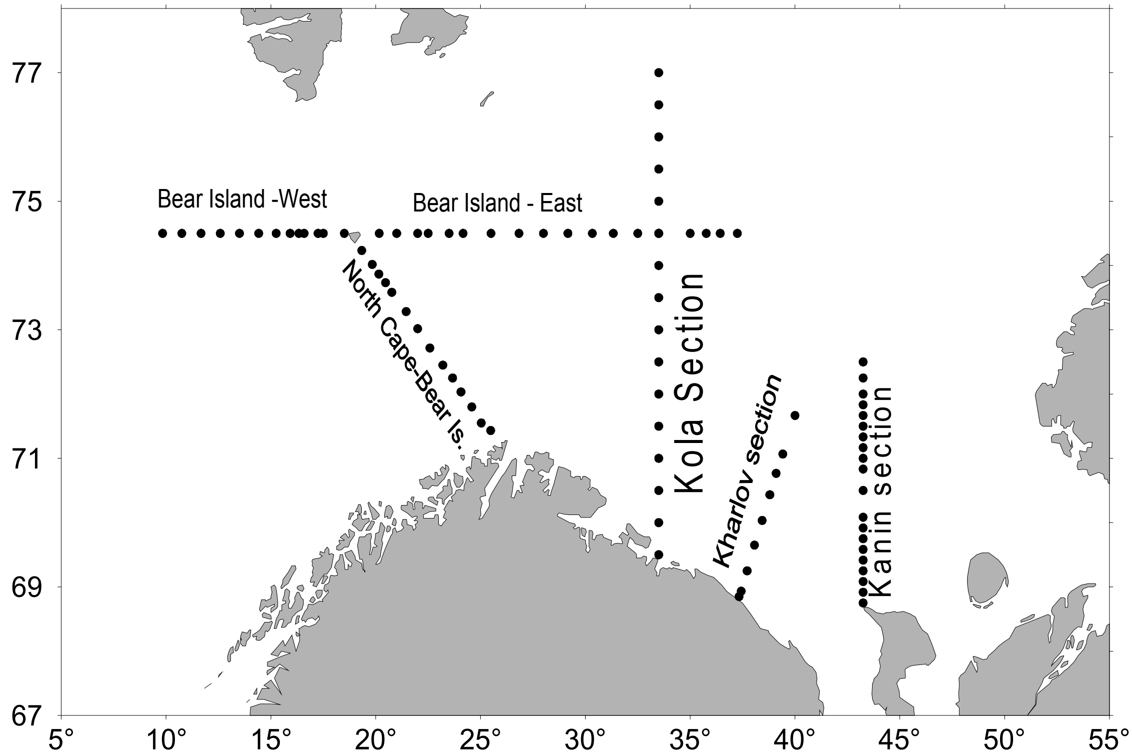


Figure A.R.1. Main Russian standard sections in the Barents Sea.

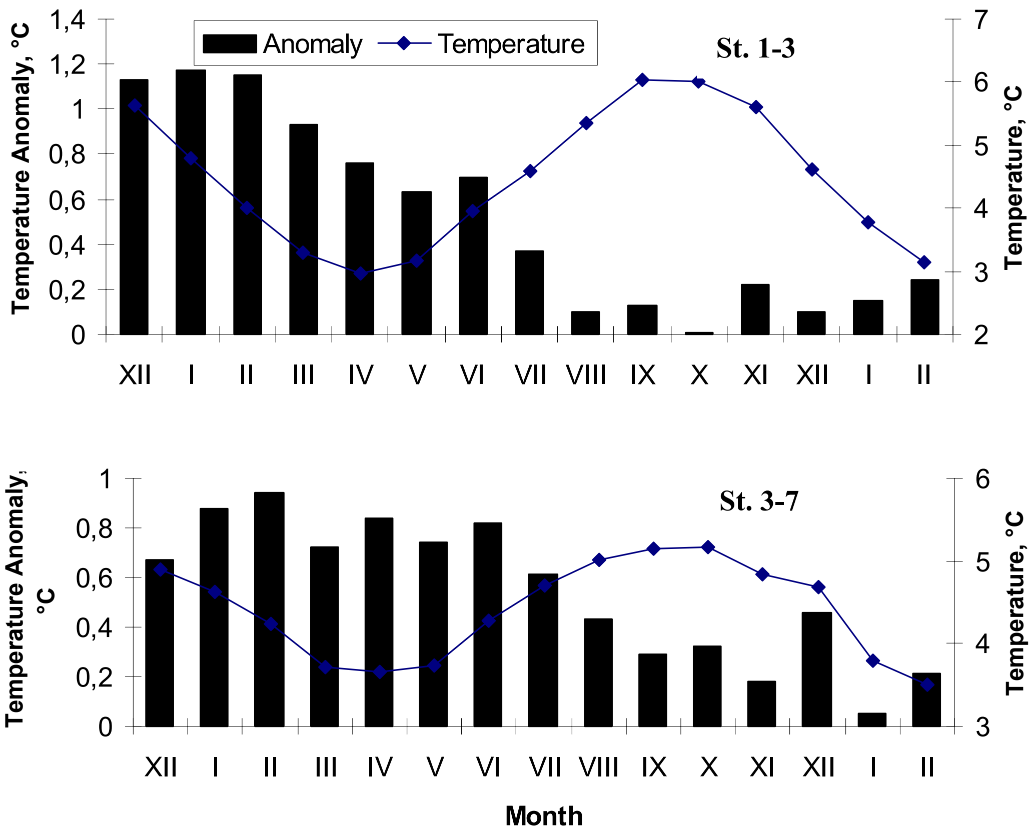


Figure A.R.2. Mean monthly temperatures and anomalies in the 0–200 m layer of the Kola section in 2001 and early 2002. St. 1–3 – Coastal branch of the Murman Current. St. 3–7 – Main branch of the Murman Current.

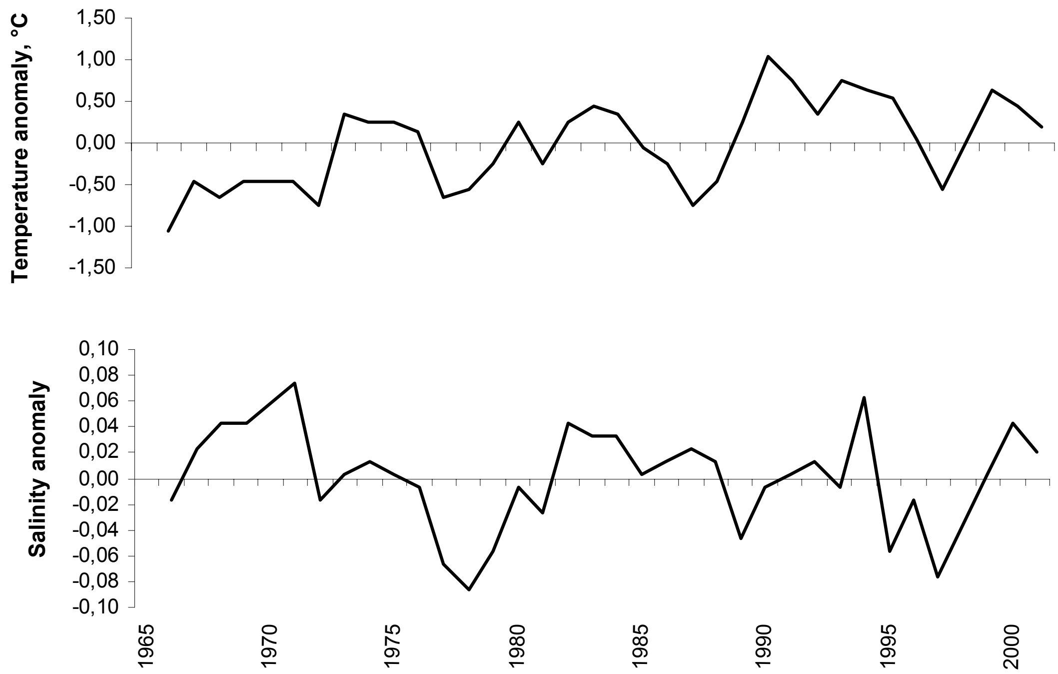


Figure A.R.3. Temperature and salinity anomalies of Atlantic water in the section Bear Island - West (74°30´N, 06°34´–15°55´E) (0–200 m) in August-September 1966–2001.

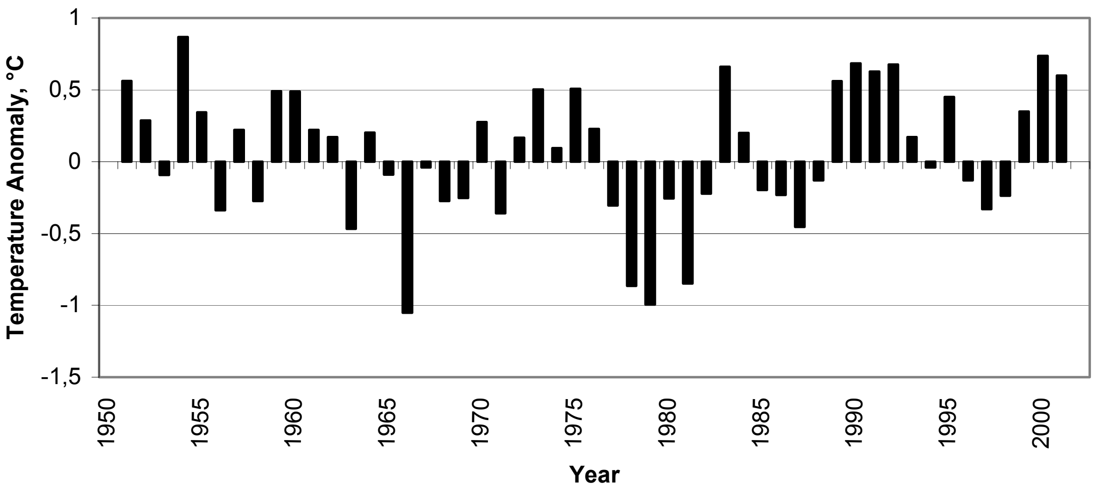


Figure A.R.4. Mean yearly temperature anomalies in the 0–200 m layer in the Kola section in 1951–2001.

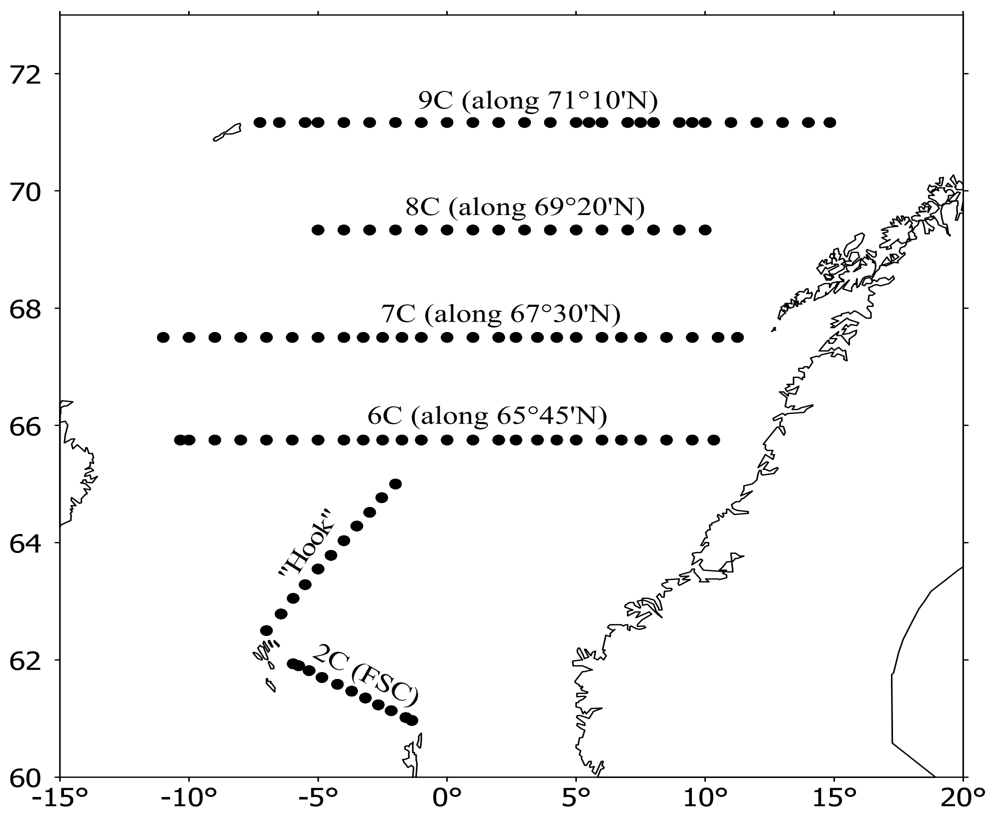


Figure A.R.5. Standard sections in the Norwegian Sea occupied in June–July 2001.

