ICES WGOH REPORT 2005

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REPORT OF THE WORKING GROUP ON OCEANIC HYDROGRAPHY (WGOH)

11-14 APRIL 2005

NARRAGANSETT, USA

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Conseil International pour l'Exploration de la Mer

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Executive Summary

- In almost all areas of both the eastern and western North Atlantic during 2004, temperature and salinity in the upper layers remained higher than the long-term average, with new records set in numerous regions. There was isolated cooling off the eastern North American coast.
- Recognising that climate change is of international concern, the WGOH strongly recommends that the Oceanography Committee and ACME should encourage the measurements of standard physical oceanography parameters in the Co-ordinated Environmental Monitoring Programme (CEMP) of the OSPAR Convention for the Protection of the Marine Environment of the North-East Atlantic. The WGOH make a number of related recommendations in this report. WGOH suggests that OCC could help better coordinate ongoing national monitoring activities within OSPAR to optimize the cost/benefit.
- The WGOH supports ICES in moving towards integrated assessments (Ecosystem Approach), but note increasing gaps between the requests for certain physical oceanography data sets/oceanographic knowledge and data available from monitoring activities. The constant need for oceanographic data as part of the overall description of the marine ecosystem should be more reflected in OSPAR`s CEMP
- The WGOH noted ongoing activities within OSPAR and its Working Group on Concentrations, Trends and Effects of Substances in the Marine Environment (SIME) as part of a review of the role of physical oceanography in the framework of the revised CEMP. It is suggested that OCC contact ACE/ACME and the Secretariat to explore OSPAR`s interest to cooperate closer with ICES/OHWG regarding the monitoring of supporting environmental factors in the ICES region. The OCC is asked to express their interest to better coordinate the ongoing national monitoring activities to optimize the cost/benefit.
- The WGOH agree that for ecosystem assessment, a regional approach is necessary, but it is still necessary to understand regional climate in the context of the wider North Atlantic. In this context. WGOH requests that ICES continue its efforts to ensure that the IAOCSS is widely distributed.
- The WGOH found that responding to ToR F related to the Regional Ecosystem Study Group for the North Sea (REGNS) assessment process required commitment of considerable time and resources. The WGOH acknowledges that this is a pilot project but would request that REGNS consider the sustainability of this approach and look at ways to provide additional support, including national funding routes that could be employed to make the work more practicable in future.
- The WGOH keenly felt that active participation in the WG by France should be encouraged. In particular, France is active in the study of eastern boundary conditions and the salinity distribution in the North Atlantic, and the IAOCSS would benefit from input in these areas.
- The WGOH noted that acoustic Doppler current profilers on commercial vessels in regular traffic offer exceptional opportunities for monitoring variability of upper ocean currents over a wide range of time scales and encourages the promotion of such systems in existing vessels and in new construction wherever practicable.
- The WGOH requests that ICES consider supporting the publication of an issue of CLIVAR Exchanges dedicated to WGOH-related activities.

1 Opening of the WGOH meeting

The WGOH were warmly welcomed to the Narragansset Bay Campus, Graduate School of Oceanography, University of Rhode Island, by the Dean of the Graduate School, David Farmer. The meeting then started with presentation of the national reports.

National reports were presented on the first day of the meeting; summaries were collated to form the 2004 ICES Annual Ocean Climate Status Summary (IAOCSS). The 2004 IAOCSS was reviewed and approved by the WGOH. This will be made available on the ICES website and on the WGOH website hosted by National Oceanography Centre, Southampton (http://www.noc.soton.ac.uk/JRD/ICES_WGOH/index.php).

2 Mini-symposium

Following a recommendation made at the 2001 Reykjavik WG meeting, a mini-symposium was held. The mini-symposium was chaired by Tom Rossby (USA) from the Graduate School of Oceanography, University of Rhode Island on the second day of the meeting abstracts of the talks are presented as Annex 4.

This is the fourth year that the WGOH meeting has included a day of scientific presentations, jointly by members of the WGOH, and by scientists from the host organisation. The mini-symposium offers an opportunity for working group members to learn about the work of scientists in the host institute. The WG recommends that a mini-symposium be included in the 2006 meeting to be arranged and hosted by the Marine Institute, Galway, Ireland.

The Agenda of the symposium ran as follows:

1) Kathy Donohue: Exploratory Study of Deep Water Currents in the Gulf of Mexico.
2) Tom Rossby: Some remarks on interannual variations in Gulf Stream and coastal transports.
3) David Mountain: Variability in the Gulf of Maine – External Forcing Influencing Local Processes.
4) Percy Donaghay: Challenges in assessing thin layer dynamics and transport.
5) Ed Durbin Biological response to external fording on Georges Bank.
6) Ross Hendry and Allyn Clarke: Argo float observations of the seasonal evolution of the Labrador Sea 2004–2005.
7) Robert Pickart: Circulation on the East Greenland shelf and slope: Some new observations.
8) César Gonzalez-Pola, Alicia Lavín and Manuel Vargas Intense warming and salinity modification of intermediate water masses in the Southern Bay of Biscay.
9) Victoriano Valencia, Almudena Fontán, and Ángel Borja: Salinity and freshwater input into the SE Bay of Biscay based in the Gironde river flow.
10) Bronwyn Cahill: Seasonal variability in the Western Irish Shelf ecosystem.
11) Elizabeth Hawker and S. Bacon: Circulation and fluxes in the Nordic Seas.
12) Vladimir Ozhigin, T. Rossby and S. Bacon: Isopycnal analyses of the Nordic Seas.
13) Agnieszka Beszczynska-Möller, U. Schauer, and E. Fachrbach: Warming events in Fram Strait.
14) Waldemar Walczowski: Transports of West Spitsbergen Current as measured by vessel- mounted ADCP, lowered ADCP and calculated from hydrography.

Abstracts from the mini-symposium are included in Annex 4 of this report.

3 Review of membership

The list of participants of WGOH is attached as Annex 2. Attendance at the meeting was lower than usual. A number of members had expressed apologies for not being able to attend.

The membership of the group was discussed, and it was noted that some members had never attended a meeting. The WGOH has about 40 members, but typically only about 20 or fewer attend the WGOH meeting for any particular year. However, as long as members submit data to the WGOH, and all the key areas are represented at the meeting, the work of compiling the IAOCSS can be done with this number - In fact a larger attendance may even make the work more difficult to manage. The list of members is presented as Annex 3.

Agnieszka Beszczynska-Möller attended the meeting, nominated by the Chair as a member from Germany. The WGOH welcomes the new rule on open recruitment to ICES Expert Groups parented by a Science Committee.

There has been cooperation with the French ICES Delegates in order to assure participation of French national oceanographers at WGOH. WGOH feels that regular representation from France at the annual meeting is highly valuable.

4 Update and review of results from standard sections and stations (ToR a)

Each Member Country/institute of the WGOH presented their national reports to the group. Some of the national reports are short and can be summarised in the ICES Annual Ocean Climate Status Summary. Other national reports contain more specific, regional details. Summaries of these reports are included in the IAOCSS and the full text is included in Annexes 5 to 14.

Annex 5: Climatic conditions off West Greenland – 2004 (Area 1)

M. Stein, Institute for Sea Fisheries, Hamburg, Federal Republic of Germany.

Annex 6: Environmental conditions in the Northwest Atlantic during 2004 (Area 2)

E. Colbourne, Fisheries and Oceans Canada, St. John's, Newfoundland, Canada.

Annex 7: Environmental conditions in the Labrador Sea 2004 (Area 2b)

R.M. Hendry, Fisheries and Oceans Canada, Bedford Institute of Oceanography, Dartmouth, Canada.

Annex 8: Hydrographic status report 2004: Spanish standard sections (Area 4).

A: A.Lavín, C. González-Pola and J. M. Cabanas, Spanish Institute of Oceanography (IEO), Spain. B: V. Valencia, A. Fontán and A. Borja, Department of Oceanography and Marine Environment (AZTI Foundation, Spain).

Annex 9: Oceanographic status report for the North Sea (Area 8 and 9)

P. Loewe and G. Becker, Federal Maritime and Hydrographic Agency of Germany (BSH), Hamburg, Germany.

Annex 10: Area 9B: Skagerrak, Kattegat and the Baltic

K. Borenas, Swedish Meteorological and Hydrological Institute, Sweden

Annex 11: Norwegian waters (Areas 8, 10, and 11)

H. Loeng, K.A. Mork and E. Svendsen, Institute of Marine Research, Bergen, Norway

Annex 12: Russian standard sections in the Barents Sea (Area 11)

V.Ozhigin, Knipovich Polar Research Institute of Marine Fisheries and Oceanography (PINRO), Murmansk, Russia

Annex 13: Polish national report (Area 10, 11, and 12)

W. Walczowski , J. Piechura, Institute of Oceanology, Polish Academy of Sciences, Sopot, Poland.

Annex 14: Hydrographic conditions in the Greenland Sea and the Fram Strait (Area 12)

A. Beszczyńska-Möller, G. Budeus, E. Fahrbach, U. Schauer and A. Wisotzki, Alfred Wegener Institute for Polar and Marine Research, Bremerhaven, Germany.

5 Consolidation of Member Country inputs into the ICES Annual Ocean Climate Status Summary (ToR B)

The national contributions are summarised to provide input to the ICES Annual Ocean Climate Status Summary (IAOCSS). The draft 2004/2005 ICES Annual Ocean Climate Status Summary (IAOCSS) was prepared and reviewed and approved by the Working Group. Sarah Hughes (UK) must be thanked for helping prepare the 2003/2004 IAOCSS. The IAOCSS was published in August 2004 as an *ICES Cooperative Research Report.*

The WG wish to see the IAOCSS distributed widely within ICES and will send an electronic copy of the report to all the chairs of ICES WGs and Committees as soon as it is complete (Chair). The email should ask recipients for feedback on the content of the report and suggestions for improvements. Members are also encouraged to email the document to colleagues and students. It was also suggested that the IAOCSS be featured as a news item on the ICES website each year (Secretariat). WGOH members attending the meeting also requested that they receive a paper copy of the IAOCSS. A poster promoting the IAOCSS will be prepared and submitted to the Euro-GOOS conference in Brest 2005.

The WGOH discussed improvements and developments to this report. Sarah Hughes (UK) presented maps created using a gridded sea surface temperature (SST) dataset. These data can provide an overview of SST anomalies over the whole North Atlantic area, and are thought to be a useful complement to the timeseries data. It should be noted that although the dataset appears to have complete coverage of the North Atlantic, much of this data is interpolated. The dataset can only be as good as the source data (in-situ and satellite data) and so is likely to be less accurate in some areas, particularly northern latitudes where in-situ data are sparse and the coverage of satellite data is reduced by cloud cover. Members agreed to assess the gridded SST dataset against data available in their own regions. It was agreed that the maps would be included in the 2005 report and a more thorough assessment of their reliability be made before the 2006 meeting.

Sheldon Bacon (UK) presented his ideas for new developments to the IAOCSS. At present datasets are presented by designated areas some of which include from more than one member state. Sheldon proposed taking a more thematic approach, linking up groups of regions based on circulation patterns and common atmospheric forcing. The aim of this re-organisation would be to improve the analysis of patterns and trends and perhaps allow prediction of future conditions in linked areas. It was recognized that this would require an additional commitment by WG members.

The WGOH discussed the usefulness of the IAOCSS to other groups within ICES and beyond. It was agreed that it would be helpful to collect a list of publications that have cited the IAOCSS and to insert a primer into the text to ensure that users referenced the IAOCSS in a consistent manner.

The WGOH keenly felt that participation by France would improve the status report's coverage of Eastern boundary conditions and salinity distribution in the North Atlantic, ,areas in which France is active. The WGOH emphasise the necessity of French participation in the proposed ToR for 2006 presented below.

The 2004/2005 ICES Annual Ocean Climate Status Summary – Overview

In almost all areas of both the eastern and western North Atlantic during 2004, temperature and salinity in the upper layers remained higher than the long-term average, with new records set in numerous regions. There was isolated cooling off the eastern North American coast.

The North Atlantic Oscillation (NAO) index during the winter of 2004 was negative, but both the Iceland Low and the Azores High weakened. A mid-latitude low pressure anomaly associated with the reduced Azores High was stronger in the west, resulting in pressure anomaly patterns over the western Atlantic consistent with a strongly negative NAO.

6 Review national monitoring programmes and OSPARs Coordinated Environmental Monitoring Programme (CEMP), in order to improve climate monitoring activities (ToR C)

The WGOH reviewed the role of physical oceanography in national monitoring programmes with specific attention to OSPAR's Coordinated Environmental Monitoring Programme (CEMP). It was generally agreed that physical oceanography needs to be incorporated as a basic component of such programmes to allow a truly integrated approach to ecosystem management. It was felt that that physical oceanography has too low a profile in many such programmes. In CEMP in particular, the WGOH discussed the contradiction between OSPARs goal to carry out co-ordinated environmental monitoring activities (CEMP) without having any comprehensive strategy to monitor the physical environment. For example, a plan to monitor dissolved oxygen content, stratification, and advection is a necessary part of OSPAR`s goal to conduct baseline and follow-up thematic and holistic assessments of the quality status of the OSPAR maritime area.

The WGOH supports the specification and execution of OSPAR`s information collection programmes. However, the WG feels that these have to be developed further or adopted to make available and sustain all kind of data for the holistic assessments, including oceanographic monitoring data.

The WGOH supports ICES in moving towards integrated assessments (Ecosystem Approach), but noticed increasing gaps between the requests for certain physical oceanography data sets/oceanographic knowledge and data available from monitoring activities. The constant need for oceanographic data as part of the overall description of the marine ecosystem should be more reflected in OSPAR's CEMP.

The WGOH noted ongoing activities within OSPAR and its Working Group on Concentrations, Trends and Effects of Substances in the Marine Environment (SIME) as part of a review of the role of physical oceanography in the framework of the revised CEMP. It is suggested that OCC contact ACE/ACME and the Secretariat to explore OSPAR`s interest to cooperate closer with ICES/OHWG regarding the monitoring of supporting environmental factors in the ICES region.

The OCC is asked to express their interest to better coordinate the ongoing national monitoring activities to optimize the cost/benefit.

Relating to this ToR a proposal was submitted to the OSPAR Commission through the German delegate. This proposal is included as Annex 15.

7 Review and improve relations with international climate monitoring programmes (ToR D)

Sheldon Bacon (UK) attended the CLIVAR (Climate Variability and Predictability Study) Atlantic Panel Meeting in Baltimore and presented information about the activities of the WGOH. This was welcomed by CLIVAR and resulted in an action ‘explore better linkages with the ICES WGOH’. There will be further discussions in the coming year with Cecilie Mauritzen (Norwegian Met. Inst., Oslo), who is both a member of the CLIVAR Atlantic Implementation Panel and Chair of the CliC (Climate and Cryosphere) Arctic Climate Panel.

The WGOH request that ICES consider supporting the publication of an issue of CLIVAR *Exchanges* dedicated to contributions from WGOH members on related activities. Sheldon Bacon (UK) and Penny Holliday (UK) will liaise with the CLIVAR office on this proposed effort.

8 Undertake an isopycnal analysis of *in situ* data (ToR E)

Tom Rossby (USA) presented a report from Vladimir Ozhigin (Russia)), Tom Rossby (USA) and Sheldon Bacon (UK) in the minisymposium. An abstract is included in Annex 4.

The WGOH agrees that this analysis should be continued and developed for different areas, mainly in the Nordic Seas. More work is necessary to develop a suitable methodology; this will be driven by Tom Rossby (USA). Vladimir Ozhigin (Russia) will continue with the analysis and Sheldon Bacon (UK) will request an extended dataset from ICES for input to this work.

9 WGOH contribution to REGNS (ToR F)

WGOH will provide summary datasets on the physical properties of the North Sea (to include salinity, temperature, tidal vectors, peak surface, mid-and bottom currents, maximum annual and 50 year significant wave heights). The data should be time averaged (annual average, seasonal cycles and annual peaks) for the period of 1984 to 2004 (where available) and spatially averaged at the scale of ICES rectangles. The data should be submitted to the secure REGNS website in preparation for the REGNS integrated assessment workshop from 9–13 may 2005.

The ICES Regional Ecosystem Group for the North Sea (REGNS) are preparing for a regional ecosystem assessment of the North Sea in 2006. During the ICES ASC in Vigo 2004, ToR F was significantly extended from the original discussed by the group at last years meeting.

The WGOH felt that the new ToR was unrealistic. As there is no dedicated support, a huge commitment of resources was demanded of the home institutes of WGOH members involved in the process. FRS and CEFAS have been able to commit some time. Without this the WGOH would not have been able to deliver to REGNS.

The WGOH members may also be able to contribute additional data that although not requested in the ToR, would be appropriate for an ecosystem assessment. These include, North Sea light levels and freshwater runoff that will be provided for REGNS by Gerd Becker (Germany).

The WGOH acknowledge that this is a pilot project but requests that REGNS consider the sustainability of this approach and look at ways to provide additional support, including national funding routes that could be employed to make the work more practicable.

Sarah Hughes (UK) will attend the REGNS workshop in May and present the WGOH contribution.

10 Discuss requirements for data management in ICES and provide input to Study Group on Management of Integrated Data (SGMID) (ToR G)

Julie Gillin, the ICES data centre manager attended the WG and gave an extremely useful and informative presentation describing recent changes that have been made to the structure of ICES and the ICES Secretariat. It was clear from the presentation that the recent changes in the structure of ICES reflected a move towards the ecosystem approach and did not represent any reduction in the level of importance that ICES places on oceanography.

There was some discussion about the role of the ICES data centre in relation to other national and international data centres. The discussion also highlighted recent problems that have occurred between the ICES data centre and other groups such as SeaSearch. This ended with a reminder that the ICES data centre needs to collaborate rather than compete with other data management projects and that the community need to support the ICES data centre and ensure that all data is submitted to ICES.

The WGOH agreed to provide advice to the data centre manager with regard to the provision of data products to the ICES community. The data centre manager agreed to consult with WGOH after receiving the results of a customer survey planned for later in 2005.

11 Review website developments (ToR H)

WGOH members are reminded that due to the recent name change of the Southampton Oceanography Centre to the National Oceanography Centre, Southampton, the website address is now:

www.noc.soton.ac.uk/JRD/ICES_WGOH/index.php

The IAOCSS and the working group reports are available for download from this site. The website is used to provide information about WGOH meetings and collects information about standards sections included in the IAOCSS. The website will also provide a forum for suggestions about improvements to the IAOCSS and other work.

The pages need to be kept up to date and members are requested to send any new information and ideas for improvements to Sheldon Bacon. It would also be useful if members could submit their reports for publication on the website prior to the meeting so that other members could view them.

It was agreed that there should be a link between the ICES WGOH website and NOC WGOH website.

12 Other business

13.1 New Chair for WGOH

The WGOH thanked the chair Alicia Lavín (Spain) for all of her hard work over the last three years.

Sheldon Bacon and Penny Holiday, both from the National Oceanography Centre, Southampton, UK, have offered to co-chair the WGOH.

13.2 Improve physical oceanography within ICES

WGOH reviewed and discussed a proposal (CM2004/conc0604-16) to the Consultative Committee by the ICES General Secretary regarding the role of physical oceanography in ICES that was forwarded to the WGOH Chair by the Chair of the Oceanography Committee. At issue was the need for physical oceanography to assume a higher profile in ICES.

WGOH shares the General Secretary’s concerns about the status of physical oceanography in ICES and the difficulties in attracting physical oceanographers to the ICES Annual Science Conference. WGOH realises that it must reach out to other disciplines to contribute to an integrated approach to marine science. The WGOH already hosts a one day mini-symposium at the start of each meeting, to allow oceanographers from the host institute to interact with WGOH members and share ideas on current research and developments. WGOH discussed possible back-to-back meetings with other WGs to raise the profile of WGOH within ICES but needs time to come up with specific proposals. WGOH members are requested to consider this for future WG meetings. The WGOH has also proposed some multidisciplinary theme sessions, such as the 2005 session on turbulence and the proposed 2006 session on climate variability and consequences.

The General Secretary’s proposal mentioned WGOH’s involvement with long time series. Some WGOH members used this discussion to express their conviction that long-term hydrographic time series have a continued useful role in monitoring ocean climate variations.

The WGOH has also reviewed the Coordinated Environmental Monitoring Programme of the OSPAR Convention for the Protection of the Marine Environment of the North-East Atlantic (Section 7). The OSPAR 2003 Strategy for a Joint Assessment and Monitoring Programme (JAMP) (revised 2004) speaks of the relationship between the JAMP and marine research and “highlights the need for marine research to study further ... the basic processes of the marine environment (biology, physics and chemistry) on different scales”. OSPAR expects that “data and information will be obtained from relevant national and international monitoring programmes and assessment activities”, including programmes in which ICES plays a role. Long time series of hydrographic measurements are valuable in this context, but the expectation that this information will continue to be available will be realized only if there is continued support by member states. If physical oceanography can assume a higher profile in ICES, then ICES will be in a better position to promote these activities.

13.3 New technology

The WGOH notes that acoustic Doppler current profilers on commercial vessels in regular traffic offer exceptional opportunities for monitoring variability of upper ocean currents over a wide range of time scales. The discussion by Tom Rossby (USA) at the mini-symposium on the analysis of interannual variations in the Gulf Stream over an 11-year period gave a good example of what this type of measurement methodology has to offer. At a WGOH meeting in Copenhagen (1996) the group discussed and endorsed the idea of starting a similar operation between Denmark and Greenland. In time this proposal was realized and is known today as the Nuka Arctica operation.

Another technology the working group thinks should be given serious consideration is the PIES instrument, an ocean bottom package that measures pressure to a precision of better than 1 cm (water column height) and integrated heat storage which can be interpreted in terms of isotherm depths given knowledge of the local/regional thermal structure. It is not a hydrographic instrument, but it can be used quite effectively to track dynamical changes in water column structure. A major advantage is its order-of-magnitude lower cost than a full water column mooring.

13.4 Theme Session at the 2005 ASC – presentation and call for papers

The WGOH members were reminded of the deadline for submission of papers to the theme session (Session J) “Recent advances in our understanding of marine turbulence in an ecological and climatological context’ at the 2005 Annual Science Conference in Aberdeen, (co-

Convenors: Hendrik van Aken (Netherlands) and Tom Osborn (USA)). Abstracts must be submitted by Monday 25th April 2005.

The WGOH hope that this will be a vibrant theme session that will attract input from other multidisciplinary groups and would allow discussion of new developments in the understanding of marine turbulence in an ecological and climatological context. The Working Group on Modelling of Physical/Biological Interactions (WGPBI) is collaborating in this theme session.

13.5 Theme Session for 2006 Annual Science Conference, Maastricht, the Netherlands

The Working Group proposes for 2006 ICES Annual Science Conference (ASC) in Maastricht (Netherlands) a special theme session on the subject "Climatic variability in the ICES area 2000-2005 in relation to previous decades: physical and biological consequences". Co-convenors: A. Lavín (Spain) and C. Reid (U.K.)

- The Intergovernmental Panel on Climate Change (IPCC) published their report in 2001, stating that the warmest years on record have occurred during the last decade of 1990 and beginning of the 2000s. Since then, the IAOCSS produced by the WGOH has shown a continued warming trend in most of the reported areas.
- The pattern of atmospheric variability described by the North Atlantic Oscillation Index was previously observed in a dipole form with alternate warming and cooling in northeastern and northwestern areas. This dipole form has not been evident in the last few years and during 2004 the warming seems to be extended all over the high latitudes.
- These recent changes in physical conditions would be expected to have an effect on all components of the ecosystem from plankton to fish in terms of distribution, abundance and phenology.
- The theme session will attempt to examine the causes and processes behind the observed changes. Contributions from all disciplines are welcome.

Contributions from all the disciplines to this theme session are encouraged. It was suggested that Alicia Lavín be a convenor. The WGOH suggested that Dr Chris Reid from SAHFOS could be approached as a possible co-convener.

WGOH members are also reminded of the request from ICES to submit contributions to a theme session on 'Integrated Data Management'in 2006.

13 Date and place of next meeting

Dr Glenn Nolan kindly extended to the Working Group an invitation to Galway, Ireland. The Working Group will meet at the Marine Institute and the University of Galway from 19–22 April 2006. It is proposed that a one-day mini-symposium be held to allow the WGOH to learn about relevant scientific activities at the host institute of relevance to WGOH.

WGOH members are reminded that the work of the group requires 4 full days and are asked, where possible, to arrange their travel after the fourth day.

14 Proposed Terms of Reference for 2006 meeting

2C06 The Working Group on Oceanic Hydrography [WGOH] (co-Chairs: S Bacon and P Holliday, UK) will meet in Galway, Ireland from 19–22 April 2006 to:

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

b) consolidate inputs from Member Countries to, and continue development of the ICES Annual Ocean Climate Status Summary (IAOCSS); S. HUGHES

c) review and improve relations with international climate monitoring programmes; S. BACON

d) formulate advice to the ICES data centre manager on the development of data products and services to improve access to physical oceanographic data for non-expert users; ALL

e) consider proposals for strengthening the role of WGOH and physical oceanography within ICES; ALL

f) continue and extend the isopycnal analysis of *in situ* data; T. ROSSBY, V. OZHIGIN, S. BACON.

WGOH will report by 2 May 2006 for the attention of the Oceanography Committee, ACME and ACE.

Supporting Information

Priority:	The activities of this Group are fundamental to the fulfilment of the Oceanography Committee's Action Plan.
Scientific Justification and relation to Action Plan	Action Plan Nos. 1.2, 1.3, 1.6, 1.7, 1.10, 5.13.4, 5.14 and 6.3. 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 2005. 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 the Working Group on Oceanic Hydrography. This agenda item will allow WGOH members to prepare the document during the meeting, thus avoiding delays in the dissemination of the information. Links have been made with the CLIVAR programme; it would be of benefit both to ICES and the international programmes to enhance internal information exchange. To assist the ICES data centre in defining physical oceanographic data products aimed in particular at non-expert users. To follow up on the ICES General Secretary's suggestions for increasing the visibility of WGOH within ICES. To develop a method for consistent presentation and inter-comparison of datasets to help improve understanding of changes.
Resource Requirements:	No extraordinary additional resources
Participants:	The Group normally is well attended but lacks participation from a number of countries committed to physical oceanographic programmes in the Atlantic, in particular France
Secretariat Facilities:	N/a
Financial:	b) Publication and reproduction costs for the IAOCSS c) Assistance with publication or distribution of a special CLIVAR *Exchanges* issue
Linkages to Advisory Committees:	ICES Annual Ocean Climate Status Summary available to the Advisory Committees on Fishery Management, Marine Environment, and Ecosystem
Linkages to Other Committees or Groups	Publications Committee; Consultative Committee; ICES/IOC Steering Group on GOOS
Linkages to Other Organisations:	IOC, JCOMM, CLIVAR

Annex 1: Agenda and Terms of Reference

2C06 The **Working Group on Oceanic Hydrography** [WGOH] (Chair: A. Lavín, Spain) will meet in Rhode Island USA, from 11–14 April 2005 to:

a) update and review results from Standard Sections and Stations; During the first day a large number of standard Sections and stations were revive and the main features occurred during 2004 were remarked.

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

c) review national monitoring programmes and OSPARs Coordinated Environmental Monitoring Programme (CEMP), in order to improve climate monitoring activities;

d) review and improve relations with international climate monitoring programmes;

e) undertake an isopycnal analysis of *in situ* data;

f) WGOH will provide summary datasets on the physical properties of the North Sea (to include salinity, temperature, tidal vectors, peak surface, mid-and bottom currents, maximum annual and 50 year significant wave heights). The data should be time averaged (annual average, seasonal cycles and annual peaks) for the period of 1984 to 2004 (where available) and spatially averaged at the scale of ICES rectangles. The data should be submitted to the secure REGNS website in preparation for the REGNS Integrated Assessment Workshop from 9–11 May 2005.

g) discuss requirements for data management in ICES and provide input to SGMID;

h) review website developments.

Annex 2: List of participants

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Annex 4: Mini-symposium abstracts

An Exploratory Study of Deep Water Currents in the Gulf of Mexico.

Kathleen Donohue, D. R. Watts, Karen Tracey

Graduate School of Oceanography, University of Rhode Island, USA.

A mesoscale-resolving array of twenty-seven inverted echo sounders with pressure gauges and fifteen deep current meters was deployed in March 2003 and recovered in April 2004 as part of the Exploratory Study of Deep Water Currents in the Gulf of Mexico and funded by Mineral Management Services with the intent to identify key circulation processes in a deep-water region in the Gulf of Mexico. The broad extent of the array, nominally 92W to 88W, 26N to 28N enables a quantitative mapping of the regional circulation. Round-trip acoustic travel time, measured by the inverted echo sounder, allows estimates of vertical profiles of temperature, salinity, and den-sity, utilizing empirical relationships established with historical hydrography. Combin-ing the deep pressure records with estimated horizontal density gradients yields ref-erenced geostrophic velocities. Main features in the upper-ocean circulation mapped from the array and satellite altimetry are consistent with one another. In addition, several deep features were revealed. A coherent 16-20 day oscillation in deep pres-sure with 5 cm peak-to-peak amplitude existed throughout the array. During experi-ment the Loop Current extended northward into the eastern portion of the array, in June a Loop Current Eddy formed and subsequently reattached to the Loop Current by the end of the month, another Loop Current Eddy, Eddy Sargassum, formed in late July and remained detached. Immediately after Eddy Sargassum detached the deep pressure field showed a burst of strong eddy activity comprising topographic Rossby waves and cyclones and anticyclones. Elevated deep energy levels occur at this time. There are clearly westward propagating topographic Rossby waves along the escarpment. Scales in the deep ocean are smaller than those in the upper ocean indicating that deep scales are set by the interaction of the upper-ocean circulation with complicated topography in the region.

Some remarks on interannual variations in Gulf Stream and coastal transports.

Tom Rossby

Graduate School of Oceanography, University of Rhode Island, USA.

A program has been underway since the fall of 1992 to measure upper-ocean cur-rents between New Jersey and Bermuda on a weekly basis with an acoustic Doppler current profiler mounted on the container vessel CMV Oleander. In this discussion we examine interannual variations in transport in the Gulf Stream and Slope Sea. Whereas past hydrographic estimates of Gulf Stream transport had large uncertain-ties due to the meandering of the current, the weekly sampling by the Oleander greatly increases the ability to discern even rather subtle variations in near-surface transport and explore their possible causes.

Over the eleven years of operation to date annual averages of Gulf Stream transport have a standard deviation of 6% but a 23% peak-to-peak range. No discernable trend in transport is evident in the eleven-year record. The westward transport in the Slope can vary by a factor two in magnitude, but unlike the Gulf Stream changes take place only very gradually. It is conjectured that the Slope Sea time scales are set by high-latitude buoyancy-related forcing, whereas Gulf Stream variability reflects tropi-cal and subtropical mechanical forcing.

The path of the Gulf Stream exhibits a correlated behavior with westward transport in the Slope Sea. When Slope Sea transport increases, the Gulf Stream shifts to the south with a concomitant hint of increased Gulf Stream transport. The southward shift of the Gulf Stream may be part of a dynamical response to this increased circulation in the Slope Sea since the

Slope Sea flow is blocked in the west by the Gulf Stream at Cape Hatteras suggesting that the path of Gulf Stream is governed more by ther-mohaline than winddriven forcing. The fast time scales of transport in the stream, on the other hand, point to winddriven forcing from the tropics and subtropics. Thus Gulf Stream position and transport would appear to be driven by quite different physical processes.

Gulf of Maine: External Forcing Influencing Local Processes

David G. Mountain

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The waters in the Gulf of Maine originate from two major sources: warm, saline Slope Water (SLW) that enters at depth through the Northeast Channel and cooler, fresher Scotian Shelf Water (SSW) that enters in the surface layer around Cape Sa-ble. The properties and volume of these inflows vary in response to large-scale forc-ing that is external to the Gulf. The North Atlantic Oscillation (NAO) can cause a change in the type of SLW entering Northeast Channel. During high NAO periods warm SLW, influenced by the Gulf Stream, enters the Gulf. When the NAO de-creases, a cooler SLW influenced by the Labrador Current can encroach westward to enter through the Northeast Channel. The two Slope Waters transport different levels of nutrients and different plankton communities into the Gulf. Large changes in the SSW inflow also have been documented, resulting in large changes in the surface layer salinity within the Gulf. This salinity variation exerts a significant influence on the extent of winter vertical convection that occurs, particularly in the western Gulf of Maine. When the salinity is high, convection extends to near bottom, resulting in a cooling of the deep layers. In years with lower surface salinity, convection is limited and the deep layers remain relatively warm. The variation in convection also causes variation in the flux of nutrients into the surface layer, the degree and timing of spring stratification, and in turn, the character of the spring primary production cycle

Challenges in assessing thin layer dynamics and transport.

Percy Donaghay

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Biological response to external fording on Georges Bank.

Ed Durbin

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Seasonal variability in the Western Irish Shelf ecosystem.

Bronwyn Cahill

Graduate School of Oceanography, University of Rhode Island, USA.

Seasonal evolution of the Labrador Sea from Argo floats 2004-2005.

Ross Hendry and Allyn Clarke.

Fisheries and Oceans Canada, Bedford Institute of Oceanography, Canada.

Temperature and salinity measurements in the upper 2km of the west-central Labra-dor Sea from a Canadian Argo float during June 2004 to March 2005 showed winter convective overturning to depths of up to 1000m. The Argo float remained within a few kilometres of its June 2004 deployment site for the entire 9 month period. Data from the U.S. Centers for Environmental Prediction (NCEP) Reanalysis project show that December 2004-February 2005 mean sea-air heat fluxes were higher than ob-served during the past 10 years, returning to values typical of 1971-2000. Changes in ocean heat content derived from the Argo temperature profiles closely resemble the cumulative NCEP heat fluxes relative to the 2002-2004 mean heat loss of 45 W/m2. Rapid heat losses during January 2005 led to vertical overturning and the develop-ment of surface mixed layers up to 1000m deep in the latter part of February 2005.

Isopycnal analyses of the Nordic Seas.

Vladimir Ozhigin, T. Rossby and S. Bacon

The Nordic Seas exhibit significant spatial and temporal variations in temperature and salinity. These changes result from vertical displacements of isotherms and variations in water mass properties. Especially in the north where convection plays a major role, one can anticipate significant variations in T/S properties depending upon wintertime conditions. In order to more clearly distinguish between dynamical variations and trends in water mass characteristics, it is convenient to map hydrographic observa-tions onto isopycnal surfaces such that their depth indicates dynamical state and temperature, salinity and other properties indicate the hydrographic state of the sur-faces.

In this talk we show some preliminary yet beautiful plots of the mean depths of and temperature and salinity on the 27.7, 27.8 and 27.9 sigma-t surfaces prepared by Dr. Vladimir Ozhigin at PINRO. The data base for these mean fields span a 40-year pe-riod since the late 1950's. The depths reveal clearly the path of the Norwegian Atlan-tic Current and how it follows the roughly 2000 m isobath around the Vøring Plateau. The property plots show clearly that the principal water mass transition between wa-ters of North Atlantic and Arctic origin takes place farther west over the Mohn Ridge. It is interesting to note that in both cases bathymetry plays a major role, for the former in guiding the baroclinic flow north, and for the latter in preventing lateral mixing.

The second part of the talk focuses on temporal changes in depth and water property during the six-year period 1986-1991. A broad scale deepening of the isopycnals took place this period relative to the 40-year mean. One can also see clearly how anoma-lies in salinity are advected south into the Iceland Sea and then southwest into the Norwegian Sea. Local maxima in salinity anomalies near Svalbard and in the Barents Sea may reflect freezing and resultant brine production. These preliminary results suggest that a more comprehensive study using all data available from the Nordic Seas could provide for a much more detailed analysis of how changes take place in this very dynamic and climatically important region.

Circulation on the East Greenland shelf and slope: Some new observations

Robert S. Pickart

Woods Hole Oceanographic Institution, USA.

High-resolution hydrographic and velocity measurements across the East Greenland shelf-break south of Denmark Strait have revealed an intense, narrow current banked against the upper continental slope. This is believed to be the result of dense water cascading over the shelf edge and entraining ambient water. The current has been named the East Greenland Spill Jet. It resides beneath the East Greenland/Irminger Current and transports roughly 2 Sverdrups of water equatorward. Strong vertical mixing occurs during the spilling, although the entrainment farther downstream is minimal. A vorticity analysis reveals that the increase in cyclonic relative vorticity within the jet is partly balanced by tilting vorticity, resulting in a sharp front in potential vorticity reminiscent of the Gulf Stream. The behavior of the spill jet may provide clues as to how shelf water is fluxed into the interior of the Irminger Sea.

Intense warming and salinity modification of intermediate water masses in th southern Bay of Biscay for the period 1992-2003.

Cesar González-Pola1, Alicia Lavín and Manuel Vargas-Yánez.

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The evolution of the intermediate water masses within the southeastern corner of the Bay of Biscay is studied from the shelf-edge and slope stations of a hydrographic standard section northward from Santander (43°30'/43º54' N; 3°47'W). The section was sampled monthly from 1991 to autumn 2003 with some gaps more frequent in the early stages due to weather conditions. Data were systematically collected up to a 1,000-meter depth (or to the maximum depth at the shallower stations) showing a detailed picture of the variability in water masses below the mixing layer. Eastern North Atlantic Central Water (ENACW) has warmed as a consequence of continuous deepening of the isopycnal levels. Changes in water properties at fixed isopycnal lev-els are less relevant and highly biased by a 1998 positive peak in temperature and salinity. The warming trend found is 0.032ºC per year on average. On the other hand, the Mediterranean Water (MW) has been modified along isopycnals (variations ten times greater than those due to isopycnal displacement) increasing progressively both temperature and salinity for the period 1994-2001. The values found are around 0.020ºC per year for temperature and 0.005 for salinity. As a final picture, all water masses below the mixing layer and down to a 1,000-meter depth in the southern Bay of Biscay have warmed up during the last decade at rates from two to six times greater than the those accepted for the North Atlantic during the last half-century.

Salinity anomalies and freshwater input into the SE Bay of Biscay based in the Gironde river flow.

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The Gironde (Garonne+Dordogne) estuarine system is one of the most important sources of the freshwater inputs into the south-eastern Bay of Biscay. Nonetheless the mixed hydrological regime (pluvio-nival) and the relatively low runoff coefficient of the Gironde river basin, the river flow correlates significantly with the precipitation re-cords in the southern Bay of Biscay. By extension, Gironde river flow correlates also with the flow of the small rivers of the Cantabrian basin that, because of the short longitude and high runoff coefficient, show a very quick response to the precipitation. So, at least in a quarterly basis, the Gironde river flow can be considered as repre-sentative of the freshwater input into the south-eastern Bay of Biscay. On the other hand, quarterly data of the average salinity of upper waters can be considered repre-sentative of the seasonal variations of both, advection and in situ modifications of the ENACW around 45°N latitude (Intergyre area of the NE Atlantic including the Bay of Biscay). In fact, good covariance has been observed in the anomaly patterns of the precipitation, precipitation minus evaporation, river flow and salinity in the south-eastern Bay of Biscay for the last two decades. A time series (1952-2004) of daily values of the Gironde (Garonne+Dordogne) river flow (from the Bordeaux Harbour Authority) is presented. Anomaly patterns and tendencies for the whole period are compared with those of some “reference periods” used frequently in trends analysis (e.g. 30 years period as 1961-1990 or 1971-2000). Seasonal anomaly patterns and tendencies are split for the period 1986-2004 and the relationships with precipitation, precipitation minus evaporation and salinity in the south-eastern Bay of Biscay are revisited. Finally, a scenario for the salinity and freshwater balance in the south-eastern Bay of Biscay (high precipitation and river flow but low freshwater exchanges across the 45° latitude) is presented by combination of advection and in situ modifica-tions of the ENACW around 45°N latitude related with the main features of the cli-matic regimen in the area.

East Greenland Coastal Current

David Wilkinson and Sheldon Bacon

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The behaviour of the East Greenland Coastal Current (EGCC) during the 20th cen-tury is investigated using historical data: ca. 50 sections taken between the 1930s and 1970s, with a gap until more recent (1997) occupations, with most sections hav-ing been taken in the summer (August). The data span the shelf region from Cape Farewell at 60˚N up to Denmark Strait around 67˚N. An error criterion leads to rejec-tion of 10% of the sections. The method for calculating seawater and freshwater fluxes is based on the analytical frontal model used previously. The basic results from this preliminary analysis are: (i) no obvious latitudinal or temporal dependence of net seawater flux, with a mean and variability of 1±1 Sv; (ii) no obvious freshwater flux dependence on latitude, with a mean and variability of ~0.04±0.04 Sv; (iii) a pos-sible dependence of freshwater flux on Greenland mean terrestrial temperature, with higher fluxes in the warm 1930s (~0.07 Sv), and lower fluxes (~0.04 Sv) at later, cooler times.

Nordic Seas Circulation and Fluxes

Elizabeth Hawker and Sheldon Bacon

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Using data from several cruises all conducted in the Nordic Seas and North-East At-lantic in July-September 1999, we generate a synoptic circulation scheme for the Nordic Seas, including exchanges with the Atlantic and with the Arctic / Barents Sea, via a 4-box 14-layer inverse model constrained with volume and salinity everywhere, and sub-surface heat, and initialised with geostrophy referenced to best-guess low-ered acoustic Doppler current profiler data. Ekman fluxes are calculated using both SOC and Hellerman-Rosenstein climatologies. Extensive sensitivity testing is per-formed using (i) inverse model variants, (ii) data alternates, and (iii) the Gauss-Markov formalism. All individual current magnitudes are in line with previous esti-mates. The principal results presented were: (i) 50% of the densification of inflowing Atlantic water is observed to occur in the ‘south box’, ie between the Extended Ellett Line and 64-65˚N off western Norway; (ii) Denmark Strait Overflow Water (DSOW) is observed to contain 50% return Atlantic Water. These results tend to confirm the Mauritzen hypothesis for DSOW formation. Additional cruises in the following winter enabled the manufacture of a winter analogue of the main Norway–Greenland sec-tion. Summer and winter heat fluxes across this section were calculated to be ca. 100 and 300 TW respectively, with errors of 35%.

Annex 5: Climatic conditions around Greenland - 2004

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Abstract

The pattern of sea level atmospheric pressure over the North Atlantic was anomalous during winter 2003/2004. The pressure anomaly fields during this winter differed considerably from a dipole pattern which is usually present in the North Atlantic region, with two pressure anomaly cells, one in the Icelandic Low area, the other in the Azores High area. As a consequence of this unusual anomaly pattern, the North Atlantic Oscillation (NAO) index for the winter 2003/2004 was weak and negative (-0.60). Air temperature climatic conditions around Greenland continued to be warmer-than-normal. The climatic conditions at Nuuk are consistent with the NAO index (negative index=mild climate).

Warmer than normal conditions were observed around Greenland during most of the year 2004 with mean air temperatures at Nuuk indicating positive anomalies (+1.1K). Based on satellite derived ice charts for all months of 2004 it is shown that winter sea ice conditions were favourable during 2004 off West Greenland. Compared to mean autumn conditions derived from the Holsteinsborg section, the temperatures in the West Greenland Current core and on the West Greenland shelf as measured during autumn 2004, are up to 2K warmer than normal. At Fyllas Bank, subsurface warming during 2004 was in the range of the warm 1960s temperatures, but was less than during autumn 2003 when temperatures were 2.44K above normal, and normal for the layer 0–200m is 2.87°C.

Figures and Captions

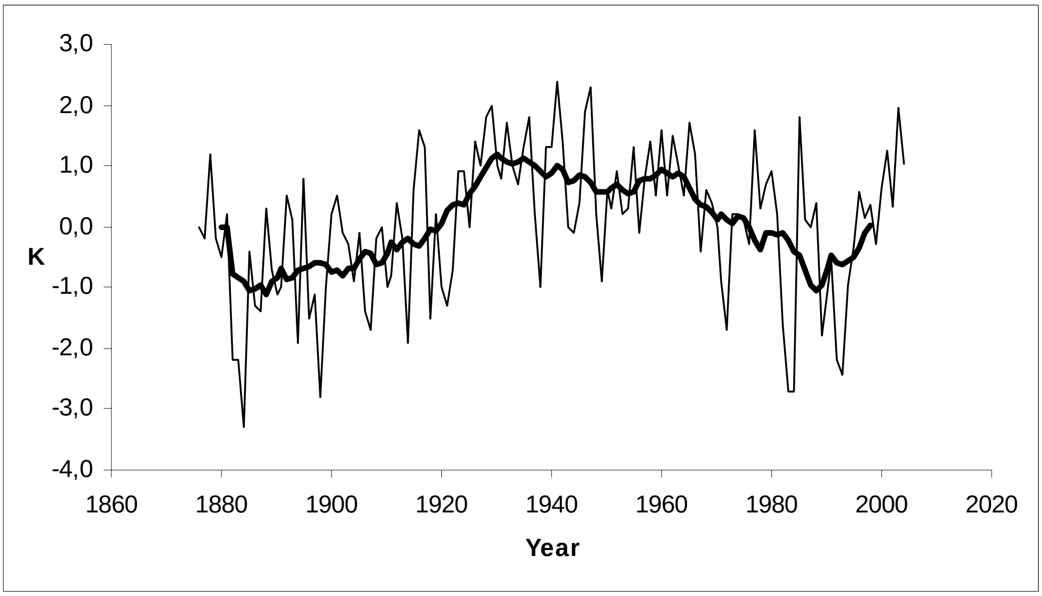

Figure 1: Time series of annual mean air temperature anomalies at Nuuk (1876–2004, rel. 1961–1990); bold: 13yr r.m.