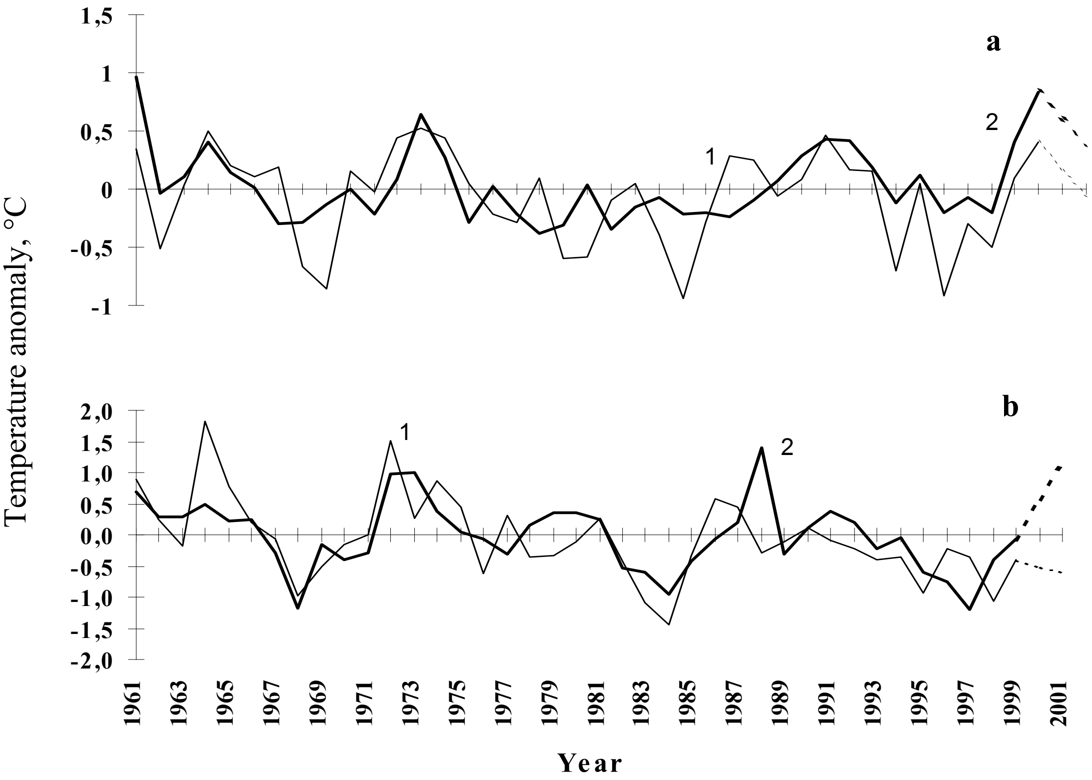


Figure A.R.6. Temperature anomalies in the upper 200 m layer of the Norwegian Current (a) and Mixed waters in the central Norwegian Sea (b) in the Sections 6c (1) and 7c (2) in June 1961–2001.

ANNEX S: POLISH NATIONAL REPORT (ICES AREA 11)

Dr J. Piechura

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2001 research was continuation of the previous years work. Stations grid is presented at Figure A.S.1. The main goal of our research was to learn more about pathways, volume, heat and salt transport and exchange with surrounding waters, of Atlantic Waters (AW) carried by the Norwegian Atlantic Current and West Spitsbergen Current. AW within these current systems flows to the North in a complicated manner. Multibranch pattern, meanders, eddies and return currents are frequently observed (Figures A.S.2 and A.S.3). Nevertheless two main branches are visible: the most intensive ones (current speed over 50 cm s^{-1}) are associated with the continental brake in the East and with the eastern slope of Mohn's and Knipovich's ridges in the West (Figure A.S.3).

Temperature of Atlantic water near its core (Figure A.S.4) decreases from over 7°C in the South to less than 4°C in the Fram Strait and salinity (Figure A.S.5) from 35.15 psu to about 35.00 psu over the same distance. What is changing the most, is the amount of AW, heat and salt carried to the North (Figure A.S.6). At the southernmost transect A the AW occupies the surface layer to the depth 700–800 m but in the vicinity of the Fram Strait it is found above 300–400 m only.

The volume transport of AW decreases from over 16.5 Sv at the latitude of 69°N to 1.5 Sv in the Fram Strait (Table A.S.1, Figure A.S.7), over 4 Sv goes to the Barents Sea (3.4 Sv through the Norway-Bear Island opening and 0.7 Sv across the transect Bear Island-Soerkapp). Some of AW is carried to the South by return currents (nearly 10 Sv at 69°N to 0.9–2.0 Sv in the North). Decrease of AW transport on its way to the North is neither linear nor continuous, at some transects an increase is observed (e.g., transects K, P, Z). This could be caused by additional branches of AW joining the main stream from the West, or by pulsating nature of the AW main flow or finally by changing proportions of the northern bound and reversing transport.

Close to the Fram Strait the West-East exchange intensifies, the western flow dominates by more then 1 Sv (4.3 Sv westward and 3.1 Sv in opposite direction) over the eastern bound flow. At the Barents Sea opening the eastward flow of AW dominates: by 3 Sv in the South and by 0.5 Sv in the North. The fluctuations of AW volume transport determine changes in heat and salt transport (Table A.S.1). At the southernmost transect AW carried nearly 100 TW of heat and over 700 tons of additional salt. About half of the heat was transported to the Barents Sea and half towards the North.

As far as interannual changes are concerned, AW transport, temperature and salinity during summer 2001 were close to the average, being a bit lower then in 2000 and 1999 but higher then in 1998 (Figure A.S.7). Inflow of AW to the Barents Sea was much higher in summer 2001 then during the previous summer.

Table A.S.1. Volume, heat and salt transport.

Transect	Northward [Sv]	Southward [Sv]	Net [Sv]	Heat [TW]	Salt [10^3 kg/s]
A	16.6	9.6	7.0	99.5	713
H	6.9	4.7	2.2	28.8	263
K	7.1	3.6	3.5	50.1	381
N	4.9	2.6	2.3	32.7	231
P	6.3	3.3	3.0	40.9	273
S	3.9	0.9	3.0	43.6	182
Z	5.2	2.3	2.9	46.7	262
EB2	3.7	1.4	2.3	27.7	45
XX	3.2	2.1	1.1	13.8	30
X	1.5	2.1	- 0.6	1.4	35
	Eastward [Sv]	**Westward** [Sv]	**Net** [Sv]	**Heat** [TW]	**Salt** [10^3 kg/s]
W	3.1	4.3	1.2	1.2	291
V1	3.4	0.4	3.0	56.4	75
V2	0.7	0.2	0.5	5.1	106

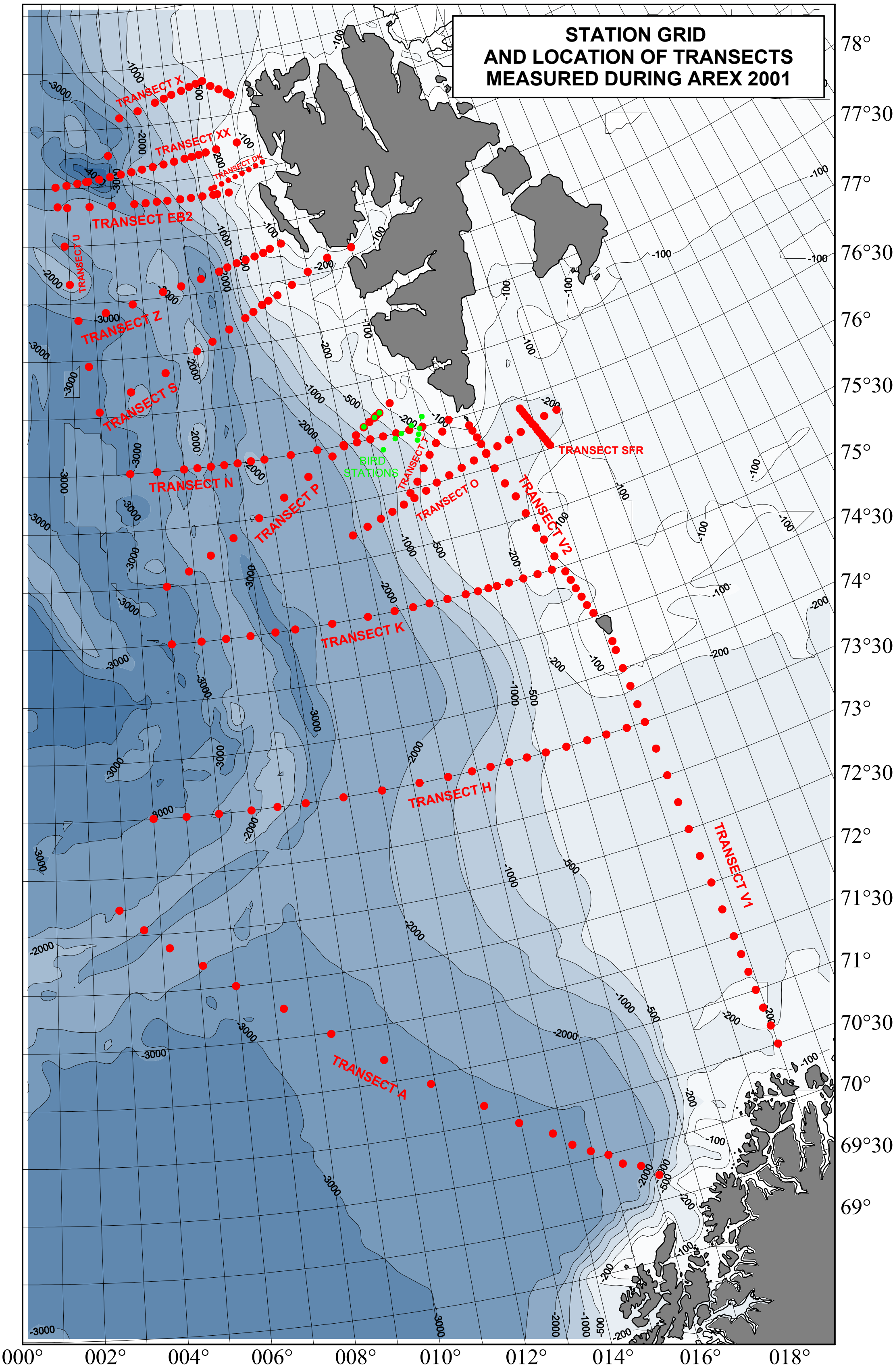

Figure A.S.1. Station grid and location of transects during AREX'2001.

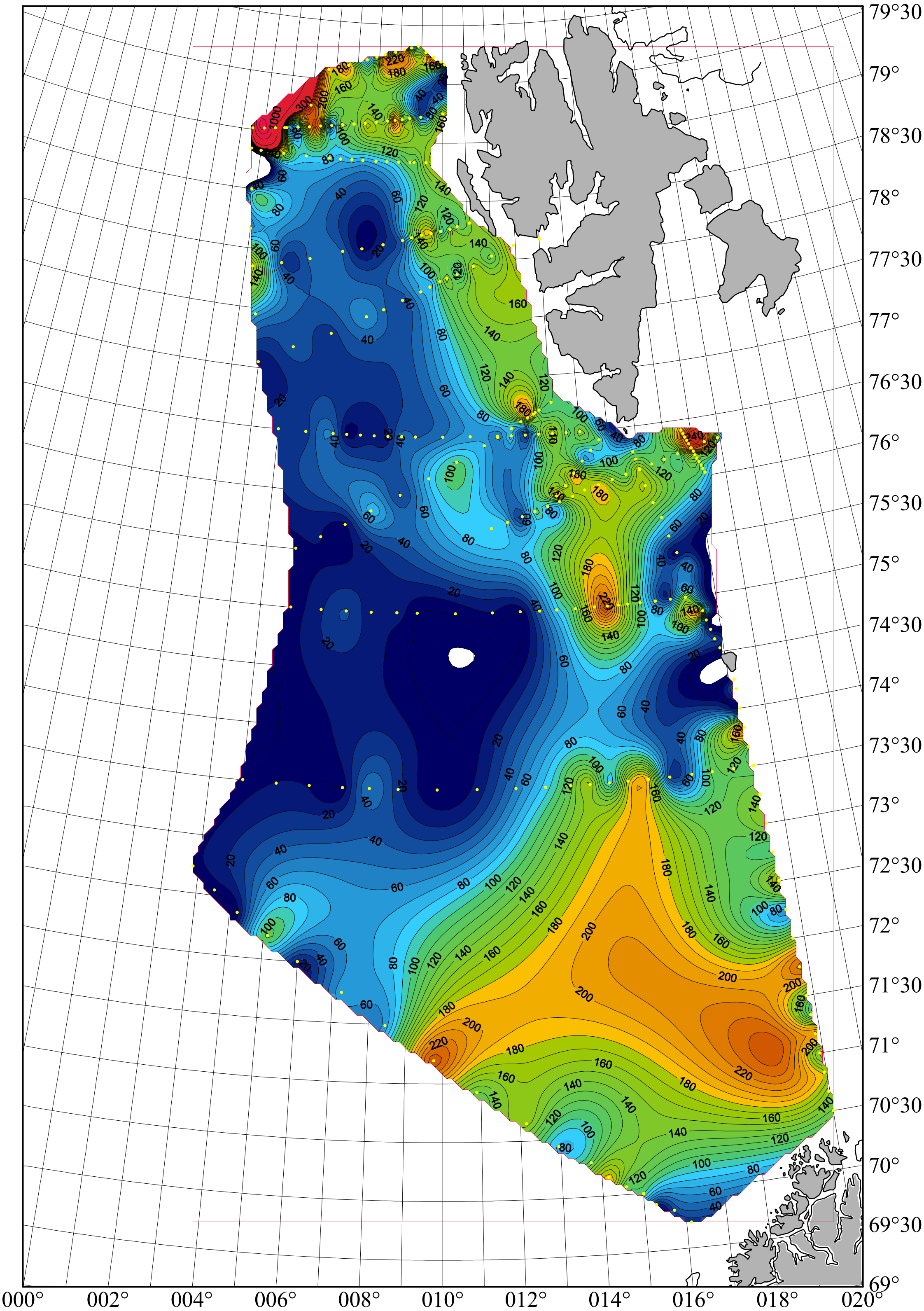

Figure A.S.2. Depth of maximum salinity layer [m] measured during AREX'2001.