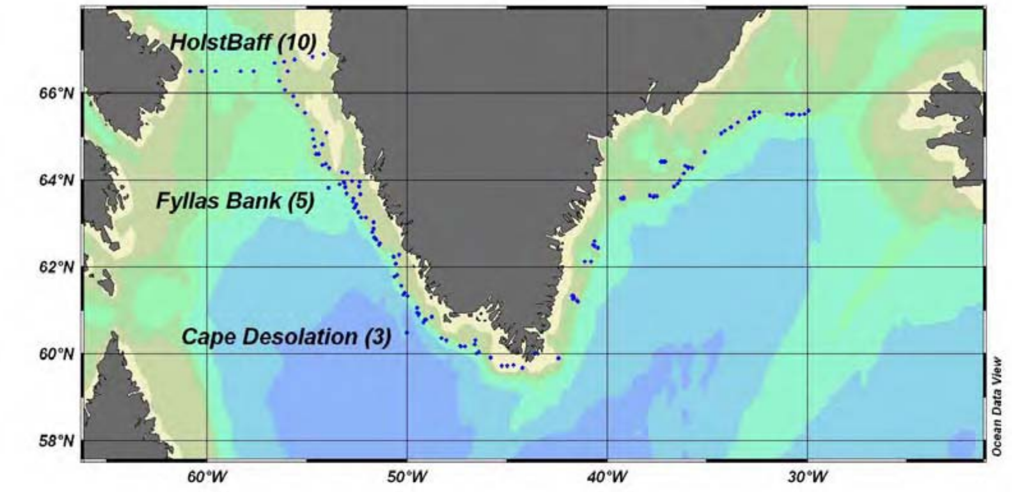

Figure 2: Positions of fishing stations off East and West Greenland (123), sampled NAFO Standard Sections: Holsteinsborg-Baffin Island (HolstBaff), Fyllas Bank, Cape Desolation; in brackets: No. of stations;

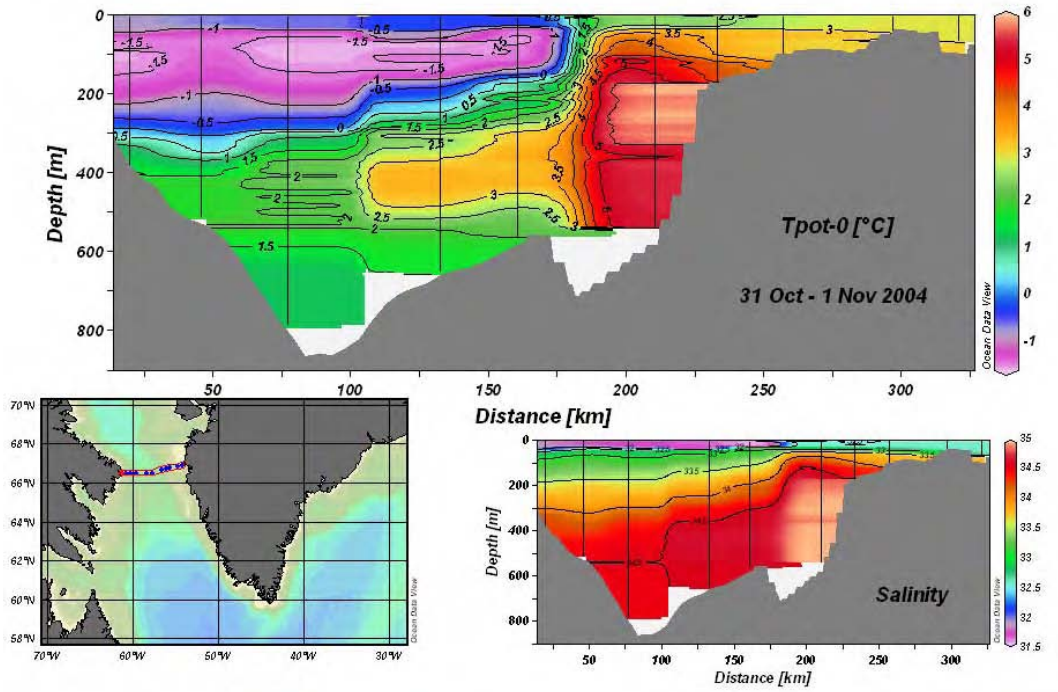

Figure 3: Vertical distribution of potential temperature and salinity along the Holsteinsborg-Baffin Island section; data: 31 October–1 November 2004.

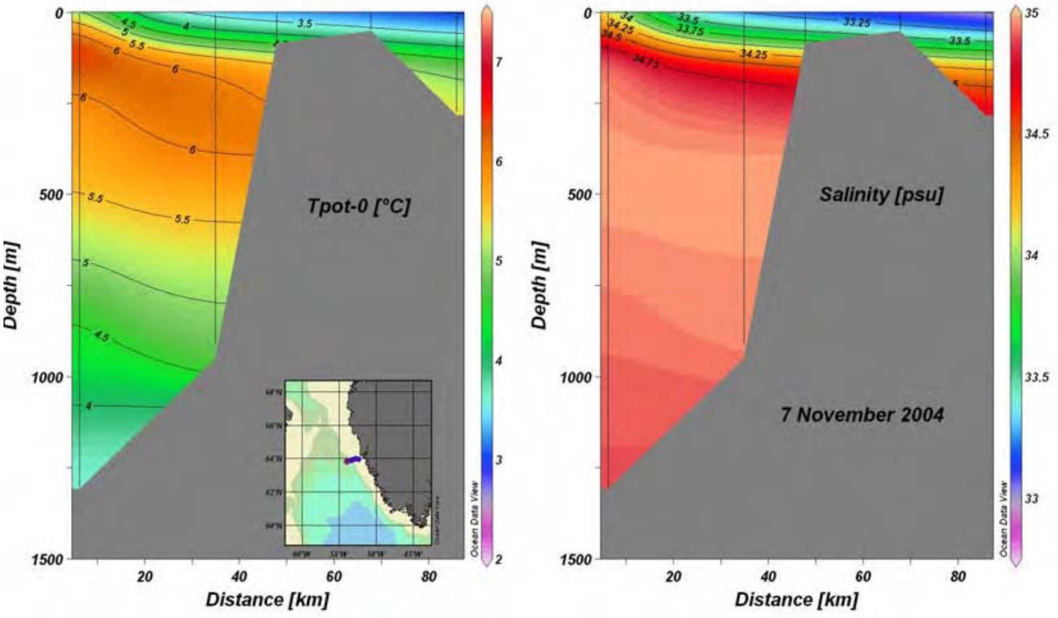

Figure 4: Potential temperature and salinity along Fylla Bank Section (7 November 2004).

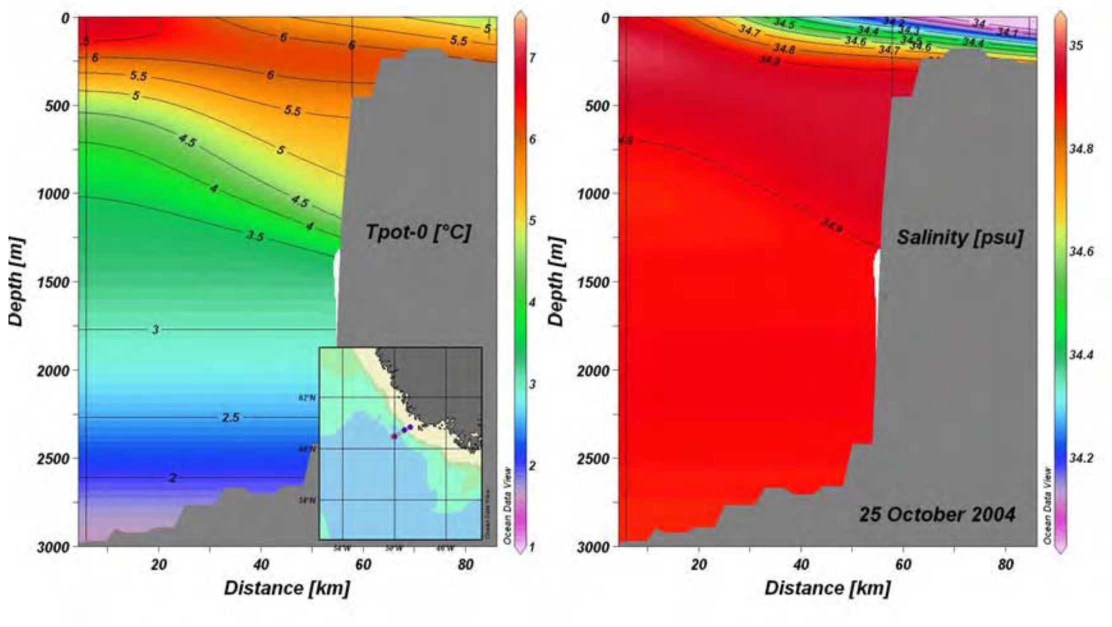

Figure 5: Potential temperature and salinity along Cape Desolation Section (25 October 2004).

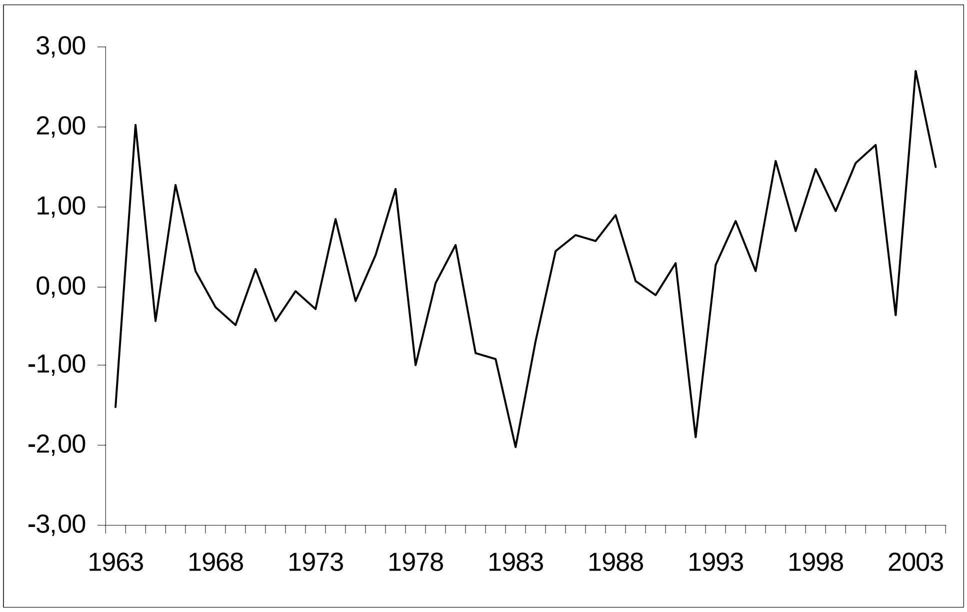

Figure 6: Mean water temperature anomalies of layer 0–200 m at station 4 of the Fyllas Bank Section during SEP-DEC; data: 1963–2004.

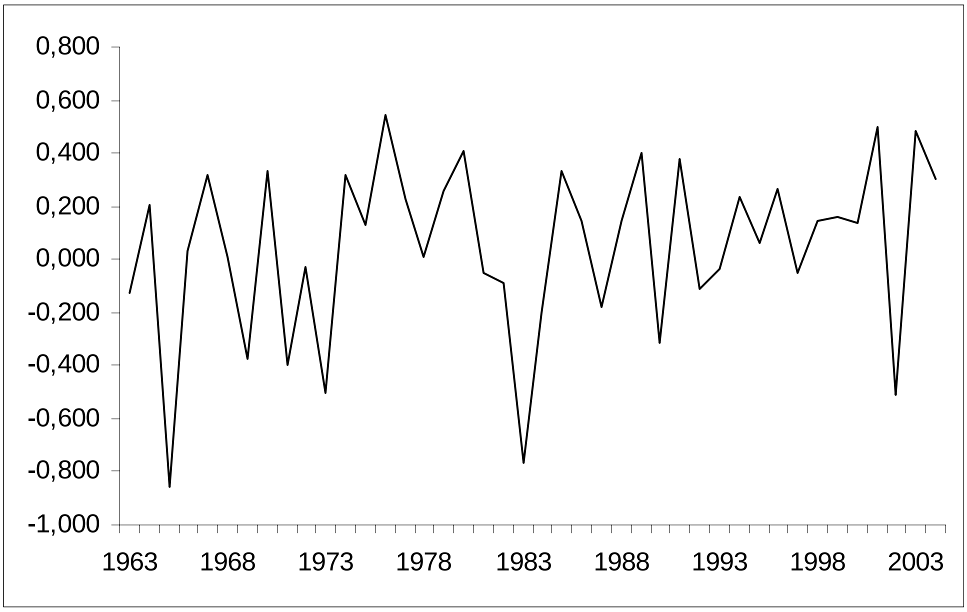

Figure 7: Mean water salinity anomalies of layer 0-200m at station 4 of the Fyllas Bank Section during SEP-DEC; data: 1963–2004.

Annex 6: Environmental conditions in the Northwest Atlantic during 2004 (ICES Area 2)

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Abstract

Meteorological and oceanographic observations from data collected at standard monitoring stations and sections in the Northwest Atlantic during 2004 are presented referenced to their long-term (1971–2000) means. Annual air temperatures throughout most of the Newfoundland and Labrador Region continued above normal during 2004 and in many areas increased over 2003 values. The North Atlantic Oscillation (NAO) index for 2004 was below normal for the third consecutive year. Winter sea ice coverage on the Newfoundland and Labrador Shelf during 2004 decreased over 2003 remaining below normal for the 10th consecutive year and to the lowest observed since 1965. The annual water-column averaged temperature on the inner Newfoundland Shelf (Station 27) for 2004 remained above the long-term mean and reached the highest value on record. Annual near-surface salinities measured at Station 27 remained above normal for the third consecutive year. The cross-sectional area of <0°C (CIL) water on the Newfoundland and Labrador Shelf during the summer of 2004 decreased over 2003 values remaining below the long-term mean along all sections, in some cases for the 10th consecutive year. Geostrophic estimates of the Labrador Current continued to show enhanced transport during the summer of 2004, however there was a slight decrease compared to 2003. The below normal trend in ocean temperatures established in the late 1980s, reached a minimum in the early 1990s, moderated by the mid-1990s, continued to increase during the late 1990s and early 2000s reaching record highs in 2004. Ocean salinities on the Newfoundland Shelf also reached near-record lows in the early 1990s, remained below normal throughout most of the 1990s and up to 2001, however, during 2002 to 2004 there was a significant increase with surface values the highest observed in over a decade.

Introduction

Meteorological and oceanographic conditions during 2004 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 compiled into time series for the standard sections and stations (Figure 1 and 2).

One of the most widely used and longest oceanographic time series in the Northwest Atlantic is from data collected at 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 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 49 occupations during 2004.

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 sections in the Northwest Atlantic from Cape Cod (USA) to Egedesminde (West Greenland) (Anon. 1978). Several of these sections are occupied annually during mid-summer on an oceanographic survey conducted by the Canadian Department of Fisheries and Oceans (Figure 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^{o} N are presented for the summer 2004 survey.

Meteorological and sea-ice conditions

Monthly and annual air temperature anomalies for 2004 relative to their 1971–2000 means at three sites in the northwest Atlantic from Iqaluit on Baffin Island to St. John’s Newfoundland are shown in Figure 3. The predominance of warmer-than-normal annual air temperatures at all three sites during 2004 is shown with annual anomalies ranging from a maximum of +2.0^{o}C at Cartwright to +0.8^{o}C at St. John’s Newfoundland. Monthly air temperatures were above normal in 8-10 months of 2004 at these sites. The main exceptions were March and December at Iqualuit and June at St. John’s when air temperatures were significantly below average. At Cartwright on the Labrador coast air temperatures were either normal or above normal in all months of 2004, reaching a maximum of over 7^{o}C above average in January. The inter-annual variability in air temperatures since 1960 at 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 and northwesterly winds over the Northwest 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 conditions on the Newfoundland and Labrador 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 fields. The NAO index for 2002 to 2004 was below normal (by about 9 mb in 2004) indicating a reduced Arctic outflow to the Northwest Atlantic during the winter months (Figure 4). The spatial patterns in the atmospheric pressure systems during the winter months of 2004 resulted in very weak Northwesterly winds over the Newfoundland and Labrador area. This caused air temperatures over much of the Northwest Atlantic to remain above normal during the winter and early spring of 2004. Overall, the 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 sea ice on the Newfoundland and southern Labrador Shelf (between 45^{o}–55^{o}N) show that the peak extent during 2004 decreased significantly over 2003 remaining below average for the 10th consecutive year (Figure 4). The average ice area during both the period of southward advancement (January to March) and northward retreat (April to June) also decreased relative to 2003, remaining much less than the heavy ice years of the early 1990s (Figure 4). In general, sea ice coverage was lighter-than-average during 2004 and the duration of ice season was shorter than normal in most areas of the Newfoundland and Labrador Shelf.

Time Trends in Temperature and Salinity at Station 27

Station 27, located in the Avalon Channel off Cape Spear (Figure 2), was sampled 49 times (38 CTD profiles, 11 XBT profiles) during 2004 down from the 59 occupations during 2003. The data from this time series are presented in several ways to highlight seasonal and interannual variations over various parts of the water column. Depth versus time contour maps of the annual cycle in temperature and salinity and their associated anomalies for 2004 are displayed in Figure 5. The cold near isothermal water column during the winter months has temperatures ranging from near 0^o to $–0.5^oC$. These temperatures persisted throughout the year below 100 m depth and even decreased to $<-1.0^oC$ during the summer months. Surface layer temperatures ranged from about 2^o to 0^oC from January to mid-April, after which the surface warming commenced. By mid-May upper layer temperatures had warmed to 3^oC and to $>15^oC$ by August at the surface, after which the fall cooling commenced. These temperatures were about 0.5^o to 1.5^oC above normal during the winter months over most of the water column. Temperatures during the spring were above normal over the entire water column. During the remainder of the year, temperatures were above normal (by $>1.0^oC$ in surface layers during the summer) except for an isolated cold anomaly at 30-50 m depth in August.

Surface salinities reached maximum values by late winter (>32.2 in mid-March) and decreased to minimum values by late summer (<31.2 in September-October). These values were slightly below normal until May after which the anomalies increased to 0.5 above normal by summer and remained above normal during the remainder of the year. In the depth range from 50–100-m, salinities generally ranged from 32.4 to 32.6 and near bottom, they varied throughout the year between 32.8 and 33.4. The most significant salinity anomaly during 2004 occurred from May to September in the depth range of approximately 50–150 m when anomalies were about 0.3 below normal. Bottom salinities increased to above normal values (>33.2) during the fall months (Figure 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 (Figure 6 and 7). At the surface negative temperature anomalies reached an all time minimum in the early 1990s, began to moderate to near-normal conditions by the summer of 1994 and have experienced an increasing trend since then, reaching a record high during 2004. Near bottom at 176-m depth, 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 average. Annual bottom temperatures from 1998 to 2004 have remained above the long-term mean with 2004 the highest since 1966. Monthly surface and bottom temperatures were above normal in all months of 2004 with the highest surface temperature on record during August (Figure 6 right panels).

Near-surface salinity anomalies (Figure 7) show the large fresher-than-normal anomaly that began in early 1991 had moderated to near normal conditions by early 1993 but returned to fresher conditions by the summer of 1995. Annual salinities approached near normal values during 1996 but decreased to mostly below normal values from 1997 to 2001. During 2002 to 2004 surface salinities increased to above normal and to the highest in over a decade. 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 sea-ice conditions and larger than normal summer cold-intermediate-layer (CIL) areas on the continental shelf (Colbourne *et al.* 1994, Drinkwater 1996). During the past several years (up to 2001) however, salinities have remained below normal during a time period of warm air temperatures and lower than normal sea ice conditions. During 2004 surface salinities were about normal for the first half of the year and above normal during the remainder, near-bottom however, they were below normal during the first half of the year (Figure 7 right panels).

The depth averaged (0–176 m) annual temperature and salinity anomaly time series at Station 27 are displayed in Figure 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 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 from 1999 to 2004 with the 2004 value the highest on record (Figure 8).

The depth averaged (0–50 m) salinity time series (Figure 8 bottom panel) show similar variability 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 1991 to 2001 annual salinities were below normal on the inner Newfoundland Shelf. During 2002 and 2004 salinities increased over 2001 values and were the highest in about 12 years in the upper water column.

Standard Sections

The Labrador Current which generally flows south eastward along the shelf break through the Flemish Pass is comprised of a relatively strong western boundary current following the shelf break and a considerably weaker component over the banks and inshore regions (Figure 1). This current is responsible for advecting cold, relatively fresh, polar water together with sea-ice and icebergs from the Arctic to lower latitudes along the Labrador Coast to the Grand Banks of Newfoundland. The water mass characteristics observed along sections crossing the Newfoundland and Labrador Shelf (Figure 2) are typical of sub-polar waters with a sub-surface temperature range of -1° to 2°C and salinities of 32 to 33.5. Along the shelf edge and into the Flemish Pass region, the water mass is generally warmer and saltier than the sub-polar shelf waters with a temperature range of 3° to 4°C and salinities in the range of 34 to 34.75. Surface temperatures warm to 10° to 12°C during late summer, while bottom temperature remain <0°C over the Grand Bank but increase to 1° to 3°C near the shelf edge below 200-m. In the deeper waters of the Flemish Pass and across the Flemish Cap bottom temperatures generally range from 3° to 4°C. Throughout most of the year the cold relatively fresh water overlying the shelf is separated from the warmer higher density water of the continental slope region by a strong temperature and density front. This water mass is generally referred to as the cold intermediate layer (CIL) which is formed during the winter months. It usually remains present throughout most of the year as the seasonal heating increases the stratification in the upper layers to a point where heat transfer to the lower layers is inhibited, although it undergoes gradual decay during the summer reaching a minimum during the fall. In general the water masses found along the standard sections undergoes seasonal modification in its properties due to the seasonal cycles of air-sea heat flux, wind forced mixing and ice formation and melt leading to intense vertical and horizontal gradients particularly along the frontal boundaries separating the shelf and slope water masses.

Flemish Cap (47o N)

Near surface temperatures along this section over the Grand Bank ranged from 9°-10°C during the summer while water with temperatures <0°C were present below 50 m depth in the inshore areas and at the edge 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. Temperatures during the summer were generally above normal except for the near-surface layer over the Grand Bank, where they were up to 1°C below normal. Bottom temperatures over the Grand Bank during the summer were above normal by about 1°C. Further offshore in the Flemish Pass and over the Flemish Cap sub-surface temperatures were above normal by 1°–2°C (Figure 9). Salinities along the section on the Grand Bank (Figure 10) are characterized by generally fresh conditions on the bank (<33), a strong horizontal gradient at the shelf break separating the saltier (>34.5) slope water offshore in the Flemish Pass. Salinity anomalies over the Grand Bank during 2004 were generally higher than average in the upper layers and near normal below 50-m depth. To the east over the Flemish Cap salinities were also above normal by over 0.5 in the surface layer.

Bonavista

The dominant water mass feature along this section during the summer months is the cold intermediate layer of <0°C water (CIL) which develops during early spring after intense winter cooling. Temperatures along the Bonavista section shoreward of the shelf break in the upper water column ranged from 8-9°C during the summer which were generally above normal (up to 2°C) in most areas except near-shore where they were below normal due to local upwelling. Bottom temperatures over the entire eastern Newfoundland Shelf were above normal by 1° – 2°C. On average along the Bonavista section during the summer the CIL extends offshore to over 200 km, with a maximum vertical extent of about 200 m. In 2004, this water mass extended offshore to about 150 km and its total area was the smallest since 1965. Salinities along the section on the inner shelf areas are characterized by generally fresh conditions (<33), a strong horizontal gradient at the shelf break separating the saltier (>34.5) slope water offshore along the shelf break. Bottom salinities ranged from 32.5 in the inshore regions, to >34.5 below 300-m depth. Salinity anomalies along this section during the summer of 2004 were generally saltier-than-normal, particularly in the surface layers.

Seal Island

The Seal Island section, which crosses Hamilton Bank on the southern Labrador Shelf (Figure 1), shows upper layer temperatures across the shelf ranging from 0°C at approximately 50-m depth to between 6°to 7°C at the surface. Temperatures below 50-m depth were generally <0°C over most of the shelf, corresponding to the CIL water mass, except near bottom where they range from 0° to 1°C due to the influence of warmer slope water. Near the shelf break in Labrador slope water, bottom temperatures increase to 2°–4°C. Temperature anomalies over the shelf were generally above normal except for an isolated cold surface anomaly over Hamilton Bank. In the offshore area particularly along the continental slope region temperatures were up to 1° to 3°C above normal. Surface salinities along this section ranged from <31.5 inshore of Hamilton Bank to >34.5 in the offshore region. Bottom salinities ranged from 32 near the coast of Labrador to 34.5 at the edge of the shelf in water depths >300-m. Near-surface salinities were saltier-than-normal. Salinities corresponding to the CIL water mass were about normal. Offshore of the shelf break and along the continental slope regions salinities were above normal by 0.1 to 1.0 unit.

Cold Intermediate Layer (CIL) Time Series

As shown in the cross-shelf contour plots (Figure 9), the vertical temperature structure on the Newfoundland Continental Shelf during the summer is dominated by a layer of cold <0°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 spatial extent of this winter chilled water mass is evident in the section plots of the temperature contours, for example along the Seal Island section (Figure 9) the CIL extends offshore to near 200 km, with a maximum vertical extent of approximately 150 m. This corresponds to a cross-sectional area of around 18 km^2. The annual summer CIL cross-sectional area anomalies defined by the 0°C contour for the Flemish Cap, Bonavista and Seal Island sections are displayed in Figure 11. Along the Flemish Cap section the CIL area was below the 1971-2000 normal in 2004, similar to conditions observed during the past 5-years with a decrease over 2003 to the lowest value since 1970. The CIL area along the Bonavista section was below normal for the 10th consecutive year ranking the second warmest year in the 56 year time series. Along the Seal Island section the area of <0°C (CIL) water decreased slightly over 2003 and except for 1997 was below normal for the 9th consecutive year. In general, the CIL area observed along all sections continue to show a decreasing trend of below normal values since at least 1995. This is in contrast to the near record high values measured during the cold period of the early-1990s on the Newfoundland and Labrador Shelf.

Geostrophic Circulation and Transport

Temperature and salinity data were used to compute geostrophic currents relative to 300 m along several sections sampled during the summer of 2004 (Figure 12). The geostrophic component of the southward flowing Labrador Current along these sections generally shows distinct inshore and offshore branches. The inshore branch is 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. The offshore branch is located at the shelf break in water depths generally >200 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 further north, on the mid-Labrador Shelf, 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 >0.25 m/s in the upper water column although the 2004 speeds were somewhat less peaking at about 0.15 cm/s. At mid-shelf the geostrophic signal is generally weak with current speeds in these areas <0.05 m/s. The exception to this occurs along the Bonavista section where the there is cross shelf flow in the offshore direction with a significant component perpendicular to the section (Figure 12). During the summer of 2004 the North Atlantic Current east of the Flemish Cap was also evident although not as strong as observed in 2003.

The historical data along these sections were used to compute time series of geostrophic transports estimates (Figure 12 right panels). A common reference level of 135-m was chosen for these calculations since this was the deepest level common to all three sections 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 show large inter-annual variations with an average transport of between 0.4-0.5 Sv 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-fresh 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 early 2000s. The geostrophic transport of the Labrador Current during the summer of 2004 decreased slightly along all sections compared to that of 2003.

Summary

Annual air temperatures throughout most of the Newfoundland and Labrador Region continued above normal during 2004 and in many areas increased over 2003 values. Annual mean air temperatures at Cartwright for example, on the southern Labrador Shelf warmed over 2003 values from 1.2°C above normal to 2°C above normal in 2004, the third highest on record.

The North Atlantic Oscillation (NAO) index for 2004 was below normal for the third consecutive year resulting in reduced outflow to the region. Winter sea ice coverage on the Newfoundland and Labrador Shelf during 2004 decreased over 2003 remaining below normal for the 10th consecutive year and to the lowest since 1965.

The annual water-column averaged temperature at Station 27 for 2004 remained above the long-term mean and reached the highest value on record. The annual surface temperature at Station 27 was 1°C above normal, also the highest on record, while the annual bottom temperature were the highest since 1966. Water-column averaged annual salinities at Station 27 remained above normal for the third consecutive year. The cross-sectional area of <0°C (CIL) water on the Newfoundland and Labrador Shelf during the summer of 2004 decreased over 2003 remaining below the long-term mean along all sections. The CIL areas were below normal along all sections from the Flemish Cap section on the Grand Bank, to the Seal Island section off southern Labrador. Off Bonavista for example, the CIL area was below normal for the 10th consecutive year. Geostrophic estimates of the Labrador Current continued to show enhanced transport during the summer of 2004, however, there was a slight decrease over 2003 values.

In summary, the below-normal trends in temperature and salinity, established in the late 1980s reached a minimum 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 continued to be 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. During 2000 to 2003 ocean temperatures were cooler than 1999 values, but remained above normal over most areas continuing the trend established in 1996. During 2004 temperatures continued to increase reaching record high values in some areas. From 1991 to 2001 the trend in salinities on the Newfoundland Shelf was mostly below normal, however, during 2002 there was a significant increase with surface values the highest observed in over a decade. Annual salinity measurements at Station 27 during 2003 and 2004 continued to show above normal values.

Acknowledgements

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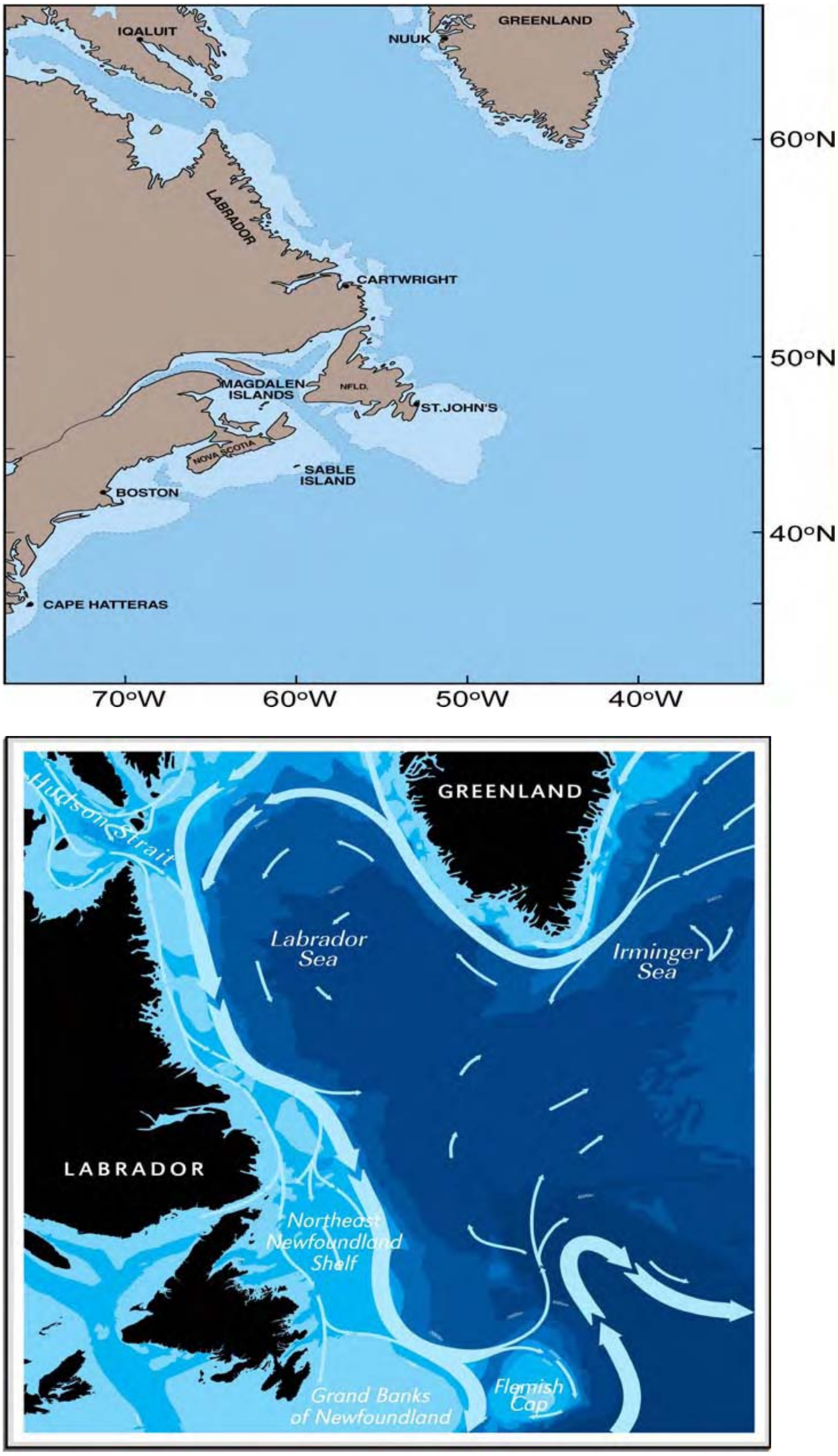


Figure 1. Northwest Atlantic showing coastal air temperature monitoring stations (top panel) and the general circulation features of the Northwest Atlantic.

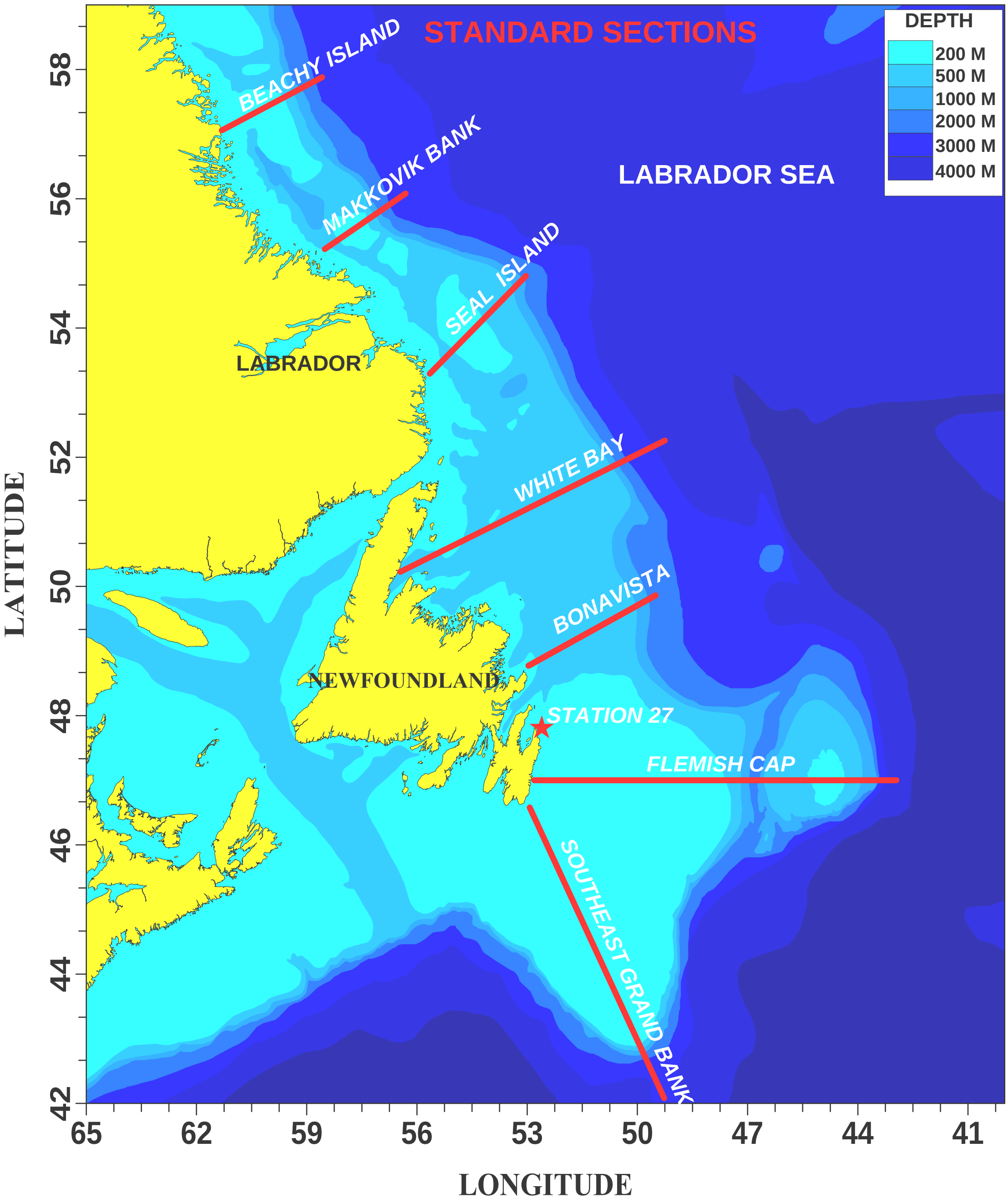


Figure 2. **Map showing the location of Station 27 and the locations of standard monitoring sections on the Newfoundland and Labrador Shelf.**

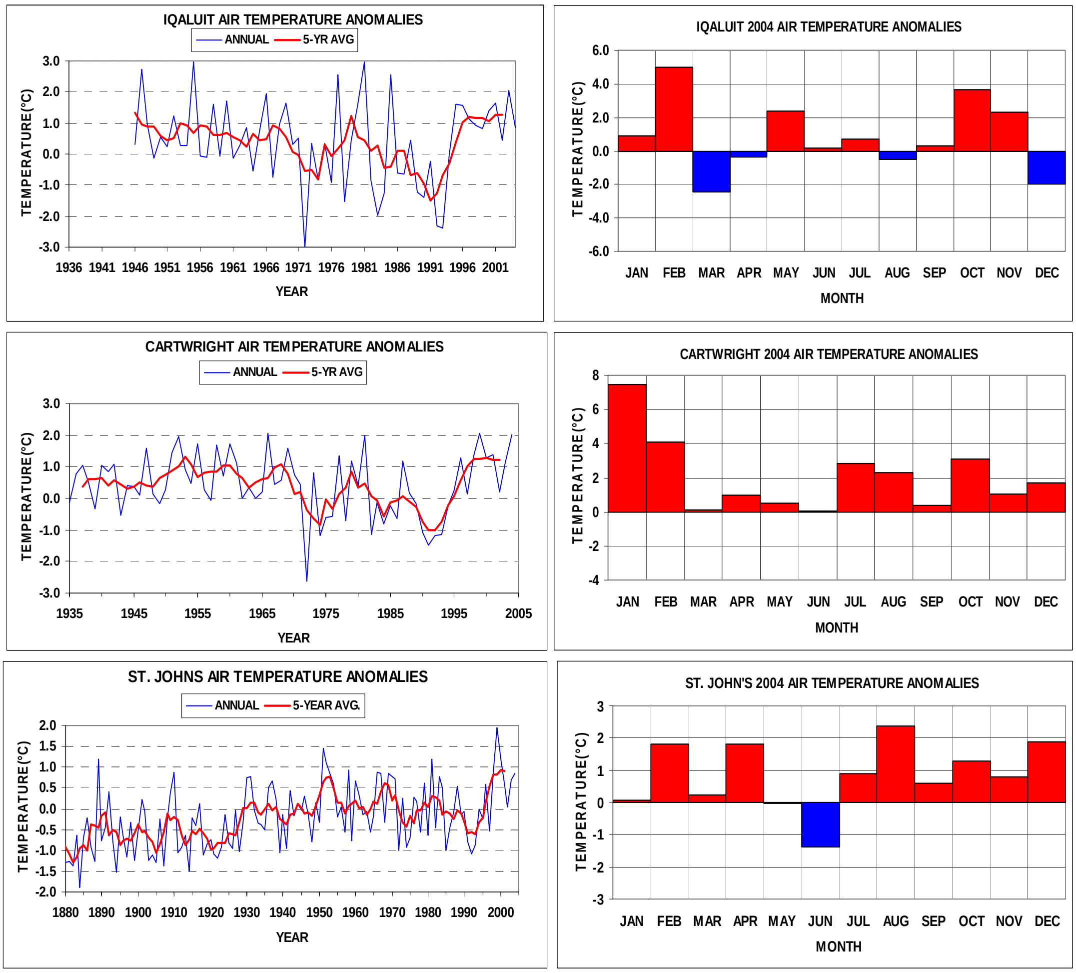


Figure 3. Annual and monthly air temperature anomalies in 2004 at selected coastal sites (see Figure 1 for locations). The anomalies are referenced to their 1971–2000 means.

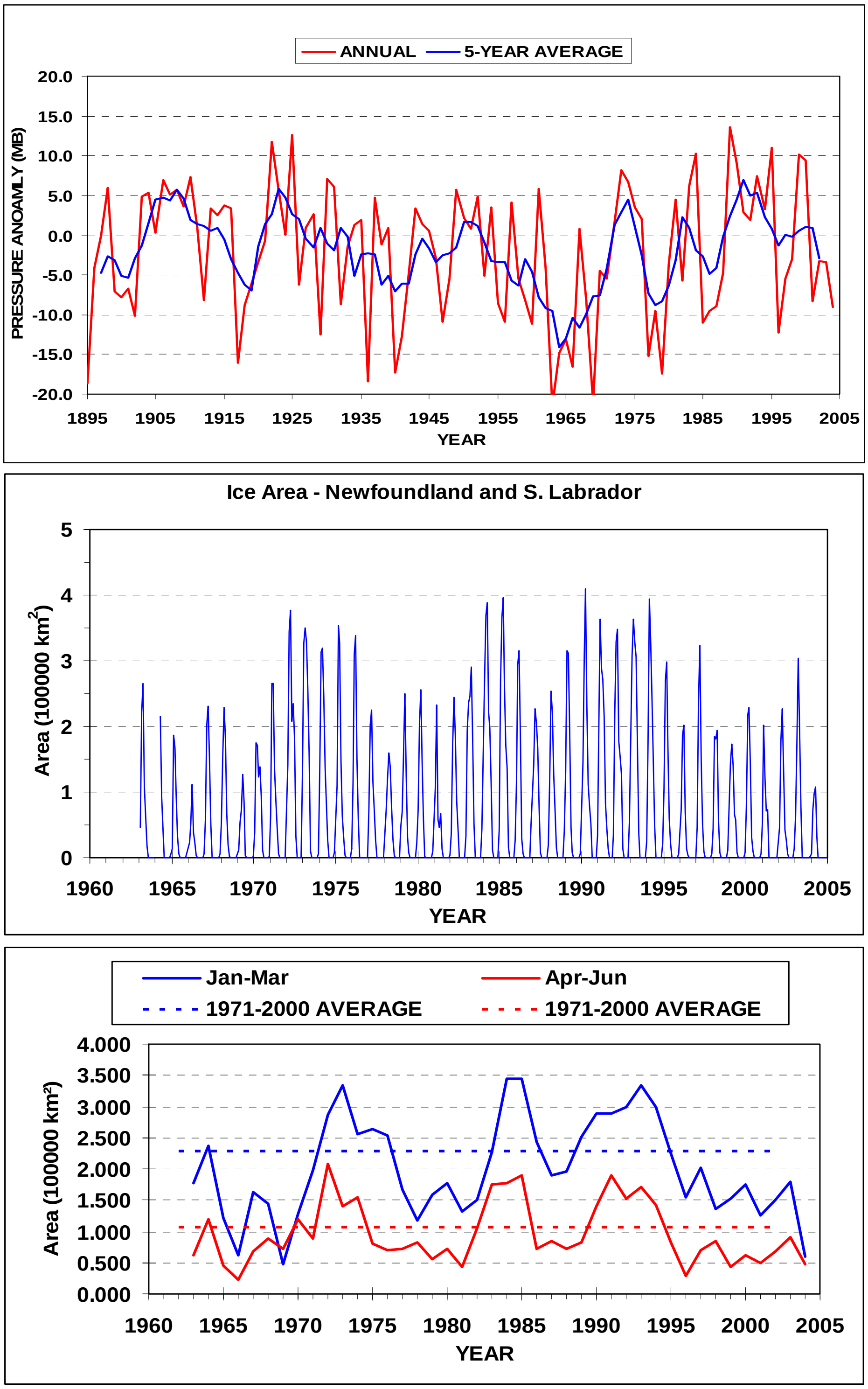


Figure 4. Anomalies of the North Atlantic Oscillation Index relative to the 1971–2000 mean (top panel), monthly mean ice areas off Newfoundland and Labrador between 45°N–55°N (centre panel) and the average ice area during the normal periods of advancement (January–March) and retreat (April–June) (bottom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

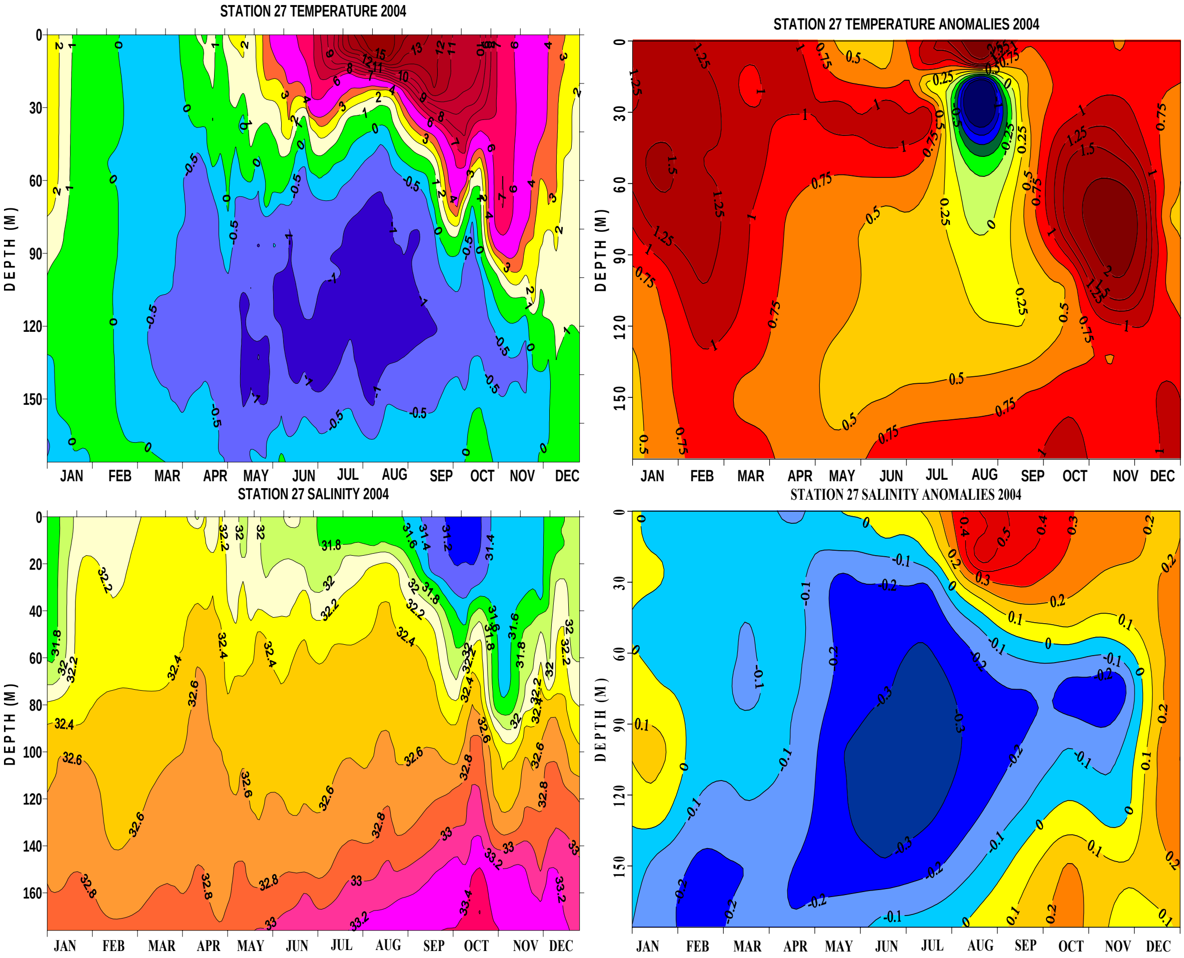


Figure 5. Contours of the annual cycle of temperature and temperature anomalies (in °C) (left panels) and salinity and salinity anomalies (right panels) as a function of depth at Station 27 for 2004.

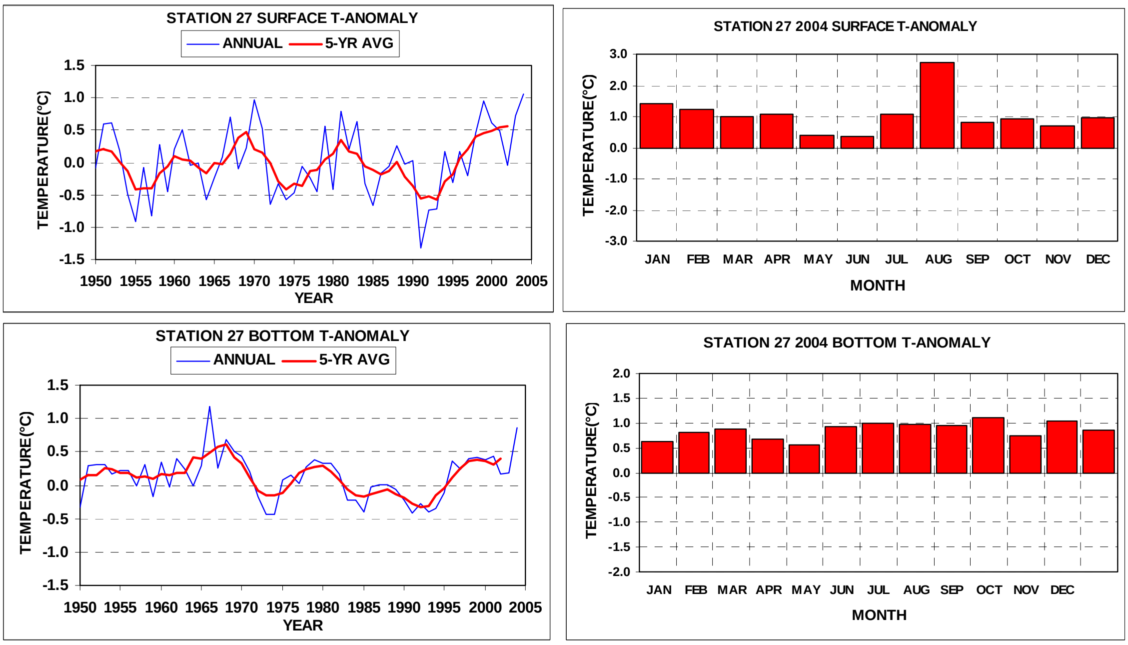


Figure 6. Monthly surface and bottom temperature anomalies at Station 27 during 2004 (right panels) and their annual anomalies with 5-year running means (left panels).

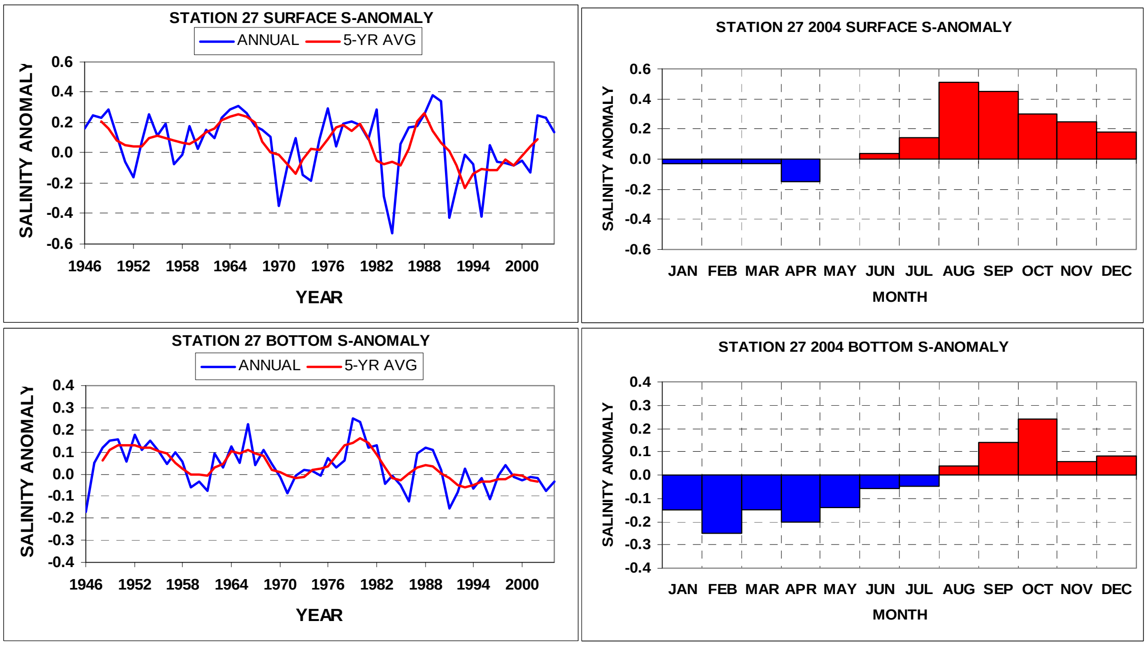


Figure 7. Monthly surface and bottom salinity anomalies at Station 27 during 2004 (right panels) and their annual anomalies with five-year running means (left panels).

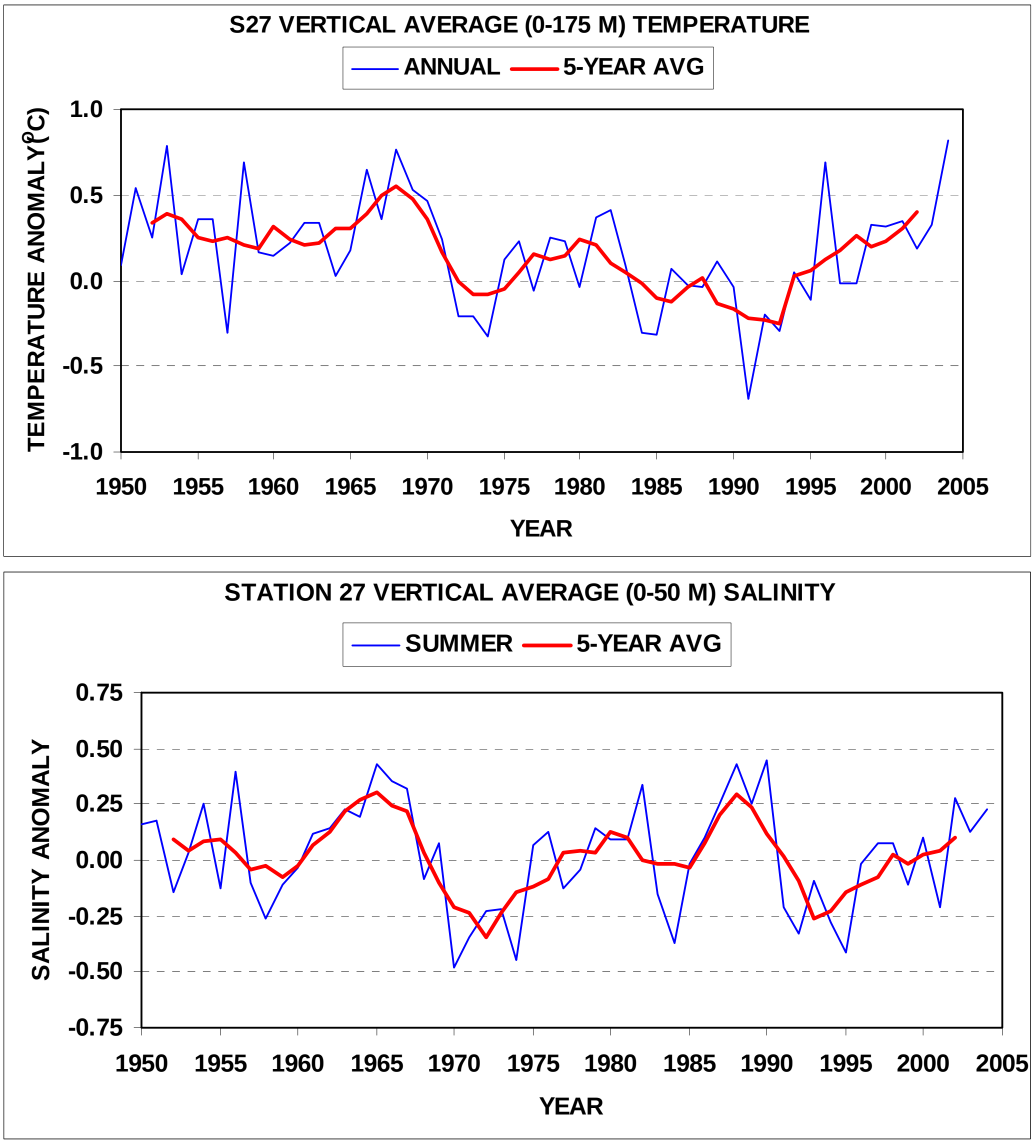


Figure 8. The annual vertically averaged Station 27 temperature and salinity anomalies.

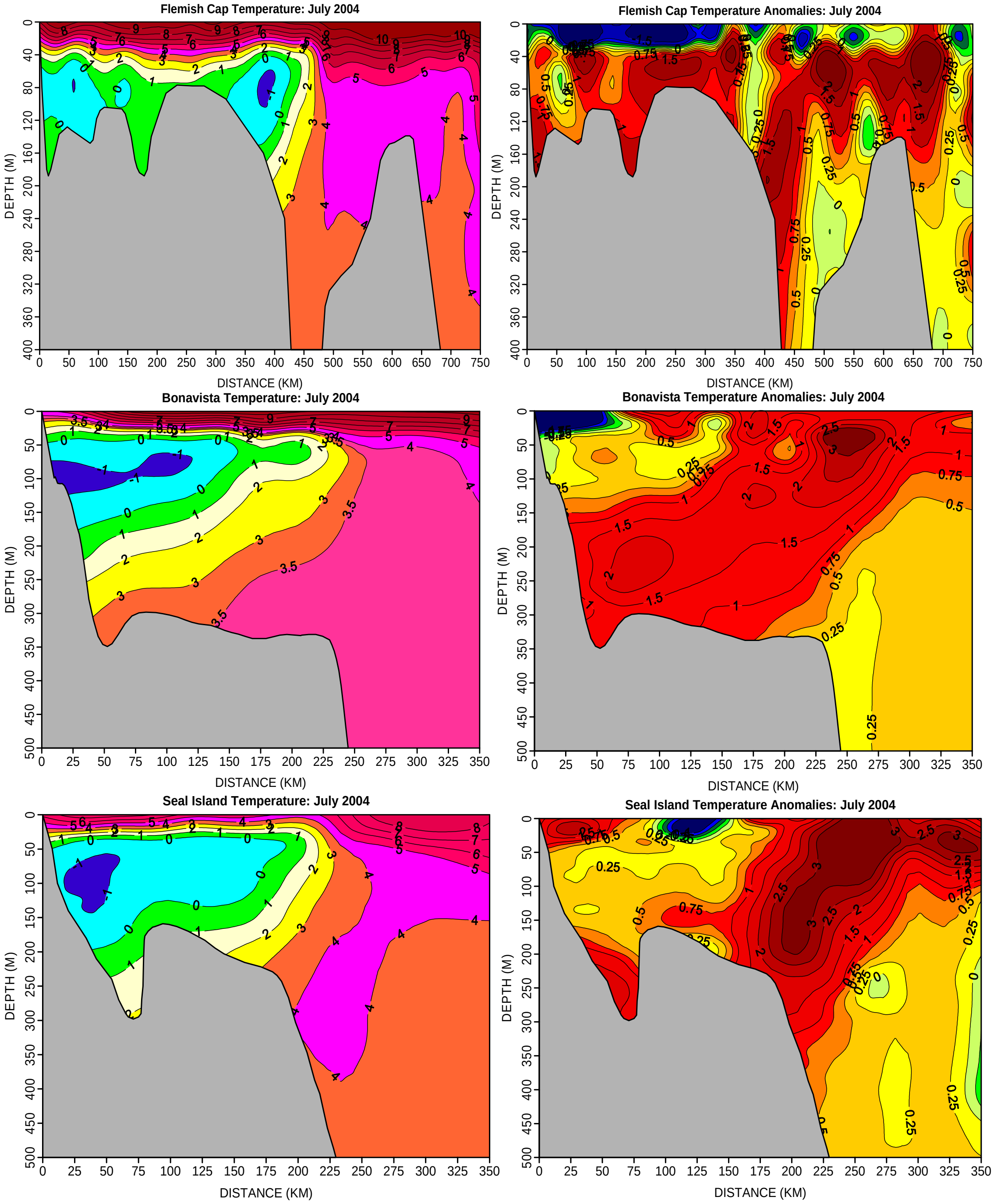
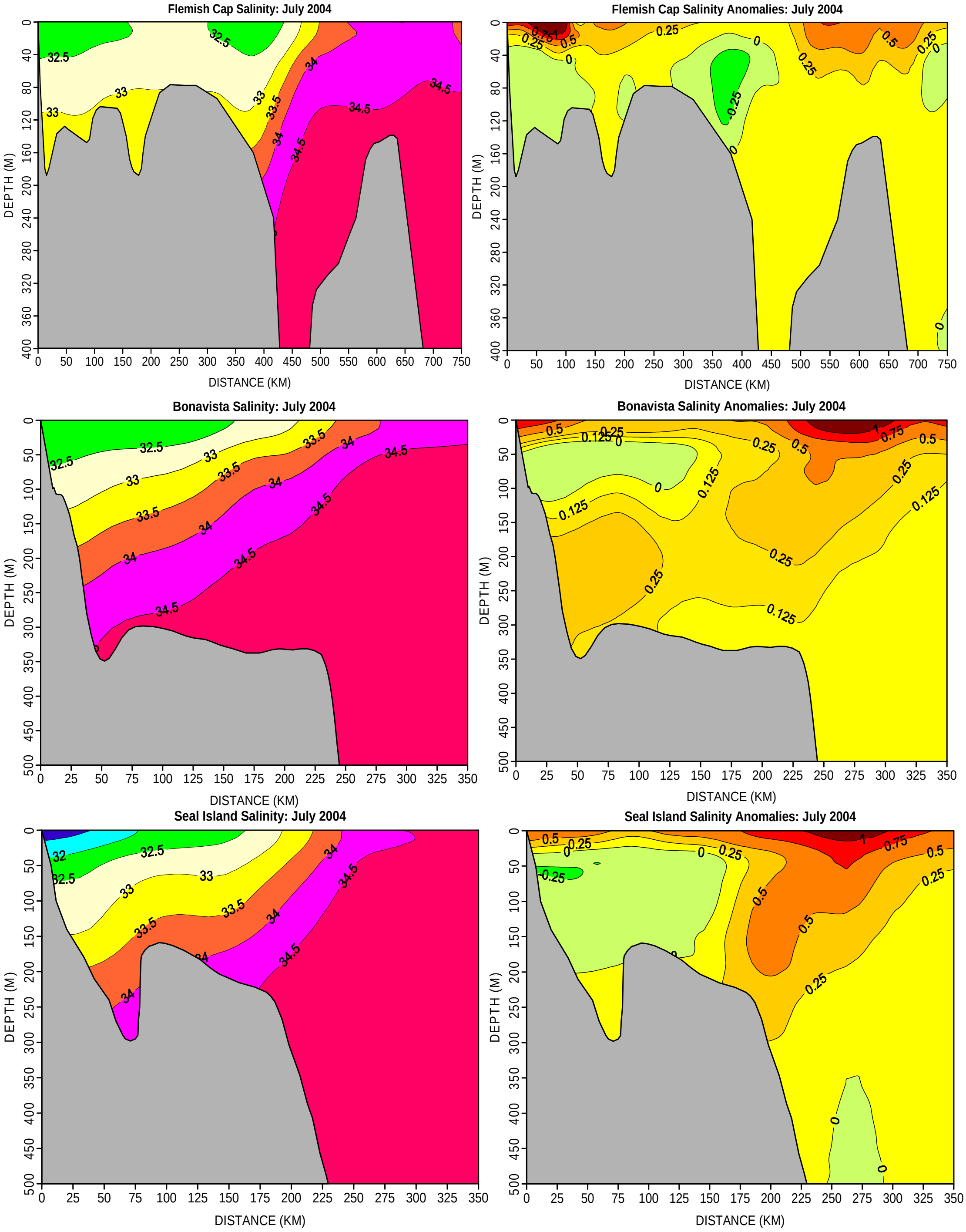


Figure 9. Contours of temperature and temperature anomalies (in °C) along the Flemish Cap, Bonavista and Seal Island sections (Figure 2) during the summer of 2004.



Flemish Cap Salinity: July 2004

Flemish Cap Salinity Anomalies: July 2004

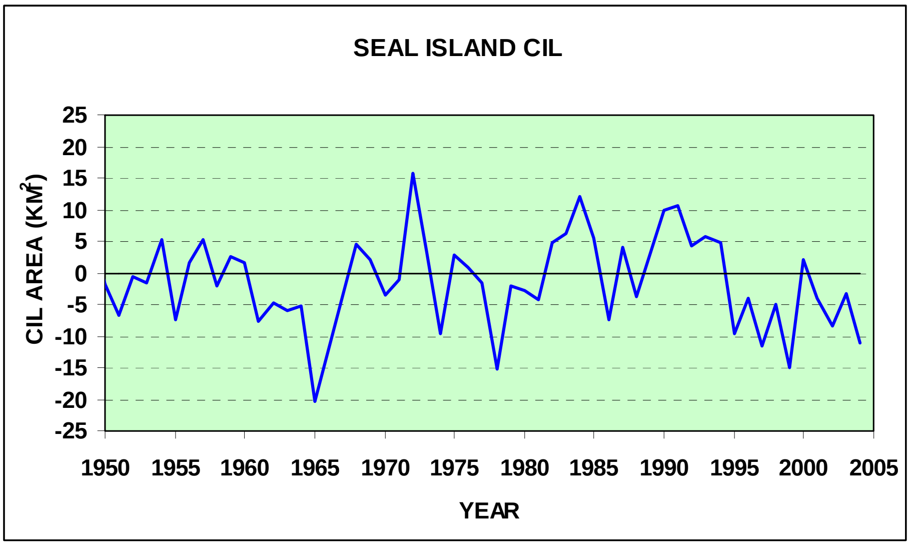
Bonavista Salinity: July 2004

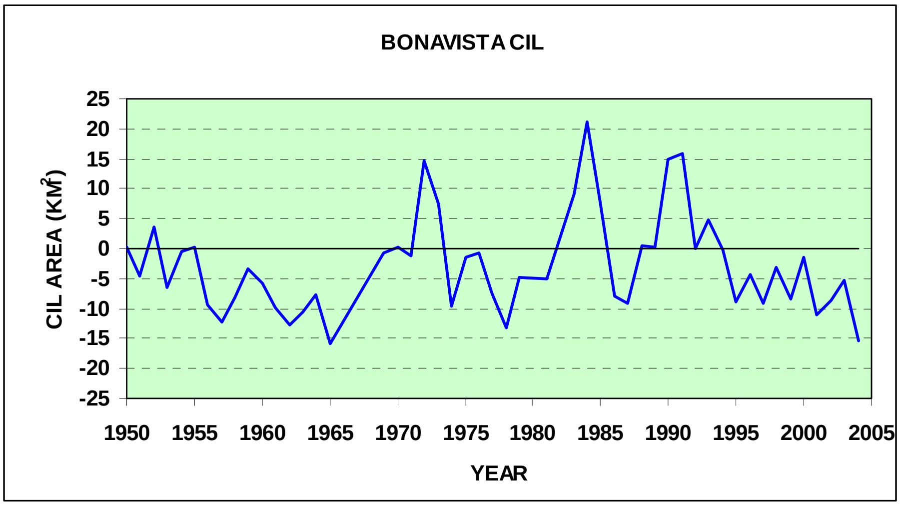
Bonavista Salinity Anomalies: July 2004

Seal Island Salinity: July 2004

Seal Island Salinity Anomalies: July 2004

Figure 10. Contours of salinity and salinity anomalies along the Flemish Cap, Bonavista and Seal Island sections during the summer of 2004.





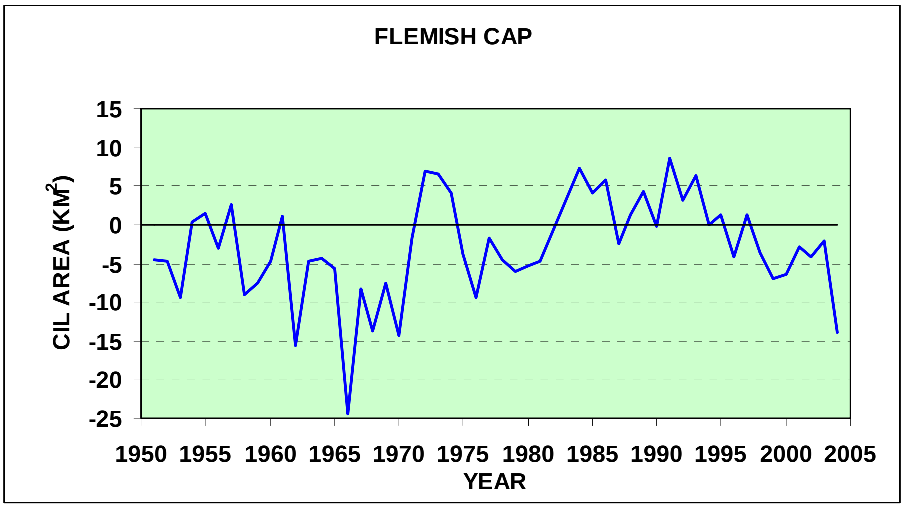


Figure 11. Annual summer CIL cross-sectional area anomalies along the Flemish Cap, Bonavista and Seal Island sections. The anomalies are references to the 1971–2000 means.

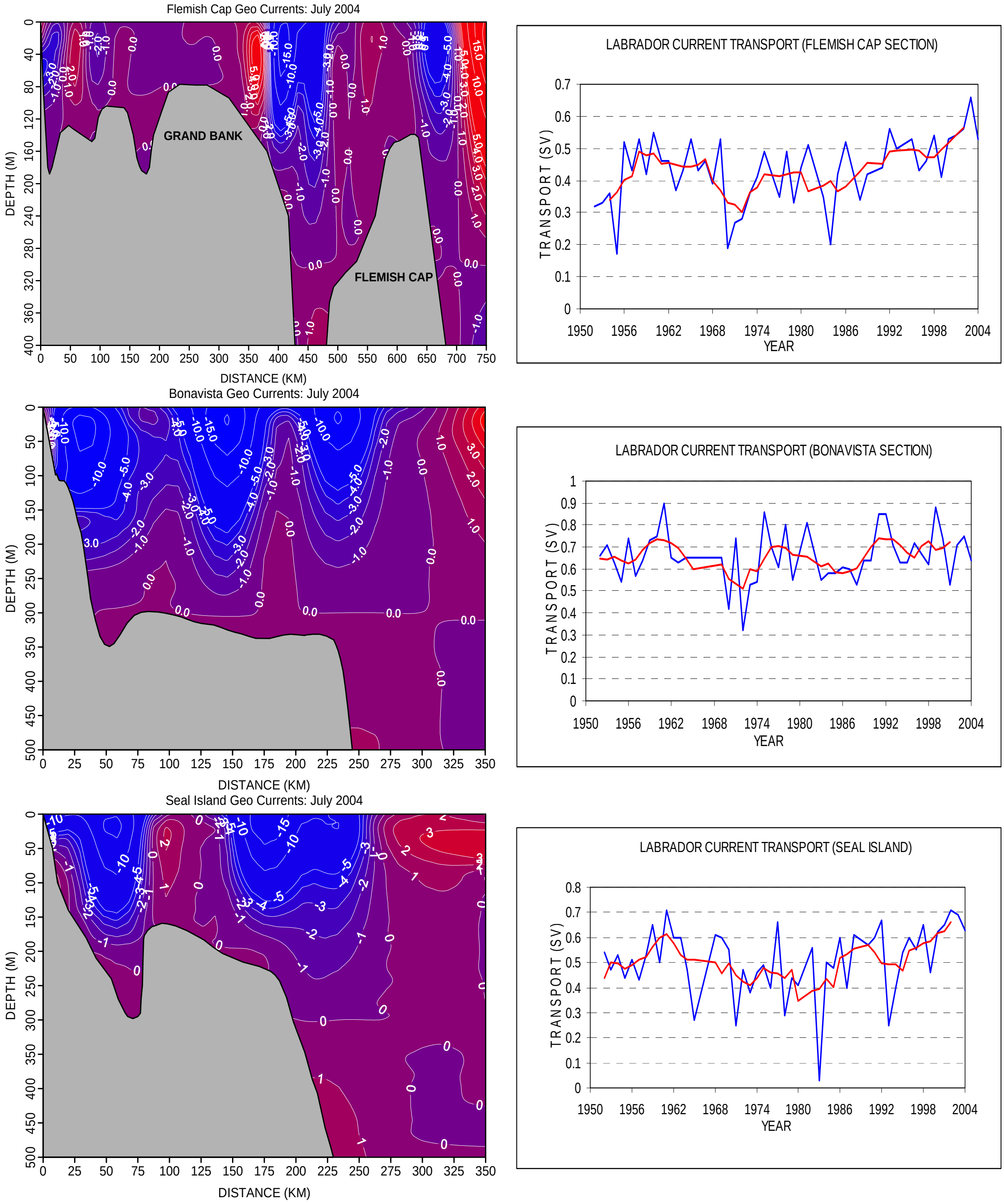


Figure 12. Contours of geostrophic currents (in cm/s) along sections on the Newfoundland and Labrador Shelf (Figure 2) during the summer of 2004 (left panels) and annual estimates of geostrophic transport (10^6 m^3/s) relative to 130-m depth of the offshore branch of the Labrador Current.

Annex 7: Environmental conditions in the Labrador Sea 2004 (Area 2)

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Summary

Labrador Sea hydrographic conditions depend on a balance between heat lost to the atmosphere and heat gained from warm and saline Atlantic Waters carried northward into the Labrador Sea by the West Greenland Current. Severe winters under high North Atlantic Oscillation (NAO) conditions lead to greater cooling: in exceptional cases, the resulting increases in the surface density can lead to convective mixing of the water column to depths of 2 km. Milder winters under low NAO conditions lead to lower heat losses and an increased presence of the warm and saline Atlantic Waters.

A sequence of severe winters in the early 1990s led to the most recent period of deep convection, which peaked in 1993-1994. Recent winters have been generally mild. Annual mean sea-air heat fluxes in the west-central Labrador Sea from the NCEP/NCAR Reanalysis project have been lower than normal since 1998. The 2004 annual mean of 39 W/m^2 was the second lowest since 1987. The January-March 2004 mean air-sea heat loss was the lowest since 1987 and the sixth lowest in the 1948-2004 NCEP Reanalysis time period.

Mean 2004 sea surface temperatures in the west-central Labrador Sea from the UK Met Office Hadley Centre HadISST 1.1 Global Sea Surface Temperature data set were the warmest in the past 45 years.

Sea level in the west-central Labrador Sea was about 6 cm higher in 2004 than during the early 1990s, based on TOPEX/POSEIDON and JASON-1 altimetry. Most of this change can be related to changes in hydrographic conditions. There has been relatively little change in annual-mean sea level in the west-central Labrador Sea during the past few years.

Ocean Sciences Division, DFO Maritimes Region has monitored hydrographic properties on the AR7W line across the Labrador Sea in the early summer of each year since 1990. The 15th annual AR7W survey took place in late May 2004. Between 1990 and 2004 there has been a general trend to warmer and saltier conditions in the upper layers of the Labrador Sea. Changes in temperature and salinity averaged over the upper 150 m during this period amount to about 1°C and 0.1 respectively.

Below the seasonal layer, the upper waters (averages over 150-1000 m or 150-1500 m) of the west-central Labrador Sea have become steadily warmer and more saline over the past four years. By this measure, conditions in 2004 were the warmest and saltiest in the 15 years of annual AR7W surveys. Density changes during the past few years have been relatively small, with changes linked to temperature and salinity nearly in balance.

The May 2004 survey encountered warm and saline conditions in waters in the offshore branch of the West Greenland Current, with maximum salinities greater than 34.95. High salinity near-surface waters extended westward into the central Labrador Sea.

The May 2004 observations suggest that the 2003-2004 winter mixed layer had maximum potential density anomalies just less than 27.73 kg/m^3 and maximum depths of about 800 m,

less than the corresponding values attained following the winter of 2002-2003 as observed in the 2003 AR7W survey.

General environmental indicators

Sea-air heat flux

On an annual average, the Labrador Sea loses heat to the overlying atmosphere. The greatest heat losses occur in January and February. Monthly-averaged air-sea flux fields are available from the co-operative Reanalysis Project (Kistler et al., 2001) of the U.S. National Centers for Environmental Prediction (NCEP) and National Center for Atmospheric Research (NCAR).

Figure 1(a) shows a map of 2004 mean NCEP Reanalysis sea-air heat flux for the Labrador Sea. Positions of the NCEP grid points are superimposed on the map. AR7W station positions occupied in May 2004 on CCGS Hudson Mission 2004-016 and the position of former Ocean Weather Station (OWS) Bravo are also marked on the map. The four highlighted stations near the OWS Bravo site are used to represent conditions in the west-central Labrador Sea. Figure 1(b) shows a similar map of 1971-2000 mean sea-air heat flux. The 30-year period 1971-2000 is used to represent normal conditions. The patterns are similar, but the maximum in the heat loss pattern for 2004 is displaced about 100 km to the northwest compared to the normal pattern. Figure 1(c) shows a map of the 2004 anomaly in sea-air heat flux relative to normal conditions. Values in the west-central Labrador Sea in 2004 were 20-30 W/m^2 less than normal. Figure 1(d) shows a time series of interannual changes in annual mean and annual mean plus residual seasonal variability in sea-air heat flux from the NCEP Reanalysis grid point at 56.2N, 52.5W. The normal value is 66 W/m^2. The seasons are defined as January-March (JFM), April-June (AMJ), July-September (JAS), and October-December (OND). The residual seasonal variability is the residual after a normal seasonal cycle is removed. The normal seasonal cycle was defined by a least-squares fit of annual plus semiannual harmonics to monthly mean heat fluxes for 1971-2000. Annual mean heat losses at this location have been less than normal for the past seven years. The 2004 annual mean of 39 W/m^2 was the second lowest since 1987, with 2001 being the lowest. The JFM 2004 seasonal residual was the lowest since 1987 and the sixth lowest in the 1948-2004 NCEP Reanalysis time period.

Sea surface temperature

The UK Met Office Hadley Centre produces HadISST 1.1, global estimates of monthly mean sea surface temperature (SST) on a one degree by one degree latitude-longitude grid. Figure 2(a) shows a map of 2004 mean SST from this source for the Labrador Sea annotated with AR7W and OWS Bravo positions as in Figure 1(a). Figure 2(b) shows a similar map of 1971-2000 mean SST. The 2004 map and the normal map show similar patterns, but again the isotherms in the 2004 map are displaced about 100 km to the northwest compared to the normal pattern. Figure 1(c) shows a map of the 2004 SST anomaly relative to normal conditions. Values in the west-central Labrador Sea in 2004 were more than 1°C warmer than normal. Figure 1(d) shows a time series of annual mean and annual mean plus residual seasonal variability averaged over nine grid points centred at 56.5N, 52.5W. The normal value is 4.34°C. The residual seasonal variability is the residual after removal of a normal seasonal cycle defined in the same way as discussed above for heat flux. Annual mean SST at this location has been warmer than normal since the mid-1990s. Both the 2004 annual mean and the 2004 JFM seasonal residual were record highs for 1960-2004.

Sea level

The French SSALTO/DUACS group uses TOPEX/POSEIDON and JASON-1 altimetric sea level measurements to produce weekly gridded Maps of Sea Level Anomalies (MSLA) with near-global geographic coverage on a 1/3° Mercator grid. These are distributed by the French AVISO group with support from the French national space agency CNES. Data coverage begins with the TOPEX/POSEIDON mission in late 1992 and continues to the present.

Figure 3(a) shows a map of 2004 mean sea level anomaly (SLA) from this source for the Labrador Sea annotated with AR7W and OWS Bravo positions as Figure 1(a). The ground tracks common to the two altimetric missions involved are also shown. The gridded MSLA are produced by a statistical interpolation that is most reliable at points close to the measurements (Le Traon, et al., 1998). The anomalies are shown relative to the mean value for 1993-2004. The map shows positive SLA values in the west-central Labrador Sea in 2004 ranging from 2 to 4 cm. There is a local minimum with values below 2 cm at the ground track crossover point near the highlighted AR7W stations used to represent the west-central Labrador Sea. Figure 3(b) shows a time series of annual mean and residual seasonal SLA from an average over 25 grid points centred at 56.7N, 52.3W near this crossover point. The normal seasonal cycle was defined by a least-squares fit of annual plus semiannual harmonics to weekly values of SLA for 1993-2004. Sea level showed a marked rise at this location from the mid-1990s to 2000, and has been relatively constant since then. The 2004 annual mean value is slightly less than the annual mean 2003 value. These values are somewhat sensitive to the spatial averaging. A larger spatial average includes 2004 SLA grid points with anomalies greater than 4 cm and gives 2004 values slightly higher than 2003. The 2003 annual mean SLA field (not shown) was less spatially variability in the west-central Labrador Sea than 2004.

AR7W hydrography

Figure 4 shows a map of the Labrador Sea with AR7W station positions occupied in May 2004 on CCGS Hudson Mission 2004-016 under the scientific direction of Dr. Glen Harrison. The 28 principal AR7W stations were occupied during the period May 20-26, 2004. The standard section spans approximately 880 km from the 130 m contour on the inshore Labrador shelf to the 200 m contour on the West Greenland shelf. Sea ice sometimes limits coverage at the ends of the section. Only the two stations nearest the Labrador coast were unreachable in 2004 even though it was relatively early in the season.

Contoured gridded sections of potential temperature and salinity as observed in May 2004 are shown in Figures 5(a) and 5(b). Along-section distance in kilometres increasing from southwest (Labrador) to northeast (Greenland) is used as the horizontal coordinate. The four stations chosen to represent conditions in the west-central Labrador Sea lie within the 320-520 km distance range.

Notable in the upper levels of Figure 5(a) (potential temperature) are cold waters (<2°C) over the Labrador Shelf. Similarly cold waters in the upper few hundred metres over the outer edge of the West Greenland shelf are associated with the inshore branch of the northward-flowing West Greenland Current. Warmer waters (>4°C) in the upper 500 m of the water column over the West Greenland slope are associated with the offshore branch of the West Greenland Current.

There is a regular seasonal cycle in both temperature and salinity that affects the uppermost layers. Near-surface seasonal warming and freshening is apparent in Figures 5(a) and 5(b) respectively.

Several extra stations were made to better define a mesoscale eddy which shows up prominently in the potential temperature and salinity fields near the 650 km mark.

In the central Labrador Sea, water at depths between 600 m and 1200 m below the seasonal thermocline has reduced vertical temperature gradients that mark vertically-mixed Labrador Sea Water (LSW) formed by winter convection in recent years. The LSW layer creates a relative minimum in potential temperature with core values near 3.2°C. The section plots are annotated with the pressure of this relative minimum in potential temperature. The LSW layer extends over much of the section, but it is most prominent in the west-central Labrador Sea where the deepest winter mixed layers are formed. Waters in the upper 500 m on the Greenland side are notably warmer than on the Labrador side, showing a greater influence of the warm Irminger Waters. Denser components of the warm and saline Irminger Water influence a layer centred near 1500 m below the LSW. The intrusion of these warm and saline waters creates a relative maximum in potential temperature with maximum values greater than 3.3°C. The section plots also show the pressure of this intermediate-depth potential temperature maximum.

In the salinity section in Figure 5(b), waters in the upper 500 m on the Greenland end of the section are notably saltier than waters in the same depth range on the Labrador end, again showing the Irminger Water influence. Traces of relatively fresh water with salinity less than 34.88 near 2000 m depth are remnants of the deep convection of the early 1990s.

Changes in upper level properties

The strongest seasonal variations occur in the upper 150 m of the water column. Survey times during the 15-year period varied from late May to late July. Climatological hydrographic data from the U.S. National Ocean Data Center (Conkright et al., 2002) were used to estimate seasonal changes in potential temperature and salinity averaged over 0-150 m depths in the west-central Labrador Sea. The inferred seasonal effects were then removed from the AR7W survey data. Figures 6(a) and 6(b) show time series of 0-150 m deseasoned mean potential temperature and salinity for stations in the 320-520 km distance range for the 15 spring and early summer AR7W occupations from 1990 to 2004. For example, the 2004 value is an average over the four highlighted stations in Figure 4. Standard deviations of individual 0-150 m station means for each survey are indicated on the plots. The 15-year changes in potential temperature and salinity estimated by least-squares regressions are about 1.1°C and 0.09 respectively. Anomalies for 2004 relative to the1990-2004 mean are 0.4°C in potential temperature and 0.03 in salinity. The 2003 potential temperature anomaly from late July 2003 was still greater. The summer of 2003 in the Labrador Sea was evidently a particularly warm one. The same feature is seen in sea surface temperature. The HadISST 1.1 2003 JAS residual in the west-central Labrador Sea was the highest in the 1960-2004 analysis period.

Water masses

As an overview of the water masses in the Labrador Sea, Figure 7(a) shows a potential temperature – salinity scatter diagram for all 2004 AR7W stations. Four water types are singled out for attention:

- Irminger Atlantic Water (IAW) with potential temperatures between 4°C and 6°C and salinities between 34.95 and 35.10 (Lee, 1968);
- Irminger Mode Water (IMW) with potential temperatures between 4°C and 6°C and salinities between 34.85 and 34.95 (Buch, 2000);
- Labrador Current Water (LCW) with potential temperatures between -1.8°C and 1°C and salinities between 32 and 34; and
- Labrador Sea Water (LSW) with potential temperatures between 3.2°C and 3.3°C and salinities between 34.82 and 34.88.

The last two definitions are nominal ones, for illustration only. LSW produced during the early 1990s had potential temperature near 2.8°C.

Figures 7(b) – 7(d) show contoured gridded sections of potential density anomaly, potential vorticity, and apparent oxygen utilization (AOU) respectively.

In principle, mixed layers formed by overturning surface waters will have initial values of zero for both potential vorticity and AOU. To the extent that these properties are conserved, they can be used to trace waters that originated in the winter mixed layers of the Labrador Sea.

Pressure ranges on stations where IAW and IMW potential temperature - salinity water types as defined above were found are highlighted in the section plots with the same colour scheme used in Figure 6(a). The IAW and IMW types are confined to the upper levels on the West Greenland end of the AR7W section. They are associated with relatively low values of potential density and relatively high values potential vorticity. IMW has been observed on the AR7W surveys in recent years. Higher salinity waters meeting the Lee (1968) IAW criterion were also seen in the 2003 survey and in a December 2002 survey, but not in 2001 or 2002.

The eddy centred near 650 km shows up prominently in all three fields.

Regions of relatively low apparent oxygen utilization near 2000 m correspond to relatively high dissolved oxygen. They are further remnants of the deep convection of the early 1990s.

Interannual changes in winter convection

Figure 8 provides an overview of interannual variability from AR7W surveys since 1990. It shows a time series of the pressure on selected potential density anomaly surfaces from average profiles in the 320-520 km distance range for each survey as a function of the median station time. This provides an update of Figure 4 in Lazier et al. (2002).

The deep convection of the early 1990s is reflected in the 1993-1995 maximum in the separation of the 27.77 and 27.79 kg/m^3 potential density anomaly surfaces bounding the deeper shaded layer in Figure 8. The volume of water in this potential density range decreased steadily from 1995 to 2000. Pressures corresponding to the minimum potential temperature in the 27.77-27.79 kg/m^3 layer for each survey are noted in the figure. The prominent relative minimum in potential temperature in this layer created by the deep convection in the winters of 1992-1993 and 1993-1994 persists until at least 1999. Changes in the separation of these isopycnals have been small since 2000.

Since 1999 or 2000 and especially from 2001 to 2003 there has been an increase in the separation of isopycnals with potential density anomalies in the range 27.72-27.75 kg/m^3 that define the shallower shaded layer in Figure 8. In 2000, this layer developed a prominent relative minimum in potential temperature with core potential temperature 3.2°C, salinity 34.83, and potential density anomaly 27.73 kg/m^3. A relative minimum in potential temperature is also present in 2002 and 2003 at increasing values of potential density anomaly. This persistent feature can be interpreted as a remnant of intermediate-depth winter convection in the west-central Labrador Sea during recent years. In 2004 the minimum potential temperature in the 27.72-27.75 kg/m^3 layer is found near the bottom of the layer.