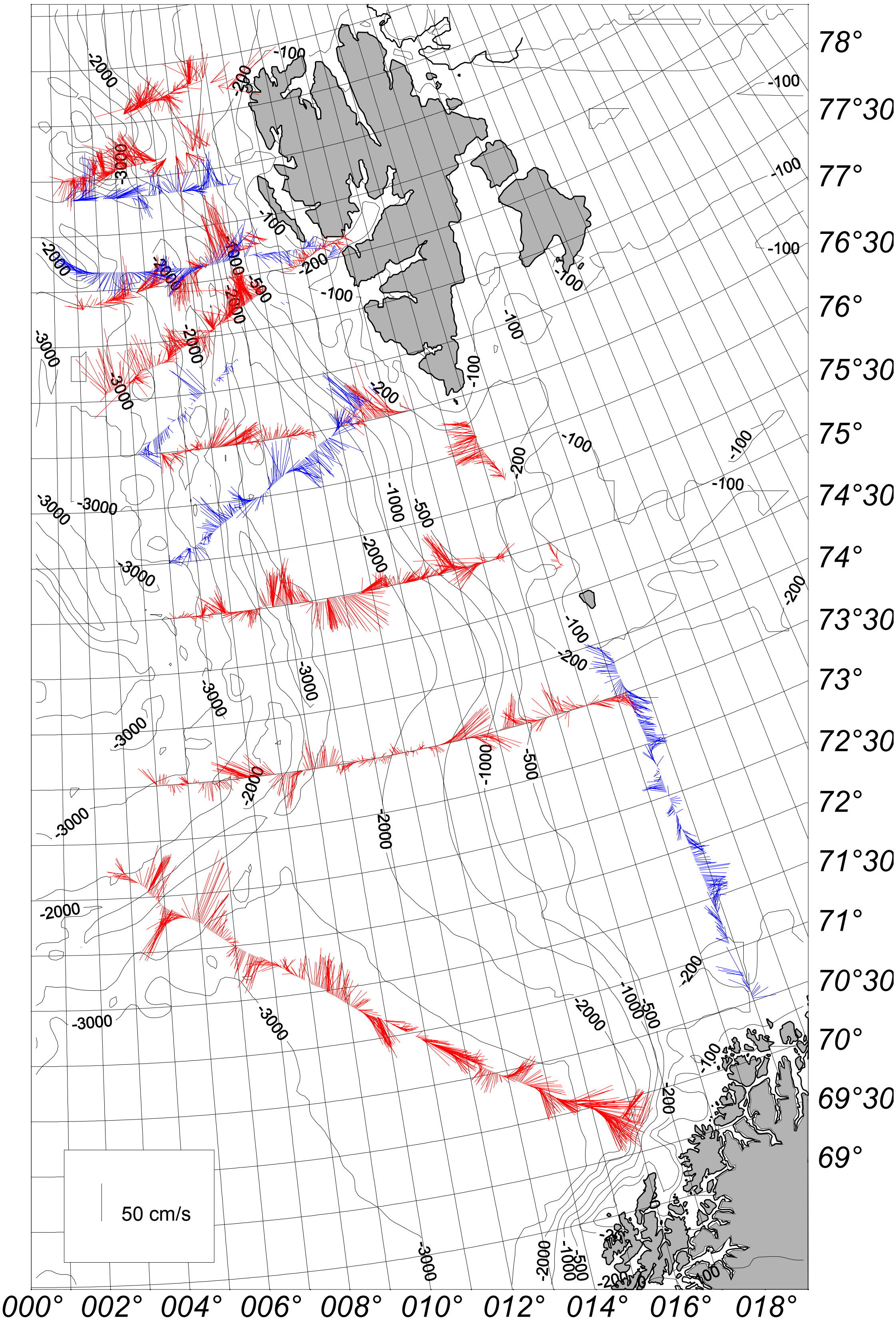

Figure A.S.3 Current sticks at the depth of 150 m measured by VM-ADCP during AREX'2001.

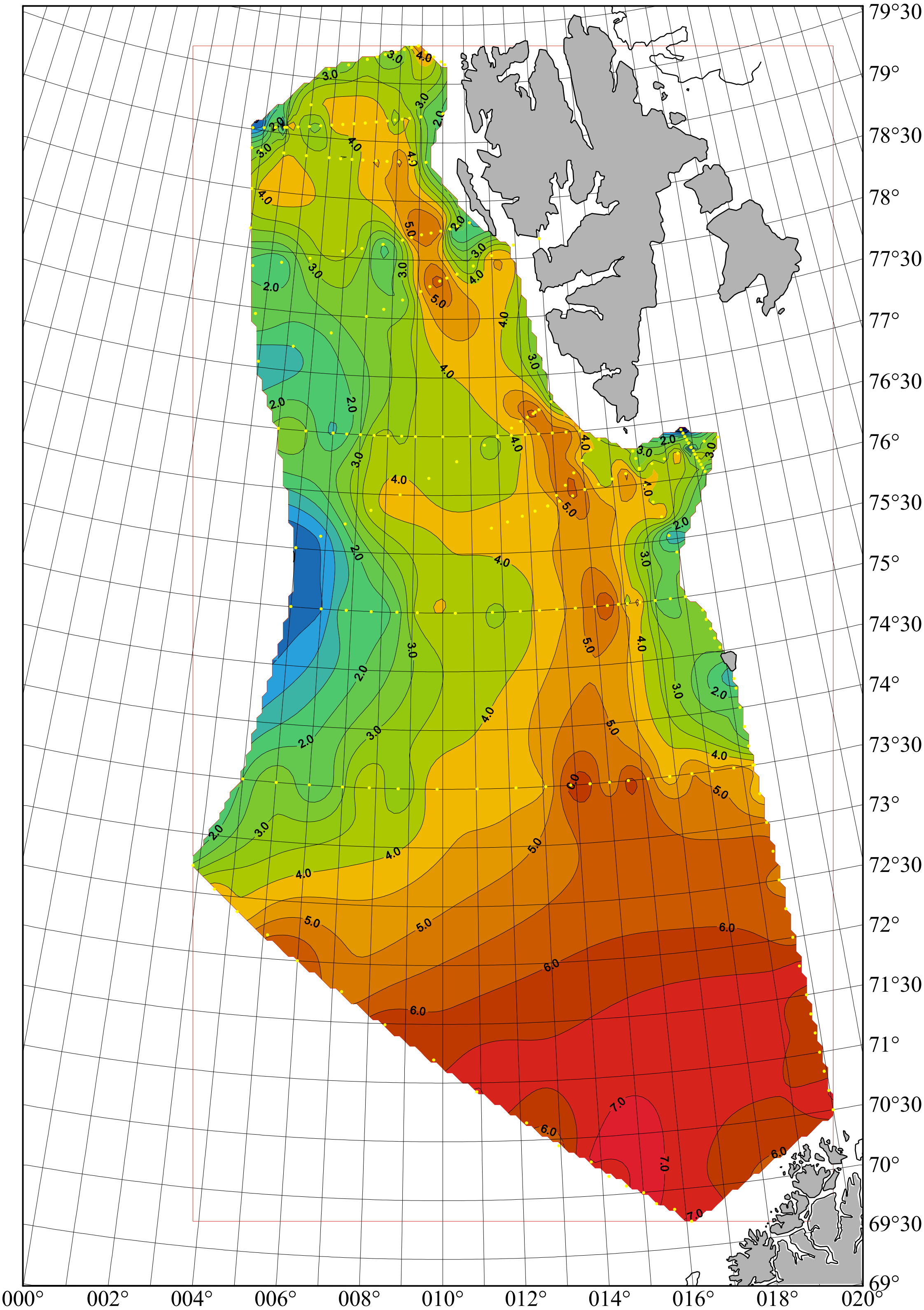

Figure A.S.4. Distribution of temperature [°C] at the depth of 100 m measured during AREX'2001.

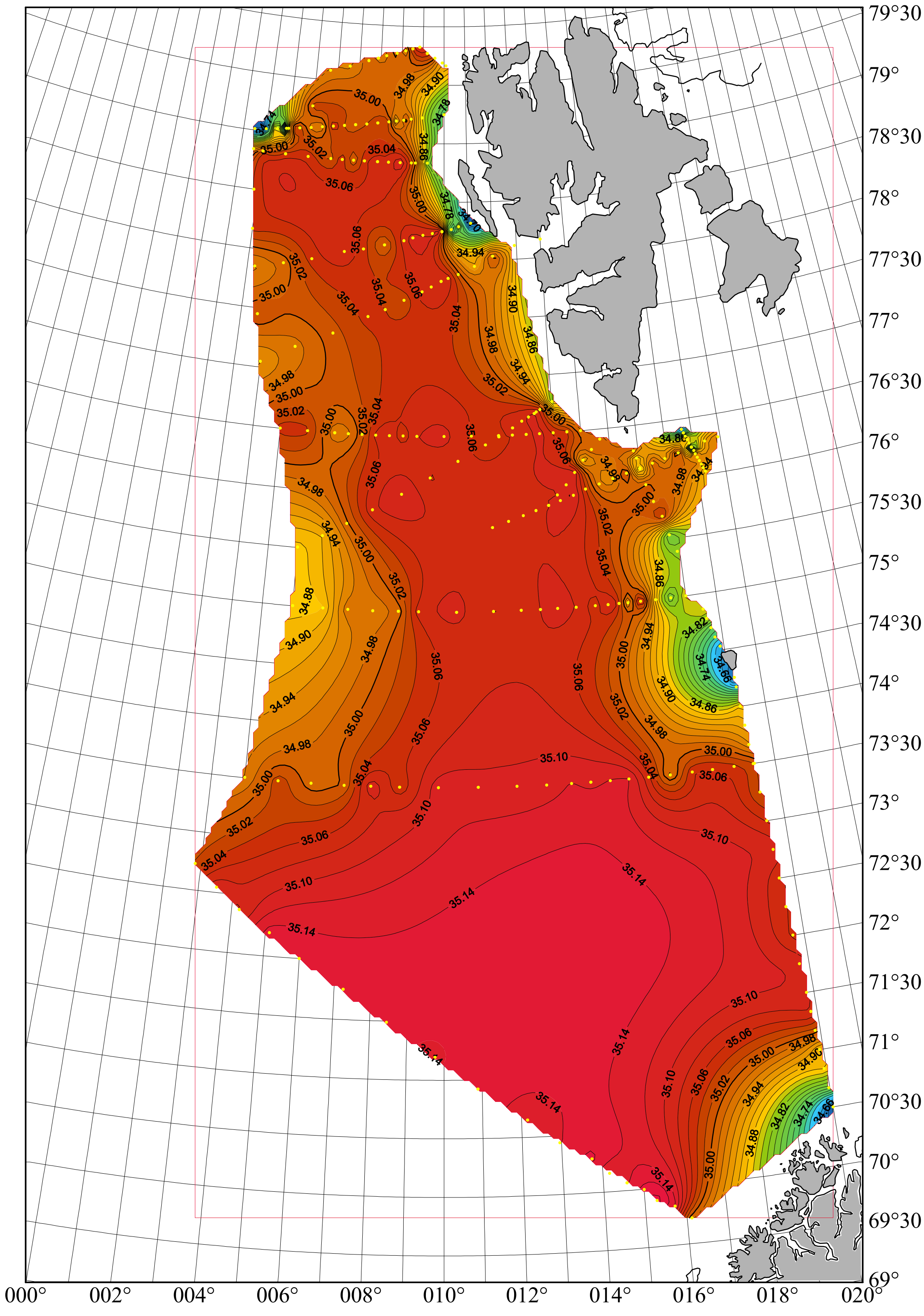

Figure A.S.5. Distribution of salinity [psu] at the depth of 100 m measured during AREX'2001.

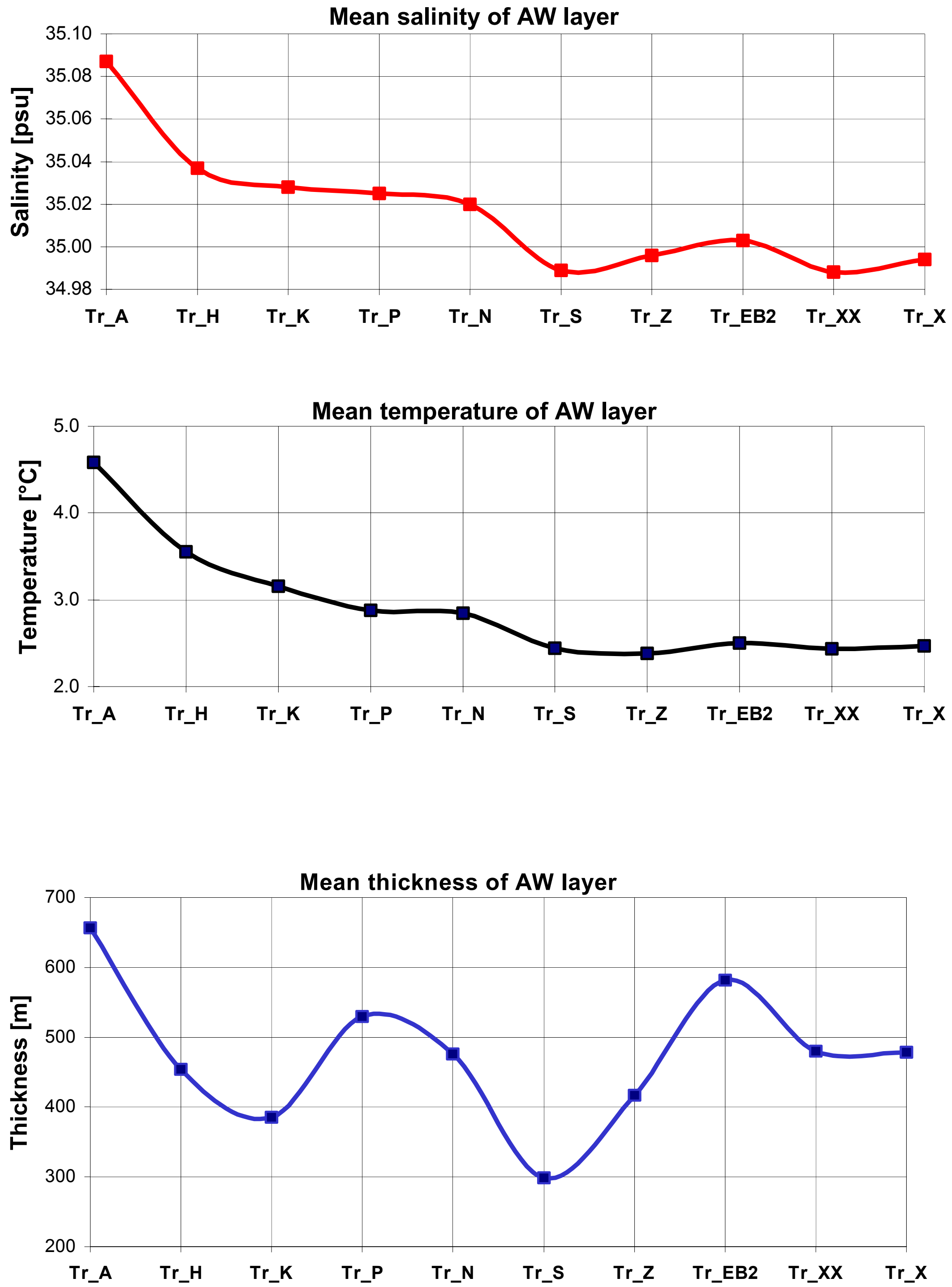

Figure A.S.6. Mean salinity, temperature and layer thickness of Atlantic Water at transects measured in 2001.