Figures 9(a)-9(b) show average profiles of potential temperature and low-pass filtered potential vorticity for stations in the 320-520 km distance range from the 2000-2004 spring and early summer AR7W occupations. Potential vorticity has been smoothed in the vertical to emphasize vertical scales of 200 m and greater. The properties are averaged on potential density surfaces and plotted against potential density anomaly. The four individual stations included in the 2004 average are shown in the background for each of the figures.

Figure 9(a) shows the relative minima in potential temperature introduced in Figure 8 at progressively higher potential densities: from 27.73 kg/m^3 in 2000 and 2001, to greater than 27.73 kg/m^3 for 2002 and 2003, to greater than 27.74 kg/m^3 in 2004. The potential temperature at the 2004 relative minimum is about 0.07°C warmer than for the previous two years. Figure 9(b) shows similar relative minima in potential vorticity at about the same potential density anomalies. Waters with potential density anomalies less than 27.72 kg/m^3 are replaced annually, so their properties vary seasonally. The 2000, 2001, and 2004 surveys took place in late May or early June. The 2002 and 2003 surveys took place in early and late July respectively.

It is not immediately obvious if the relative minima in potential temperature and potential vorticity observed in 2004 are remnants of convection during the winter of 2003-2004 or remnants of convection during a previous winter. In the latter case, mixing would tend to increase the values of potential temperature and potential vorticity at the respective relative minima.

Figure 9(c) shows similar profiles of potential vorticity and apparent oxygen utilization (AOU) averaged on pressure surfaces and plotted as a function of pressure. Figure 9(c) is identical to Figure 9(b) with pressure substituted for potential density anomaly as the independent variable. The 27.72-27.74 kg/m^3 layer in Figure 9(a) corresponds to pressures from 360 to 1250 dbar in Figure 9(c).

Figure 9(d) shows larger differences in the vertical structure in AOU for 2002-2004 than seen in potential vorticity (calibrated CTD oxygen data for 2000 and 2001 were not available for this report). In particular, 2003 shows a layer from 700-1200 dbar with nearly constant AOU near 0.6 mL/L. This pressure range corresponds to the low potential vorticity layer in Figure 9(c). It includes potential density anomalies in the range 27.73-27.74 kg/m^3. The 2004 survey shows a generally strong increase in AOU with increasing pressure in the same pressure range. The exception is the 700-800 dbar range in which AOU is also nearly constant with about the same 0.6 mL/L value. The potential density anomaly is just less than 27.73 kg/m^3 in this range of pressures. The appreciable gradients in AOU deeper than about 800 dbar suggest that the convective mixed layer formed in the winter of 2003-2004 did not reach potential density anomalies greater than 27.73 kg/m^3, corresponding to a maximum depth of about 800 m.

Interannual changes in heat, salt, buoyancy, and geopotential

The changes in heat and salt from 1990 to 2000 were discussed by Lazier et al. (2002). Time series of the changes in heat, salt, buoyancy, and geopotential in selected layers from spring and early summer AR7W surveys from 1990 to 2004 are shown in Figures 10(a)-10(d). Each series is plotted as an anomaly relative to its 1994 value. Any averages involving the 0-150 dbar range have been corrected for seasonal changes in the 0-150 dbar layer as discussed above.

The ranges of heat and salt content in the 0-2000 dbar layer in Figures 10(a) and 10(b) are approximately 5 GJ/m^2 and 100 kg respectively. A heat gain of 1 GJ/m^2 by this layer would increase its mean temperature by about 0.12°C. An increase of 20 kg/m^2 of salt in the same layer raises its mean salinity by about 0.01.

The heat content in the 0-1500 and 0-2000 dbar layers increased in 2004 compared to 2003. This continued a 4-year increasing trend and gave 2004 the highest values observed in the 15 spring and early summer AR7W surveys. The heat content of the 0-1000 dbar layer in 2004 was nearly identical to the 2003 value because the 0-150 dbar layer was warmer in 2003.

The salt content of the 0-1000 dbar layer shows more-random changes than the heat content. Since 2001, however, the salt content of this layer shows an increasing trend. The 2004 value is the highest in the record. The 1000-1500 dbar and 1500-2000 dbar layers show much smoother changes in salt content with time. The salt content in both deep layers increased steadily from 1994 to 2000 or 2001, when the shallower recent convection regime began to establish itself. Salt content decreased in the 1000-1500 dbar layer between 2001 and 2003. This is related to the deepening of isopycnal surfaces in that pressure range and an increased presence of lower density and lower salinity water in the 1000-1500 dbar pressure range. In contrast, the 1500-2000 dbar layer shows a steady increase in salt content since 1994. The net result is that the salt content, or equivalently the mean salinity, in the 0-2000 dbar range has increased for each of the past four years. The 2004 value is a record high.

Higher temperatures correspond to lower water densities and higher salinities correspond to greater water densities. The trends to warmer and saltier conditions have opposite effects on density or buoyancy. Figure 10(c) shows changes in buoyancy relative to 1994 associated with the same pressure layers as dealt with in Figures 10(a)-10(b). The warming of the upper 1000 dbar layer from 1994 to 1999-2000 while salinity remained relatively constant produced a large increase in buoyancy. Recent years have seen both warmer and saltier upper-layer conditions. There is no clear trend in buoyancy over the past six years.

Figure 10(d) shows time series of the changes in geopotential at the minimum layer pressure relative to the maximum layer pressure for four of the same layers featured in Figure 10(c). The geopotential changes are all relative to 1994 values. Also shown are time series of annual mean and annual mean plus seasonal residual sea surface geopotential relative to the 1994 annual mean derived from the satellite altimetry. These correspond to the sea level anomaly time series in Figure 3(b). There is close agreement between the 0-2000 dbar geopotential difference from hydrography and geopotential changes related to changing sea level. Another way of putting this is that the sea level changes are largely explained by steric effects in the upper 2000 m of the water column. Hydrographic changes in the upper 1000 m have the greatest effect in sea level, but changes deeper than 1000 m also have an appreciable influence.

Acknowledgments

Dr. R. Allyn Clarke at the Bedford Institute of Oceanography has provided overall scientific direction to the AR7W repeat hydrography programme for many years. Dr. Glen Harrison at the Bedford Institute of Oceanography was Chief Scientist of CCGS Hudson Mission 2004-016 for the most-recent AR7W occupation.

The HadISST 1.1 Global Sea Surface Temperature data set was provided by the Hadley Centre for Climate Prediction and Research, Met Office, Bracknell, UK. [http://www.metoffice.com/research/hadleycentre/obsdata/HadISST1.html]

Data from the NCEP Reanalysis were provided by the NOAA-CIRES Climate Diagnostics Center, Boulder, Colorado, USA, from their Web site at http://www.cdc.noaa.gov/.

MSLA altimeter products were provided by the French AVISO/Altimetry operations centre at the CLS Space Oceanography Division. [http://www.aviso.oceanobs.com/]

Climatological hydrographic data were provided by the U.S. National Oceanographic Data Center. [http://www.nodc.gov/]

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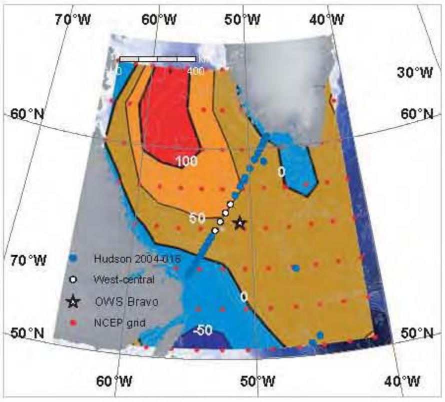

Fig. 1(a) NCEP/NCAR Reanalysis 1 mean sea-air heat flux (W/m^2) over the Labrador Sea for 2004 from monthly mean flux fields on a T62 Gaussian grid.

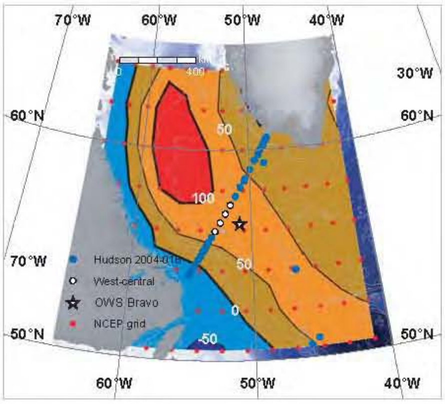

Fig. 1(b) NCEP/NCAR Reanalysis 1 annual mean sea-air heat flux (W/m^2) over the Labrador Sea for the 30-year normal period 1971-2000.

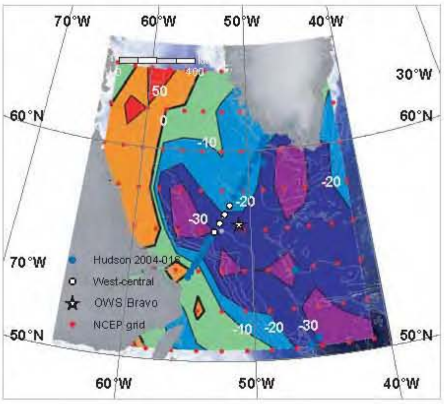

Fig. 1(c) Sea-air heat flux anomaly (W/m^2) over the Labrador Sea for 2004 relative to 1971-2000.

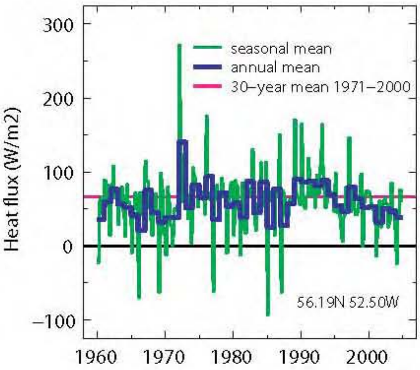

Fig. 1(d) Time series of annual mean and annual mean plus seasonal residual NCEP/NCAR Reanalysis 1 sea-air heat flux from 56.2N, 52.5W in the west-central Labrador Sea. The normal value is 66 W/m^2.

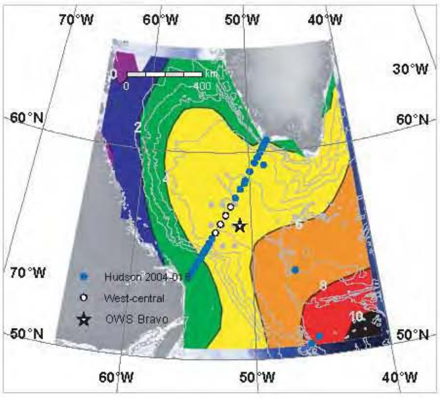

Fig. 2(a) HadISST 1.1 mean sea surface temperature (^{0}C) over the Labrador Sea for 2004 from monthly mean values on a 1 degree x 1 degree grid.

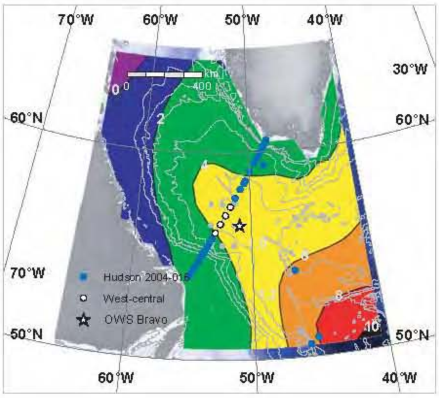

Fig. 2(b) HadISST 1.1 mean sea surface temperature (^{0}C) over the Labrador Sea for the 30-year normal period 1971-2000.

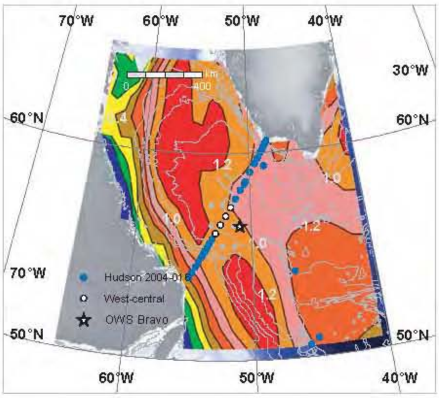

Fig. 2(c) HadISST 1.1 SST anomaly (^{0}C) over the Labrador Sea for 2004 relative to 1971-2000.

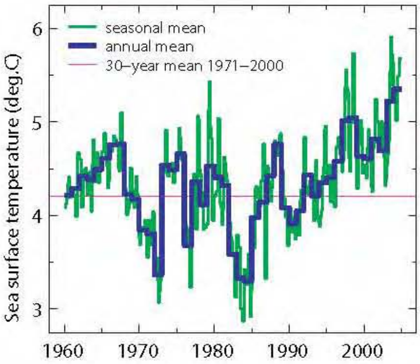

Fig. 2(d) Time series of annual mean and annual mean plus seasonal residual HADISST 1.1 SST averaged over 9 grid points centred at 56.5N, 52.5W in the west-central Labrador Sea. The normal value is 4.34^{0}C.

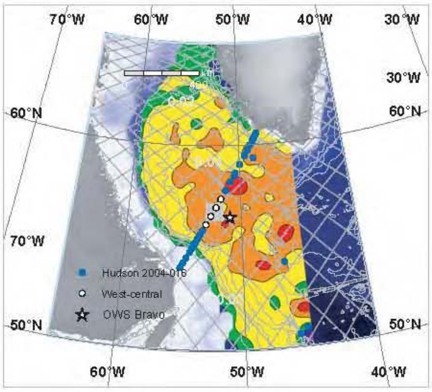

Fig. 3(a) Aviso mean SLA (m) for 2004 relative to 1993-2004 over the Labrador Sea from anomalies at 7-day intervals on a 1/3 degree Mercator grid. Topex/Poseidon – Jason-1 ground tracks are also shown.

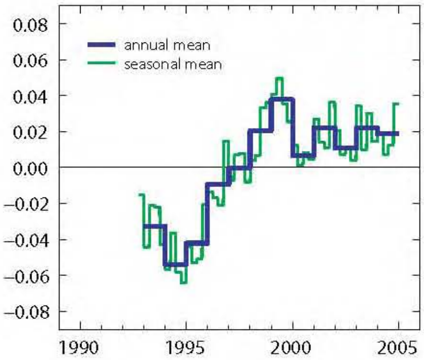

Fig. 3(b) Time series of annual mean and annual mean plus seasonal residual Aviso SLA relative to 1993-2004 averaged over 25 grid points centred at 56.7N, 52.5W in the west-central Labrador Sea.

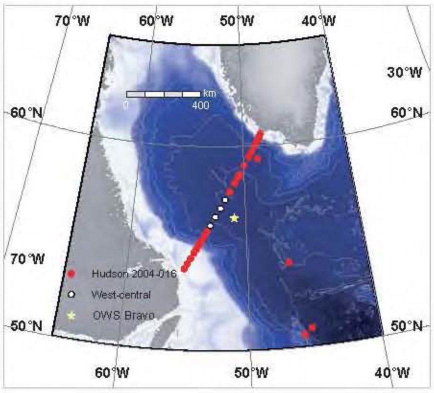

Fig. 4 Map of the Labrador Sea showing station positions from CCGS Hudson Mission 2004-016 during May 15 – 30, 2004 including the 2004 occupation of AR7W. The highlighted stations are used to represent conditions in the west-central Labrador Sea in subsequent figures.

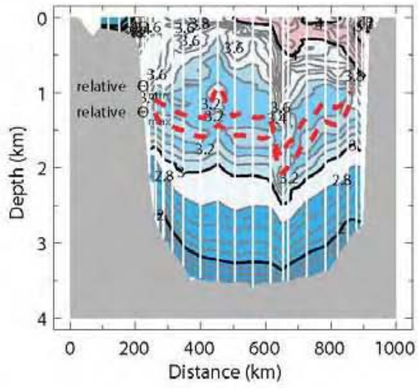

Fig. 5(a) Potential temperature (°C) on the AR7W section in late May 2004. Station positions are indicated by vertical lines. The dashed lines trace layers of relative minimum and maximum potential temperature.

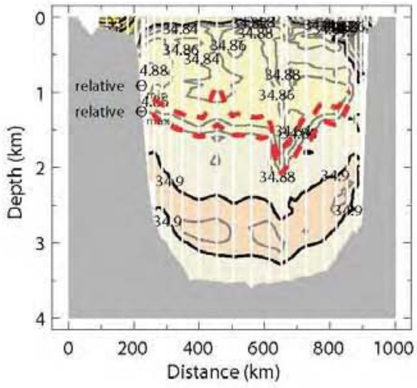

Fig. 5(b) Salinity on the AR7W section in May 2004 as in Fig. 5(a).

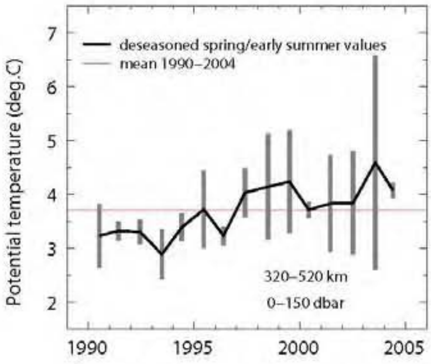

Fig. 6(a) Mean 0-150 m deseasoned potential temperature averaged over stations in the 320-520 km distance range for spring and early summer AR7W occupations. Error bars are among-station standard deviations of 0-150 m means for each cruise.

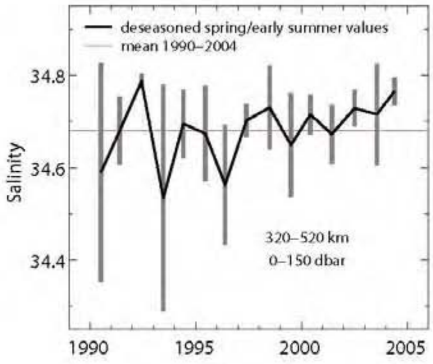

Fig. 6(b) Mean 0-150 m deseasoned salinity averaged over stations in the 320-520 km distance range for spring and early summer AR7W occupations as in Fig. 6(a).

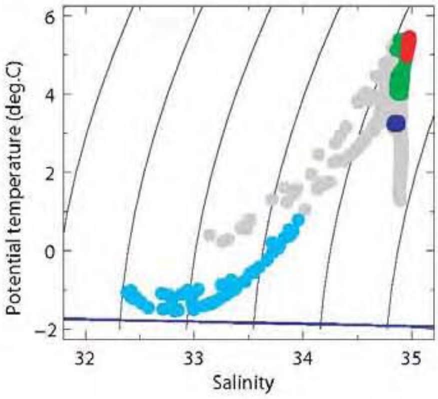

Fig. 7(a) Potential temperature – salinity scatter diagram from the May 2004 AR7W section. Highlighted water types LC (cyan), LSW (blue), IAW (red), and IMW (green) are defined in the text.

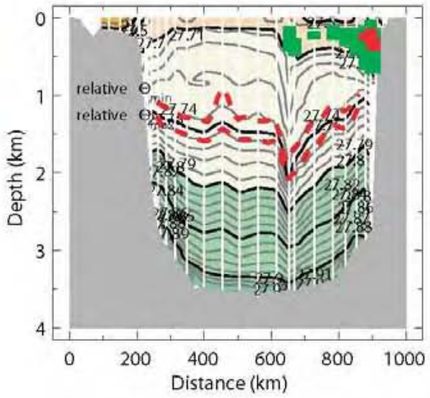

Fig. 7(b) Potential density anomaly (kg/m^3) on the AR7W section in late May 2004 as in Fig. 5(a). Water types IAW (red) and IMW (green) are highlighted as in Fig. 7(a).

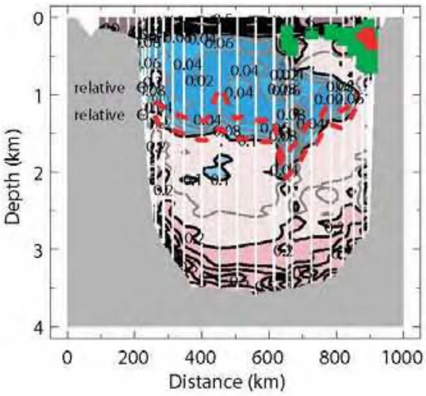

Fig. 7(c) Potential vorticity [10^{-10} (m•s)$^{-1}$] on the AR7W section in late May 2004 as in Fig. 5(a). Water types IAW (red) and IMW (green) are highlighted as in Fig. 7(a).

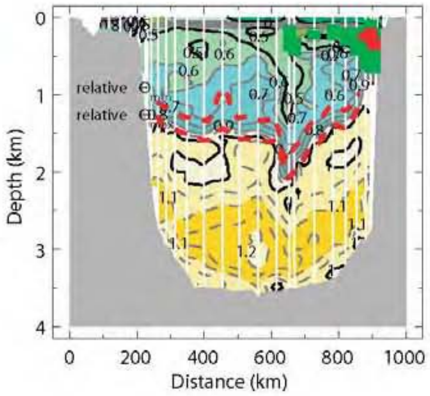

Fig. 7(d) Apparent oxygen utilization (mL/L) on the AR7W section in late May 2004 as in Fig. 5(a). Water types IAW (red) and IMW (green) are highlighted as in Fig. 7(a).

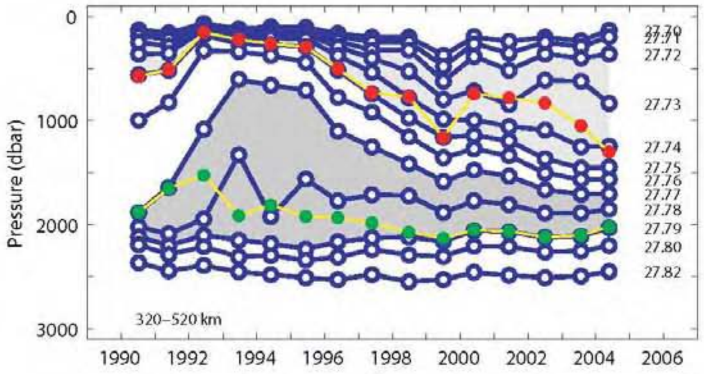

Fig. 8 Time series of pressure on selected potential density surfaces as labelled averaged over stations in the 320-520 km distance range on AR7W spring and early summer occupations during 1990-2004. Filled symbols mark pressures at minima in potential temperature in two shaded layers 27.72–27.75 kg/m^3 (upper) and 27.77–27.79 kg/m^3 (lower). The density surfaces in the lower layer were exposed to the atmosphere in winters in the early 1990s. A shallower winter convection regime appears to have been established beginning in 2000.

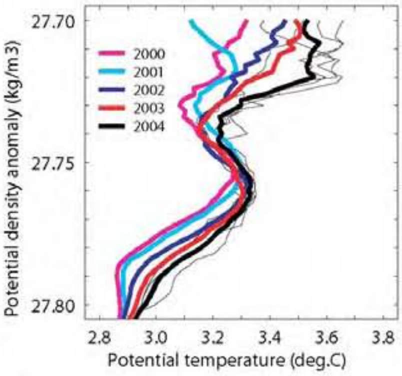

Fig. 9(a) Potential temperature averaged on potential density surfaces for stations in the 320-520 km distance range plotted against potential density anomaly for 2000-2004 spring and early summer AR7W occupations. The four individual stations included in the 2004 average are shown in the background.

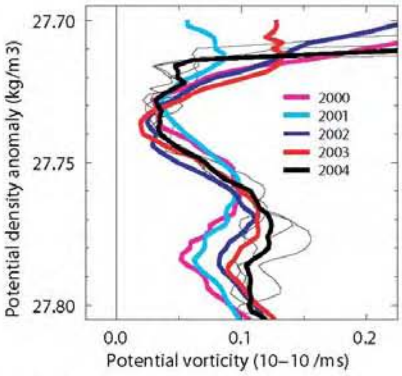

Fig. 9(b) Low-pass filtered potential vorticity averaged on potential density surfaces for stations in the 320-520 km distance range plotted against potential density anomaly for 2000-2004 spring and early summer AR7W occupations as in Fig. 9(a).

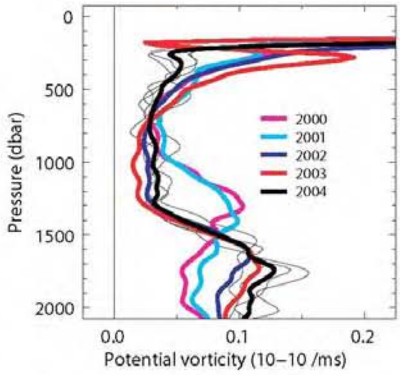

Fig. 9(c) Low-pass filtered potential vorticity averaged on pressure surfaces for stations in the 320-520 km distance range plotted against pressure for 2000-2004 spring and early summer AR7W occupations as in Fig. 9(a).

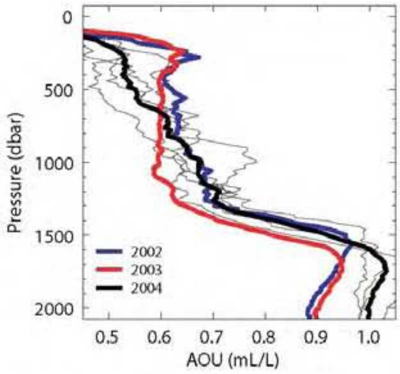

Fig. 9(d) Apparent oxygen utilization (AOU) averaged on pressure surfaces for stations in the 320-520 km distance range plotted against pressure for 2002, 2003, and 2004 spring and early summer AR7W occupations as in Fig. 9(a).

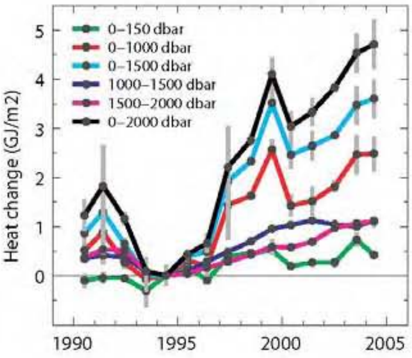

Fig. 10(b) Heat content in selected layers relative to the 1994 value from spring and early summer AR7W occupations averaged over stations in the 320-520 km distance range. Climatological seasonal changes in the upper 150 dbar have been removed from affected layers.

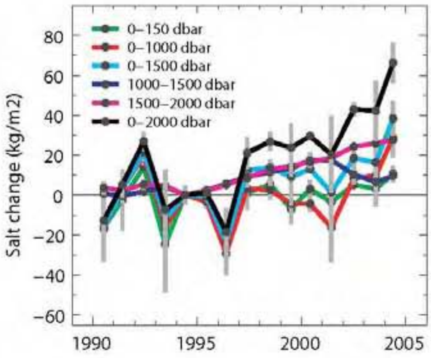

Fig. 10(b) Salt content in selected layers relative to the 1994 value from spring and early summer AR7W occupations averaged over stations in the 320-520 km distance range as in Fig. 10(a).

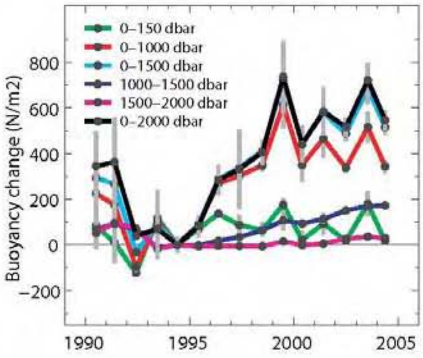

Fig. 10(c) Buoyancy content in selected layers relative to the 1994 value from spring and early summer AR7W occupations averaged over stations in the 320-520 km distance range as in Fig. 10(a).

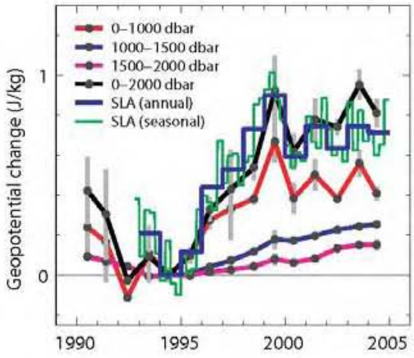

Fig. 10(d) Geopotential from hydrography for selected layers from spring and early summer AR7W occupations as in Fig. 10(a) and geopotential from altimetric sea level measurements relative to the 1994 mean as in Fig. 3(a).

Annex 8: Hydrographic Status Report 2004, Spanish standard sections (Area 4)

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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, located in Santander (43.5ºN, 3.8ºW), which is the largest, two in Asturias (43.6ºN, 6.2ºW) and from year 2001 (43.6ºN, 5.6ºW), A Coruña (43.40ºN, 8.3ºW) and Vigo (42.1ºN, 9.0ºW). Additionally to the area covered by the Instituto Español de Oceanografía, AZTI collected oceanographic data at 43.30ºN, 2ºW (San Sebastián Section) over the continental shelf of the SE Bay of Biscay from year 1986 (Figure 1).

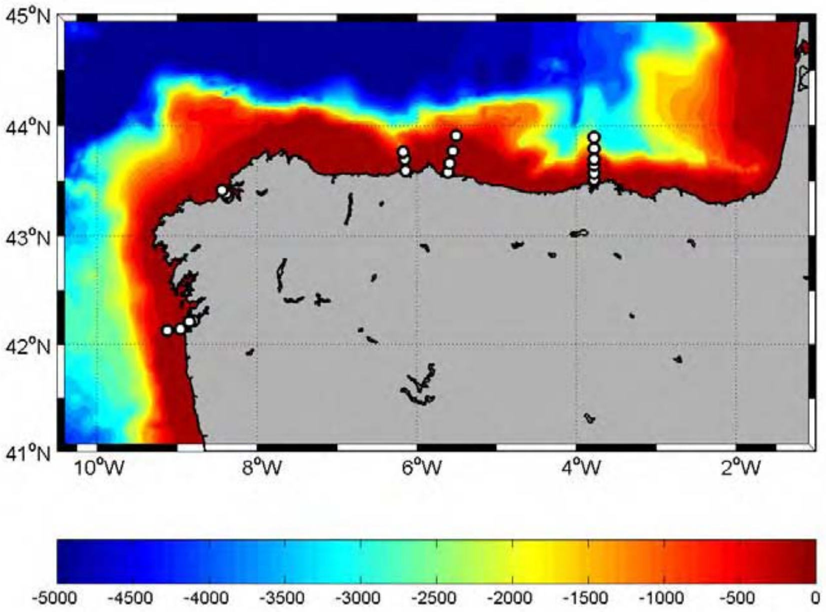


Figure 1. Spanish Standard Sections from the 'Instituto Español de Oceanografía' (Vigo, Coruña, Asturias, Santander and from AZTI (San Sebastián).

Meteorological Conditions

Atmospheric temperature

Meteorological conditions in the north of the Iberian Peninsula in 2004 (source: Centro Meteorológico Zonal de Cantabria y Asturias and Observatorio Meteorológico de Igeldo of the Instituto Nacional de Meteorología) indicate that, as a whole, it was an average year resulting from a cold winter and a warm summer. The annual mean air temperature over the southern Bay of Biscay during 2004 has remained at nearly the average, around 14.5 °C, 0.1 ºC over the 1961-2004 average in Santander and 0.1 ºC below the average value of the 1986-2004 period in San Sebastián. Nevertheless, average atmospheric temperature in 2004 was noticeably lower than in the former year as well as colder, by 0.4 ºC, than the average value of the last 25 years in Santander. Figure 2 shows the plot of the annual means and total average.

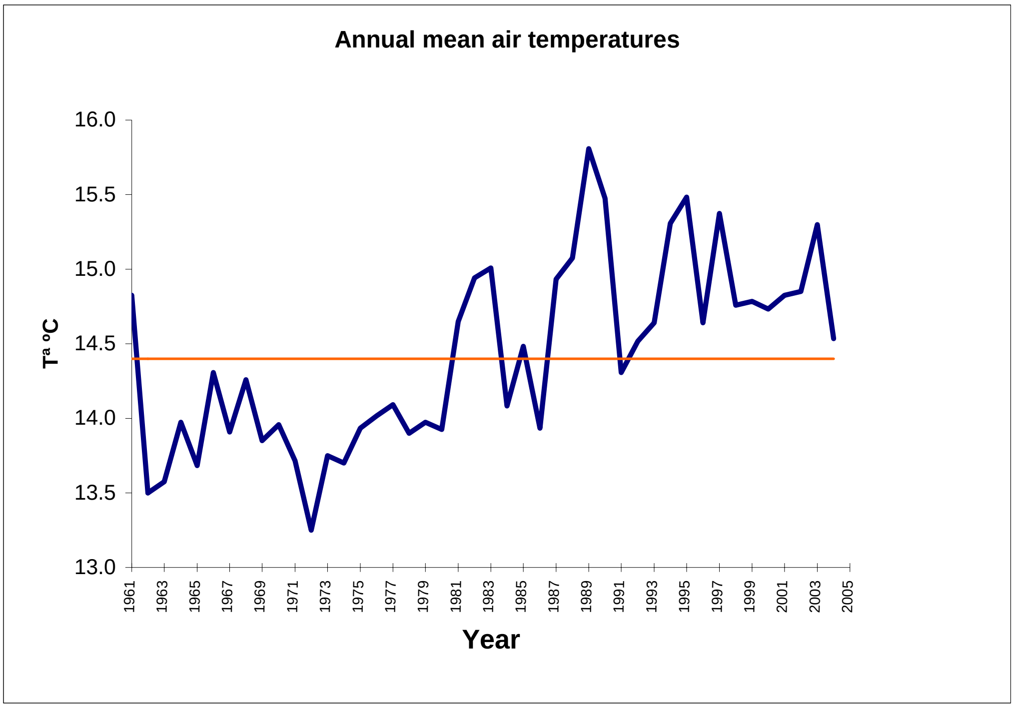


Figure 2. Annual mean temperatures in Santander (43.5ºN, 3.8ºW). Courtesy of the 'Instituto Nacional de Meteorología'

Negative anomalies in the annual cycle appear in the winter and early spring (February–May), and in autumn (November–December). In June and from August to October positive thermal anomalies have been recorded with values over one standard deviation in June both in Santander and San Sebastián. Figures 3a and 3b show the monthly mean air temperatures with the standard deviation in Santander and San Sebastián respectively. In 2004 the seasonal cycle amplitude was 10.7 ºC from February to August. The general behaviour was similar but not as extreme as in the year 2003 (13.2 ºC from February to August) or as the low value of 6.7 ºC (August–February) in 2002. The range of the monthly average air temperature was also different in time from the 11.9 ºC (August–December) in 2001.

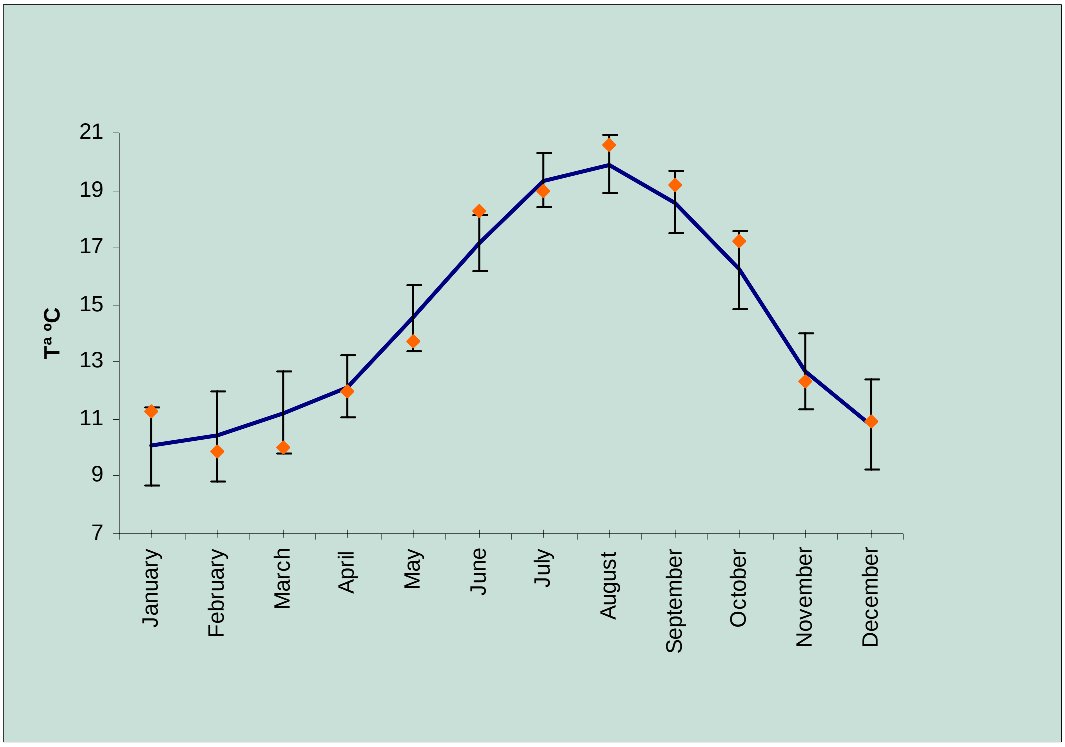


Figure 3a. Air temperatures in 2004 in Santander (43.5ºN, 3.8ºW) and mean value (1961-2004) and standard deviation. Courtesy of the 'Instituto Nacional de Meteorología'

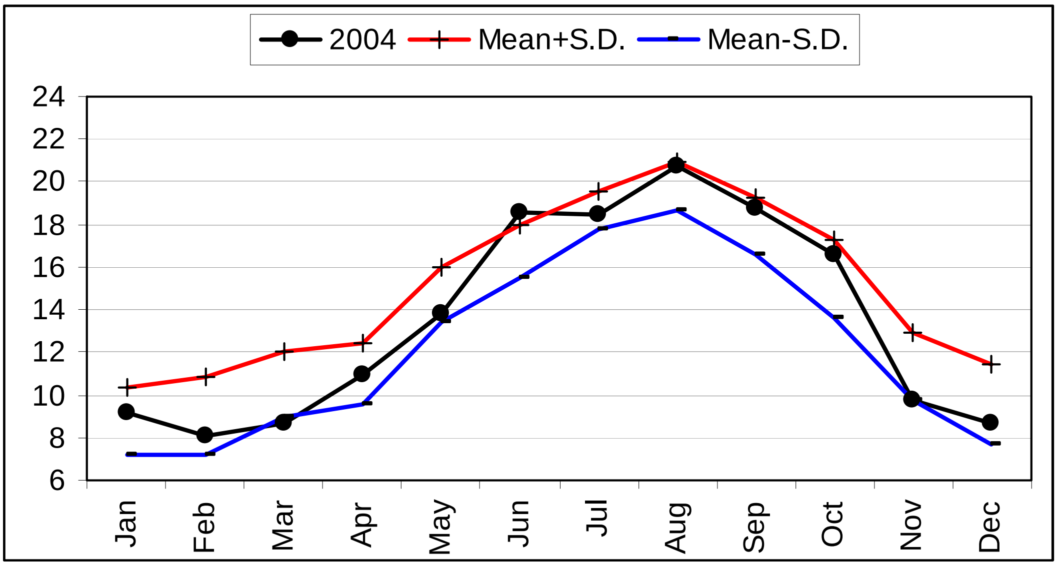


Figure 3b. Monthly mean atmospheric temperatures (°C) in San Sebastián (43°18.5′N, 02°2.37′W) in 2004 compared with the mean ± standard deviation for the period 1986-2004. Courtesy of the 'Instituto Nacional de Meteorología'

The peculiarities of the air temperature in 2004 can be observed in the context of the monthly mean temperatures of the period (1986-2004) and the evolution of the accumulated anomalies (Figure 4).

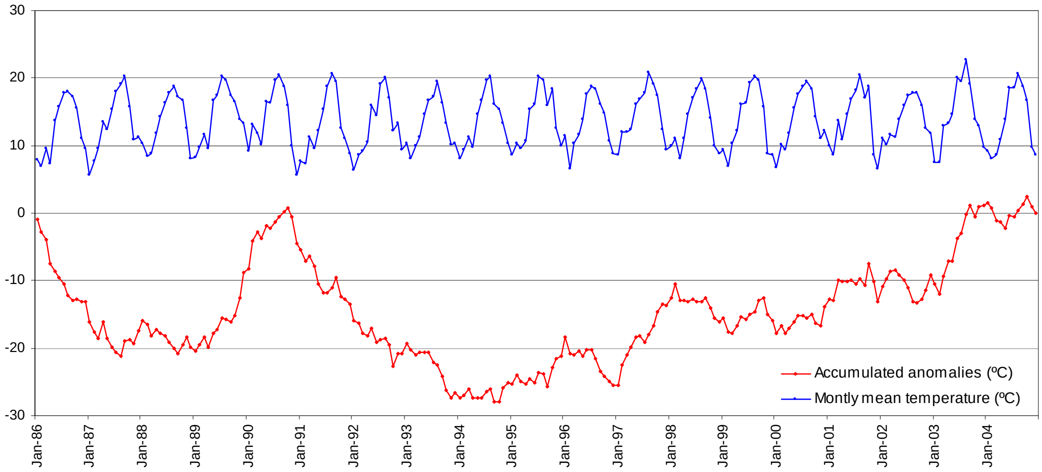


Figure 4. Monthly mean temperatures in San Sebastián (43°18.5′N, 02°2.37′W) in 1986-2004 and accumulated anomalies. Data Courtesy of the 'Instituto Nacional de Meteorología'.

Precipitation and evaporation

The year 2004 was a relatively dry year on the historical series (90 mm less than the average precipitation in Santander and 42 mm less than the mean in San Sebastián). Moreover, the evaporation in San Sebastián was 44 mm higher than the 1986-2004 average. Figure 5 shows the monthly precipitation with the standard deviation in San Sebastián.

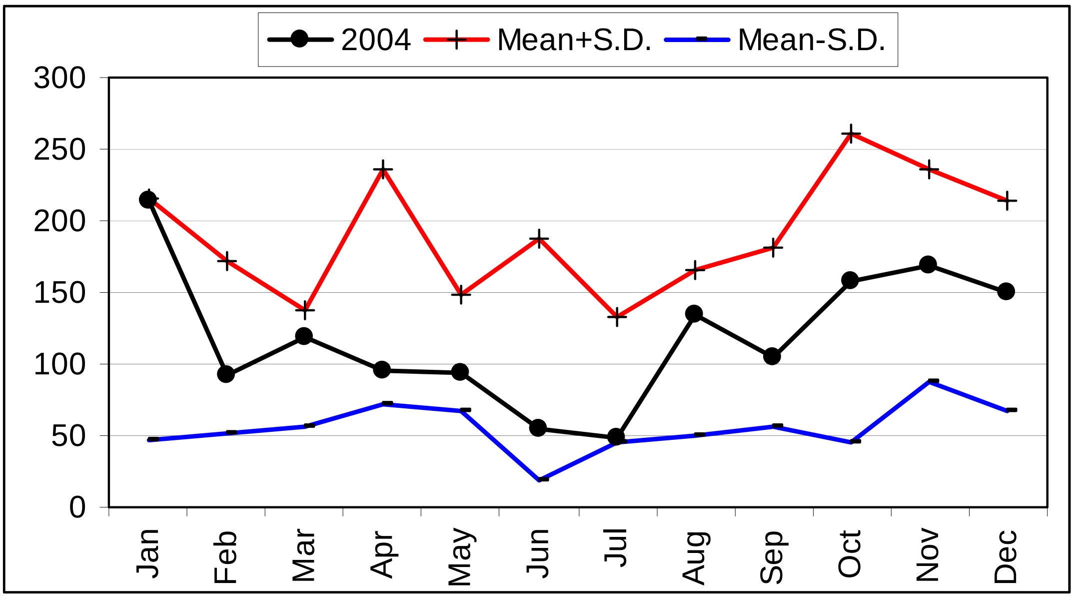


Figure 5. Monthly precipitation (mm) in San Sebastián (43°18.5′N 02°2.37′W) in 2004 compared with the mean ± standard deviation for the period 1986-2004. Data Courtesy of the 'Instituto Nacional de Meteorología'

In similar way as for atmospheric temperature, with regard to water balance, 2004 year was not extreme in terms of precipitation. The monthly mean precipitation during 2004 (119 mm) was around the 1986–2004 average (123 mm). Nevertheless, some differences respect to the mean seasonal cycle can be remarked (Figure 5). January, March and August accumulate the most remarkable positive anomalies while April–July period accumulates up to 162 mm of negative anomaly (Figure 5).

In terms of evaporation, the period from April to October accumulated 610 mm (with a positive anomaly of 122 mm with respect to the 1986-2004 average). The precipitation minus evaporation balance was positive in all months except in June and July and the whole balance for the year 2004 was 479 mm (97 mm of negative anomaly, i.e. 20% lower than the average, due mainly to the dry spring season). So, in general, autumn and winter 2004 is characterised by wet weather (excluding February), whereas dry weather is dominant in spring and early summer 2004. In the context of the previous years, the second half of 2002, the early 2003 and 2004 show a slight recuperation in the precipitation, after the very dry autumn 2001 and winter 2002 seasons (Figure 6). In addition, the precipitation minus evaporation balance reinforces that 2004 was a relatively dry year in terms of water balance (Figure 7).