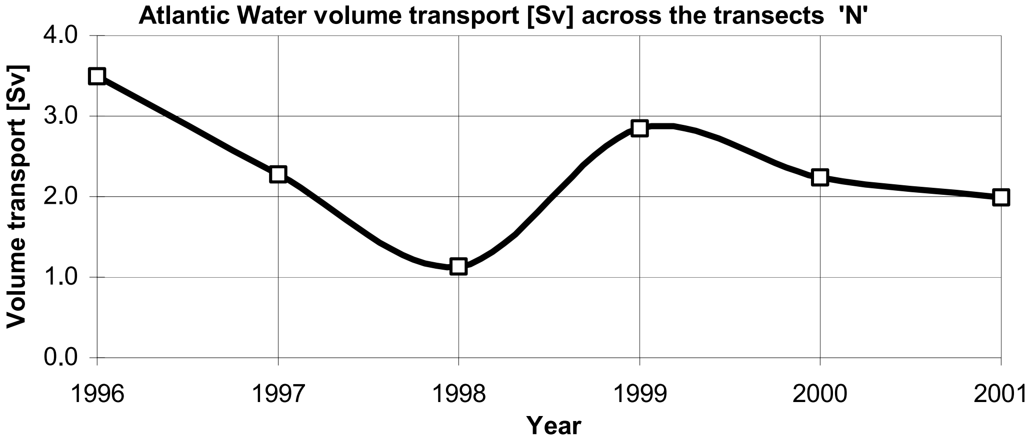

Figure A.S.7. Net volume transport of Atlantic Water across the transect 'N' (along 76°30´N) measured in 1996–2001.

ANNEX T: HYDROGRAPHIC CONDITIONS IN THE GREENLAND SEA AND FRAM STRAIT (ICES AREA 12)

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In summer 2001, the time series of hydrographic measurements in the Greenland Sea (along 75°N, G. Budeus) and in Fram Strait (along 79°N, U. Schauer) were continued by the AWI. These sections are performed to monitor the throughflow towards the Arctic Ocean and back and also the hydrographic changes within the central Greenland Sea to determine the amount of local watermass modification and renewal. It is planned to continue these time series with cruises scheduled in 2002.

The properties of the Atlantic Water and the Return Atlantic Water observed on the CTD-transect at 75°N are displayed in Figure A.T.2. The properties of the Atlantic Water are given as temperature and salinity averages over a depth range from 50 to 150 m of the stations between 10° and 13° E, which have a spacing of 10 nautical miles. The Return Atlantic Water is characterized by the temperature and salinity maximum below 50 m averaged over three stations west of 11.5°W which have a spacing of less than 5 nautical miles. The salinities for 1989 and 1990 are of reduced accuracy because of instrumental problems with an erroneously working Salzgitter CTD, while all other data was obtained with a SBE911+.

The Atlantic Water on the eastern side of the transect, within the West Spitsbergen Current, was colder in summer 2001 (3.90°C) than in the previous summer (3.98°C) and shows the lowest value of the time series (since 1989). The salinity of this area was in summer 2001 just the same as in the previous summer (35.08). The Return Atlantic Water on the western side of the Greenland Sea was just slightly colder (2.04°C instead of 2.06°C) and more saline (34.97 instead of 34.96) in summer 2001 than in the previous summer.

To monitor the subsurface conditions in the center of the Greenland Sea, the mean temperature and salinity between 5°W and 3°E along 75°N below 300 m depth and more than 300 m above the persistent intermediate temperature maximum (which was located e.g., 1999 in ca. 1500 m depth) were determined (Figure A.T.1). Between summer 2000 and summer 2001, the mean subsurface temperature and salinity show both an increase, while measurements with a moored deep sea profiler show a mean ventilation depth of about 800 m in the central Greenland Sea. Changes of these properties are caused by advection and winter ventilation. Because of the strong influence of Atlantic Water, an increase in both parameters cannot be used as an indicator for absent ventilation (e.g., in the winter 94/95 the ventilation reached down to more than 1000 m). Further hydrographic measurements show that during winter 2000/2001 the ventilation reached down to 2500 m depth in isolated areas with a diameter of about 10 km.

The variations of the watermass properties in Fram Strait are displayed in Figure A.T.2. 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 hast 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 hast to be taken into account.

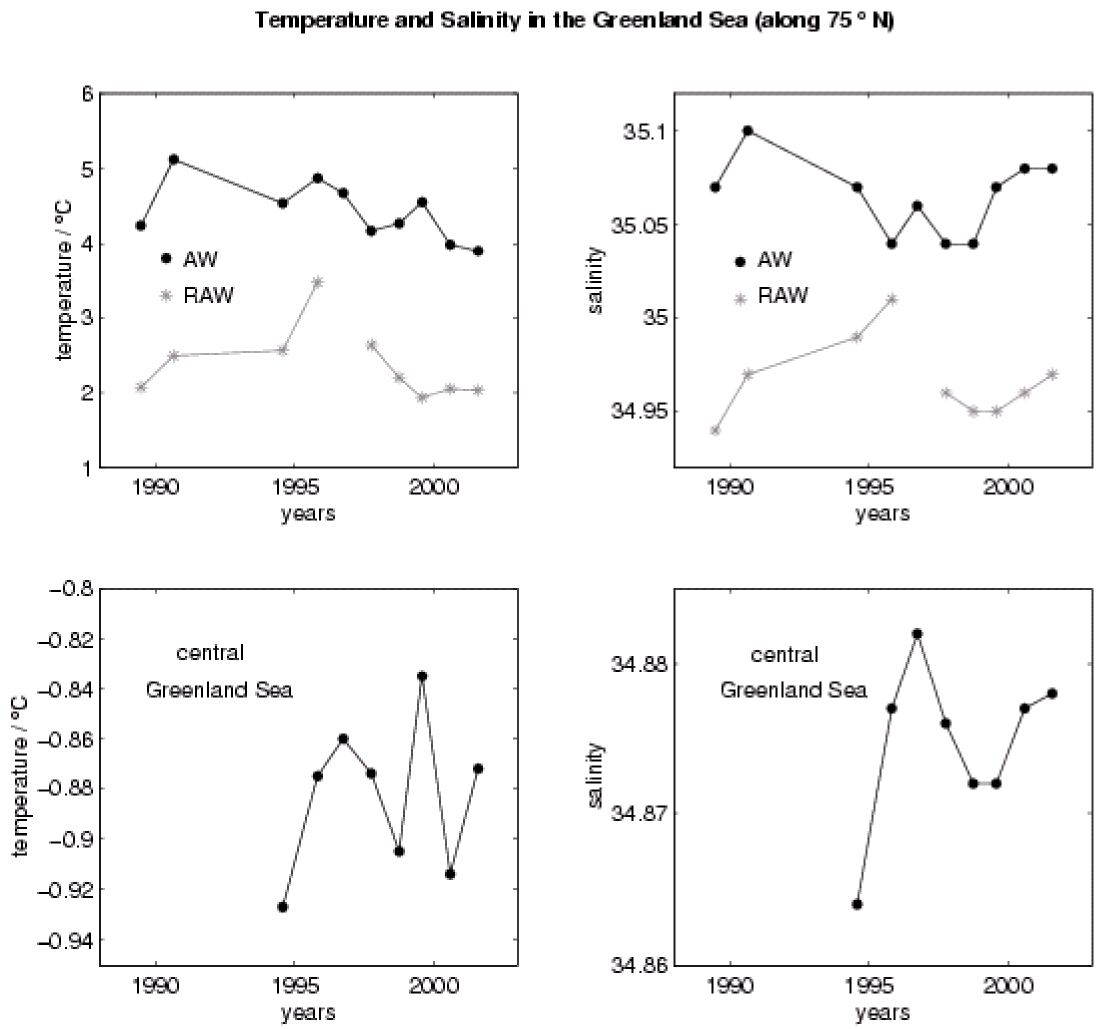


Figure A.T.1. Properties of the Atlantic Water (AW), the Return Atlantic Water (RAC), and the subsurface conditions in the central Greenland Sea observed on the CTD-transect at 75°N (G. Budeus).

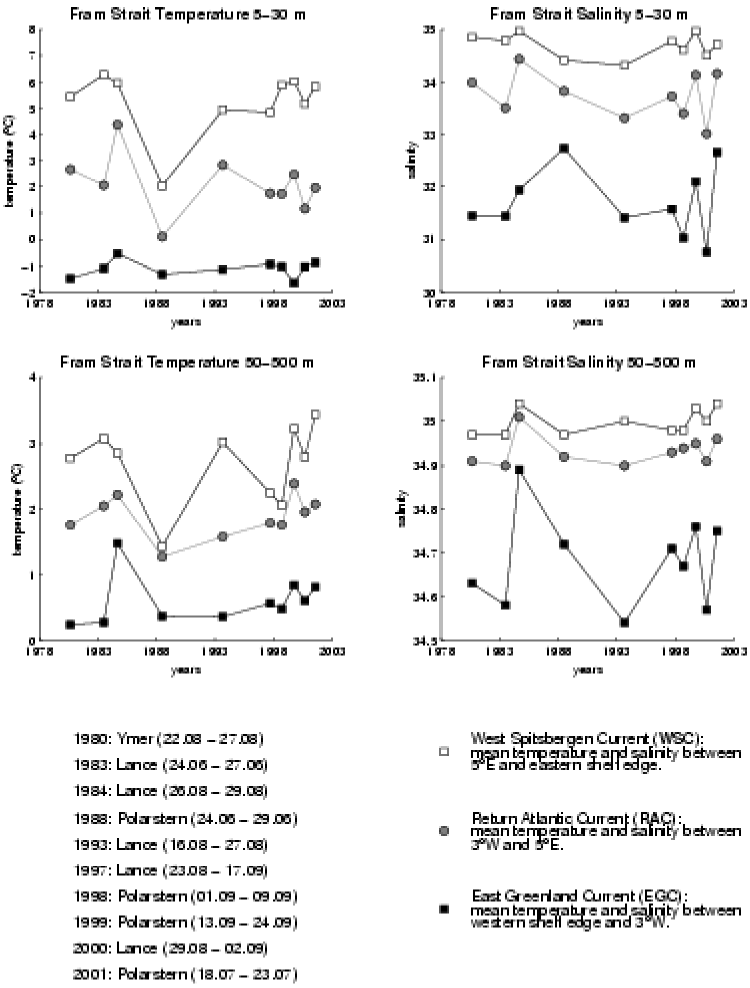


Figure A.T.2. The variations of the mean temperature and salinities in Fram Strait in the West Spitsbergen Current (WSC), the Return Atlantic Current (RAC), and the East Greenland Current (EGC). The values for the last years were calculated by U. Schauer and H. Rohr. Earlier values were supplied by M. Marnela and B. Rudels from the Finnish Institute of Marine Research. Additional data were obtained from the ICES Data Centre in Copenhagen.

ANNEX U: TEXT OF THE 2001/2002 ICES ANNUAL OCEAN CLIMATE STATUS SUMMARY

Overview

The NAO: The North Atlantic Oscillation (NAO) index has been slowly recovering to positive values since the extreme negative value of 1996. However, during the winter preceding 2001 it again became negative. The response seen throughout the ICES area to the 1996 switch of the NAO has not been observed in 2001, probably due to a different pattern of sea level pressure over the North Atlantic. In 2001 the pattern exhibited a large weak positive anomaly stretching from northern Scandinavia to Newfoundland.

Area 1: Ocean temperatures off West Greenland showed considerable warming during the summer and autumn of 2001. This warming was similar to that observed during the 1960s. Anomalously high salinities were observed in the off-slope surface waters during the autumn.

Area 2: Annual mean air temperatures over all areas of the Northwest Atlantic were above normal during 2001, but decreased compared to the records set in 1999. The amount of sea ice on the eastern Canadian continental shelf continued to be below normal for the fourth consecutive year. Except for southern areas of the Newfoundland and the northern Scotian shelves, ocean temperatures were above normal, continuing the warm trend established in the late 1990s.

Area 2b: The upper layers of the Labrador Sea were observed to be warmer, saltier, and less dense in the summer of 2001 compared with conditions in 2000. These changes seem to be due largely to the inflow of Atlantic waters. There is no evidence that convective overturning during the winter of 2000–2001 reached depths greater than 400–500 m.

Area 3: In Icelandic waters there were relatively high temperatures and salinities, as there have been for the previous 3–4 years following the very cold years of 1995 and 1996. However, 2001 temperatures and salinities were slightly cooler and fresher than in 1999 and 2000.

Area 4: The Bay of Biscay continued to show a progressive decrease in salinity, which began in 1999. Averaged upper water layer temperature was low compared to values obtained during the last decade, whereas yearly averaged air temperature remained at the same level as the preceding three years.