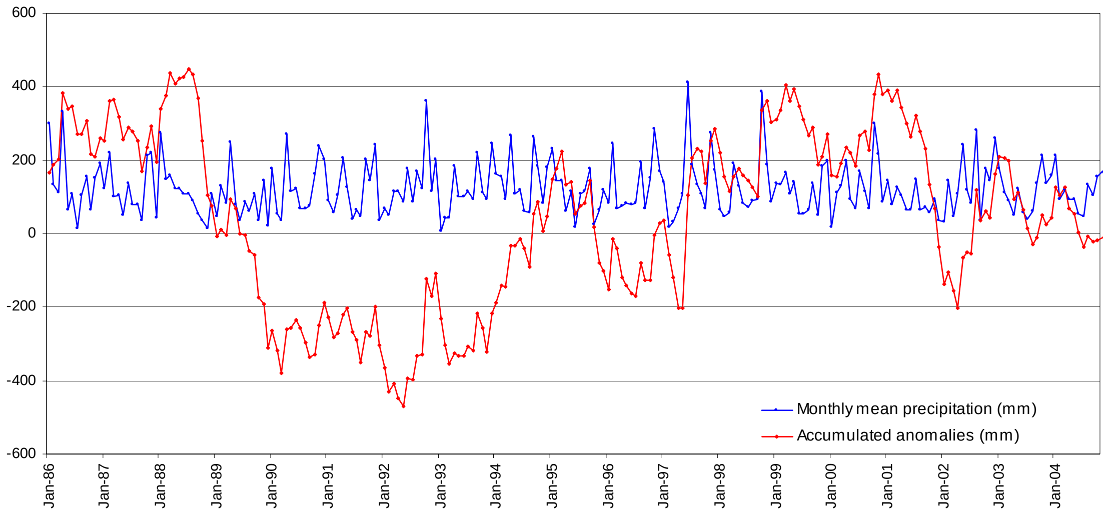


Figure 6. Monthly precipitation (mm) in San Sebastián (43°18.5′N 02°2.37′W) in 1986-2004 and accumulated anomalies. Data Courtesy of the 'Instituto Nacional de Meteorología'.

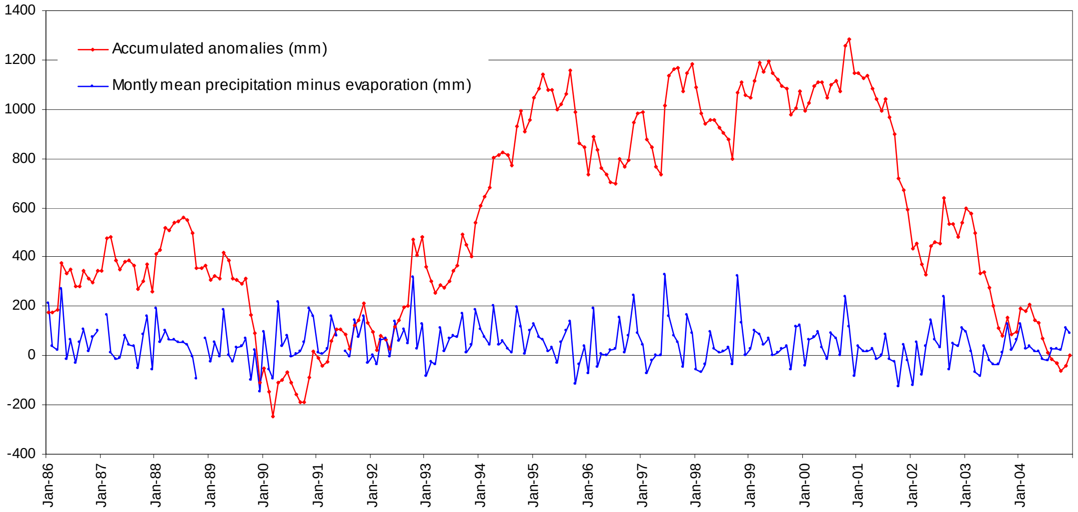


Figure 7. Monthly precipitation minus evaporation (mm) in San Sebastián (43°18.5′N 02°2.37′W) in 1986-2004 and accumulated anomalies. Data Courtesy of the 'Instituto Nacional de Meteorología'.

Continental runoff

The Gironde (Garonne + Dordogne) river runoff values represent well the continental water inputs into the SE Bay of Biscay. In a quarterly basis, the Gironde river flow correlates significantly with the precipitation in San Sebastián as well as with the flow of the Adour river and the other small Cantabrian rivers incoming into the southern Bay of Biscay (see Table 1**)**.

Table 1. Correlation matrix for the Gironde river flow, precipitation in San Sebastián (PP) and precipitation minus evaporation balance in San Sebastián (PP-EV) in a quarterly basis. NS: not significant; *P=0.01; **P=0.005 ***P=0.001. Degrees of freedom=17.

	FLOW WINTER	FLOW SPRING	FLOW SUMMER	FLOW AUTUMN
PP WINTER	0.74***			
PP-EV WINTER	0.71***			
PP SPRING		NS		
PP-EV SPRING		NS		
PP SUMMER			0.64**	
PP-EV SUMMER			0.60*	
PP AUTUMN				0.69***
PP-EV AUTUMN				0.70***

In winter 2004 highest river flow was recorded in January (Figure 8) in coincidence with the large precipitations along this month (Figure 5). Usually the Gironde flow declines from winter to spring season, but remains above the year average because both the spring precipitation (frequently high in April) and the spring thaw in the Garonne river upper basin. In spring 2004 the precipitation in April and May was below the average values but Gironde river flow shows a positive anomaly, especially in May. This fact seems to be related with the lag of the spring warming and the consequent delay of the snow melt in the upper basin of the river (relatively high precipitation during March, with low response on the river flow).

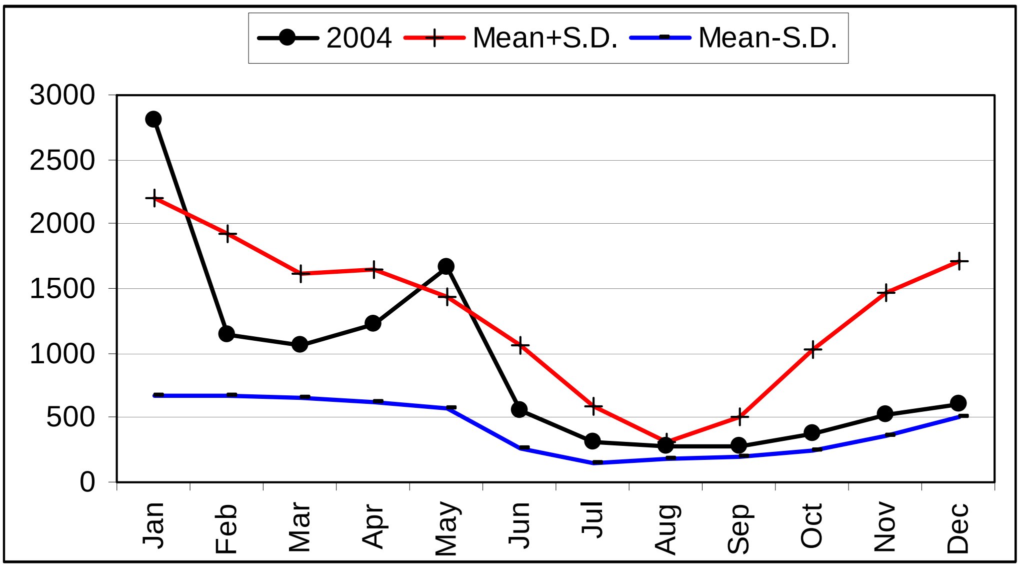


Figure 8. Monthly mean flow (m^3 s^{-1}) of the Gironde river in 2004 compared with the mean ± standard deviation for the period 1986-2004. Data Courtesy of the 'Bordeaux Harbour Authority'.

From June to December negative anomalies was prevalent for the river flow values in coincidence with the overall precipitations in the area. The most remarkable exception is the positive anomaly in August, coincident with high precipitation events for this month (Figure 5). Finally, the high values in January and May compensate the negative anomalies in summer and autumn and, again, the year 2004 can be considered as an average year even if it was not regular with reference to the mean annual cycle of the continental runoff.

The peculiarities of the Gironde river flow in 2004 can be observed in the context of the monthly mean values of the reference period (1986-2004) and the evolution of the accumulated anomalies (Figure 9).

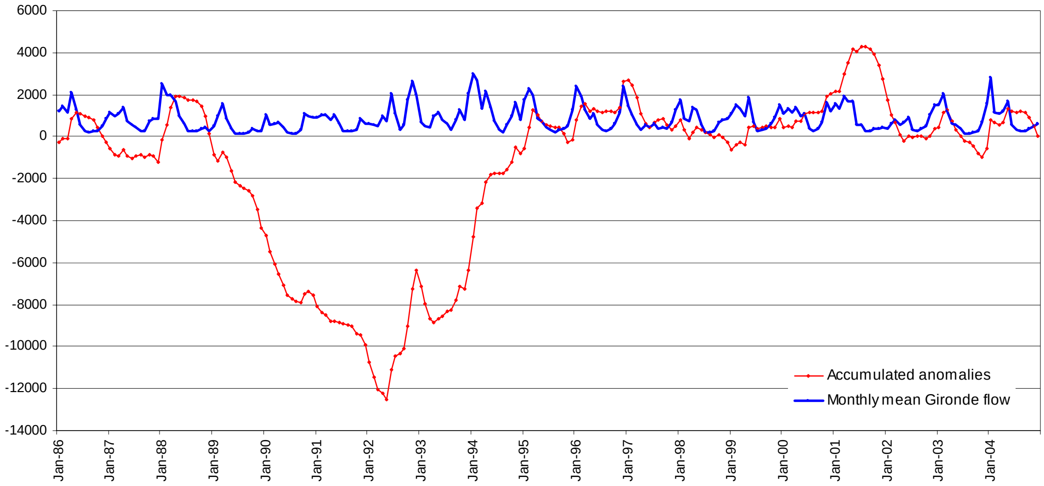


Figure 9. Monthly mean flow of the Gironde river ($m^3 \cdot s^{-1}$) in 1986-2004 period and accumulated anomalies. Data Courtesy of the 'Bordeaux Harbour Authority'.

Wind induced turbulence, mixing and Ekman transport

In the SE Bay of Biscay wind velocities below the monthly average were prevalent along year 2004. Following the usual dominance settled in autumn 2003, the southerly wind regime prevails in early winter, mainly during January. Wind speed decays notably in February starting a period of occurrence of relatively weak winds both in terms of average velocities of the dominant wind as well as for the monthly mean values. The main exceptions, with positive anomalies, were January for the monthly mean value and October for the dominant wind speed.

Moreover, the southerly wind regime was stopped in March, earlier than under the usual conditions. So, from late winter to September weak northerly wind was dominant. In October restart the southerly wind regime but in November the wind decayed strongly and, newly, northerly regime was dominant. These conditions are quite irregular with reference to the standard seasonal cycle in the area (Figure 10).

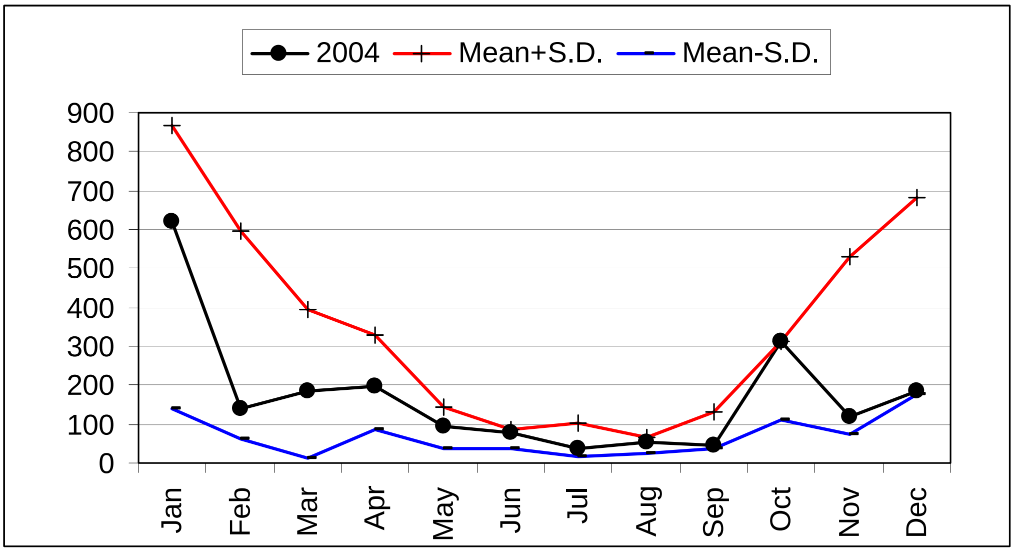


Figure 10. Monthly mean turbulence in the SE Bay of Biscay (m^3 s^{-3}) in 2004 compared with the mean ± standard deviation for the period 1986-2004. Computed from the PFEL-NOAA wind data at 45° N 2° W.

In this context, the winter turbulence was low as in the previous autumn (January 2004 value is the only value above the average). So, even taking into consideration the enlargement of the cold period in late winter-early spring 2004, the winter mixed layer depth can be considered reduced and the transmission of the accumulated anomalies of the previous year into the deep layers can be considered also limited.

In the same way, northward and eastward transport characteristic of the winter season (winter poleward current in the Eastern North Atlantic) can be considered lower than the average. Because of the geographical features of the Basque and French coasts, downwelling in these coasts is representative of eastward and northward transport respectively. Calculated upwelling and downwelling indices from the PFEL-NOAA vectorial wind data at 45° N 2° W indicated that winter 2004 downwelling was less intense than the average (except in January). Conversely, spring upwelling vs. downwelling balance (that is usually almost neutral in the area because of the lowering of the wind speed and the change of the wind regime) results clearly favourable to downwelling (due to the April values).

Summer 2004 value was also negative indicating prevalence of the downwelling (due mainly to the August values) and represents a remarkable seasonal anomaly in the area, which is characterised by a prevalent offshore Ekman transport in summer (even weaker than in other upwelling areas as the western coast of the Iberian Peninsula). The usual reactivation and prevalence of donwelling in autumn was limited to the strong inshore Ekman transport recorded in October. On the contrary, values for November and December indicated dominance of upwelling, which represent a remarkable and very unusual anomaly (Figure 11).

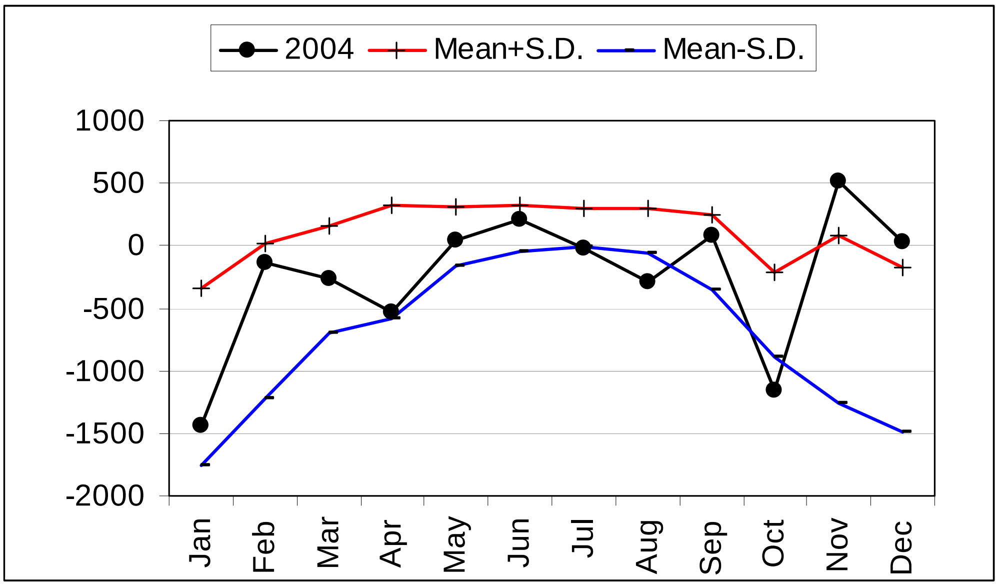


Figure 11. Monthly average upwelling (combined Ekman transport perpendicular to the French and the Basque coasts) in the SE Bay of Biscay (m^3 s^{-1} km^{-1}) in 2004 compared with the mean ± standard deviation for the period 1986-2004. Computed from the PFEL-NOAA vectorial wind data at 45° N 2° W.

Overall, in the year 2004 downwelling and convective inshore transport predominated in the SE Bay of Biscay. Nevertheless, the prevalence of downwelling was lower than for an average year. In any case the most remarkable anomaly for 2004 was more related with the irregularity of the seasonal pattern, with reference to a standard year, than with the final values of the upwelling vs. downwelling balance.

Summary of meteorological conditions in the year 2004

The above revised meteorological variables indicate that the year 2004 was, as a whole, a year not very different of the average year inferred from the historical data series. Nevertheless, annual cycle in 2004 was apart of the standard annual cycle in the area and, so, several monthly and seasonal anomalies can be remarked:

i) Relatively cold winter and delay of the spring warming in opposition to warm summer and early autumn high temperatures.

ii) Prevalence of relatively dry regime and irregular seasonal distribution of the precipitation and the continental runoff.

iii) Very irregular seasonal distribution of the wind stress and direction and the subsequent Ekman transport: low advection of warm ENACW (northward and eastward winter poleward current into the southern Bay of Biscay in winter 2004 and, also, low upwelling and advection of cold and relatively less saline subpolar ENACW in summer).

Therefore, in general, several hydrographical variables reflect a strong seasonal cycle but the mean values in 2004 are close to the time series averages. Moreover, surface waters and almost all the water column in the coastal areas and over the continental shelf show some irregular, or even extreme, monthly or seasonal values as consequence of the short term anomalies above referred. Nevertheless, the lack of persistent poleward current, upwelling events and precipitations kept mean annual values close to the time-series average.

Hydrography

Coastal and shelf waters

Figure 12 shows the evolution of the mean monthly sea surface temperature (SST) in San Sebastián (time series from the Aquarium of the Sociedad Oceanográfica de Gipuzkoa). In general, warm temperatures of sea surface water can be observed excluding March to May period. The annual mean SST in San Sebastián during 2004 (16.55°C) was higher than the 1986–2004 average temperature (16.32°C). Sea surface temperature reflects well the seasonal cycle and the features described for the atmospheric temperature in 2004. The main differences are the smoothed maximum in August (due to the influence of rain and vertical mixing events) and the slow decrease of the temperature from October to November (due to the thermal inertia and, also, to the influence of the vertical mixing).

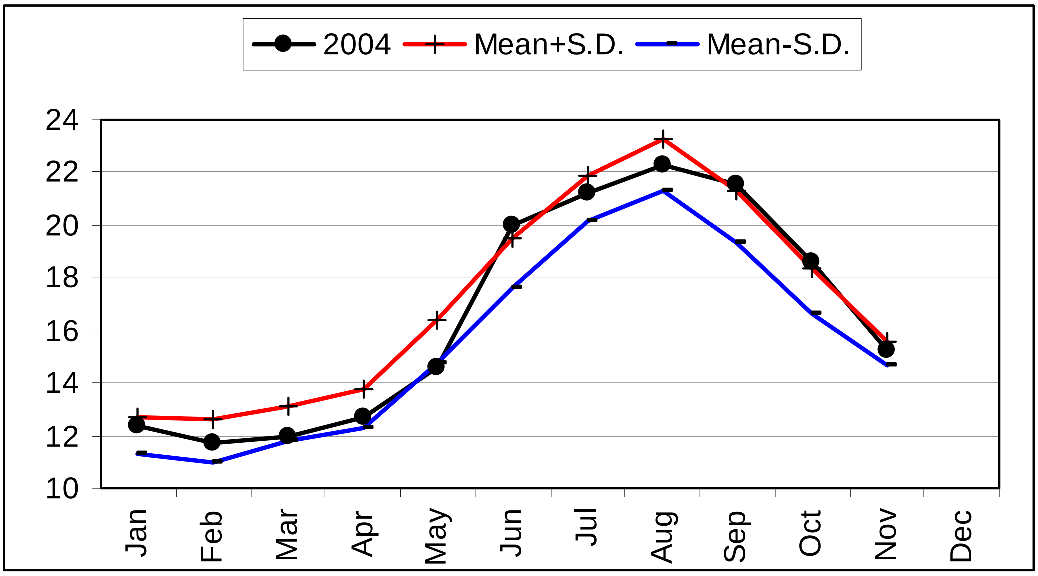


Figure12. Monthly mean sea surface temperature (°C) in San Sebastián (43°20′N 02°00′W) in 2004 in comparison with the mean ± standard deviation for the period 1986-2004. Data Courtesy of the 'Sociedad Oceanográfica de Gipuzkoa'.

The peculiarities of the SST in 2004 can be observed in the context of the monthly mean temperatures of the reference period (1986-2004) and the evolution of the accumulated anomalies (Figure 13). In comparison with the year 2003, along the 2004 annual cycle, lower range of temperature and smoother and longer both cold and warm season can be remarked.

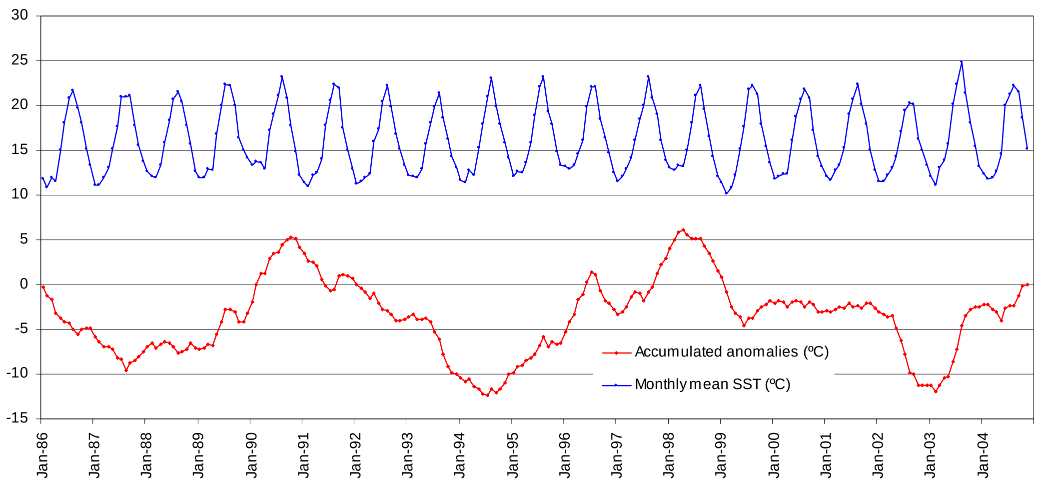


Figure 13. Monthly mean SST (°C) in San Sebastián (43°20′N 02°00′W) in 1986-2004 period and accumulated anomalies. Data Courtesy of the 'Sociedad Oceanográfica de Gipuzkoa'.

In order to get a first approximation of the hydrographic conditions in the shelf waters of the SE Bay of Biscay during 2004, TS diagram of the waters over the continental shelf of the Bay of Biscay (43°30′N 02°00′W) is shown in Figure 14.

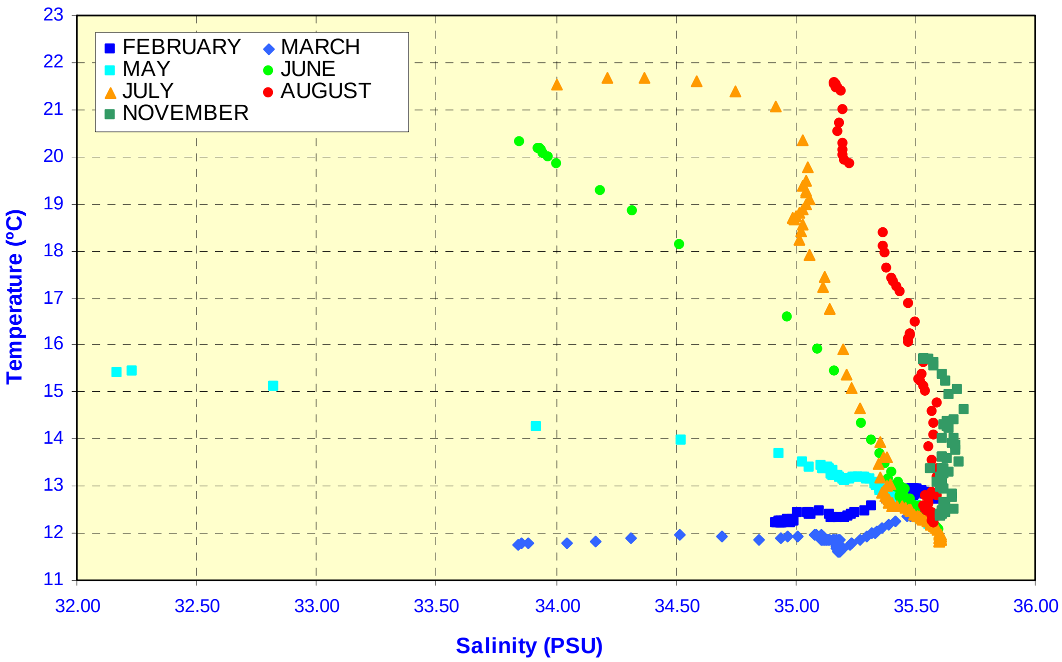


Figure 14. TS diagram of the waters over the continental shelf of the SE Bay of Biscay (43°30′N 02°00′W) during 2004.

The response of temperature and salinity of the upper layers to the meteorological factors described is clearly observable in Figure 14. Thermal stratification develops between May and November. Moreover, more or less extended haline stratification is present along almost all the year. The TS diagram shows also the variability in the temperature and salinity values and in the T-S relationships for the waters located below the seasonal thermocline.

The lack of some monthly data prevents a meticulous analysis. Nevertheless, the dispersion of the T-S values indicates the effect of the meteorological conditions on both the advection and the *in situ* modification of the ENACW. The occurrence of slightly modified ENACW in the water column over the continental shelf was scarce all around the annual cycle in 2004 because of the limited advection into the area of ENACW$_T$ in winter and ENACW$_P$ in summer. The upper layer, more or less modified, of these water masses of subtropical and subpolar origin respectively, appears occasionally close to the bottom (as signify the thermal inversion in the deep layer in February and March as well as the cold and relatively high salinity waters in July). Conversely, the whole increase of the salinity from July to August against the disappearance of the cold waters indicates the substitution of northerly ENACW$_P$ waters because of the relaxation of the upwelling conditions and the dominance of downwelling and convection of warmer offshore waters.

In a similar way, the evolution of the heat content (in terms of mean temperature) and the salt content (in terms of mean salinity minus 35) of the water column (100 m) over the continental shelf of the SE Bay of Biscay can be observed in Figure 15 and Figure 1, respectively.

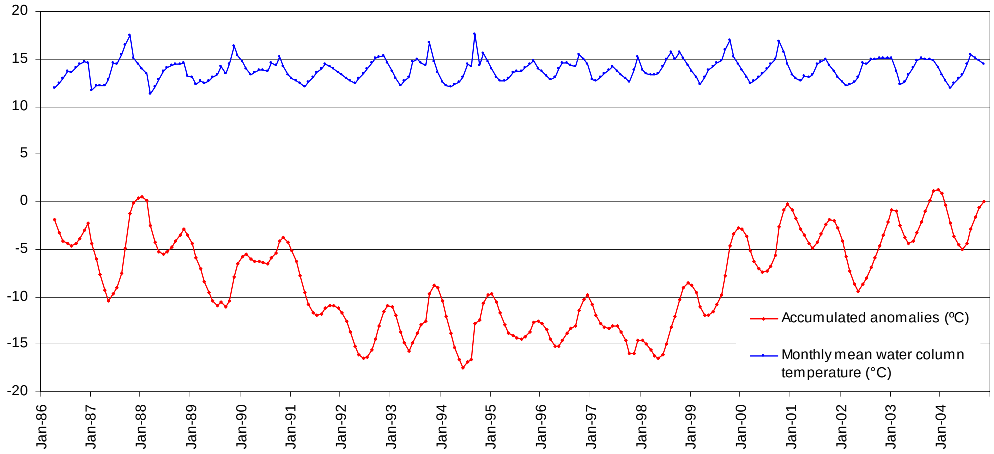


Figure 15. Monthly mean water column temperature (°C) in San Sebastián (43°30′N 02°00′W) in 1986-2004 period and accumulated anomalies.

In the SE Bay of Biscay the 14°C isotherm represents the mean annual temperature of the 100 upper meters water column and also the lower layer of the thermocline during the spring and summer stratification. In May the 14°C isotherm depth was 5 m and from June to August, this layer was placed around 50 m. The intense fluctuations of the 14°C isotherm depth along the summer season, as well as the sequence of the T-S values at 50 m water depth and at the bottom layers, indicates a dominance of downwelling processes. From October to November, breakdown of stratification, downwelling and vertical mixing close, as usual, the annual cycle.

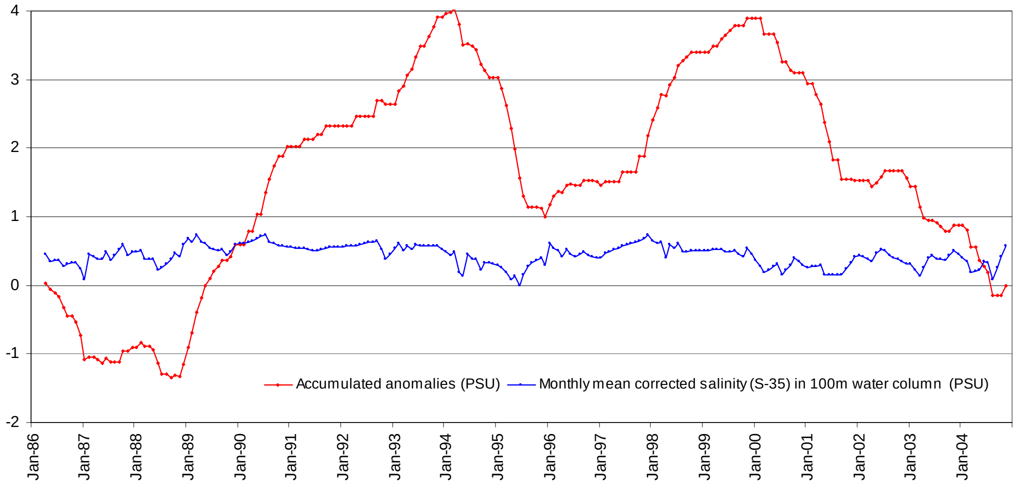


Figure 16. Monthly mean corrected salinity (S-35) in 100m water column in San Sebastián (43°30′N 02°00′W) in 1986-2004 period and accumulated anomalies.

In similar way, contours of temperature and salinity (over the shelf, 100 m depth) in the Santander section are shown in Figures 17a and 17b. The seasonal cycle in temperature is clearly marked in the upper layers. Stratification develops between April-May and October-November, and during the rest of the period the water column is mixed. Summer stratification in 2004 presented a deeper picture similar to 1999 but with a sort period. Bottom cooling seems to indicate some upwelling episodes. Salinity contours show high salinity at the beginning of the winter due to the poleward current and in spring and autumn due to seasonal upwelling events. In summer low salinity appeared in the upper layers due to the advection from the east of warm surface water from river discharges in the corner of the Bay of Biscay. During 2004 the advection and river overflow was low compared with the previous years, mainly 2001 and 1995. High salinity values over most of the shelf, which appeared from the strong incursion of saltier and warm water in 1997 have reduced since January 2000 to values of the same order as in 1995.

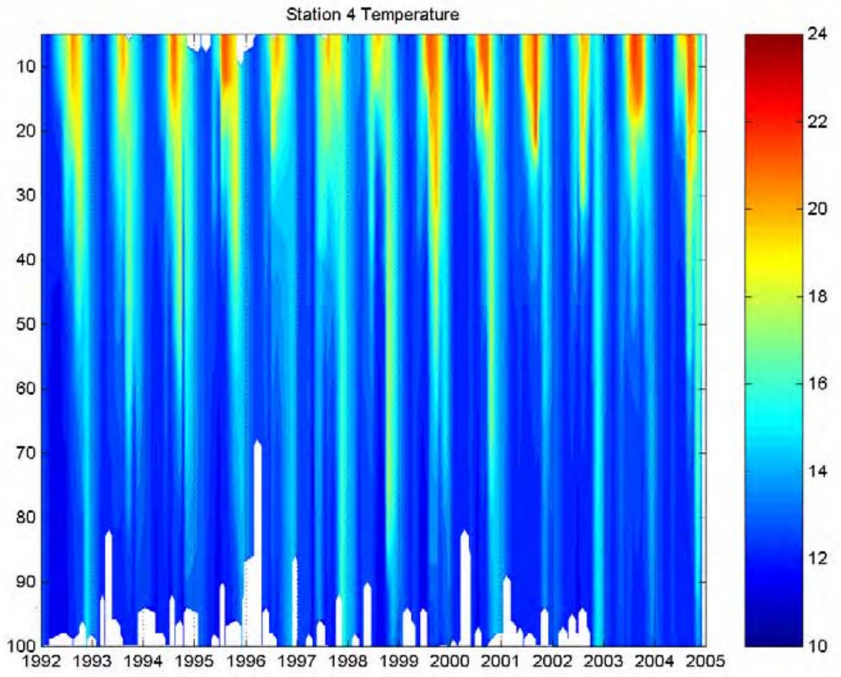


Figure 17a. Temperature evolution at Santander station 4 (shelf) .

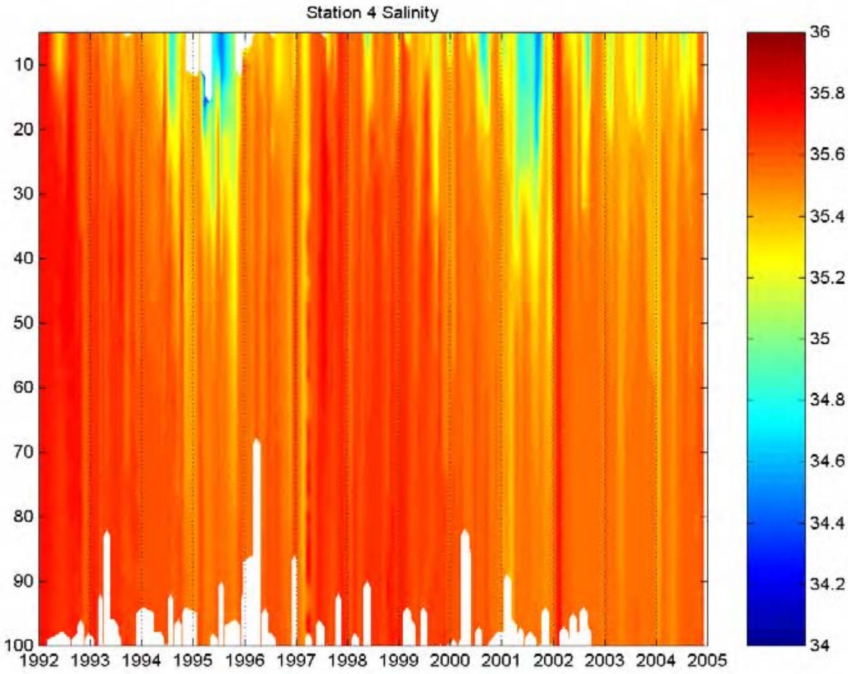
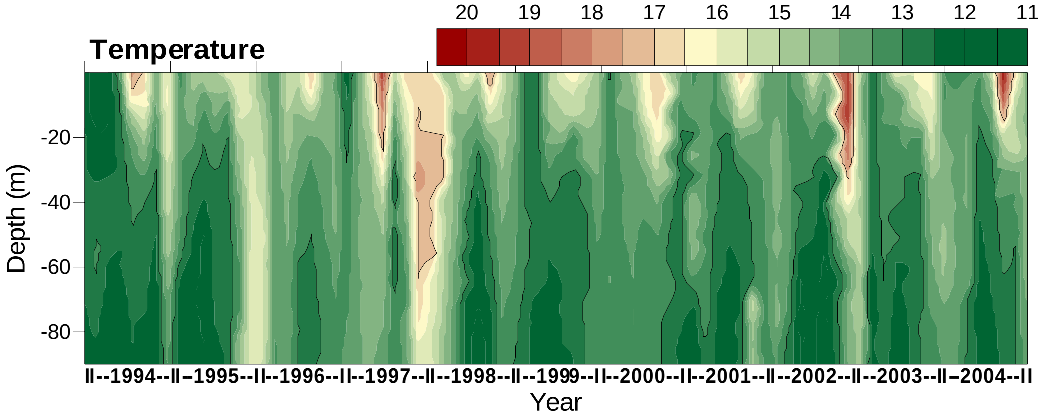


Figure 17b. Salinity evolution at Santander station 4 (shelf).

As a consequence of the different geographical location and coast orientation the mean hydrographical features the annual cycle at the Vigo standard section is moderately different of the standard cycles in Santander and San Sebastián. The differences are related mostly with a stronger influence in this area of the main advection mechanisms (winter poleward current and summer upwelling). Anyway, even if the range of the anomalies may be different because of local climatic and morphologic peculiarities, the anomaly patterns and the general trends can be considered referable to those described for the sections located in the southern Bay of Biscay. In summer cold waters were present at depth due to upwelling, while warm waters were at the surface in summer due to insolation. Occasionally in autumn-winter there is a coastal poleward surface current that transports warm water. The strongest influence of the poleward current occurred in winter 1997 and 2002.

Contours of temperature and salinity over the shelf (94 m depth) in the Vigo section from 1994 to 2004 are presented in Figure 18.



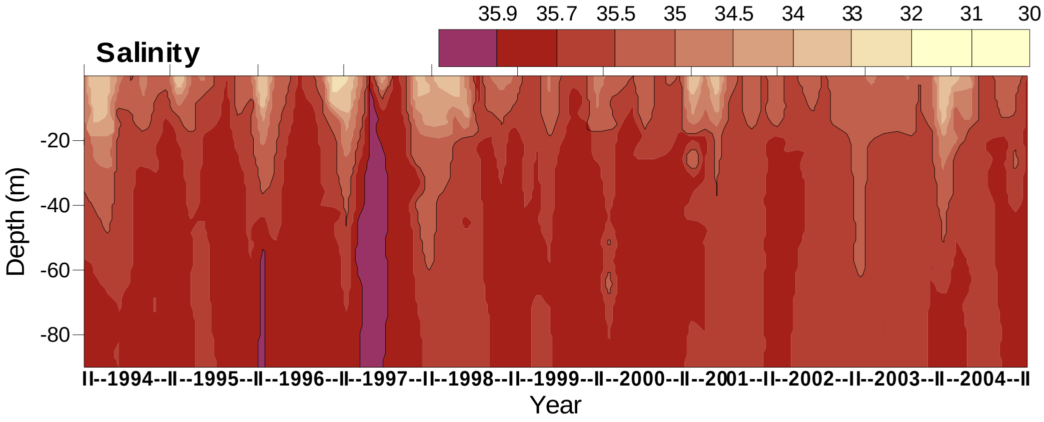


Figure 18. Evolution of temperature and salinity at Vigo station (42.1ºN, 9.0ºW) for 1994-2004 period.

In the transition autumn-winter 2003-2004 the poleward current can be considered as moderate or even low. In any case, increase of salinity values close to the bottom indicates pulses of northward transport. Upwelling was also low in the summer season. Combination of reduced upwelling with high atmospheric temperature allows high temperature in the upper layer and strong thermal stratification in the water column in summer 2004. Autumn 2004 was characterised by cold northerly winds unfavourable to poleward current progression and accordingly the coastal waters remained cold.

So, in a similar way as has been pointed for the San Sebastián and Santander sections, the main anomalies recorded in the Vigo section along 2004 are related with the irregular seasonal cycle. In addition to the monthly or seasonal anomalies in atmospheric temperature and precipitation, in this case, the deviation from the standard wind regime and his influence on the water transport appears as the main factor affecting the evolution of temperature and salinity of the water in the shelf area.

Offshore and Slope waters

Contours of temperature and salinity over the shelf-break (600 m depth) in the Santander section are presented in Figures 19a and 19b. During the first period (1992-1994) only upper layers were sampled. As happened over the shelf, the period of low salinity in the upper waters (1994–1995 and 2000–2001) was reduced to a greater extent during 2002, 2003 and 2004. Below the mixed layer, salinity fell from 1992 to 1995 and increased again to 1997/1998 before falling once more until 2001. The 2002 winter poleward current showed increasing salinity in the upper 300 m, decreased in spring but seemed to increase again at the end of the year. Also in temperature this warm water mass is detected until 300m depths. 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, with the autumn mixing marked even up to 300 m depth.

Salinity contours show high values after the end of the mixing period at the beginning of the winter, the warm period sometimes extending at those depths due to the poleward current. Winter 1996 was a good example, in 1998 it looks strong and in 2002 it was also detected, but not during 2003 and 2004.

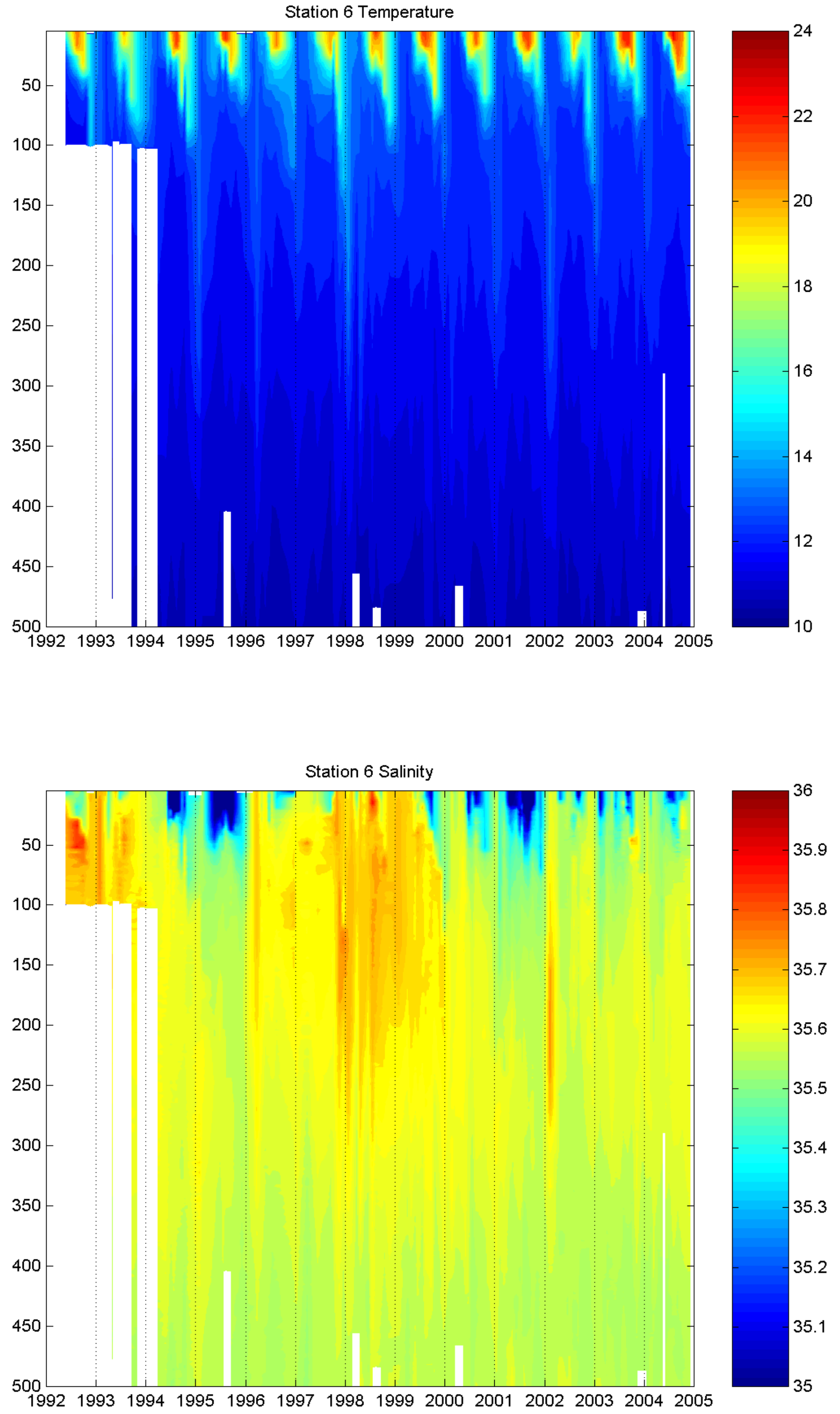


Figure 19 a,b. Temperature and Salinity evolution at Santander station 6 (shelf-break).

A similar way of visualizing the behaviour of the hydrography compared with the historical data is to superimpose several time series at different depths. Figure 20 shows such a representation for station 6. We can see how years with low salinity values in surface waters (NE regimes) enhance a shallow sharp thermocline.