Area 5: The Rockall Trough began to cool and freshen slightly during 2001, although both temperature and salinity remained high compared to the long-term mean, with values similar to previous peaks in the early 1980s.

Area 6: The temperature and salinity of Atlantic water passing through the Faroe Bank Channel and across the Iceland-Faroe Ridge have remained fairly constant since 1997.

Area 7: With respect to the last four decades, Atlantic waters in the Faroe Shetland Channel are generally warming and becoming more saline. However, there was little change between 2000 and 2001.

Areas 8 and 9: In terms of the surface temperatures of the North Sea, 2001 was generally warmer than normal. The summer of 2001 exhibited a reduced influence of Atlantic water in the northern North Sea and also in the Southern Bight. The low salinities in the southern North Sea suggest stronger than normal run-off from the continental rivers. The Baltic outflow south-west of Norway in summer 2001 was stronger than normal.

Area 9b: In the Baltic, surface waters generally became fresher due to high freshwater inputs following a wet winter. Surface temperatures were warmer than average. There were deep-water inflows into the Baltic Sea from the North Sea in the autumn of 2001.

Area 10: In the Norwegian Sea conditions continued a long term warming trend, and in 2001 the area occupied by Atlantic water was the greatest since 1991.

Area 11: The Barents Sea was warmer than average during 2001, but the temperature gradually decreased throughout the year from nearly 1°C to just 0.1°C above average. The ice condition was therefore favourable.

Area 12: Conditions in the Greenland Sea were generally warmer and more saline in 2001 compared to 2000. Although on average winter convection went down to 800m, in small isolated patches convection reached 2500m.

Prognosis

Though March is still in progress at the time of writing, the winter NAO index for 2002 is likely to show a limited recovery from 2001, in an overall pattern across the ICES area, which is unlike the classical dipole pattern normally observed. Hence we may expect continued near average conditions in most areas, with room for surprises.

The North Atlantic Oscillation (NAO) Index

Since the NAO is known to control or modify three of the main parameters which drive the circulation in the ocean area covered by this climate summary (i.e., wind speed, air/sea heat exchange and evaporation/precipitation) a knowledge of its past and present behaviour forms an essential context for the interpretation of observed ocean climate change in 2001/2002.

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 and northwest European shelf seas, and with cooling in the Labrador and Nordic Seas. Low index years generally show the reverse.

When we consider the NAO index for the present decade, and the present decade in the context of this century (Figure 1), the 1960s were generally low-index years while the 1990s were 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 subsequently rose from the extreme low of 1996, and the recovery continued during the winter preceding 2000. However, during the winter preceding 2001 the NAO index again became negative.

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 (see the 2000/2001 IAOCSS).

It would appear that the winter of 2000/2001, while exhibiting another reversal similar to that seen in 1995/1996, has experienced a different dipole pattern resulting in far less dramatic effects compared to the earlier reversal event. Text Box 1 has the details.

In the remainder of this ICES Annual Ocean Climate Status Summary (IAOCSS) for 2001/2002, 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).

LINK TO NAO DATA HERE

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).

Figure 2. Schematic of the general circulation of the North Atlantic in relation to the numbered areas presented in the 2001/2002 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: a return to NAO-negative conditions

Background

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 NAO index underwent a large and rapid decrease during the winter preceding 1996 and recent IAOCSS describe the recovery to more positive values since then. During the winter preceding 2001, the "recovering" NAO index has undergone a further reversal to negative values.

The NAO in winter 2001

The 2000/2001 IAOCSS reported early indications of a sharp return to NAO negative conditions, although at the time of writing only December 2000 and January 2001 values of the Jones index (www.cru.uea.ac.uk) were available. Sea Level Pressure (SLP) anomaly fields for the first 3 months of the 2001 winter (December, January, February) showed a pattern which we would associate with a negative NAO index. Once the full 2001 winter data became available, the early indications were confirmed. The Hurrell winter NAO index (www.cgd.ucar.edu/~jhurrell/nao.html) reported a value of–1.89. The NCEP/NCAR reanalysis SLP anomaly composite for the winter 2001 (Figure 3a) shows a clear negative anomaly in the pressure dipole.

Figure 3a. The pattern of Sea Level atmospheric pressure during the winter (December, January, February, March) of 2001 from which the NAO index is calculated (Iceland to the Azores).

The 2001 Reversal compared to the 1996 Reversal

The reports from the ICES regions contained in this IAOCSS do not suggest a repeat of the extreme conditions observed following the 1996 NAO reversal. Examination of the SLP anomaly patterns for the two winters (Figure 3a and 3b) illustrates a possible reason for the markedly different response to the negative NAO forcing. Firstly 1996 was a much stronger negative NAO year. Secondly, the SLP anomaly of 1996 suggests strong south-easterly wind anomalies over the North Sea, the north-east Atlantic and the Labrador Sea. The 2001 dipole pattern is more zonally constant, with maximum gradients further north than in 1996.

Is the North Atlantic Oscillation always the dominant control on Atlantic variability?

In many of the IAOCSS we describe possible associations between various parameters of Atlantic hydrography and the winter pattern and amplitude of the NAO. 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. Also, from the mid 1960s to the 1990s, 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 long-term records. Examples include the warm period between 1925 and 1960 (See the 2001 ICES WGOH report for more details), and zones of minimal correlation with the NAO such as the Rockall Trough. In addition, over the Atlantic as a whole, the NAO only explains 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, 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.

Figure 3b. The pattern of Sea Level atmospheric pressure during the winter (December, January, February, March) of 1996 from which the NAO index is calculated (Iceland to the Azores).

Regional Descriptions

Area 1 - West Greenland

West Greenland lies within the area, which normally experiences warm conditions when the NAO index is negative, which it was in the winter preceding 2001 and hence climatic conditions at West Greenland were anomalously warm. The 2001 mean annual air temperature at Nuuk was –0.1°C, which is about 1.3°C above normal (Figure 4). 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 water temperature at Fyllas Bank during autumn (Figure 5), with the 2001 temperature value for the upper 200m being the second highest temperature anomaly observed since 1963 (1.78°C).

In summary, oceanographic conditions off West Greenland during autumn of 2001 were warmer and more saline due to mild atmospheric conditions and an inflow of Irminger water which was found as far north as 62°N (Frederikshaab Bank).

LINK TO AREA 1 DATA HERE

Figure 4. Area 1 - West Greenland. Nuuk mean annual air temperature anomaly (relative to the 1961–1990 climatic mean).

Figure 5. Area 1 - West Greenland. Fyllas Bank (Station 4) autumn temperature (upper figure) and salinity (lower figure) anomaly averaged over the 0–200 m layer.

Area 2 - North West Atlantic: Newfoundland and Labrador Shelf

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.

Annual mean air temperatures warmed slightly during 2001, compared to 2000, values in northern areas and remained above normal in many regions of the Northwest Atlantic (Figure 6). Maximum air temperature anomalies occurred on southern Baffin Island, where values were up to 1.5°C above their long-term mean. Seasonally, air temperatures in these areas were above normal in 9 out of the 12 months of 2001. Air temperature in the southern regions, St. John's Newfoundland for example, cooled slightly over 2000 values but remained above normal for 8 out of 12 months, with an annual anomaly of +0.5°C.

Sea ice on the Newfoundland and Labrador Shelves during 2001 generally appeared late and left early, resulting in a shorter duration of ice than normal. The total ice coverage in these areas during 2001 decreased slightly over conditions in 2000, remaining below average for the 4th consecutive year. 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 (1971–2000) average in 1999 through to 2001. Summer salinities, which were below normal during most of the early 1990s, returned to near normal values during 2000 but decreased again to below normal values in 2001.

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 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 near record high values. During 2001, the CIL remained below normal and on the Newfoundland Shelf it was the lowest observed in 23 years.

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 greater than 1.5°C on the Grand Bank and greater than 1°C on the southern Labrador Shelf. During 2001 mean bottom temperatures decreased over 2000 values during the spring but increased by about 0.5°C during the autumn.

In general, ocean conditions in the Northwest Atlantic during 2001 (except for the spring) warmed slightly over 2000 values thus continuing the warm trend experienced in the Northwest Atlantic during the past several years.

Figure 6. Area 2 - North West Atlantic: Newfoundland and Labrador Shelf. 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 Newfoundland and Labrador Shelves and the annual mean bottom temperatures on the Grand Bank and Hamilton Bank.

Area 2 - Northwest Atlantic: Scotian Shelf

The continental shelf off the coast of Nova Scotia is characterised by complex topography consisting of numerous offshore shallow (< 100 m) banks and deep (> 200 m) mid-shelf basins. It is separated from the southern Newfoundland Shelf by the Laurentian Channel and borders the Gulf of Maine to the southwest. The surface circulation is dominated by a general southwestward flow interrupted by clockwise movement around the banks and counter-clockwise around the basins with the strengths varying seasonally. Temperature and salinity conditions over the Shelf are largely determined by advection of water from southern Newfoundland and the Gulf of St. Lawrence as well as offshore slope waters.

In 2001, annual mean air temperatures over the Scotian Shelf were above average but have been declining from the records set in 1999 (Figure 7). These higher-than-normal values have been observed from southern Labrador to the southern Gulf of Maine. Seasonally, air temperatures from winter to summer were near their long-term (1971–2000) means but the autumn (October, November and December) in 2001 was very warm.

The amount of sea ice on the Scotian Shelf was low in 2001, conditions that have persisted for the past four years. The area and duration of ice have been increasing, however, since the minimum in 1998.

The Scotian Shelf is divided by topography into at least two separate regions. The lower layers in the north-east tend to be covered by relatively cold waters (1°C-4°C), whereas the basins in the central and south-western regions contain bottom temperatures of 8°C-10°C. The origin of the latter is the offshore slope waters whereas in the northeast their source is from the Gulf of St. Lawrence. The interannual variability of the two water masses is different. Misaine Bank temperatures at 100 m capture the changes in the northeast. Monthly mean temperatures from Misaine Bank indicate colder-than-normal conditions in 2001 after two years of above normal temperatures. These followed an extended period from 1985 to 1997 of below average temperatures. In Emerald Basin, temperatures in 2001 were slightly above average and continue a trend that has existed since the mid 1980s, except for the exceptionally cold period in 1998. The latter occurred when cold Labrador slope water replaced warm slope water at the edge of the continental shelf and subsequently penetrated onto the Scotian Shelf. The presence of the Labrador slope water was caused by an increase in the volume transport of the Labrador Current and was believed to have been a delayed response to the large decline in the NAO index in 1996.

Surface waters over the entire Scotian Shelf have been warmer and fresher than average during the past several years, including 2001. The higher temperatures are due to the warmer atmospheric conditions and the low salinities have been related to upstream influences off Newfoundland.

LINK TO AREA 2 DATA HERE

Figure 7. Area 2 - Northwest Atlantic: Scotian Shelf. Annual air temperatures at Sable Island on the Scotian Shelf, monthly means of ice area seaward of Cabot Strait and the near-bottom temperatures in the north-eastern Scotian Shelf (Misaine Bank, 100 m) and central Scotian Shelf (Emerald Basin, 250 m). The vertical line in the plot of air temperatures represents the long-term (1971–2000) average.

Area 2b - The Labrador Sea

The Labrador Sea is 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. Warm and saline waters from more southern latitudes flow northwards into the Labrador Sea on the Greenland side and become colder and fresher as they penetrate northward and eventually recirculate to the south on the Labrador 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 2000m. 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 the winter of 1994–1995, relatively warm winters have produced only shallow convection.

Since the winter of 1994–1995, mild winters (low values of the NAO index) have produced only shallow wintertime convection. During the 1999–2000 winter, winter heat loss was great enough to reverse the warming trend and overturn the surface waters to a maximum depth of about 1000m. The recent mild 2000–2001 winter saw a return to shallower winter mixed layers and a warming trend in the upper waters, but still less than the maximum observed in the summer of 1999. The upper 1000m warmed by up to 0.3°C in spring 2001 relative to the previous year. At the same time, the upper waters increased in salinity by up to 0.02, but the overall trend was to less-dense waters in the upper 1000m.

The decrease in density of the upper layers of the Labrador Sea was accompanied by a 1–2 cm rise in sea level that is also seen in satellite altimeter measurements (Figure 8). Average mid-Labrador Sea sea level was slightly above the mean for the available record beginning in late 1992.

LINK TO AREA 2B DATA HERE

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

Area 3 - Icelandic Waters

Iceland is situated at the meeting point of warm currents and cold currents on the Greenland-Scotland Ridge (Figure 9). The warm Irminger Current arrives from the south, and the East Greenland Current and the East Icelandic Current from the north. The ocean climate influences the climate of Iceland to a great extent, as well as the biological conditions in the waters around Iceland.

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

Hydrographic conditions in Icelandic waters in 2001 revealed generally favourable temperatures and salinities. The salinity of the warm water from the south continued at a relatively high level in 2001 (> 35.15), although it was slightly lower than in 1999 and 2000 (Figure 10). The inflow during 2001 of warm and saline water into North Icelandic waters was also relatively strong as in previous years (Figure 11). No trace was found of the low-saline surface layer above the warm inflow as was observed in 1996–1998. Temperature and salinity in the cold East Icelandic Current were relatively high in 2001 as in the previous two years (Figure 12). The relatively mild conditions in Icelandic waters in 2001 continued the improved conditions during the last years following the extremely cold conditions in 1995.

LINK TO AREA 3 DATA HERE

Figure 10. Area 3 - Icelandic Waters. Salinity at 100m depth in the Irminger Current south of Iceland (station Sb-5) for the period 1971–2001.

Figure 11. Area 3 - Icelandic Waters. Temperature and salinity at 50m depth in spring in north Icelandic waters (station Si-3) for the period 1952–2001.

Figure 12. Area 3 - Icelandic Waters. Mean salinity at 25m depth in the East Icelandic Current north-east of Iceland for the period 1952–2001.

Area 4 - Bay of Biscay and Eastern Atlantic

The Bay of Biscay is located in the eastern part of the North Atlantic. It is almost an adjacent sea and the general circulation, which follows the subtropical anticyclonic gyre, is relatively weak (1–2 cm/s). In the southern part of the Bay of Biscay, east flowing shelf and slope currents are common in autumn and winter due to westerly winds, whereas in spring and summer eastern winds are predominant and coastal upwelling events are frequent.

During 2001, salinity continued a progressive decline, which began in 1999 following the relative maximum in 1997–1998. By September, average salinity for the upper 300m reached its minimum value for the 9-year time series and remained at very low values until the end of the year (Figure 13). This behaviour is caused by a reduction in advection of western Iberia Peninsula waters, as a consequence of changes in the wind regime and of runoff from the major rivers.

The presence of fresher water occupying the surface layer in the region supported the formation of an anomalous sharp thermocline in summer. Despite the winter 2001 being mild in the area and summer weather conditions extended until late October, the mean temperature for the whole mixing layer remained moderate without the common autumn-winter temperature peak (Figure 13). A similar situation for both temperature and salinity has been previously observed in 1995.

LINK TO AREA 4 DATA HERE

Figure 13. Area 4 - Bay of Biscay. Potential temperature (upper figure) and salinity (lower figure) averaged over the upper 300 meters layer waters.

Area 5 - Rockall Trough

The Rockall Trough is situated west of the British Isles and separated from the Iceland Basin by the Hatton and Rockall Banks and from the Nordic Seas by the shallow (500m) Wyville-Thomson Ridge. It is one pathway by which warm North Atlantic upper water reaches the Norwegian Sea, where it 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 1200m, the deep Labrador Sea water is trapped by the shallowing topography to the north, which prevents through-flow but allows recirculation within the basin.

In 2001 the Rockall Trough began to cool and freshen slightly, following a peak in temperature and salinity in 1998–2000 (Figure 14). However both temperature and salinity remained high compared to the long-term mean, with values similar to previous peaks in the early 1980s.

LINK TO AREA 5 DATA HERE

Figure 14. Area 5 – Rockall Trough. Temperature and salinity anomalies for the upper ocean (0–800m) of the northern Rockall Trough (average across the section, seasonal cycle removed).

Area 6 – Faroe Bank Channel and Faroe Current

The North Atlantic Current sends one branch towards the Nordic Seas that crosses the Greenland-Scotland Ridge on both sides of the Faroes. The water mass transported by this flow is traditionally described as modified North Atlantic water and in the upper layers of the Faroe Bank Channel; its characteristics can be monitored before it crosses the Ridge.

Average temperature and salinity values from this layer were fairly low in the mid 1990s, but have remained almost constant since 1997 (Figure 15). A part of the modified North Atlantic water crosses the ridge between Iceland and the Faroes where it is termed the Faroe Current. Interannual changes of temperature and salinity in the core of this current are similar to those in the Faroe Bank Channel and have remained fairly constant since 1997.

LINK TO AREA 6 DATA HERE

Figure 15. Area 6 – Temperature and salinity at standard stations in the Faroe Bank Channel (southwest of Faroe – left figures) and the Faroe Current (north of Faroe – right figures). Faroe Bank Channel values are averages over the 100–300m depth layer at two stations. Faroe Current values are from the core of the current (defined as having maximum salinity averaged over a 50m depth layer). The typical seasonal variation has been removed from all curves.

Area 7 – Faroe Shetland Channel

The continental Slope Current flows along the edge of the northwest European shelf, originating in the southern Rockall Trough. It carries warm, saline Atlantic water into the Faroe Shetland Channel. A proportion of this Atlantic water crosses onto the shelf itself, and enters the North Sea, where it is diluted with coastal water, and eventually leaves that area in the Norwegian Coastal Current. The remainder enters the Norwegian Sea to become the Norwegian Atlantic Current. Cooler, less saline Atlantic water also enters the Faroe Shetland Channel from the north, after circulating around the Faroe Islands. This second branch of Atlantic water joins the waters originating in the Slope Current, and also enters the Norwegian Sea.

Atlantic water in the Slope Current is generally warming and becoming more saline (Figure 16). Temperatures have been rising from a minimum in the late 1960s at a rate of approximately 0.3°C/decade. Salinity has increased from minimum values in the mid 1970s, with the trend showing a decadal scale variability associated with the NAO. However, temperature and salinity in 2001 were similar to those in 2000.

Trends in the cooler, fresher modified Atlantic water flowing around Faroe and entering the Channel from the north are similar to those in the Atlantic water of the Slope Current (Figure 17). The warming trend is slightly less in the modified water, while the mid 1970s low salinity period was more extreme. Again conditions in this water in 2001 were similar to those in 2000.

LINK TO AREA 7 DATA HERE

Figure 16. Area 7 – Faroe Shetland Channel. Temperature and salinity anomalies in the Atlantic water in the Slope Current.

Figure 17. Area 7 – Faroe Shetland Channel. Temperature and salinity anomalies in the modified Atlantic water entering the Faroe Shetland Channel from the north after circulating around Faroe.

Areas 8 and 9 - Northern and Southern North Sea

The North Sea oceanographic conditions are determined by the inflow of saline Atlantic water mainly through the northern entrances and to a lesser degree through the English Channel. The Atlantic water mixes with run-off mainly from the continent and the lower salinity Baltic outflow along the Norwegian coast. The temperature of the North Sea is mainly controlled by local solar heating and heat exchange with the atmosphere. Both the salinity and the temperature of the North Sea reflect the influence of the NAO on the movement of Atlantic water into the North Sea and the meteorological forcing of the ocean-atmosphere heat exchange. The balance of tidal mixing and local heating force the development of seasonal stratification from April/May to September in most parts of the North Sea. Numerical model simulations show strong differences in the North Sea circulation depending on the state of the NAO.

In terms of the surface temperature of the North Sea in 2001, the area averaged mean surface temperature of 10.4°C (same as 2000) made 2001 the 6th warmest year on the record dating from 1971. Except for April and June, North Sea surface temperatures exceeded climatological monthly means at all times. The strong heating from June to July caused a persistent warm anomaly, which peaked in October and November and made these months the warmest in the time series dating from 1971 (Figure 18). In both months the surface temperature anomaly amounted to 1.4°C. Again the tendency of warmer than normal autumn surface temperature during the decade of the 1990s continued at the beginning of the new century (Figure 19).

Figure 18. Areas 8 and 9 - North Sea. Surface temperature anomalies in November 2001.

Figure 19. Areas 8 and 9 - North Sea. Annual surface temperature cycle of the area averaged North Sea surface temperature, 2000 (thin line), 2001 (thick line) and monthly climatology (symbols).

Oceanographic measurements made in summer 2001 show a lesser influence of Atlantic water in the northern North Sea and also in the Southern Bight. The surface salinity anomaly calculated as departures from the long-term monthly means for July shows differences of up to 0.5 in both areas (Figure 20). Only in the central North Sea and west of the Skagerrak was a belt of higher salinities observed. The salinity distribution in the German Bight suggested a stronger than normal run-off from the continental rivers. The Baltic outflow southwest of Norway in summer 2001 was stronger than normal resulting in negative salinity departures of up to 1.5. On the southern side of the Skagerrak the salinity was above the long-term average.

Figure 20. Areas 8 and 9 - North Sea. Surface salinity anomaly distribution, surface layer 0–10 m. Anomaly is departure from the North Sea digital data Atlas.

The long time series of the annual mean sea surface temperature and salinity at the Helgoland station showed the long-term warming of the German Bight with a pronounced decadal variability (Figure 21). The large variability in salinity did not allow a long-term trend to be determined. However, in general the year 2001 was warmer than normal and the salinity lower than average.

LINK TO AREA 8,9 DATA HERE

Figure 21. Area 9 – Southern North Sea. Annual mean surface temperature and salinity at station Helgoland Roads.

Area 9b – Baltic, Kattegat and Skagerrak

The seas around Sweden are characterised by large salinity variations. In the Skagerrak, water masses from different parts of the North Sea are present. The Kattegat is a transition area between the Baltic and the Skagerrak. The water is strongly stratified with a permanent halocline (sharp change in salinity at depth). The deep water in the Baltic proper, which enters through the Belts and the Sound, can be stagnant for long periods in the inner basins. In the relatively shallow area south of Sweden, smaller inflows pass relatively quickly and the conditions in the deep water are very variable. The surface salinity is very low in the Baltic proper and the Gulf of Bothnia. The latter area is ice covered during winter.

The effect of the high freshwater discharge to the Gulf of Bothnia in 2000 was reflected in the lower than normal values of the surface salinity in the Baltic this year (Figure 22). The trend of decreasing values of the surface salinity in this area, which has occurred since the late 1970s, thus continues. During the first half of the year the river runoff to the west coast of Sweden was unusually large. The changes in surface salinity were in evidence mainly at the coastal stations. In the late autumn of 2001 deep-water inflows of comparatively high salinity took place through the Sound and the Belts. The surface temperatures were generally higher than normal during the first part of the summer (Figure 23). In the Baltic, high values were also found during the beginning of the year, and these continued the warm period that occurred at the end of 2000.

LINK TO AREA 9B DATA HERE

Figure 22. Area 9b –Surface temperature and salinity in the Gulf of Bothnia (coastal station BY15 – upper figures), Fladen (Kattegat – central figures) and Skagerrak (lower figures). Mean values (from the period 1986–1995) are shown (solid lines) as well as associated standard deviations (dashed lines) and values for 2001 (symbols).

Figure 23. Area 9b – Baltic. Annual mean surface salinity east of Gotland.

Area 10 - Norwegian Sea

The Norwegian Sea is characterised by warm Atlantic water on the eastern side and cold Arctic water on the western side. The border zone between these two water masses is known as the Arctic Front. Atlantic water enters the Norwegian Sea through the Faroe Shetland Channel and modified Atlantic water enters between the Faroes and Iceland, flowing eastward along the Iceland Faroe Front, into the Norwegian Sea. A smaller branch, the North Icelandic Irminger Current, enters the Nordic Seas on the western side of Iceland. The Atlantic water that flows northward along Norway as the Norwegian Atlantic Current splits when it reaches northern Norway. One part enters the Barents Sea while the other part continues northward into the Arctic Ocean as the West Spitsbergen Current. Arctic waters are transported into the Norwegian Sea from the southward flowing East Greenland Current mainly via the East Icelandic and Jan Mayen Currents. Fluctuations in fluxes and water-mass properties in this current system are of decisive importance for the distribution and structure of the water masses in the Norwegian Sea.

In the southern Norwegian Sea there is a long-term trend towards higher temperature in the Atlantic Water. The temperature has increased since 1981 by 0.3°C. In 1997–1999 the temperature was the highest observed in the time series, but in 2000 it fell considerably followed by approximately the same value in 2001. The area occupied by Atlantic water has shown a long-term decrease. However, since the mid 1990s there has been a positive trend and in 2001 the area had the largest value since 1991.

Over the slope, east in the Norwegian Sea, a warming has taken place since 1996 (Figure 24). In 2001 the warming continued in the central (69°N) and northern section (76°N) while a cooling occurred in the southern section (63°N). The northern section has long-term trends toward higher temperature and lower salinity. Since 1996 the temperature in that section has been below the long-term average, except for 2001 when it reached that level.

LINK TO AREA 10 DATA HERE

Figure 24. Area 10 – Norwegian Sea. Average temperature and salinity above the slope at three sections, Svinøy (approx. 63°N – upper figures), Gimsøy (approx. 69°N – central figures) and Sørkapp (approx. 76°N – lower figures), representing the southern, central and northern Norwegian Sea.

Area 11 - Barents Sea

The Barents Sea is a shelf sea, receiving an inflow of warm 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. Regular measurements of the magnitude of the Atlantic inflow to the Barents Sea started in 1997. The first half of 2001 had the lowest inflow ever observed for that period.

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 25), while the temperature in the eastern areas stayed below the average during 1998 (Figure 26). 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, and the temperature has stayed above average since then.

The temperature in the western Barents Sea was more than 0.5°C above the long-term mean during the first half of 2001. During the second half, the temperature decreased gradually, and at the end of the year the temperature was only 0.1°C above the average. In the eastern Barents Sea, the temperature has been relatively higher through the entire year than in the western areas. In the beginning of 2000, the temperature was 0.9°C higher than the average but there was also a gradual decrease to 0.3°C above the mean at the end of the year. The annual mean temperature for the eastern Barents Sea was 0.6°C above the average. As a consequence of the relatively high temperatures, the Barents Sea had the best ice conditions since satellite observations started in 1970. It is expected that 2002 will have lower temperatures than 2001.

LINK TO AREA 11 DATA HERE

Figure 25. Area 11 – western Barents Sea. Temperature anomalies and area of Atlantic inflow through the section Norway-Bear Island in the western Barents Sea

Figure 26. Area 11 – eastern Barents Sea. Temperature and salinity anomalies in the Kola section (0–200 m).

Area 12 - Greenland Sea

The Greenland Sea and its northern border, the Fram Strait, form one of the pathways which the Atlantic water takes before entering the Arctic Ocean. Part of the Atlantic water also recirculates within Fram Strait and returns towards the south in the East Greenland Current. Besides the advection, water mass modification such as deep water renewal, determine the hydrographic conditions in the region.

At the eastern side of the Greenland Sea, within the West Spitsbergen Current, the Atlantic water along 75°N (between 10°E and 13°E and in 50–150m depth) was colder in summer 2001 (3.90°C) than in the previous summer (3.98°C). This was the lowest value in the time series, which started in 1989. The salinity of this area was the same in the summer of 2001 as in the previous summer (35.08).

The returning Atlantic water on the western side of the Greenland Sea, characterized by the temperature and salinity maxima below 500m averaged over three stations west of 11.5°W along 75°N, was slightly colder (2.04°C instead of 2.06°C) and more saline (34.97 instead of 34.96) in summer 2001 than in the previous summer.