If we look at thin layer superficial waters, we expect to find an approximate mirror of atmospheric forcing. Due to the thermal inertia of the seawater surface, the temperature seasonal cycle does not follow a sinusoidal cycle but presents a rapid warming period in late spring, whereas the autumn cooling is less abrupt. As mentioned previously, superficial salinity presents a seasonal decrease produced by the advection of fresher water from the east of the Bay of Biscay, usually in spring-summer time, when the wind regime is from the first quadrant. The poleward winter signal in February is presented at all depths, but mainly at 200m. This effect is more intense than during the previous poleward episodes in winter 1996 and 1998.

As has been done for air temperature, fitting the temperature signal by two harmonic terms plus a linear trend, we can reproduce the signal approximately (Figure 21). Taking this into account, we can compare the year 2004 with the climatological mean for surface waters. Following the cold air temperature in winter, SST from January to May was under the mean value and in March and May the lower value of the time series. The rest of the year SST was higher than the average, specially in August when 22,7ºC were measured, the highest value of the time series. The amplitude of the seasonal cycle of SST was of 10.4ºC, quite close to the air temperature seasonal cycle. The anomalous cold winter and warm summer produce a year temperatures close to the average. (Figure 22).

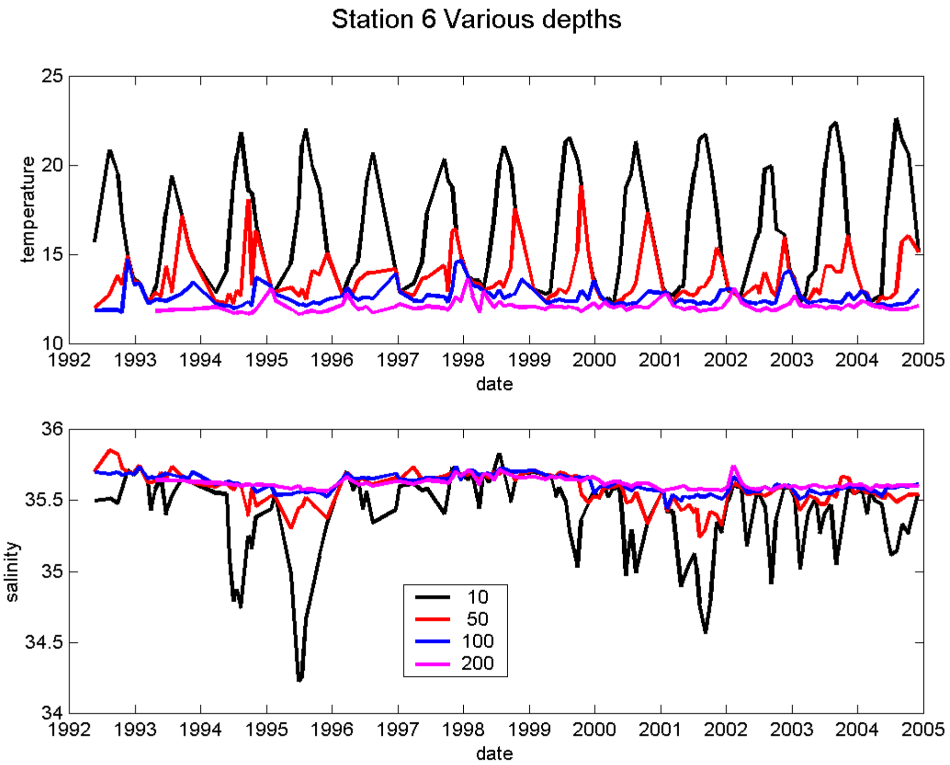


Figure 20.Temperature and Salinity at various depths, Santander station 6 (shelf-break).

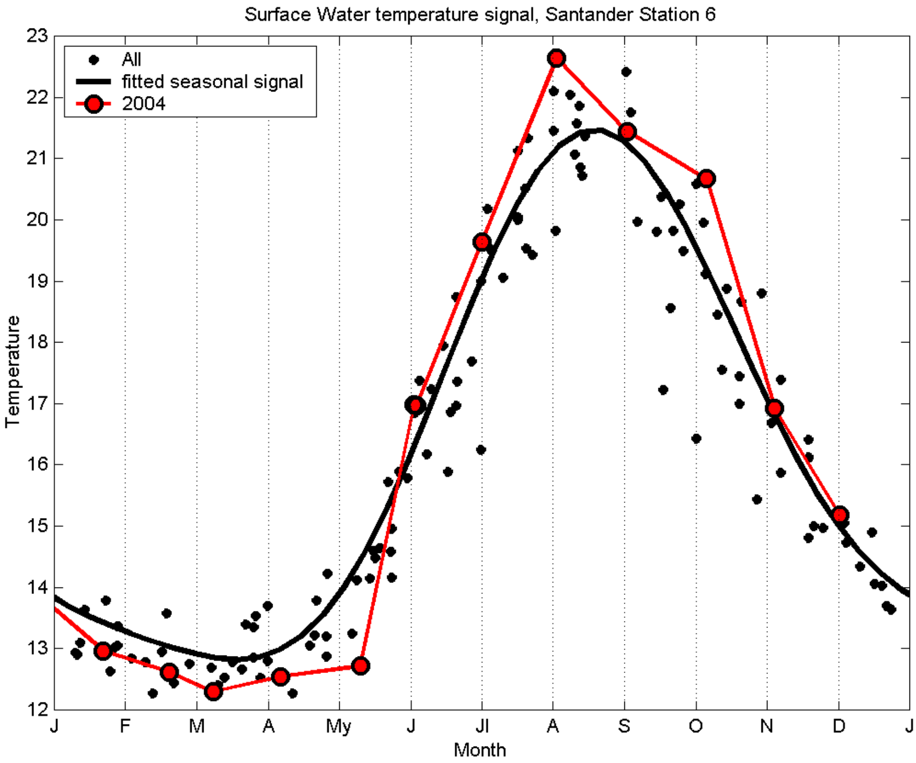


Figure 21. Seawater Surface Temperature at Santander station 6 (shelf-break).

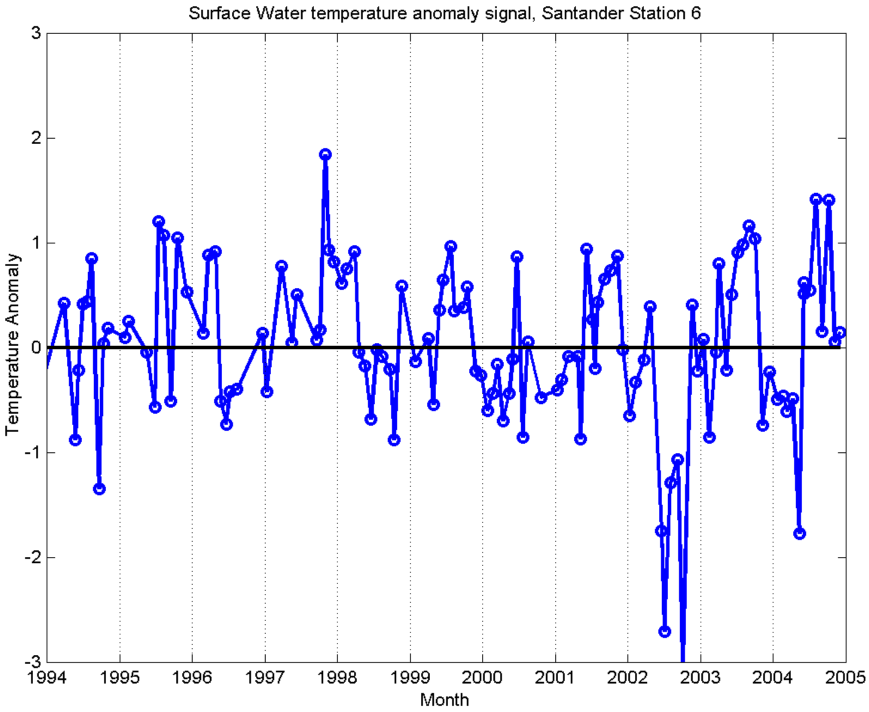


Figure 22. Seawater Surface Temperature anomalies at Santander station 6 (shelf-break).

Between 1998 and 2001, evidence of a decline in salinity was found up to a depth of 300 m. In 2002 this trend was inverted, especially during the poleward episode at the beginning of the year. An average of this layer (0–300 m) is shown in Figure 23 for station 6. The same behaviour is found for shelf stations. Down to this depth salinity evolution does not have clear cycles (positive trends seem to appear at lower levels).

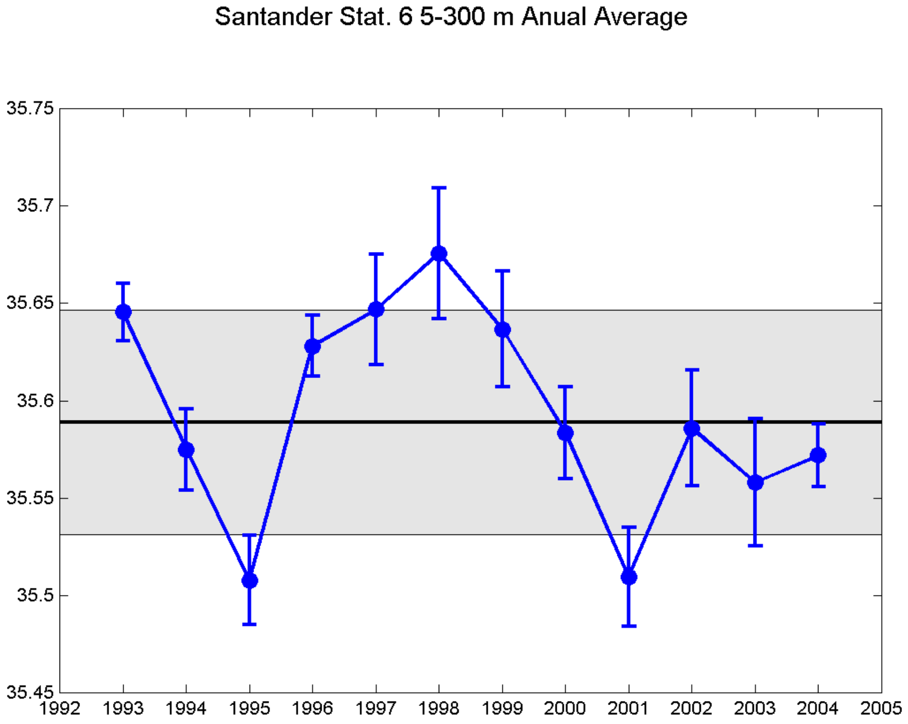


Figure 23. Annual average salinity (5–300m. at Santander station 6 (shelf-break).

Heat Content

Heat content during 2004 seems to have a strong seasonal cycle reflecting the cold winter and warm summer. In the upper layers the seasonal cycle is one of the strongest in the time series. In the 300–500m layer heat content was high all over the year, following a progressive increase also detected in water masses analysis. This tendency has been compensate in the upper layers because the later very cold winters that have reduced the heat content of the upper 300m layer. Winter poleward episodes produce high heat content, as the 1996, 1998 and 2001 values at 200-500m, autumn mixing produces less heat than the previous years but an increase occurs at the end of the year. In Figure 24 we can see evolution in both the mixing layer and NEACW. Total heat content for the whole 500m first layer during the last three years followed a repetitive annual cycle.

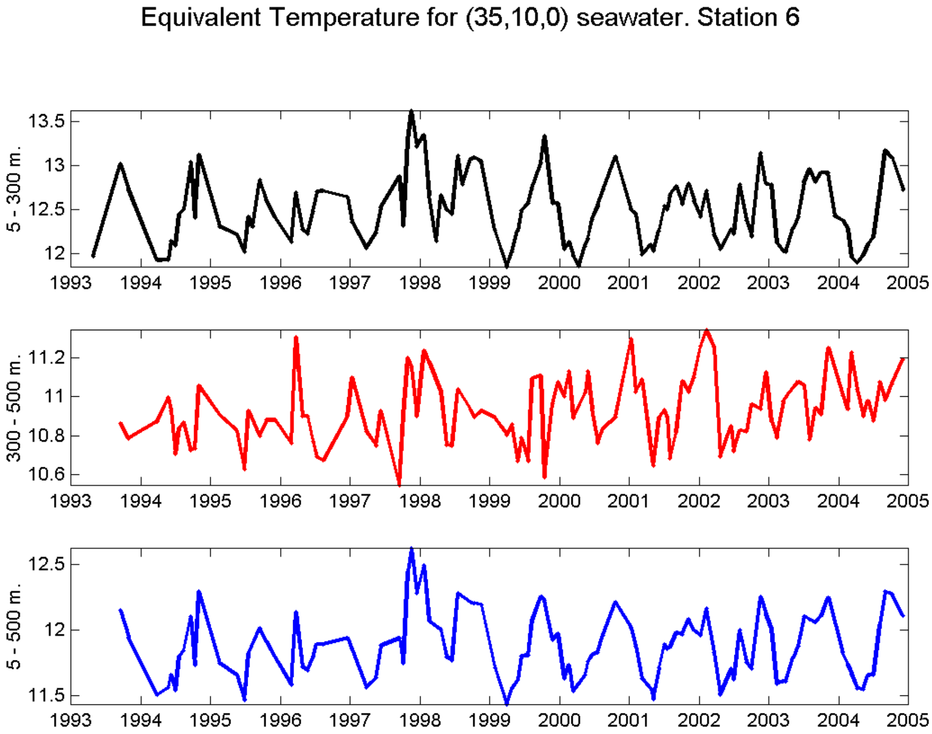
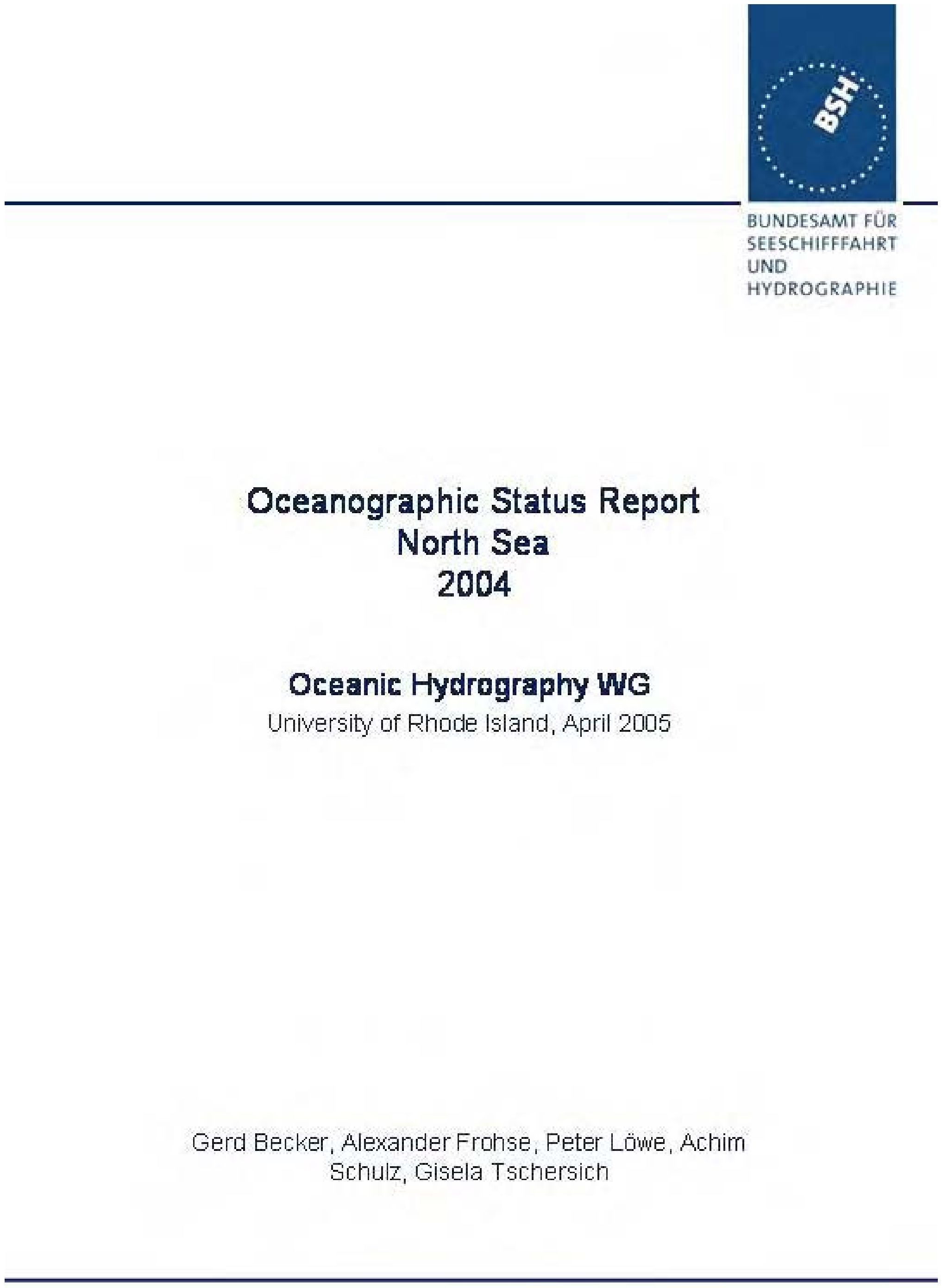


Figure 24. Heat stored in the water column at Santander station 6.

Annex 9: The North Sea (Areas 8 and 9)



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2004

Oceanic Hydrography WG

University of Rhode Island, April 2005

Gerd Becker, Alexander Frohse, Peter Löwe, Achim
Schulz, Gisela Tschersich

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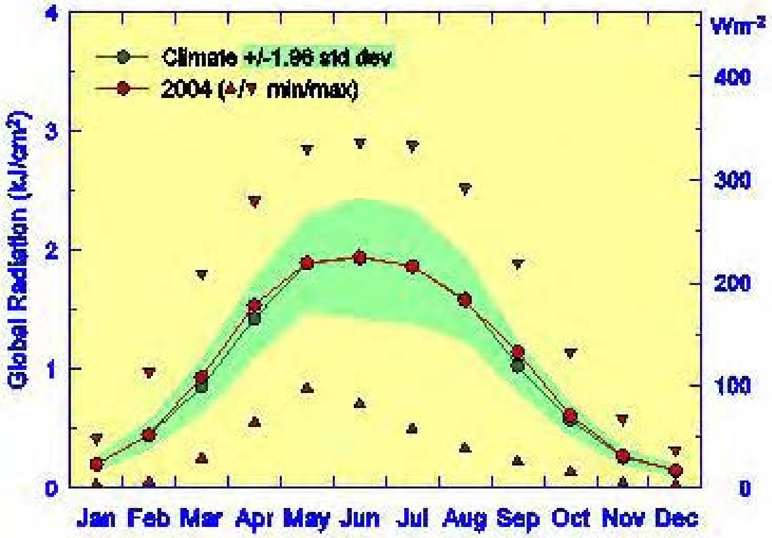

Data: DWD Hamburg

- Fig. 1 Monthly mean global radiation at Norderney 2004

The global radiation at the east Frisian island Norderney in 2004 was very close to the long term 30 year mean.In spring and autumn only the radiation was very slightly above average.
It has to be stressed that measured radiation data for the open North Sea are not available and the thermal forcing of the different North Sea models is performed with meteorological model data.

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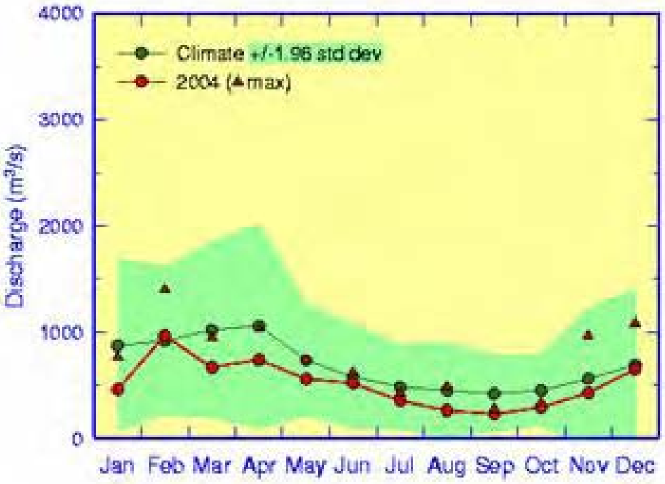

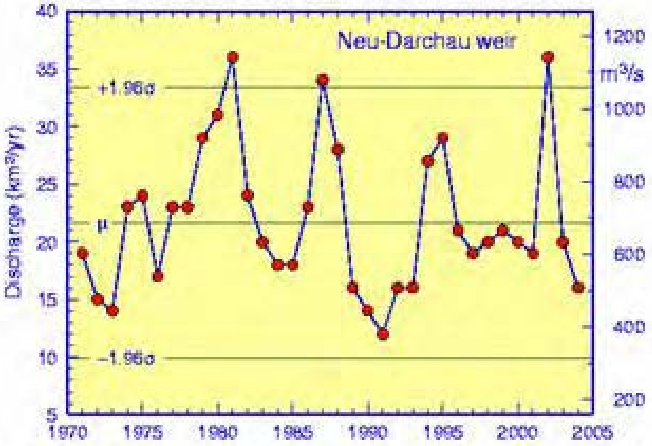

Fig. 2a. Annual cycle of the Elbe river run-off at weir Neu-Darchau.
Fig. 2b. Mean annual run-off 1971 to 2004.

With the exception of february the run-off of the whole year 2004 was below the long-term mean for the river Elbe (and probably all other continental rivers). The annual mean was about 200 m³/s below long-term average of 700 m³/s .

Data both figures: WSA Lauenburg

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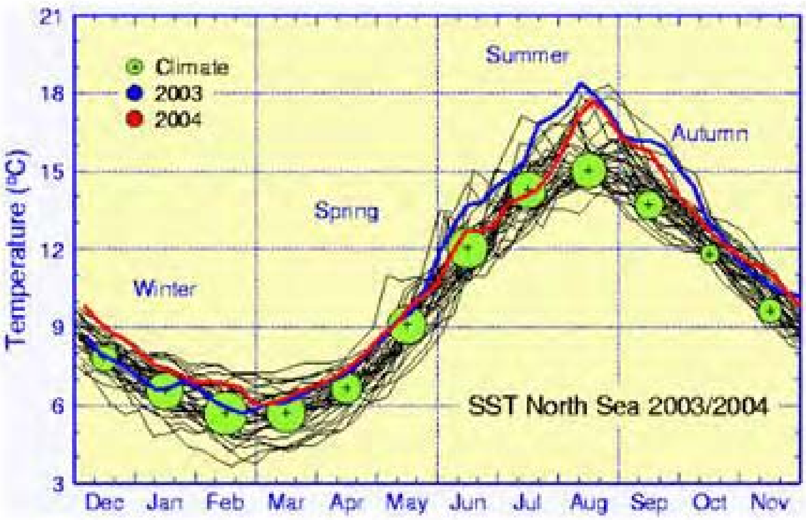

- Figure 3. Seasonal cycle of areal mean weekly SST of the North Sea from December 2003 through November 2004 and ensemble corrosponding cycles since 1968. Size of monthly climate bullets (radius) gives the interannual deviation.

The area averaged annual SST cycle of the North Sea was in 2004 above average the whole year. In July the monthly SST was close to the long-term mean.
The August of 2004 was the second warmest month in the time series since 1968. The area averaged positive anomaly which started in June 2002 continued until February 2005. This seems to be the longest positive monthly anomaly run observed in the North Sea. This run ended after 44 months in March 2005, probably (the April data are not finished yet)

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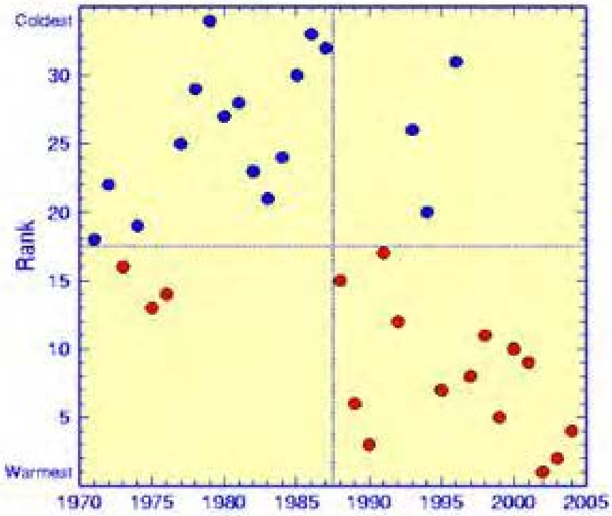
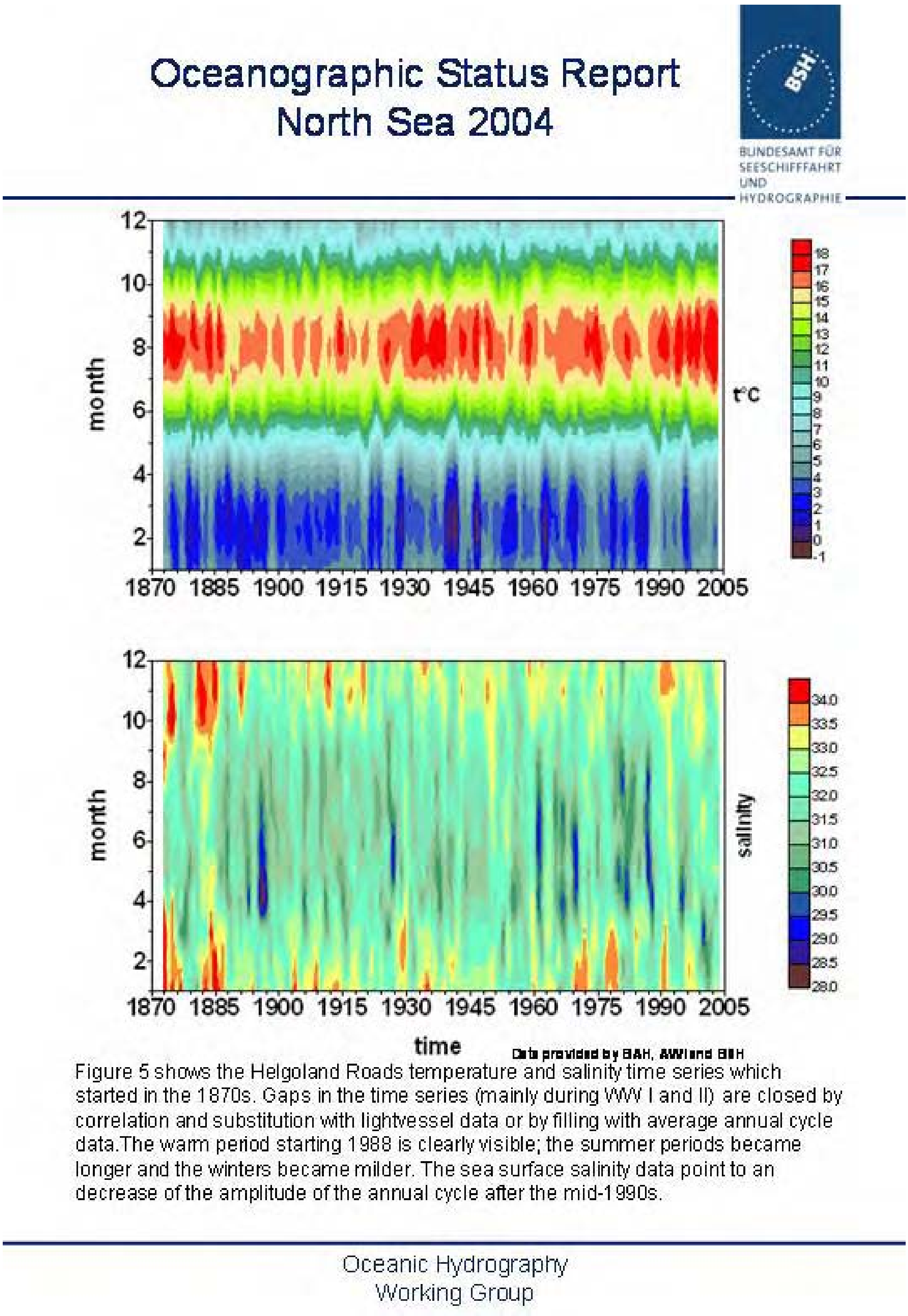


- Fig 4 Ranked annual mean North Sea SST

Figure 4. Shows the ranked annual mean North Sea SST since 1969. Only the very short cold period in the mid-nineties disrupt the long-lasting warm period which started in 1988 and continues until February 2005. The rank statistics show the twelve warmest years occured in the period after 1990. Probably a system shift has occurred at about 1988 and the mean North Sea conditions have changed to generally warmer conditions. *But as long as we do not understand the mechanism or causes for these shifts any predictions are very prognostic.*



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Data provided by BAH, AWI and BSH

Figure 5 shows the Helgoland Roads temperature and salinity time series which started in the 1870s. Gaps in the time series (mainly during WW I and II) are closed by correlation and substitution with lightvessel data or by filling with average annual cycle data.The warm period starting 1988 is clearly visible; the summer periods became longer and the winters became milder. The sea surface salinity data point to an decrease of the amplitude of the annual cycle after the mid-1990s.

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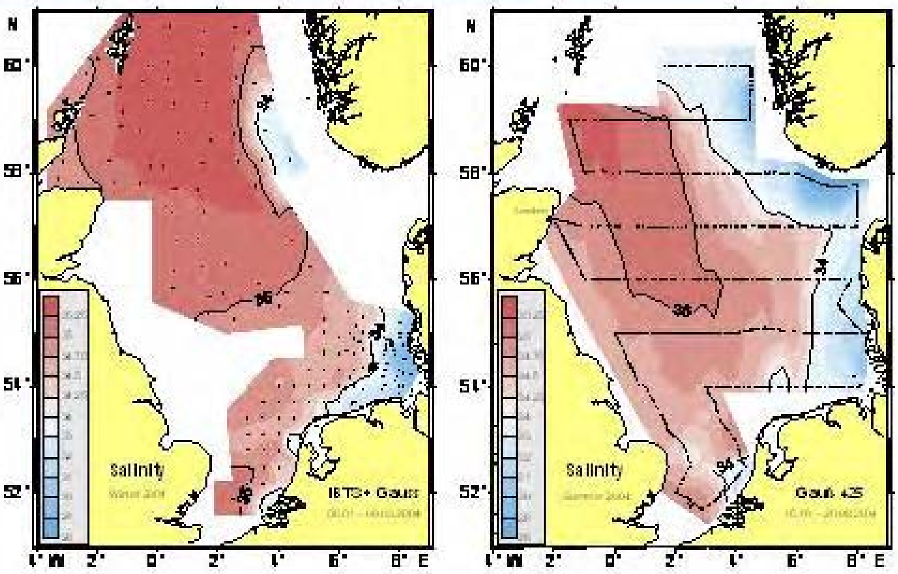
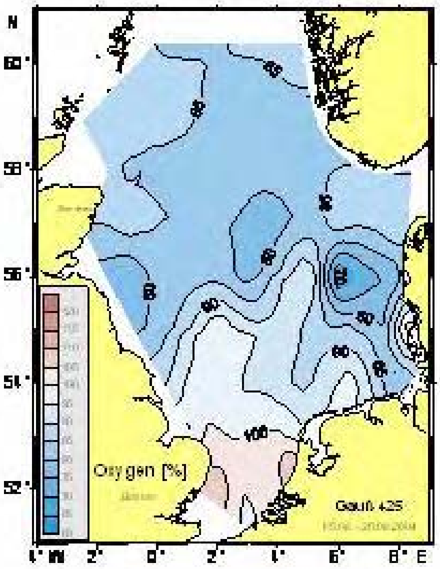


Fig. 6a, 6b. Sea Surface Salinity in winter and in summer of 2004.



The salinity data point to an increasing influence of the Atlantic water in the north and also in the south.

The IBTS data distribution clearly show the fishery biologist interests in doing this survery. Large areas are not covered by stations. In the German Bight the IBTS data have been supplemented by Eutrification monitoring data of BSH.

The oxygen saturation data in summer during maximum stratification and just before the upbrake of stratification show rather good conditions. Off the Jutland coast the minimum was below 70 %, which is not dangerous to benthic animals.

Fig. 7 Oxygen saturation close to the bottom in % in summer 2004.

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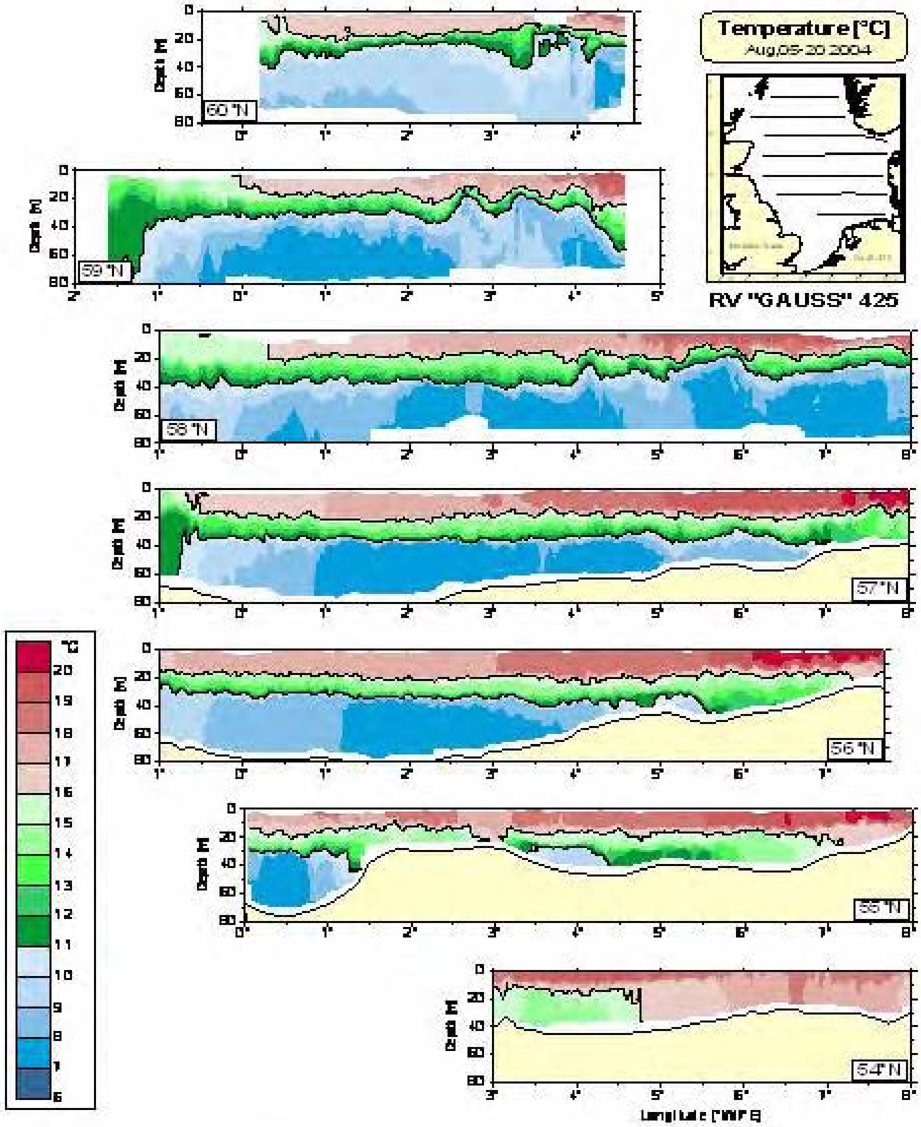

Abb. 1: Temperatur Vertikalverteilungen (FS Gauß, Reise 425)

Fig. 8. Temperature stratification in August 2004.

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Stratification 2004

Well developed deeper and broad thermocline; surface layer warmer than normal.

Bottom water layer beneath the thermocline also warmer due to the mild winter 2003/2004.

No stratification in the shallow parts of the German Bight, close to the Fair isle passage and off the Scottish coast due to high tidal current induced turbulence.

The shallow Dogger Bank in the central North Sea surprisingly stratified.
West of the Dogger Bank the stratified „cold pool", topped by a warmer surface layer (no fog which is very often observed due to upwelling of cold water).

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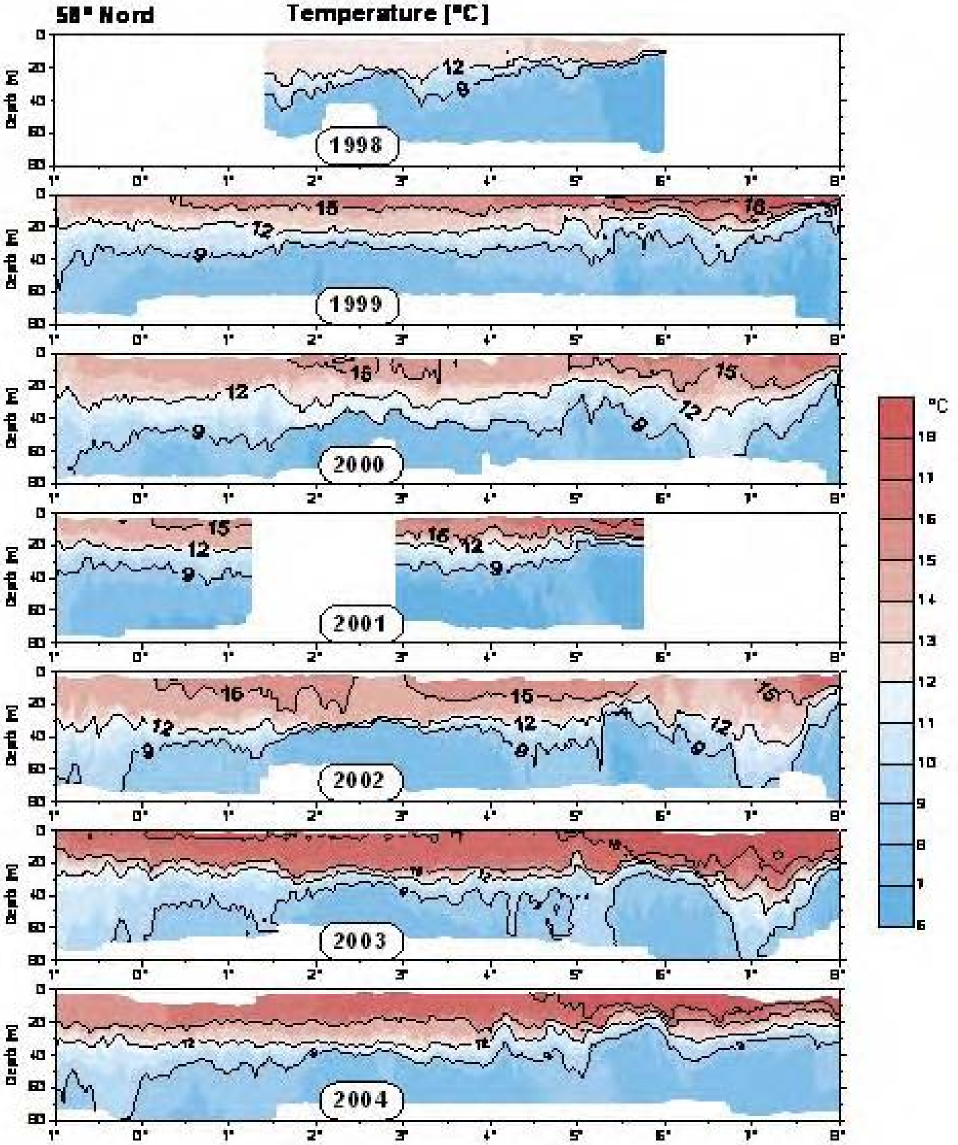

Fig. 9. Evolution of temperature stratification of section 58 °N from 1998 to 2004.