The subsurface conditions in the centre of the Greenland Sea (between 5°W and 3°E along 75°N) below 300m depth (and more than 300m above the intermediate temperature maximum) underwent an increase in temperature and salinity between summer 2000 and summer 2001. Despite this increase, moored deep-sea profilers found an average ventilation depth of 800m in the central Greenland Sea during the winter of 2000–2001. Further hydrographic measurements also suggested that during the winter 2000–2001 the ventilation reached down to 2500m depth in isolated areas, with diameters of about 10km.

Further north, within the Fram Strait (ca. 79°N), temperatures and salinities were higher in summer 2001 than in the previous summer in all three surveyed areas (West Spitsbergen Current between 3°E and eastern shelf edge, returning Atlantic water between 3°W and 5°E and East Greenland Current between the western shelf edge and 3°W) and at both depth intervals (5–30m and 50–500m). Nevertheless, the values stayed in the usual range without forming any obvious trend (Figures 27, 28 and 29).

LINK TO AREA 12 DATA HERE

Figure 27. Area 12 – Greenland Sea. Temperature and salinity in the returning Atlantic water in the East Greenland Current (left figures) and the Atlantic water in the West Spitsbergen Current (right figures) at 75°N.

Figure 28. Area 12 – central Greenland Sea. Temperature and salinity in the central Greenland Sea.

Figure 29. Area 12 – northern Greenland Sea. Temperature and salinity at 50–500m depth in the Fram Strait. Upper figures are the West Spitsbergen Current, central figures are the returning Atlantic water and lower figures are the East Greenland Current.

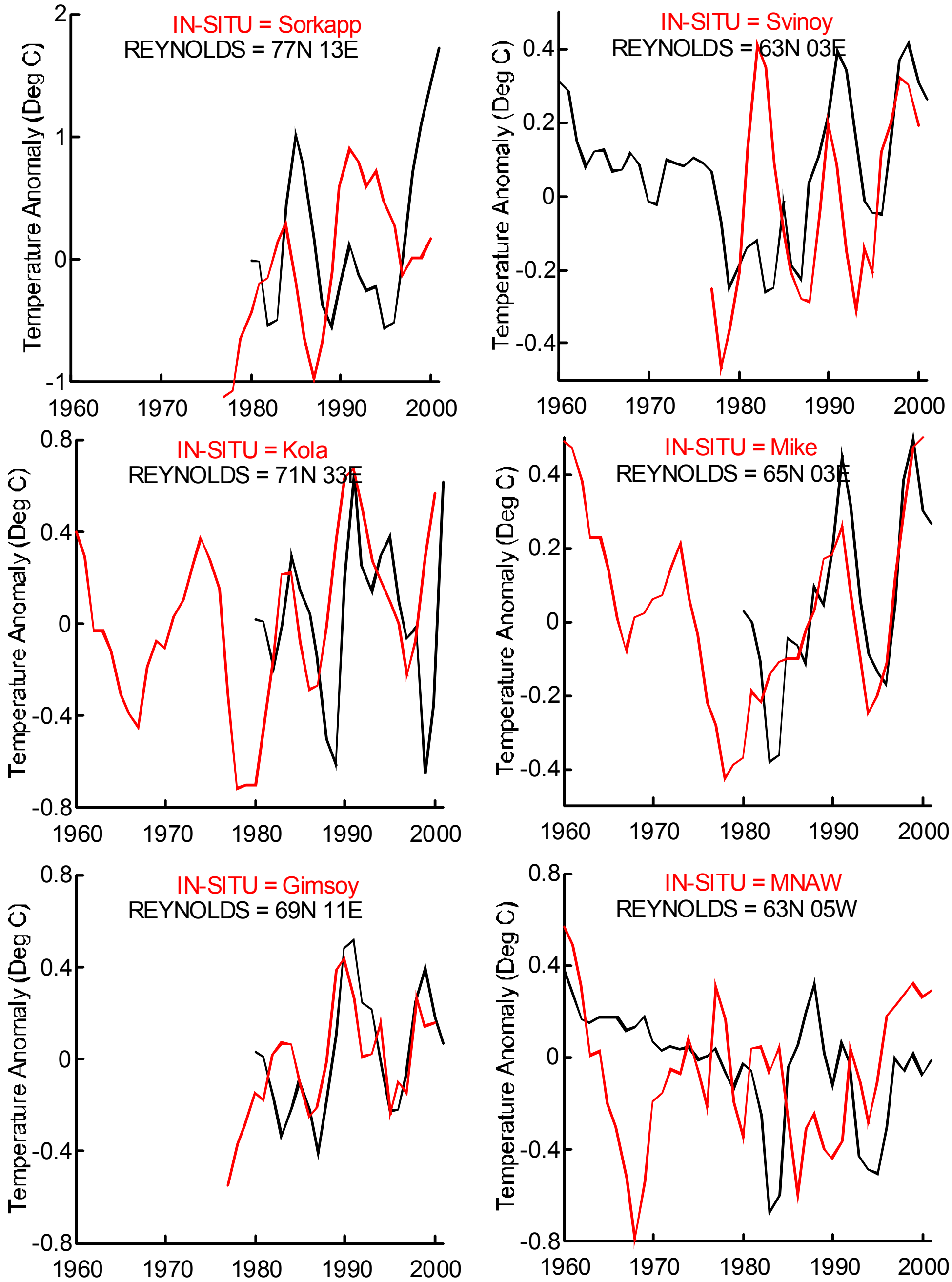
ANNEX V: COMPARISON BETWEEN ICES WGOH *IN SITU* DATA AND THE REYNOLDS SST DATA SET

The graphs below present a comparison between the *in situ* temperature data, as reported by members of the WGOH at each annual meeting, and the Reynolds SST data set.

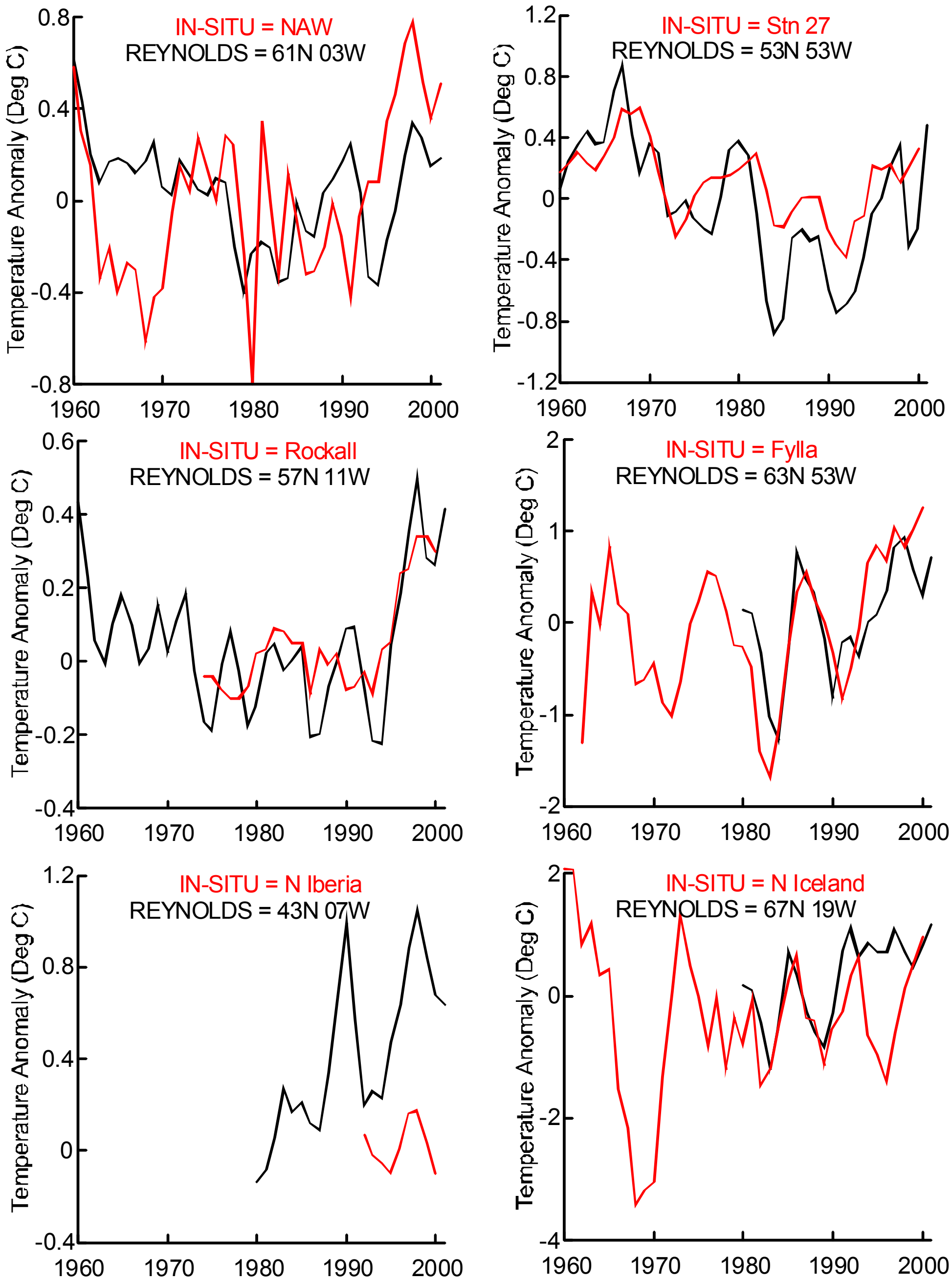
In situ: Data varies between sources. Most are derived from survey data, with surveys at least three times per year. Some sites (e.g., Mike, Kola, Stn 27) are more frequent. Most are averaged over a set depth range rather than just SST. Seasonality has been removed by contributors in various ways, and given as annual anomalies. These have then been filtered with a three-year running mean.

Reynolds: From DODS web site: "A new interpolation method was developed using empirical orthogonal functions (EOFs) to produce *in situ* analyses of SSTs from 1950–1981. The first step was to produce the spatial EOFs from the optimum interpolation (OI) analyses of Reynolds and Smith (1994). The dominant EOF modes were used as basis functions and were fitted to the *in situ* data for the period 1950–1992 to determine the time dependence of each mode. A global field of SSTs was then reconstructed from these spatial and temporal modes. For details of the EOF reconstruction method see Reynolds *et al.* (1995) and Smith *et al.* (1995). All fields were computed on the COADS 2-degree grid. All reconstructed fields were computed as anomalies. However, because of limited *in situ* data, the reconstructed anomalies were only computed from 45S to 69N with some missing values in the North (see Figure A.V.2 in Smith *et al.*, 1995). To produce the mean presented here, the anomaly was added to the climatology after multiplying the anomaly by weights. The weights were 1 over defined ocean areas, otherwise 0. To provide a smoother transition between defined and undefined open ocean areas, the weights along these open ocean boundaries were set to 0.5 (e.g., at 45S). In addition any SST mean value less than -1.8C was set to -1.8C. The original Reynolds reconstructed SST data is available from NOAA, Climate Diagnostics Centre. See the Reynolds SST page at: http://www.cdc.noaa.gov/cdc/data.reynolds_sst.html"

The Reynolds data has had monthly means (1961–1990) removed, and then the same three-year running mean applied.



IN-SITU = Sorkapp
REYNOLDS = 77N 13E
IN-SITU = Svinoy
REYNOLDS = 63N 03E
IN-SITU = Kola
REYNOLDS = 71N 33E
IN-SITU = Mike
REYNOLDS = 65N 03E
IN-SITU = Gimsoy
REYNOLDS = 69N 11E
IN-SITU = MNAW
REYNOLDS = 63N 05W
Temperature Anomaly (Deg C)
1960
1970
1980
1990
2000


IN-SITU = NAW
REYNOLDS = 61N 03W
IN-SITU = Stn 27
REYNOLDS = 53N 53W
IN-SITU = Rockall
REYNOLDS = 57N 11W
IN-SITU = Fylla
REYNOLDS = 63N 53W
IN-SITU = N Iberia
REYNOLDS = 43N 07W
IN-SITU = N Iceland
REYNOLDS = 67N 19W
Temperature Anomaly (Deg C)

ANNEX W: A POSSIBLE US CONTRIBUTION TO THE IAOCSS

Tom Rossby

Graduate School of Oceanography, University of Rhode Island.

When the WGOH asked whether there were any 'standard sections' that the US might include in the annual surveys, it made me wonder why we haven't been reporting the XBT sections that are taken monthly from a container vessel in transit between New Jersey and Bermuda (NJ-Bda). Although it is not a hydrographic section, it does include surface salts and these are quite interesting. I will discuss with the people in charge of the XBT work whether they would mind including the XBT sections in an annual report; I think it would be a good idea. There has been considerable discussion about recent changes (trends?) in the faunal make-up of the waters in the mid-Atlantic bight. (To the best of my knowledge we take no standard hydrographic sections here in the northeast, but will check with the NMFS.)

We have worked a bit with the historical data from the NJ-Bda section, and I include some figures below. These types of Hovmöller (time-distance) plots of temperature, salt and other derived properties might be an effective way to look for patterns in other repeat hydrographic sections we discuss. I am thinking particularly of those that are repeated several times in the course of the year, such as the 100 year long Kola section, those around the Iberian Peninsula and the many repeat sections around Iceland and the Faroes.

The top panel in Figure 1 shows salt at the surface from 1977 to the present. No special equipment was involved; all salts were taken at the surface while the vessel was underway. The data are collected on a monthly schedule and are averaged into bins 20 km x 1 month (no smoothing). The Gulf Stream was not included in this sampling program (alas), but the northern edge of it shows up at the very bottom of the panel where salinities >36 PSU. The bottom panel shows the anomaly of salt after removal of the observed annual cycle for each 20 km bin. On sees striking low frequency variations in surface salinity that are highly coherent across the entire Slope Sea and continental shelf, i.e., all waters north of the Gulf Stream which shows up as the highly saline waters at maximum range from New Jersey. The shelf break is located at about 200 km.

If anyone is interested, I would be happy to send the Matlab code that was used to generate these figures. All you would need to do is assemble your data into a suitable matrix. Bob Benway at the National Marine fisheries Service has played a major role in keeping this program going for all these years. He and I wrote a note in GRL about what might be causing the salinity variations in Figure A.W.1 and the slow variations in the mean path of the Gulf Stream in Figure A.W.2. It was published in January 2000.

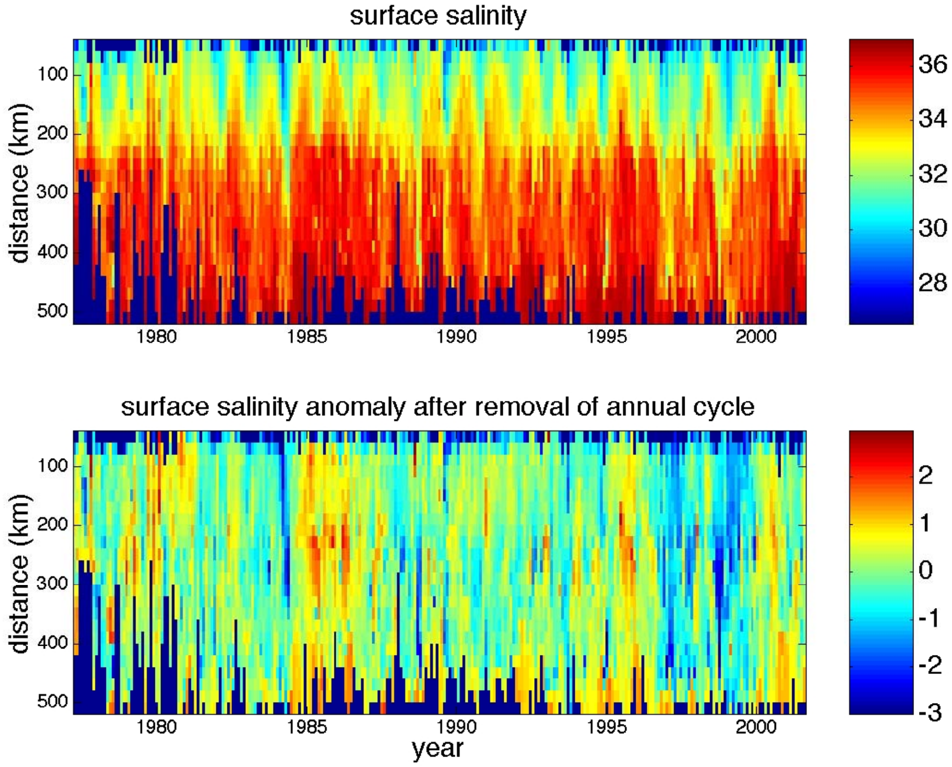


Figure A.W.1.

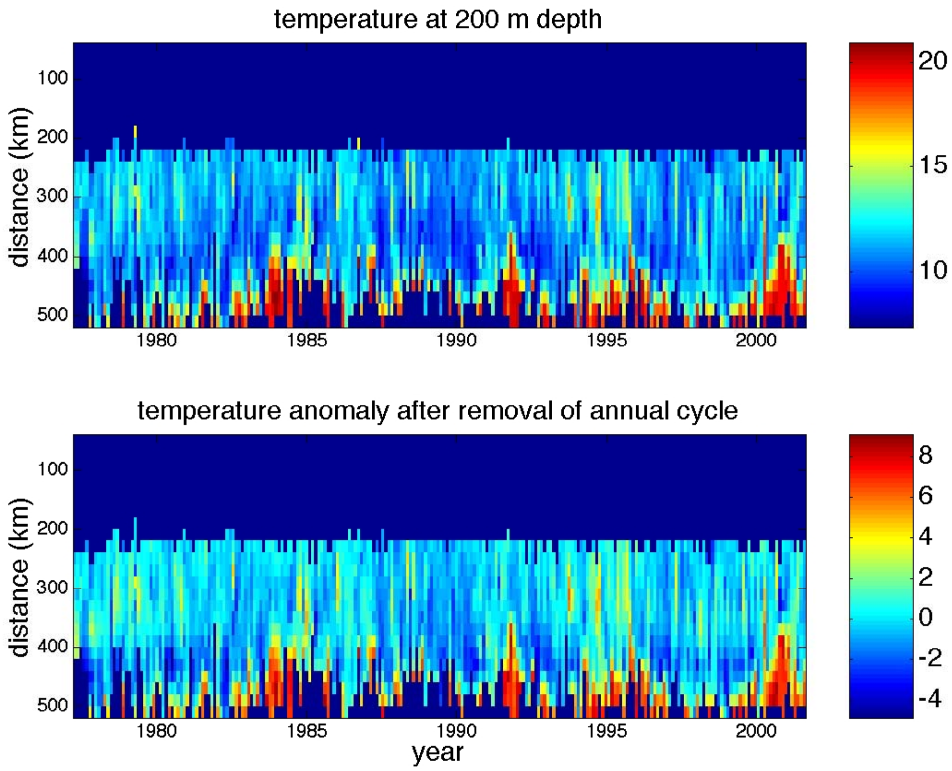


Figure A.W.2

ANNEX X: TIMETABLE OF DATES AND DEADLINES OF ASOF-RELATED PROGRAMMES

The following timetables list the initial dates and deadlines of ASOF and ASOF-related programmes.

European Union

Mid-October 2001	Last call EC Framework Programme 5
December 2001	3-part ASOF-EC cluster bid awarded GO rating
Feb 2002	Funding confirmation expected from FP-5 programme Committee
March 2002	Contract negotiation stage begins
Early summer 2002?	ASOF-EC programme begins under FP-5
March-June 2002	PI discussions begin on possible Large Scale Integrated Programmes bid as a successor ASOF project under EC FP-6.
June 2002	Deadline for receipt of Expressions of Interest for Large Integrated Programmes, EC Framework Programme 6, 2002–2006
Summer 2004	End of ASOF-EC project of FP-5

US National Science Foundation - Arctic Hydrology

February 2002	Program solicitation by NSF OPP (NSF-02–071) for proposals on Arctic Freshwater Cycle: land/upper-ocean linkages; $30M 5 years, SEARCH-ASOF.
3 June 2002	Full proposal deadline at NSF

UK NERC Rapid Climate Change Thematic Program

17 January 2002	1st science AO and monitoring system AO announced
1 Feb 2002	Town Meeting
28 March 2002	Closing date for outline bids
30 April 2002	SC meets to assess outline bids
Early-mid may 2002	Feedback to applicants
15 July 2002	Closing date for full bids
Mid-Nov 2002	Assessment meeting (SC + coopted PRC)
Early 2004	Second AO
TBD	Third AO

Norway NOClim Program Implementation

5–7 December 2001:	All Staff Fall meeting
11 March 2002:	Scientific Steering Group(SSG)-meeting
15 April 2002:	closing date registration NOClim Science meeting 2002
13–15 May 2002:	NOClim Science meeting 2002 (Gardermoen, Oslo)
20 June 2002:	SSG-meeting
15 August 2002:	closing date for bid for NOClim II (to be confirmed)
31 December 2002:	End of NOClim
1 January 2003 – 31 December 2004:	Possible NOClim II

ASOF Next outputs

ASOF Summary Implementation Plan	ASSW Groningen April 2002
ASOF Brochure	April-June 2002
ASOF Data & Data-access Plan	Post 2nd ISSG Mtg Hamburg, ∴Oct-Dec 2002
1st Circumarctic ASOF Assessment	Late 2003

ANNEX Y: A PROPOSAL TO THE ICES WGOH FOR SAMPLING AND LONG-TERM STORING OF WATER FOR FUTURE TRACER ANALYSIS

At the Faroese Fisheries Laboratory, we have recently initiated a routine where we on each of our quarter-annual standard cruises sample water from a few key- locations and depths for permanent storing. The inspiration for doing this was recent developments in the iodine isotope analysis. This technique offers great promise in distinguishing between water masses of different origins in some areas and it can be applied to small-volume samples collected and stored like conventional salinity samples. At present, the analysis of each sample is costly, but that may change, funds may become more available, and analytical techniques for other tracers may improve.

Whenever the technical and financial conditions for analysing a certain tracer in an area are met, the main problem will be samples, and usually, you will want a time series of the tracer concentration in each area or water mass. This is especially important when the tracer has a pulse-like or variable source function. Often, you will, however, only realise the utility of these samples long afterwards. This has been our motivation for initiating this procedure. The fact that no special sample preparation or preservation is carried out will, of course, limit the utility, but, as demonstrated by the iodine example, important parameters can still be determined. We expect future technical developments to increase the utility.

In our procedure, we have decided to sample water from two standard stations, one in the Faroe Bank Channel and one north of the Faroes. At each location, we sample from two depths in order to sample four different water masses. From each depth we draw four samples from a 5-liter Niskin bottle for long-term storage. From the same bottle, we draw two additional samples for immediate salinity analysis. This information, together with the CTD data from the sample, is stored with the samples.

At present, we have no specific plans for analysis of these samples, but with very little extra manpower and expenses, we obtain samples that we believe to have large future potential. We propose that other laboratories that run standard cruises, consider a similar procedure.

Bogi Hansen, Tórshavn, 8 March 2002

ANNEX Z: A PROPOSAL TO THE ICES WGOH FOR ISOPYCNAL MELDING OF HYDROGRAPHIC SURVEYS

The hydrographic database for the North Atlantic and Nordic Seas is enormous reflecting the many surveys that have been taken over the last 100 years. Given that most surveys consist of individual sections, it is quite natural that one should focus on the vertical structure of these and examine their evolution over time. Significant changes to the hydrographic make-up of the region have taken place over the years, but it is not always easy to quantify these because the data sets may come from slightly different regions, with different sampling densities, and with survey patterns dictated by the particular requirements of a project. So the question then arises how best to examine these data sets to search for and chart patterns of change in a systematic way. A method that allows for the consistent presentation and intercomparison of observations wherever they come from is to plot the observations on isopycnal surfaces. More specifically, we suggest the construction of a climatology of temperature and salt for a few key isoycnal surfaces. This climatology will define a 'mean state'. As new data for a given time window become available, changes in the hydrographic state of the region should show up clearly by plotting the departure of the observations from this climatology.

Waters move around the ocean along isopycnal surfaces, in response to the forces acting on the fluid. In some areas these motions may be relatively simple, perhaps reflecting a constraint imposed by topography, whereas in other areas more complex eddy motions might dominate, perhaps due to instabilities along fronts. Vertical movement consists of two parts, displacements due to the heaving of isopycnals, which is substantial, and motions due to diapycnal mixing. The latter, so far as we know, is quite small except in the presence of convection. As a result fluid parcels undergo three-dimensional, time-dependent trajectories, but their physical properties change only gradually since they are constrained to move and mix along surfaces, and not between surfaces. It is the vertical motions that tend to dominate the variability one sees in section plots of hydrographic data. The properties on the isopycnals, on the other hand, tend to be much more stable. Thus, an efficient way to display hydrographic information is to show the depths of the isopycnals as a first indication of the dynamic state of the system, and to show properties, such as temperature and oxygen, as a function of sigma-theta or specific volume anomaly to determine the hydrographic state of the system. This has become an increasingly common mode of data presentation in the literature. But we can take the process one step further, particularly for areas with extensive spatial and temporal coverage.

We propose to create a base climatology for the depth (pressure) and properties of chosen key isopycnals. This base state will define the properties of a region for the period in question. Given this climatology, surveys for a given period can then plot their properties relative to this 'base' state. This provides a framework for coherent use and melding of observations from separate surveys. Such a climatology would consist of two parts, maps showing the mean pressures of a given sigma-theta surface, and the properties on that surface. These will be relatively smooth fields as a result of all the data used to construct it. The observations would be binned into regions as small as possible consistent with data availability. This gives essentially equal weight to all regions included in the climatology. These bin-averages would then be mapped to map create the climatology. For the surfaces chosen, we would have pressure, temperature, salt, oxygen and any other property of interest (stratification, nutrients, and the variances of all).

To test the above ideas I propose that we conduct a pilot study of the Norwegian-Greenland Sea along the above lines. After an initial study to select a couple of isopycnals, one to represent the inflow of Atlantic Waters, and another to tag the spreading Arctic Intermediate Waters, I (in collaboration with anyone who might be interested in taking part) will take all available hydrographic station data and compute the pressure and properties on these isopycnals. We will not ask for all data, and in fact we would prefer that various groups prepare these subsampled data sets directly from their own archives. Each Nansen cast consists of samples of temperature and salinity as a function of pressure. We propose that the pressure and properties for a given surface be obtained by linear interpolation between adjacent bottles. The resulting data files would consist of location, time, Nx(pressure, temperature, salt, oxygen?) where N represents the number of sigma-t surfaces to be mapped. These will become the input data to the geographic binning process.

The objective here will be to construction the 'base' climatology which would consist of the mean pressure of the selected isopycnals and the mean properties on those surfaces. Once these are ready, we can look for anomalies that might exist for certain periods or in certain areas by the appropriate subdivision of the data. This framework emphasizes the horizontal dimension: The depth of the isopycnal surface - which is of dynamical interest - and the properties on that surface - which tells us about the movement of water mass anomalies. The latter may have a stronger signature since many times T and S anomalies tend to cancel such that the dynamical impact is minor.

If these data sets could be prepared over the next six months, I think the remaining step of preparing the mean state of these surfaces can be prepared quite quickly and made available to the WGOH members, and other interested parties. The expectation is that we would report on this effort at the next WGOH meeting in Bergen. Hopefully, by making the climatology available in good time, we could coordinate this year's surveys to look for developing patterns in time for next year's report.