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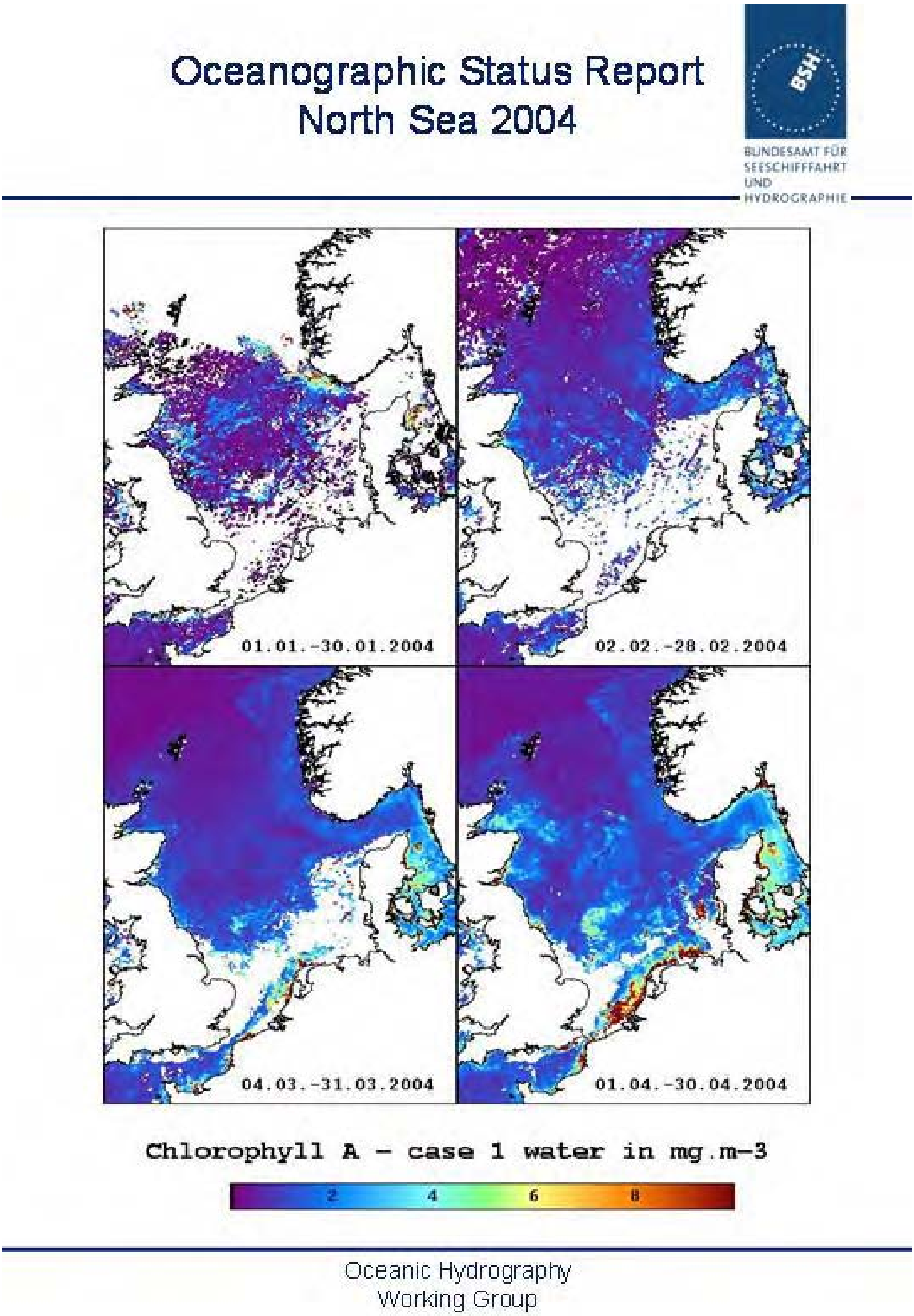

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Chlorophyll A – case 1 water in mg.m-3

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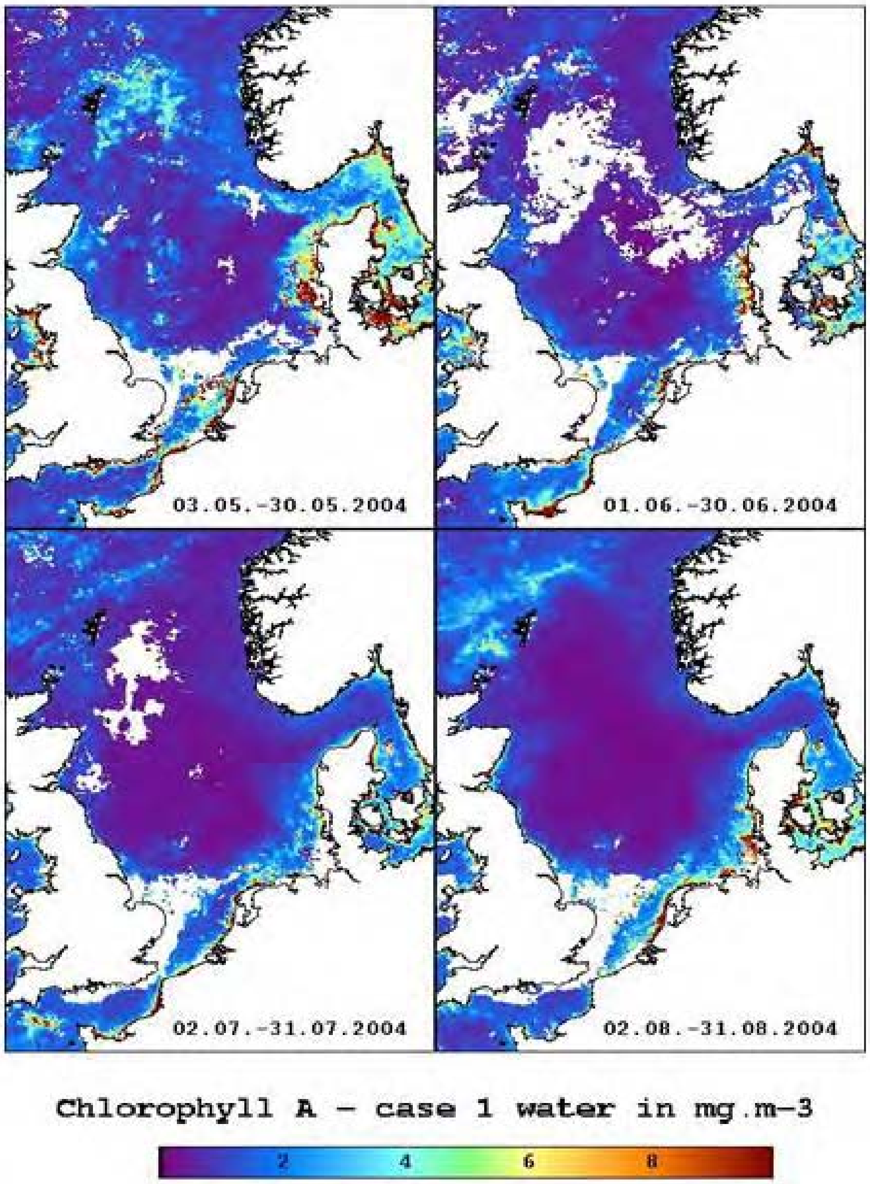

Chlorophyll A - case 1 water in mg.m-3

Oceanic Hydrography
Working Group

Oceanographic Status Report
North Sea 2004

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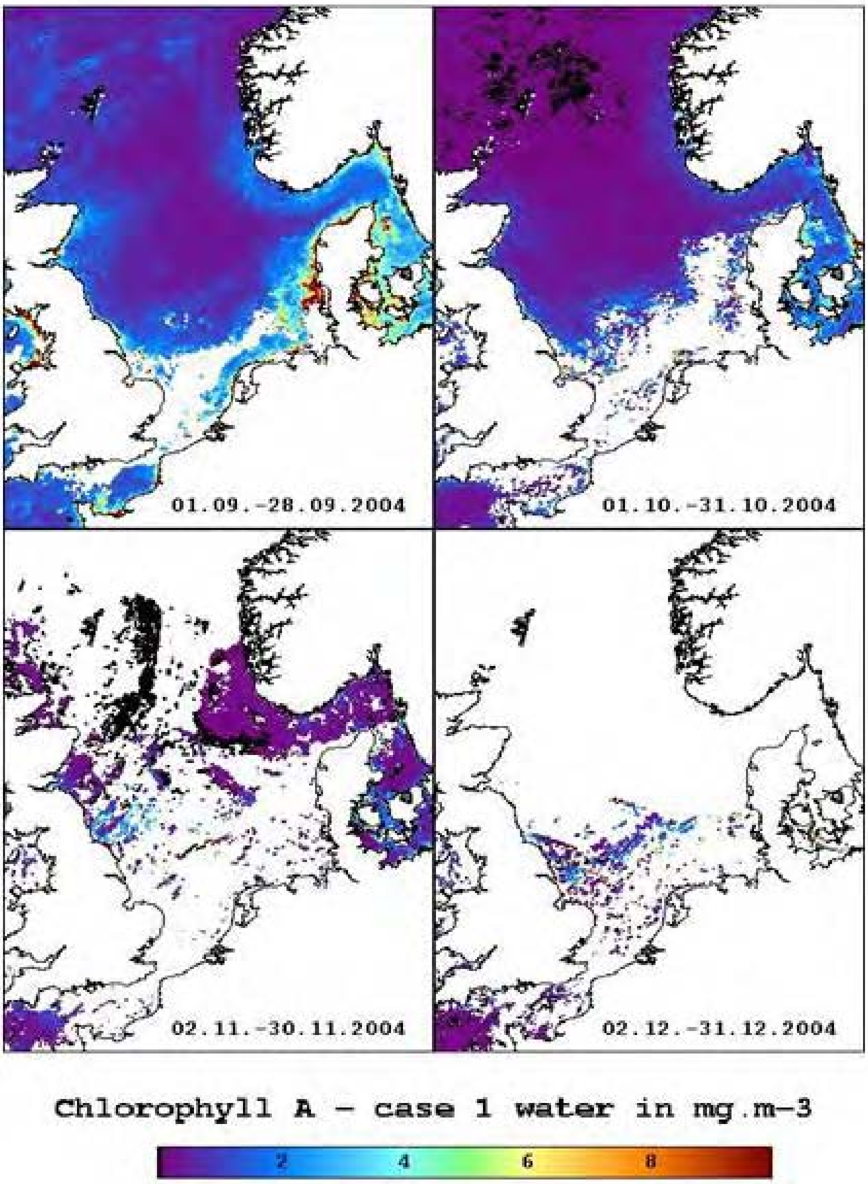
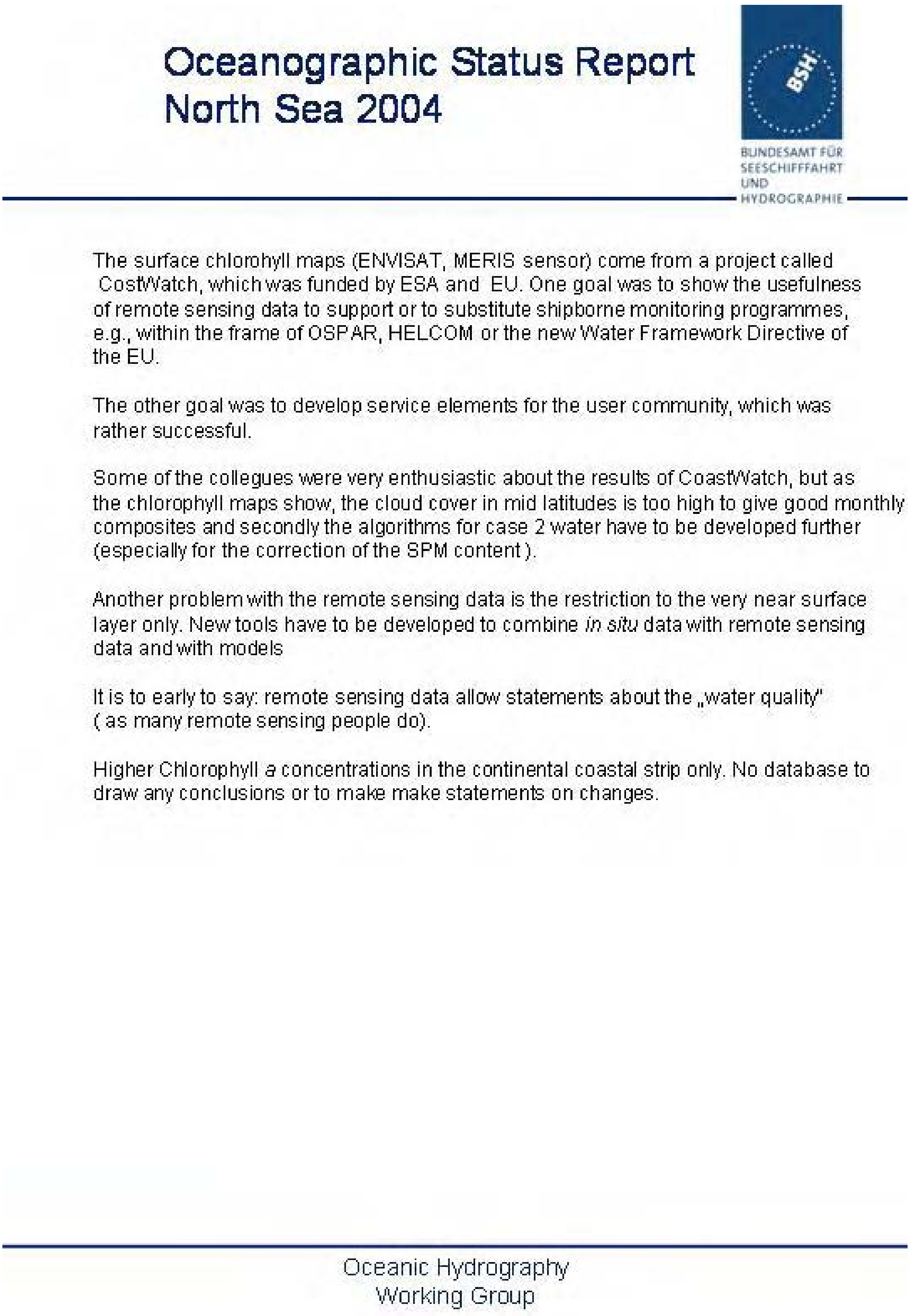


Chlorophyll A – case 1 water in mg.m-3

Oceanic Hydrography
Working Group



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The surface chlorohyll maps (ENVISAT, MERIS sensor) come from a project called CostWatch, which was funded by ESA and EU. One goal was to show the usefulness of remote sensing data to support or to substitute shipborne monitoring programmes, e.g., within the frame of OSPAR, HELCOM or the new Water Framework Directive of the EU.

The other goal was to develop service elements for the user community, which was rather successful.

Some of the collegues were very enthusiastic about the results of CoastWatch, but as the chlorophyll maps show, the cloud cover in mid latitudes is too high to give good monthly composites and secondly the algorithms for case 2 water have to be developed further (especially for the correction of the SPM content).

Another problem with the remote sensing data is the restriction to the very near surface layer only. New tools have to be developed to combine *in situ* data with remote sensing data and with models

It is to early to say: remote sensing data allow statements about the „water quality" (as many remote sensing people do).

Higher Chlorophyll *a* concentrations in the continental coastal strip only. No database to draw any conclusions or to make make statements on changes.

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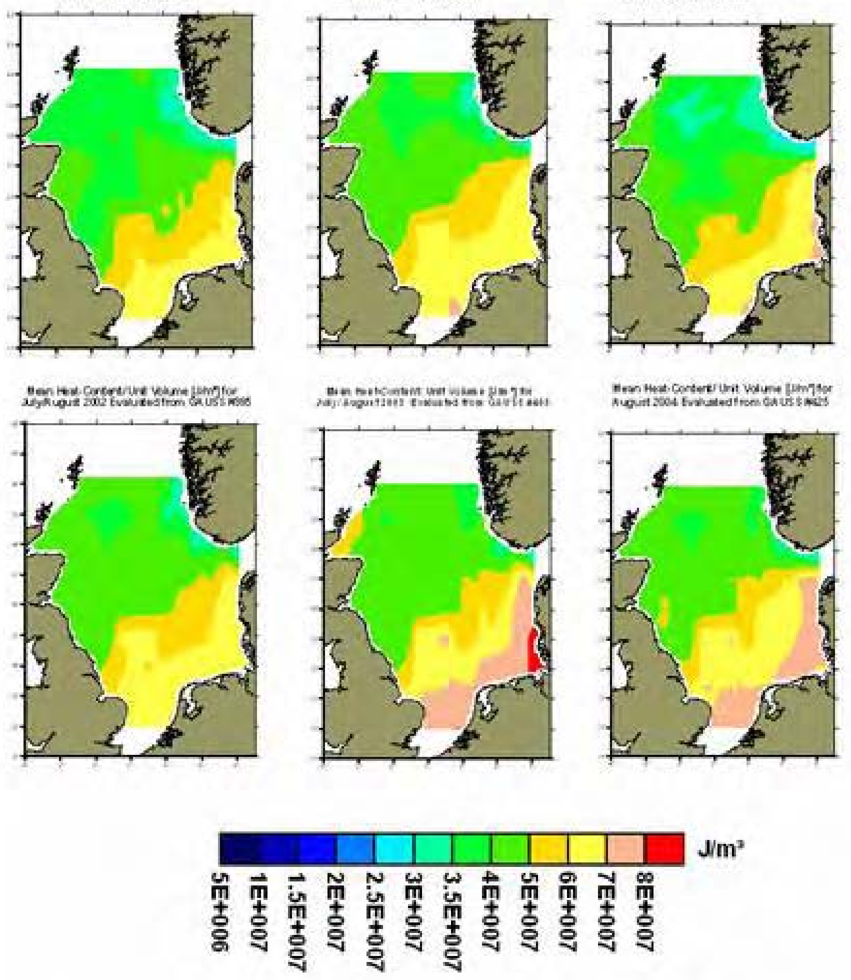

month	total heat content [J]	cruise	year
9- Jul	[illegible]	G335	1999
16- Aug	[illegible]	G353	2000
27- Jul	[illegible]	G370	2001
25-Jul	[illegible]	G385	2002
04-Aug	[illegible]	G405	2003
12-Aug	[illegible]	G425	2004

Fig. 10 Total Heat Content of the North Sea 1999-2004, normalized to an unit volume

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Annex 10: Skagerrak, Kattegat, and the Baltic (Area 9b)

Karin Borenäs, Pekka Alenius, Bert Rudels and Jan Piechura

A large number of hydrographic stations are regularly visited in the Baltic Sea, the Kattegat and the Skagerrak, as exemplified in Figures. 1 and 2 in which the Swedish and Finnish stations are displayed. The hydrographic conditions in these areas were close to average during most of the year although some slightly anomalous periods could be noted. During the spring and early autumn warmer than average surface temperatures were found in some parts of the Baltic, as demonstrated by the record from station Seili in the Archipelago Sea (Figs. 3 and 4). The largest deviation in this region was found in the beginning of August, which was unusually warm.

The annual cycles of the surface temperature and salinity for a number of Swedish stations are shown in Figure 5. A typical feature is that not only the surface salinity, but also its variability, decreases when entering the Baltic. The most striking event in 2004 was exceptionally low values of the surface salinity found in April in the central Skagerrak (Å17). From underway temperature and salinity data (see Figure 6), together with some current measurements, it was deduced that the Baltic current had formed a bight returning southwards west of E 10° 40.

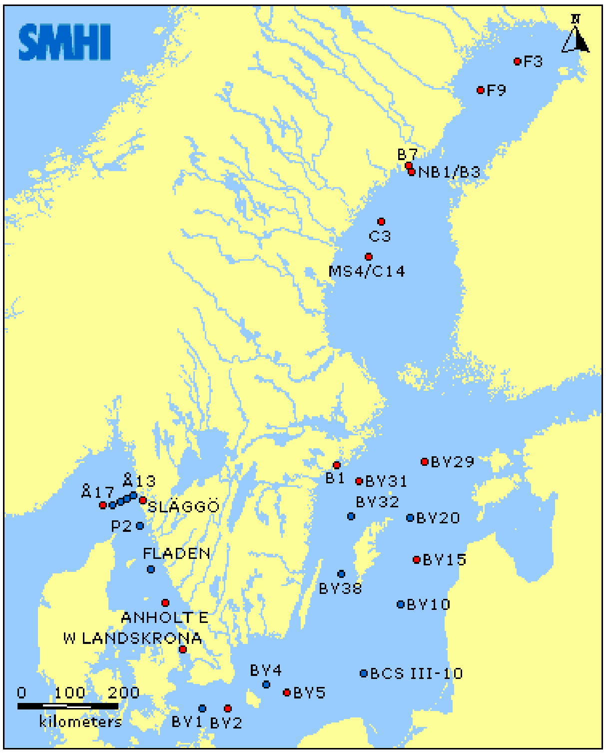


Figure 1. Position of stations visited on a regular basis. Stations marked with red pertain to the Swedish National Monitoring Programme while stations in blue are additional stations sampled by SMHI.

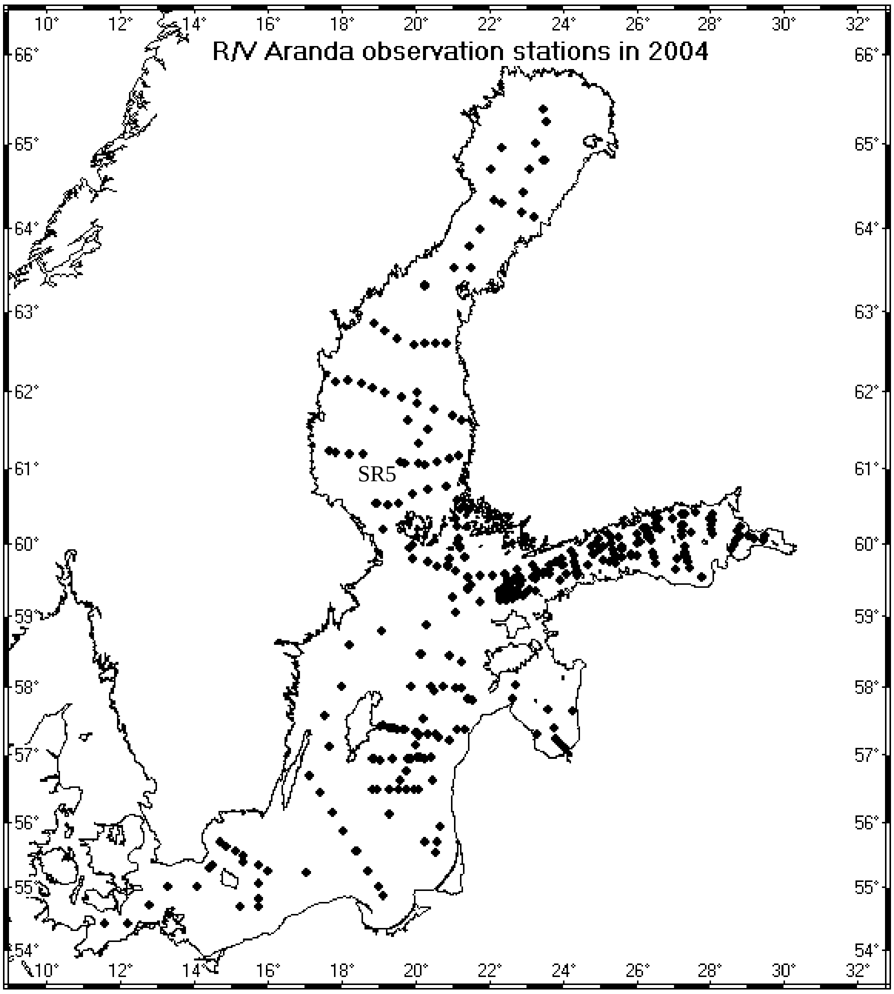


Figure 2. Observation stations of R/V Aranda in 2004. Aranda visited altogether 483 stations in 2004.

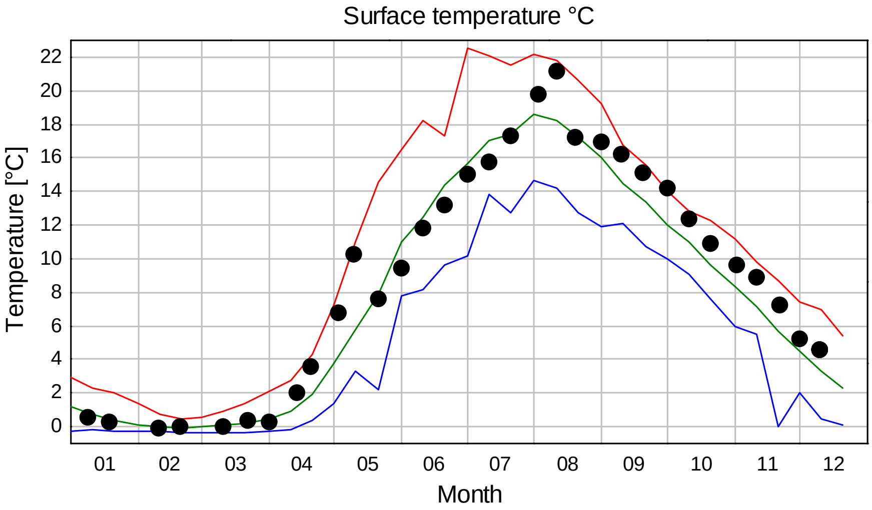


Figure 3. Sea surface temperature at fixed oceanographic station Seili in the Archipelago Sea (dots) compared to mean, maximum and minimum values during the period 1971–2000 (solid lines).

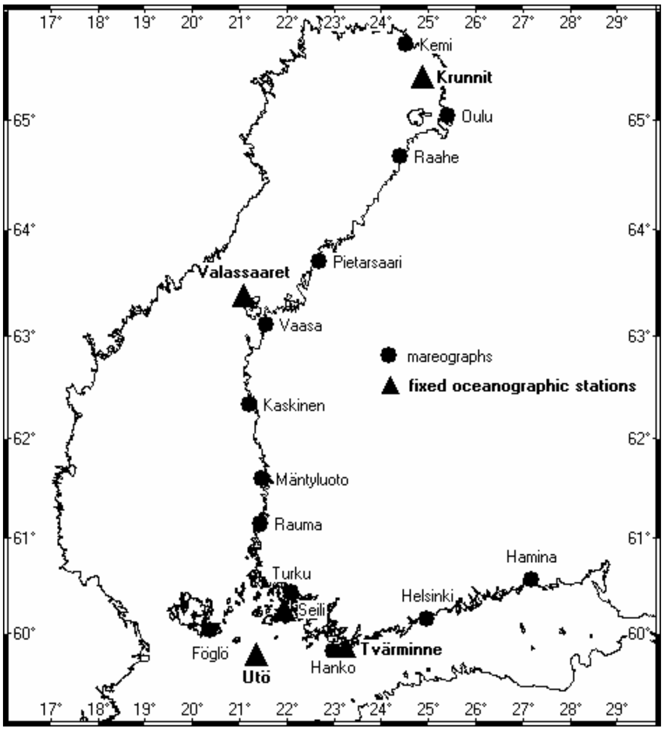
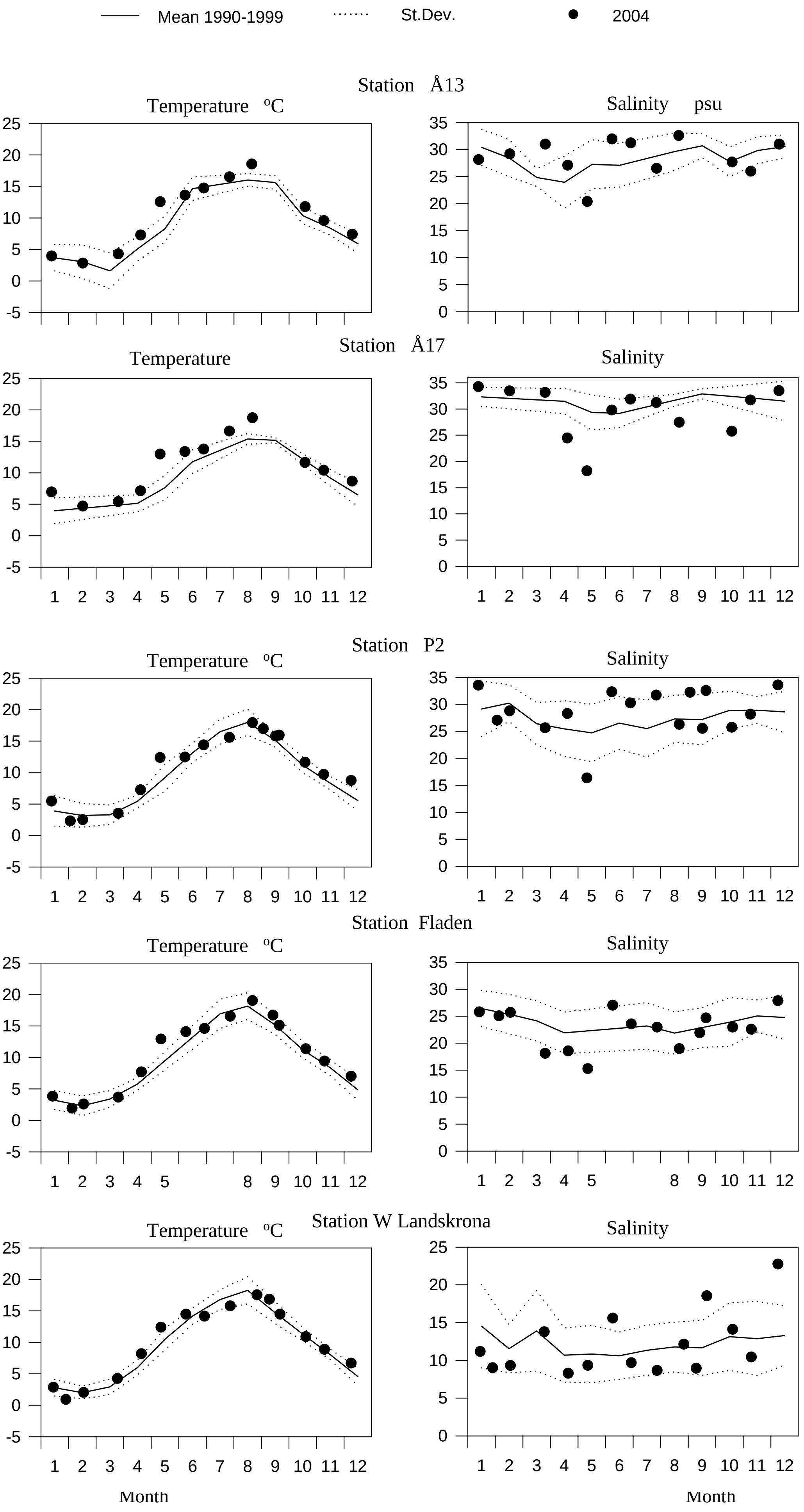


Figure 4. Map showing the position of station Seili.

The exceptional warm water inflow into the Baltic Sea in summer 2002, which preceded the major Baltic inflow of January 2003, was surprisingly repeated in modified form in summer 2003 and again in summer 2004 (Feistel *et al.*, 2004). Since the inflow was warm it only had minor effects on the conditions in the deeper parts of the Baltic. Hypothetically, the repetition of these warm, baroclinc inflows could be regarded as a possible regional indicator for climate change. In Figure 7 the temperature series from two positions in the Bornholm Basin are shown for the period 2003–2005.

Annual Cycles, surface water



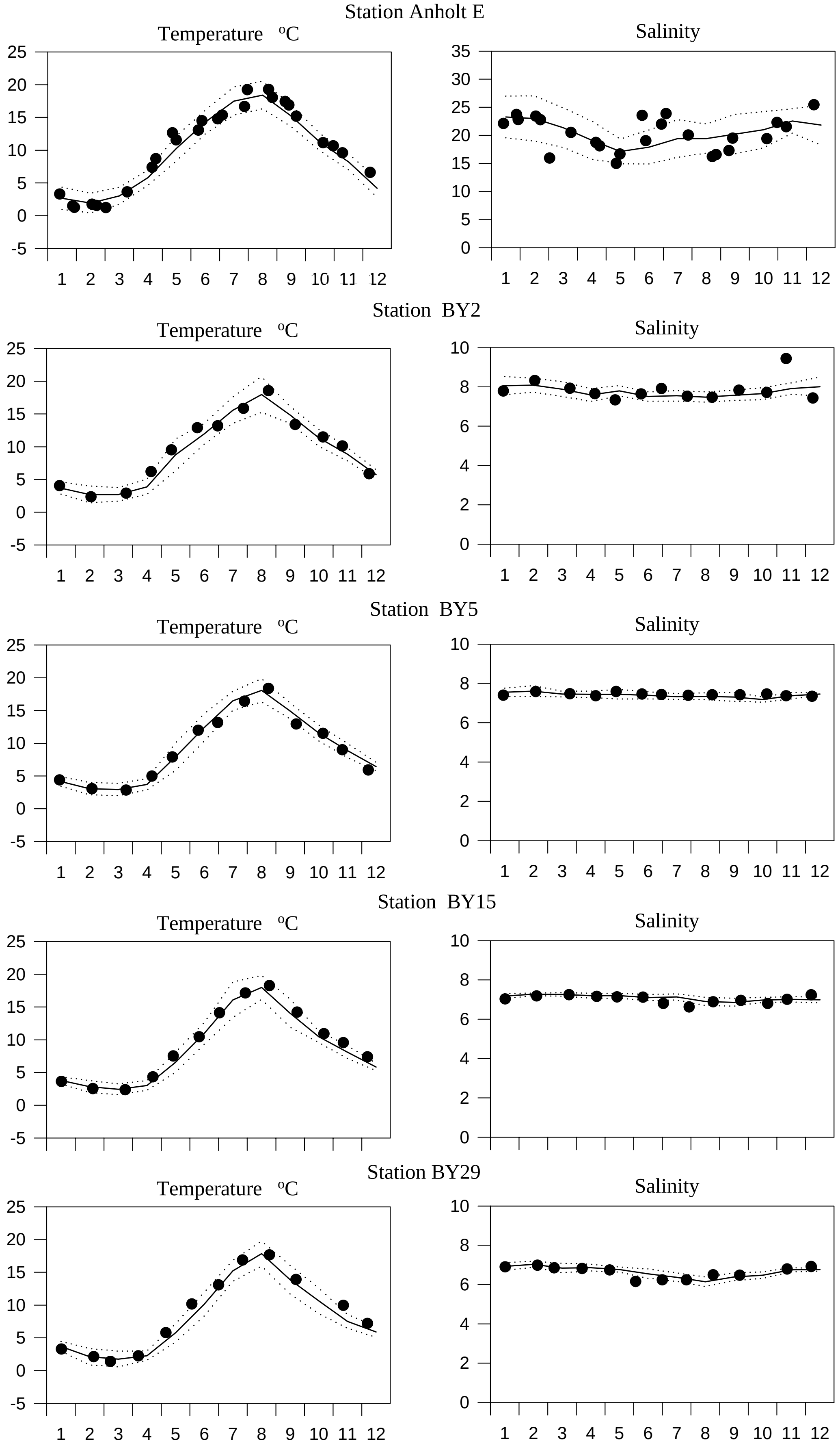


Figure 5. Annual cycles of temperature and salinity, see Figure1 for station positions.

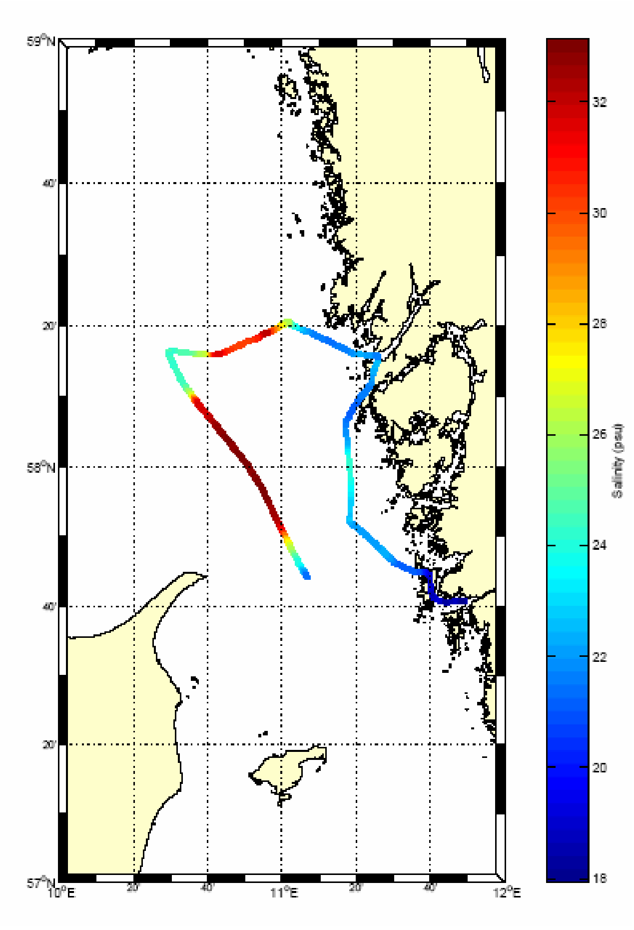


Figure 6. Underway surface salinity measured by R/V Argos in April 2004.

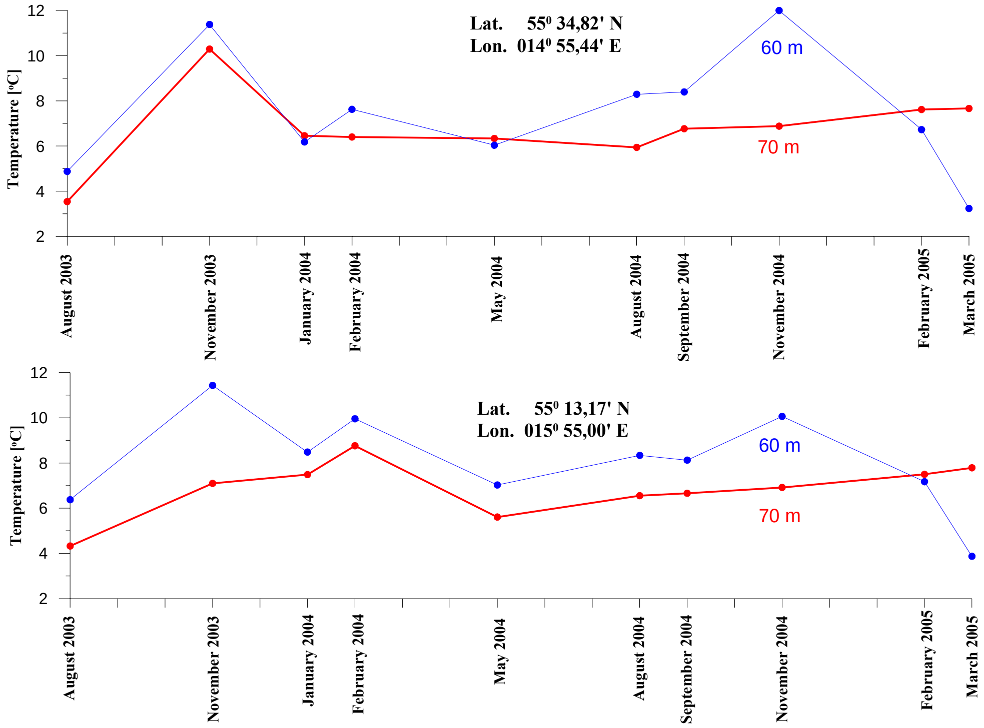


Figure 7. Changes of water temperature in the Bornholm Basin 2003–2005.

Long-term time-series of the salinity are shown for a number of stations in the Baltic. In Figs. 8 and 9 the surface and deep-water salinity is displayed for station LL7 in the Gulf of Finland and SR5 in the Bothnian Bay. These time-series cover the period 1991-2004. For station BY5 in the Baltic Proper, surface salinity data from 1965 to 2004 have been plotted in Figure 10. The decrease in surface salinity, which has been observed for several years, did not continue in 2004.

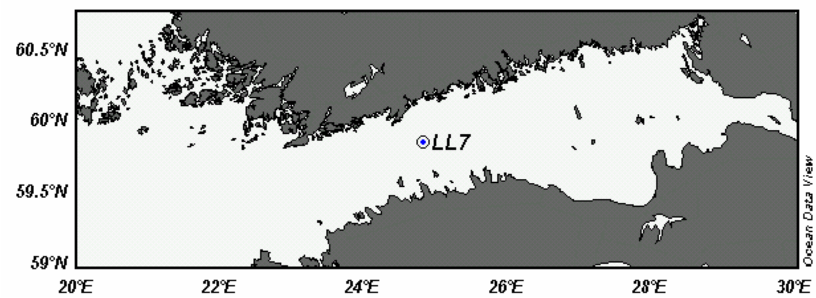


Figure 8a: Position of station LL7.

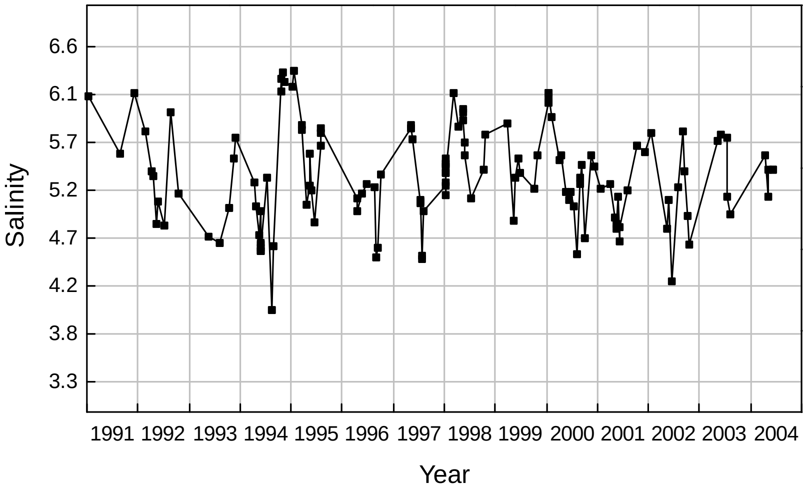


Figure 8b: Surface salinity at station LL7.

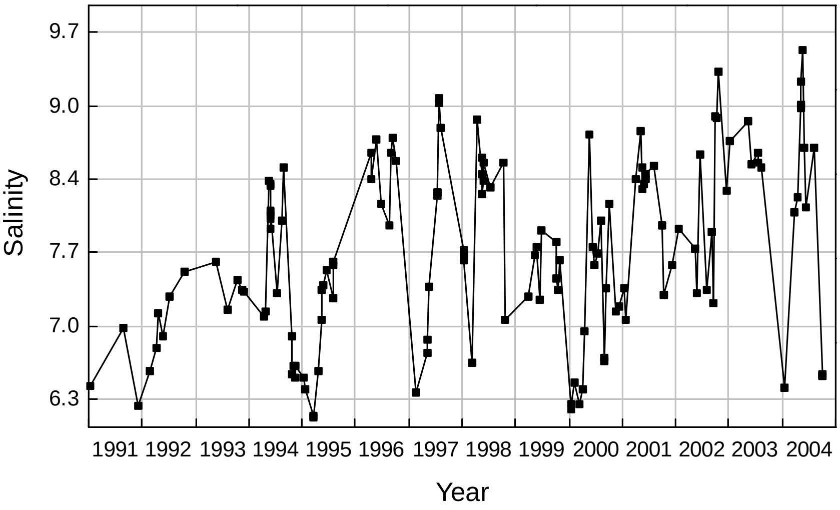


Figure 8c. Deep water (below the halocline) salinity at LL7.

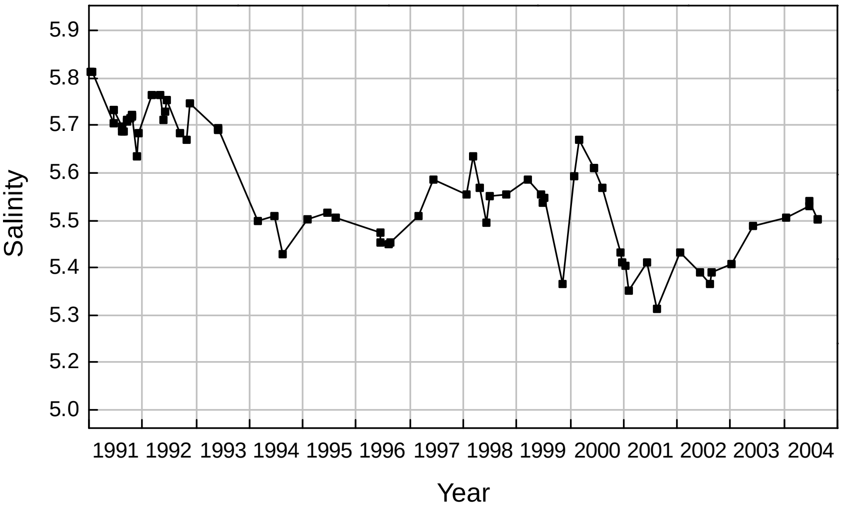


Figure 9a. Surface salinity at SR5 in the middle of the southern Bothnian Sea.

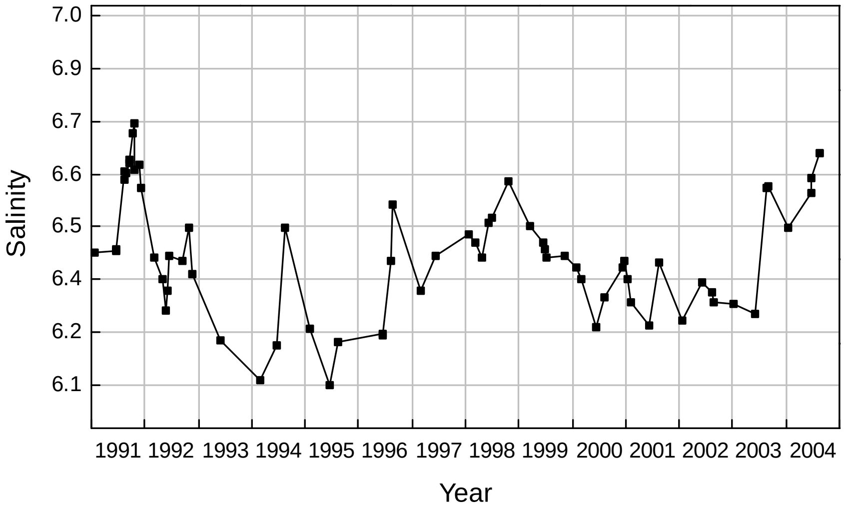


Figure 9b. Deep water salinity at SR5 in the middle of the southern Bothnian Sea.

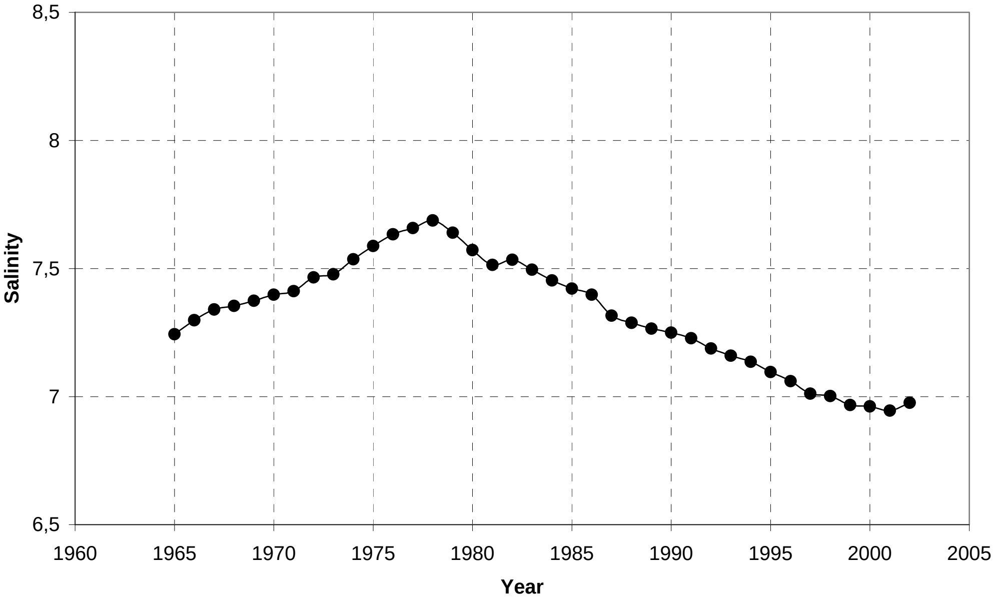


Figure 10. Surface salinity at BY15 (see Figure 1) in the Baltic proper (5-year running mean).

The ice winter 2003/2004 was classified as average with the maximum ice extent occurring on 11 March 2004, see Figure 11. At this time 152 000 km^2 of the Baltic Sea was ice covered, including the Bothnian Bay, Gulf of Finland, Gulf of Riga and most of the Bothnian Sea.

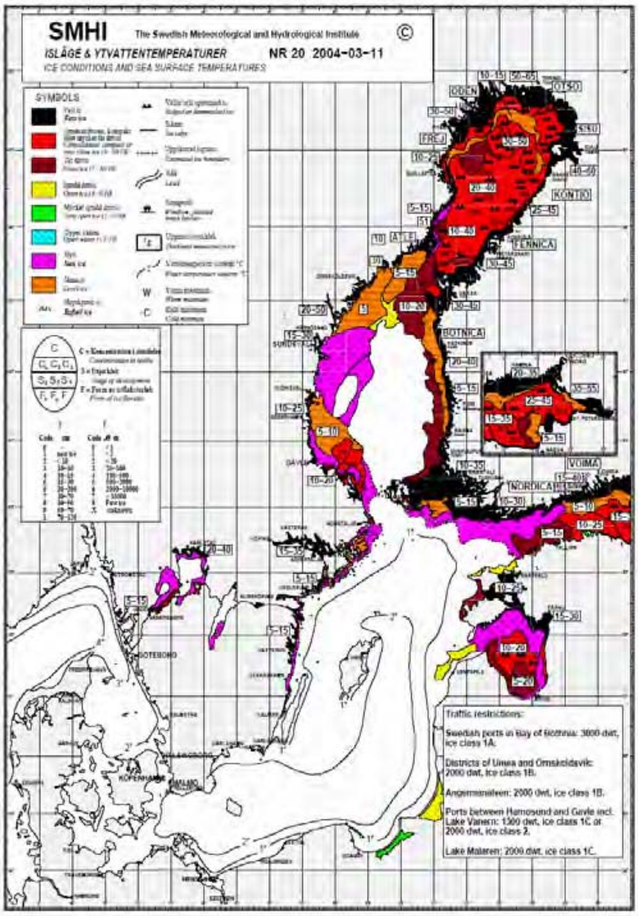


Figure 11. The maximum ice extent in the Baltic Sea during the winter 2003/2004. The map was constructed by the Ice Service at SMHI.

A time-series of the maximal ice extent for the period 1660-2004 has been constructed at SMHI (Axell 2004) using data from ice charts and historical reconstructions, see Figure 12. The diagram also shows the corresponding series obtained by FIMR. Statistical methods have been used to calculate trends for various parts of the time-series. For the period 1960-2004 the trend is statistically significant and negative.

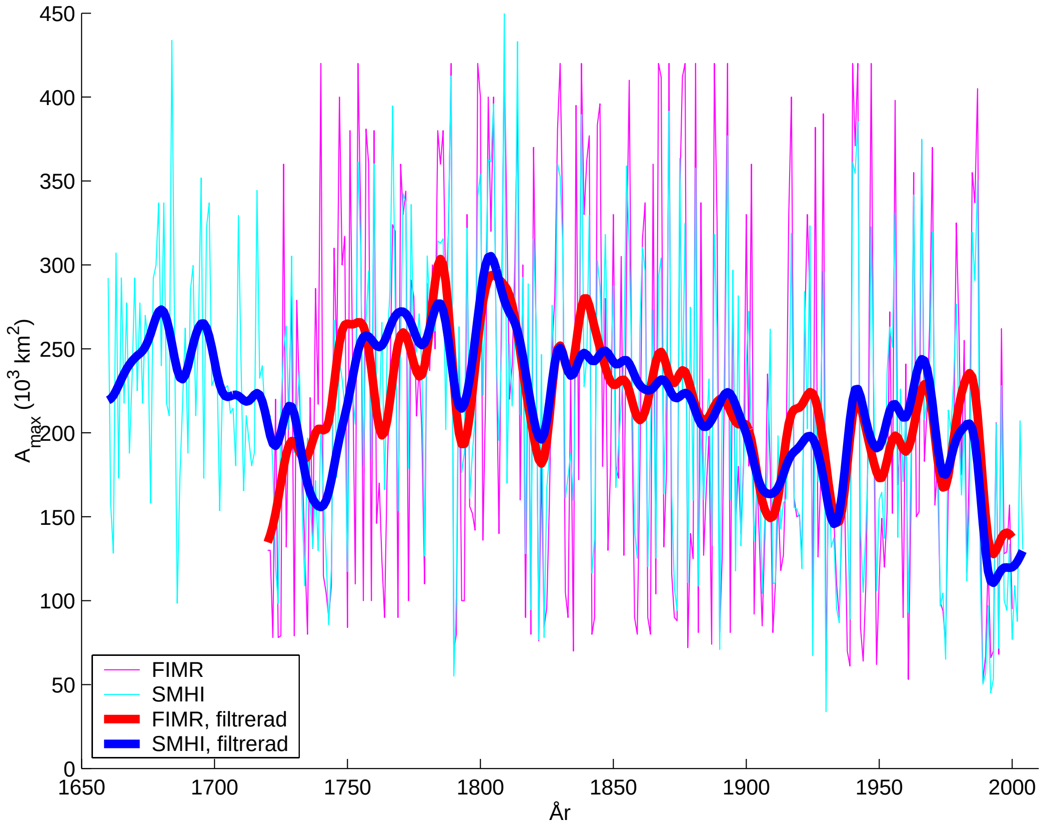


Figure 12. Yearly maximal ice extent (thin lines) and low pass filtered data (thick lines). From Axell (2004).

References

Axell, L. 2004. Reconstruction of maximal ice extent in the Baltic for the period 1660–2004, manuscript.

Feistel, R., Nausch, G., Heene, T., Piechura, J., Hagen, E. 2004. Evidence for a warm water inflow into the Baltic Proper in summer 2003, Oceanologia, 46(4): 581–598.

Annex 11: Norweigan water (Areas 8, 10, and 11

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Summary

The temperature of the southern Barents Sea was approximately 0.5–1.1°C higher than average during 2004 and there was less sea-ice than average. In 2004 the Atlantic water in the Norwegian Sea was 0.5–0.8 °C warmer than normal. In the North Sea, the temperature was above to the long-term mean in 2004.

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

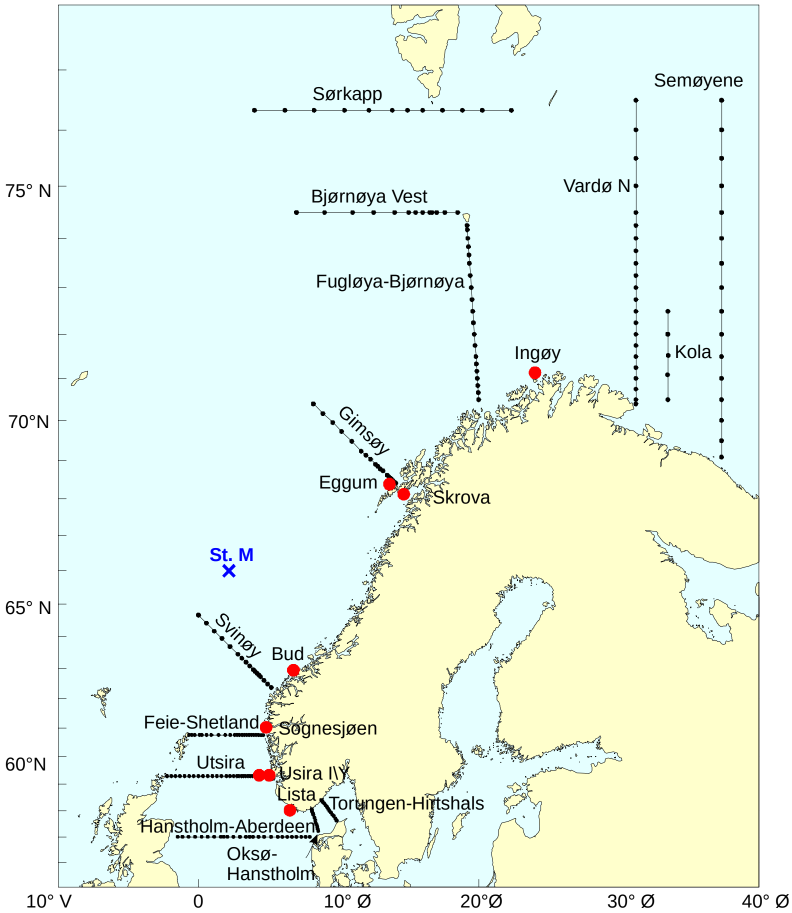

Figure 1. Standard sections and fixed oceanographic station worked by Institute of Marine Research, Bergen. The University of Bergen is responsible for station M, while the Kola section is operated by PINRO, Murmansk (Anon., 2002)

The Norwegian Sea

High values of temperature were observed in Norwegian Sea. In the southern Norwegian Sea averaged Atlantic water was about 0.5 °C above the long-term-mean. Along the Norwegian continental slope the core of Atlantic Water was in 2004 0.5–0.8 °C warmer than normal with highest anomaly in the south. The salinity was also high in 2004 and in southern Norwegian Sea it was the highest ever in the time-series.

Figure 2 shows the development in temperature and salinity in three different sections from south to north in the Norwegian Sea (Figure 1). Since beginning of the 1990s the temperature and salinity in the Svinøy section has increased. In the last three years the temperature had the largest values in the time-series. The salinity had also large values the last three years. In 2004 it was the highest ever (about 0.09 above normal) in the time-series. The temperature was in 2004 the next largest in the time-series, about 0.8 ^{o}C above normal. The Gimsøy and Sørkapp sections had also large values of temperature and salinity for 2004. It was then about 0.6 °C and 0.5 °C higher than normal for temperature and 0.05 and 0.04 higher than normal for salinity, for Gimsøy and Sørkapp section, respectively.

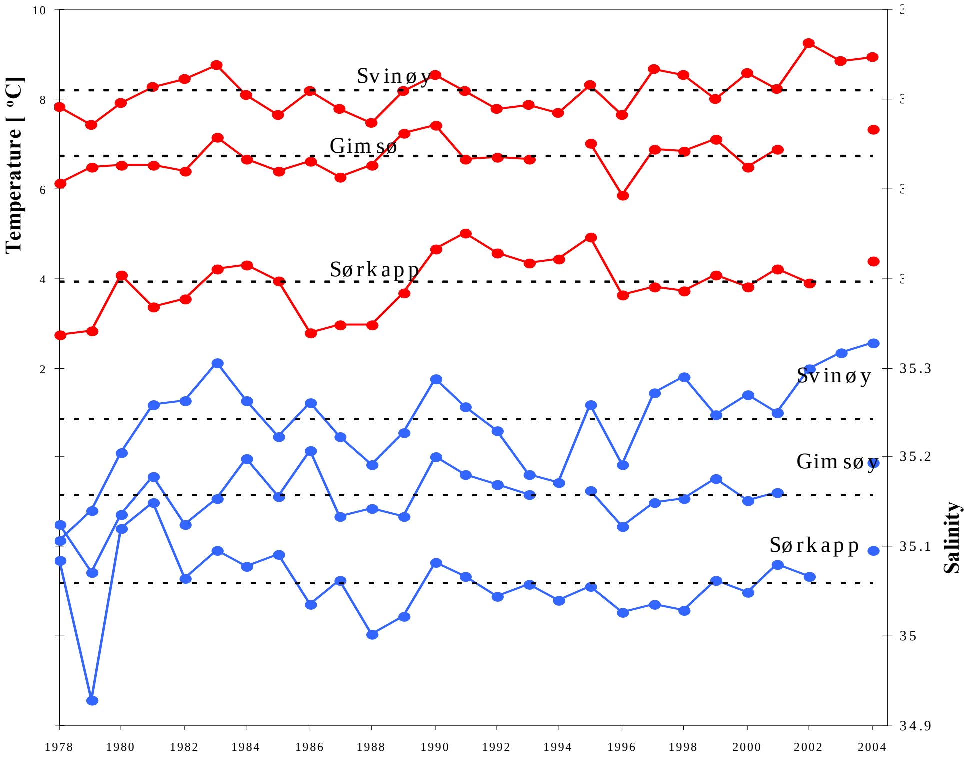

Figure2. Temperature and salinity, observed in July/August in the core of Atlantic water in the sections Svinøy-NW, Gimsøy-NW and Sørkapp-W, averaged between 50 and 200 m depth. (Anon., 2005).

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 for summer are shown in Figure 3. There are considerable variations both in the area of Atlantic water distribution and its temperature. The distribution area of Atlantic water decreased since the beginning of 1980s to mid 1990s and increased from there to present. The temperature has shown a steady increase. Since 1978 the Atlantic water has been about 0.6°C warmer. In 2002 the temperature increased considerable and had in 2003 the largest value in the time-series. The temperature the last three years has been the largest values in the time-series and in 2004 the temperature was about 0.5°C higher than the long-term-mean. The area of Atlantic water in 2004 was close to the long-term-mean.

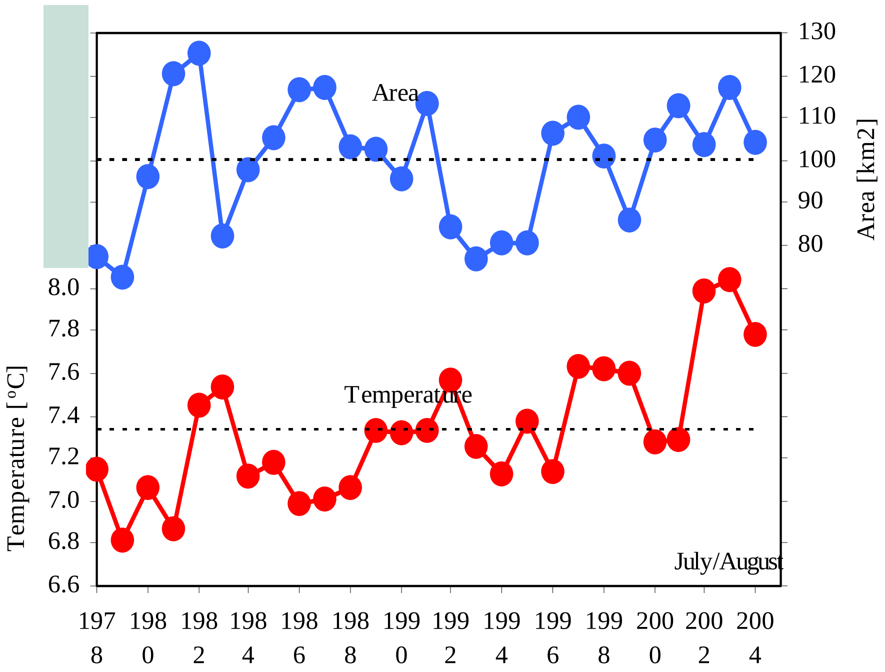

Figure 3. Time-series of area (in km^2) and averaged temperature (red) of Atlantic water in the Svinøy section, observed in July/August, 1978–2004 (Anon, 2005).

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 have been carried out in the Fugløya- Bear Island section continously since August 1997.

The hydrographic observations were carried out according to the plan. Figure 4 shows the temperature and salinity anomalies in the Fugløya-Bear Island section in the period from 1977 to end of 2004. Temperatures in the Barents Sea were 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 winter of 2004 the temperature was 0.5°C above the long-term average in the BSO, but during spring the temperature raised 1.0°C above the long-term mean. During the summer the temperature stayed stable at this level, and in October it reached it maximum by being 1.14°C above the average. For first time the average temperature in the core of the Atlantic inflow passed 7°C in this area. The salinity variations are similar to those in temperature, and there has been an increased salinity during the last 1.5 years.

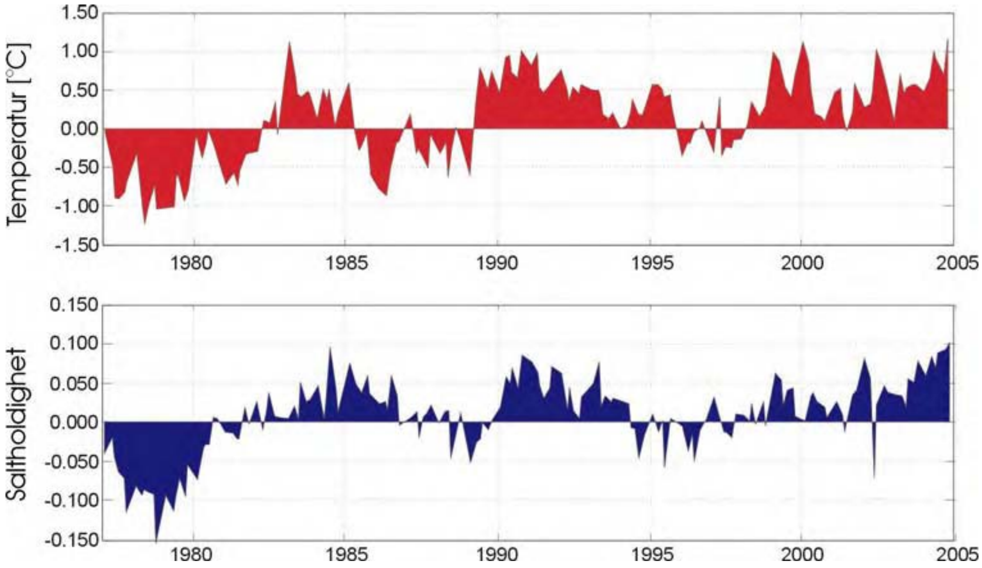

Figure 4. Temperature anomalies (upper panel) and salinity anomalies (lower panel) in the section Fugløya – Bear Island section.

Figure 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. 2004 had a negative ice index, which means more ice than average. This was very surprising since the sea temperature was high. There were two reasons for this. Firstly the really ice melt did not start before mid June, which is about one month later that usual. Secondly, the ice melt during summer was extremely low, most likely due to atmospheric forcing. In 2004 there was little ice due to high ocean temperature.

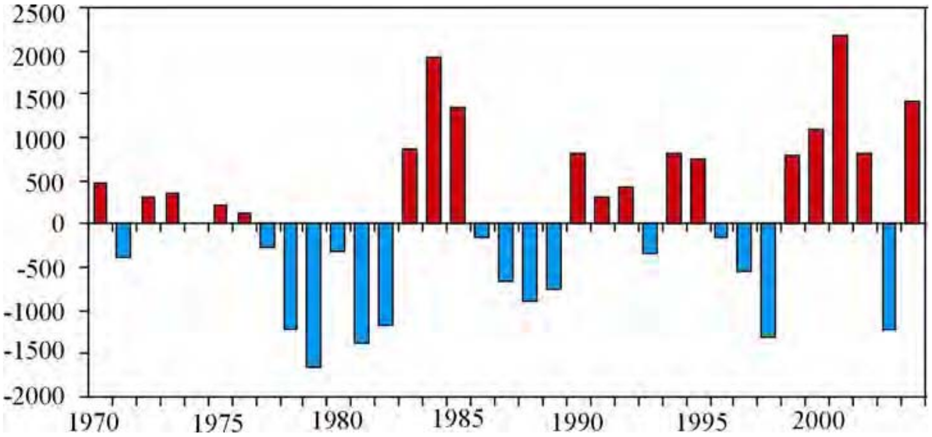

Figure 5. Ice index for the period 1970-2004. Positive values means less ice than average, while negative values show more severe ice conditions.

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 two-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 EU-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 by accumulation of water and/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 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 the first half of 2003 the inflow was high, which may explain the rapid temperature increase between January and March. The intensity of the flow was reduced during spring and summer.

The time-series of volume transports shows a relatively high inflow during 1997 and 1998, before the transport decreased and reached a minimum in end of 2000. Then there was a strong increase in the transport until beginning of 2003. Earlier it has been believed that the temperature and the volume transport varied in a similar manner; that is that high temperature was linked to high volume transport and lower temperature was linked to reduced inflow of Atlantic water. However, Figure 6 show that there seems to be no correlation between the fluxes and the temperature of the inflowing water. In fact, in periods the temperature increase while the volume flux decreases, and high positive anomalies observed in 2004 are not due to an increased inflow, as we did believe earlier. This shows that in the Fugløya-Bear Island section the temperature is independent of the volume flux into the Barents Sea. The reason is simply that while the temperature of the inflowing water depends on the temperatures upstream in the Norwegian Sea, the volume flux depends mainly on the local wind field. This shows the importance of measuring both volume transport and temperature, since they not always are varying in the same manner. This is a new discovery that we can relate to ASOF-N.

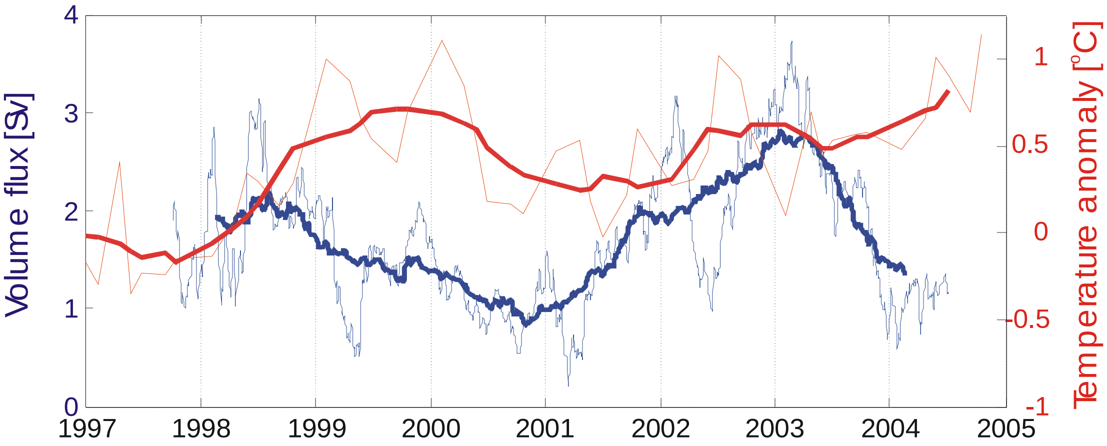

Figure 6. The blue lines show Atlantic Water volume flux across the section Norway-Bear Island. Time-series are 3 and 12 months running means. The red lines show temperature anomalies the section Fugløya – Bear Island section. Time-series are actual values and 12 months running means.

In collaboration with Øystein Skagseth (Bjerknes Centre for Climate Research) we have started to compare current meter data in the Norwegian Sea with current meter data in the Barents Sea and the Fram Strait. The objectives are to investigate signal propagation from the Norwegian Sea to the Barents Sea and Fram Strait, and to try to quantify how much of the Atlantic Water that is entering the Barents Sea compared to the Fram Strait.

A dynamic-thermodynamic sea ice model has been coupled to a three-dimensional ocean circulation model for the Barents Sea region (Budgell, 2004). The ocean model component is based on ROMS (Regional Ocean Modelling System) version 2.1. ROMS is a three-dimensional baroclinic general ocean model. It uses a topography-following coordinate system in the vertical, with 32 s-coordinate levels. Orthogonal curvilinear coordinates are used in the horizontal. The average horizontal grid size is 9.3 km. The present model forcing includes surface forcing (wind and radiation) from the NCEP/NCAR Reanalysis and open boundary conditions from a large scale implementation of ROMS covering the area from the southern Atlantic to the Polar Ocean.

The model performs well (Budgell, 2004) with the most appearant discrepancies with observations mainly being due to uncertainties in the prescribed forcing fields.

A comparison of modelled and observed sea surface temperature (SST) with data from the Pathfinder AVHRR satellite, show that in March, the model produces a realistic transport of warm water northward west of Spitzbergen and the region encompassed by the 2 degree isotherm matches the satellite SST dirtibution. The model results for September also show good agreement with the satellitre SST field (Figure 7).

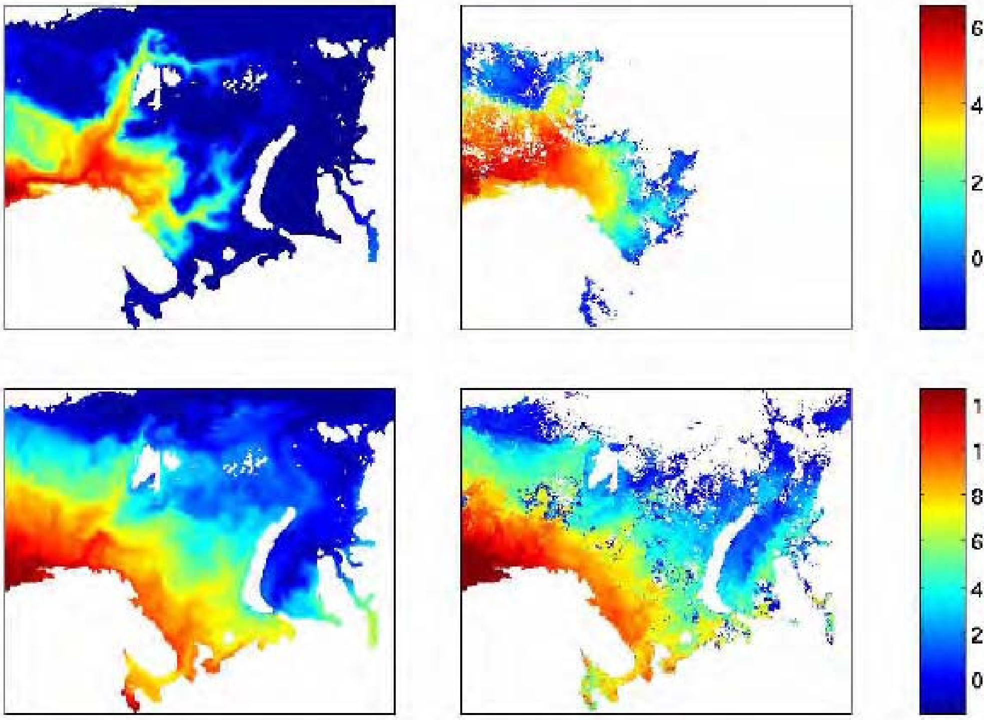

Figure 7. Modelled vs. Pathfinder AVHRR monthly-mean SST. The top row is from March, 1993, the lower row is from September, 1993. The left-handed column contains the ROMS model fields, the right-hand column contains the Pathfinder AVHRR fields.

The sea ice concentration in the Barents Sea can exhibit considerable variation both seasonally and inter-annually, and a comparison with an integral estimate of monthly-mean total area ice cover with observations from the SSM/I satellite show excellent agreement for the winter and an excessive ice melting in the model during summer (Figure 8). This melting is most likely due to poor surface forcing during summer.

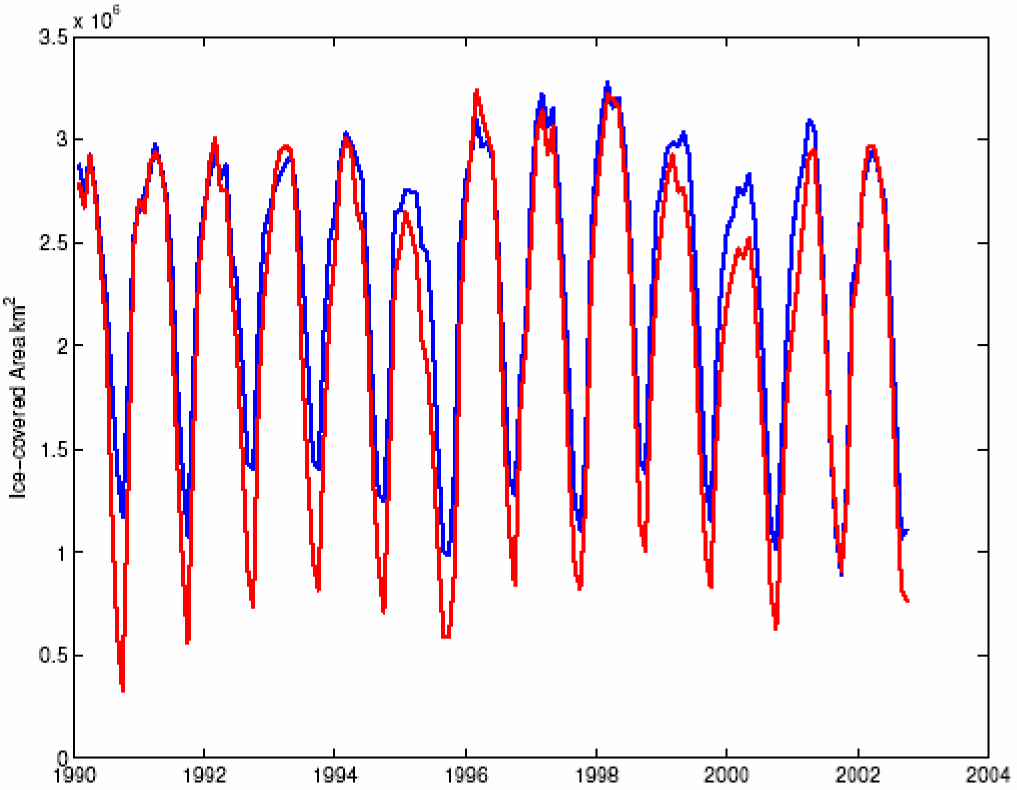

Figure 8 Monthly mean modelled (red) and SSM/I (blue) time-series of the ice-covered area in the Barents Sea model domain.

At present, the Barents Sea model is producing an archive of results from 1990 up till today.

The North Sea

The temperature of the upper layer of most of the North Sea was between 0.5 to 1.5°C warmer than normal, with the exception of the western Norwegian coastal water which was close to normal during the first half year. Intense and mild weather from the south and west during the last part of the year and the beginning of 2005 has resulted in more than one degree warmer water than the norm in December and January (05) and about two degrees warmer in the Skagerrak. Figure 9 shows the development of temperature and salinity at two positions, one (A) near bottom in the north-western part of the North Sea and the second (B) 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 9). Also the salinity is slightly lower at the plateau. In both places there was extremely high temperature and salinities in 2004. This is a result of very high salinity in the inflowing Atlantic water and the effect of a mild winter.

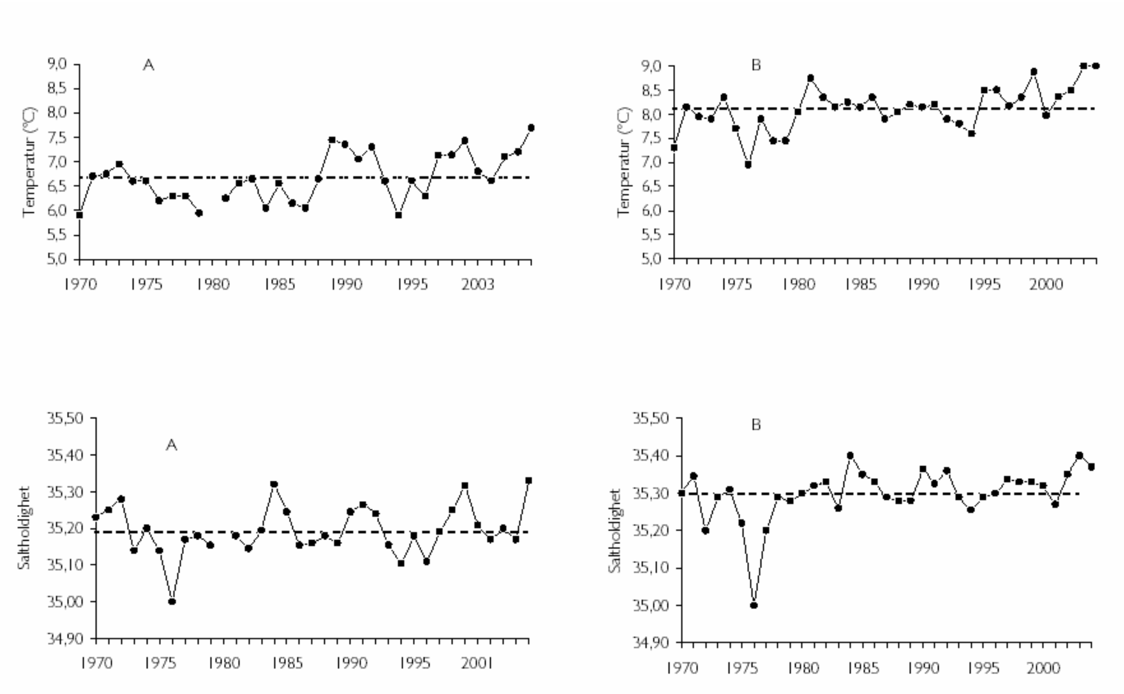

Figure 9. Temperature and salinity near bottom in the northwestern part of the North Sea (A) and in the core of Atlantic water at the western shelf edge of the Norwegian Trench (B) during the summers of 1970-2004 (ANON. 2005).

Estimates from a numerical ocean circulation model showed that the circulation in the North Sea was quite normal throughout 2004. Also the inflow of Atlantic water to the northern and central North Sea was at a normal level, with somewhat higher values at the end of the year due to heavy south and westerly winds (Figure10). The inflow through the English Channel was also at a normal level. In October and December 2003 and August, September and December 2004 relatively warm and high salinity Atlantic water masses (>35.3) was observed along the slope of the Danish side in the Skagerrak. Such high values have not been observed since autumn 1991 and relates well with observations in the northern North Sea and the Faeroe-Shetland channel. The Atlantic water transports large amounts of nutrients to the North Sea. A coupled numerical model (NORWECOM) shows as expected relatively normal annual primary production due to normal inflows of Atlantic water and relatively normal wind conditions. The production after the spring bloom was unusually low in the Skagerrak, related to the somewhat lower than normal modelled production in the south and south eastern North Sea.

The catches of horse mackerel during the autumn in the North Sea, have for many years been strongly linked with the northern modelled inflow of Atlantic water during winter (1. quarter) approximately half a year earlier. In 2004 the model prognosis was 20.000 ton while the following catches were 11.000 ton.

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 10-30 m. The temperature in the deeper Skagerrak water (150 m) was 1–.5°C above normal most of the year, and the salinity was most of the year more than one st.dev. above long-erm mean. As predicted in 2003 there was renewal of the deep oxygen-rich water in February to April, without significant higher density. We therefore expect a new renewal in 2005.

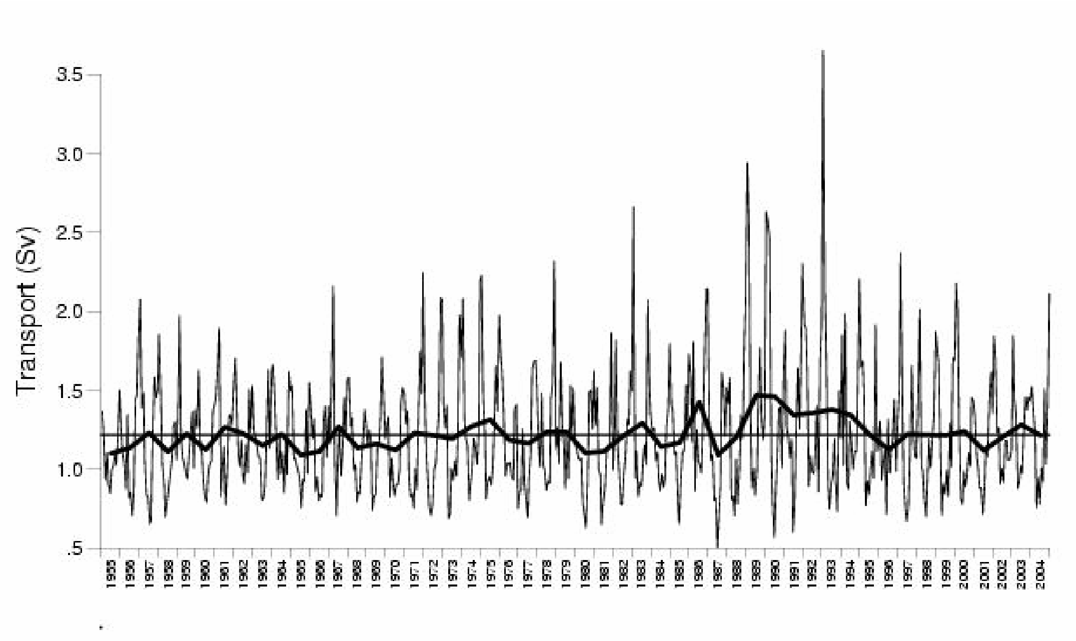

Figure 10. Time-series (1955-2004) of modelled annual mean (bold) and monthly mean volume transport of Atlantic water into the northern and central North Sea southward between the Orkney Islands and Utsira Norway. 1 Sv = $10^6 m^3 s^{-1}$. (Anon. 2005)

Annex 12: Russian Standard Sections in the Barents Sea, 2004 (Area 11)

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The Barents Sea

Climatic conditions in the Barents Sea are closely linked to the large-scale sea level pressure patterns and atmospheric circulation. In winter 2004, low pressure dominated over the Barents Sea with westerly and south-westerly winds prevailing over its southern part while northerly and north-easterly winds were typical of the northern Barents Sea. In spring, the Iceland Low was centred between Iceland and Greenland, and a low gradient air pressure pattern caused prevalence of weak southerly winds over the Barents Sea. In summer, light easterly and south-easterly winds in the southern and western Barents Sea were caused by a high pressure cell centred over the north-eastern Barents Sea. In autumn, there was a return to the air pressure pattern typical of the wintertime; a low pressure was centred over the southern Barents Sea and caused south-westerly winds in the south and north-easterly winds in the north.

Air temperatures averaged for the western Barents Sea (70–76°N, 15–35°E) were generally warmer-than-normal throughout the year with large positive anomalies (2.5–3.0 °C) in April, July and December. Slightly warmer-than-normal air temperatures (1.0–2.0 °C) prevailed in the eastern Barents Sea (69–77°N, 35–55°E).

Mean annual sea surface temperatures (SST) exceeded those in 2003 and were generally warmer-than-normal. In the north-western Barents Sea (76–79°N, 8–25°E), SST had been increasing after minimum in January–February (–0.5 °C) and stayed close-to-average during the rest of the year. In the southern Barents Sea, SST was mostly above normal with maximum (1.6–1.8 °C) in August.

Warmer-than-normal air and sea surface temperatures resulted in considerable reduction of the ice coverage (evaluated as % of the total Barents Sea area) compared to both 2003 and the long-term average. A rapid ice cover reduction occurred in April, and ice coverage was 6–18% lower-than-normal during the rest of the year.

Figure 1 shows main Russian standard sections in the Barents Sea. The Kola section runs from the Kola Fjord mouth northwards, along 33°30’E, and crosses the coastal and main branches of the Murman Current. In 2004, the Kola section was occupied 10 times. Measurements along other sections were done 2–3 times during the year.

Figure 2 shows monthly temperature anomalies in the upper 200 m layer of the coastal (St. 1–3; 69°30´–70°30´N, 33°30´E) and main (St. 3–7; 70°30´–72°30´N, 33°30´E) branches of the Murman Current.

The temperature in the Kola section, both in coastal water and in the main branch of the Murman Current, was higher than that in 2003 and the long-term mean during the whole 2004. The temperature of the coastal water was 0.5–1.3 °C warmer-than-normal; the highest anomalies were registered in May–July. In the main branch of the Murman Current positive temperature anomalies ranged from 0.7 to 1.1 °C. In July–September the temperature of the Atlantic water was the highest on record (1.0–1.1 °C above normal) since the early 1950s. High temperature anomalies continued into 2005, and the temperature was higher-than-normal by 1.1–1.2 °C.

The annual mean temperature in the main branch of the Murman Current was 0.9 °C above normal (Figure 3). 2004 was the sixth warm year since 1999 and the warmest year since 1951.

The annual mean temperature in the upper 200 m layer in the Kola section in 2005 is expected to be warmer than the long-term average.

The section Bear Island - West (along 74°30´N) was occupied 3 times in 2004. The temperature in the Norwegian Current (74°30´N, 06°34´–15°55´E) in the layer 0–200 m was warmer-than-normal by 0.8 °C in August. In October and November the temperature increased and was about 1.2 °C higher than the long-term mean.

The section Bear Island - East (along 74°30´N) was occupied in August and October. A positive temperature anomaly in the northern branch of the North Cape Current (74°30´N, 26°50´–31°20´E) in the layer 0–200 m decreased from 1.1 °C in August to 0.7 °C in October.

Measurements in the Kanin section (along 43°15´E) were performed in March, August, and December. The temperature of Atlantic water (71°00´–71°40´N, 43°15´E) in the upper 200 m layer decreased from 0.8 in March to 0.3 warmer-than-average in August, and than increased to 1.2 °C above normal in December.

The Kharlov section was occupied 3 times in 2004. The temperature was 0.6 °C warmer than normal in March; then positive anomaly increased to 1.0 °C in October and 0.9 °C in December.

In the near bottom layer close to normal and higher-than-average temperatures prevailed over most of the Barents Sea throughout the year. Figure 4 shows bottom temperature anomalies in August–September. The anomalies were calculated using the data acquired during joint IMR/PINRO 0-group fish and pelagic fish surveys. Most of the bottom was dominated by warmer-than-normal temperatures. The warmest anomalies ranging between 1.0 °C and 2.0 °C were registered in the north-western and central Barents Sea. Colder-than-normal temperatures spread over its eastern part.

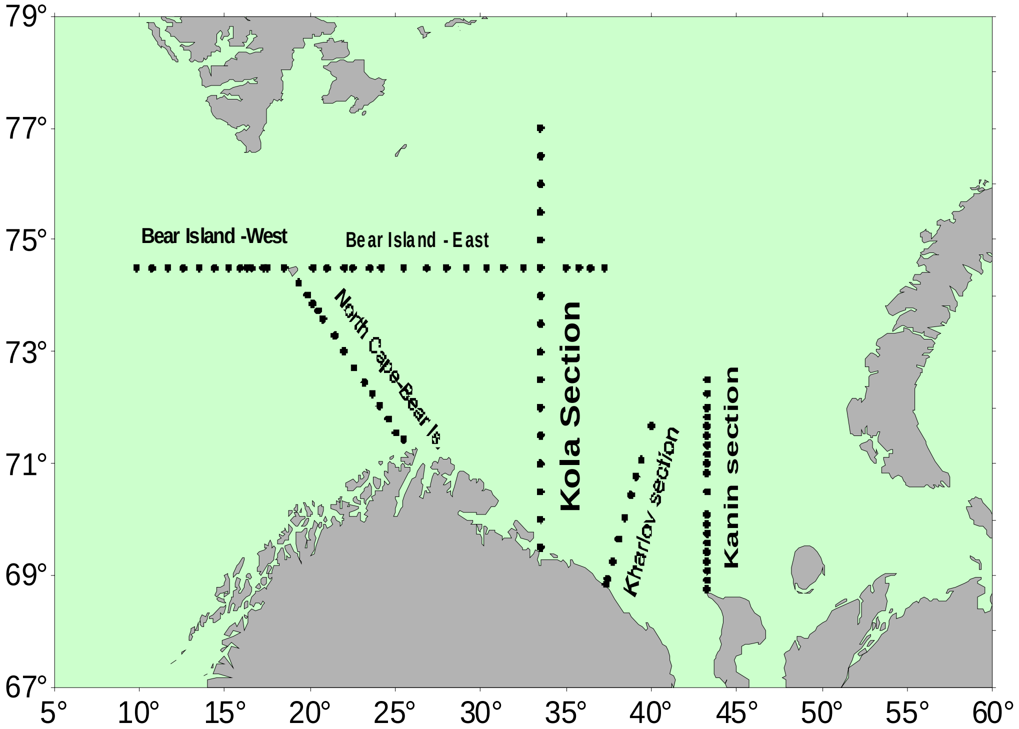

Figure 1. Main Russian standard sections in the Barents Sea

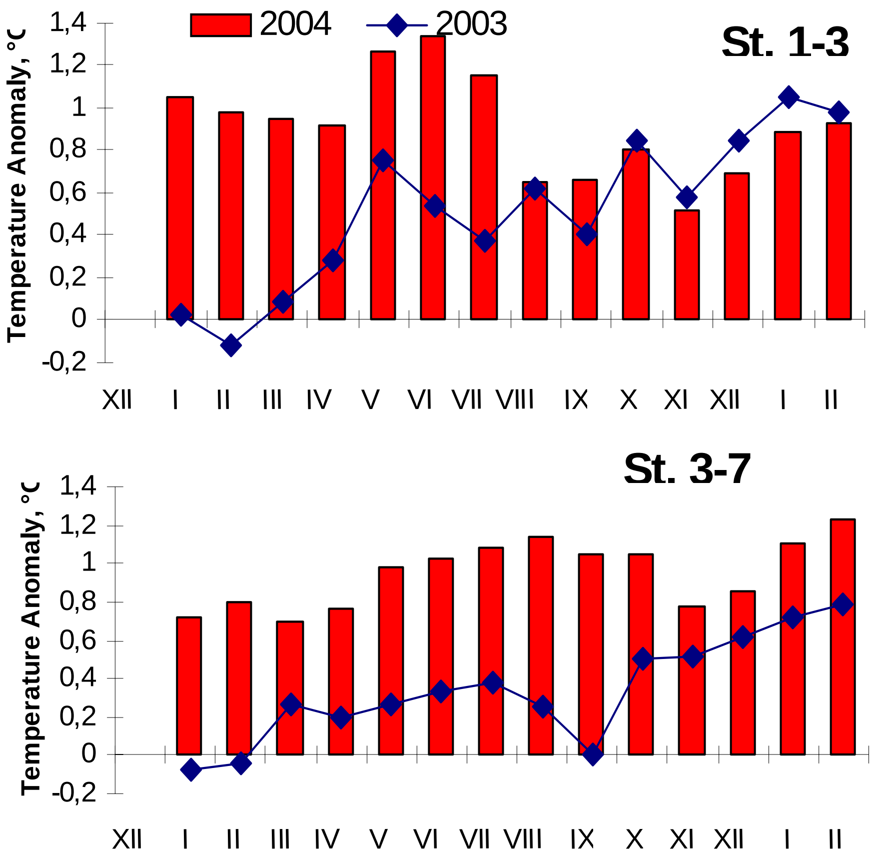

Figure 2. Monthly mean temperature anomalies in the 0–200 m layer of the Kola section in 2004 and early 2005. St. 1–3 – Coastal branch of the Murman Current. St. 3–7 – Main branch of the Murman Current.

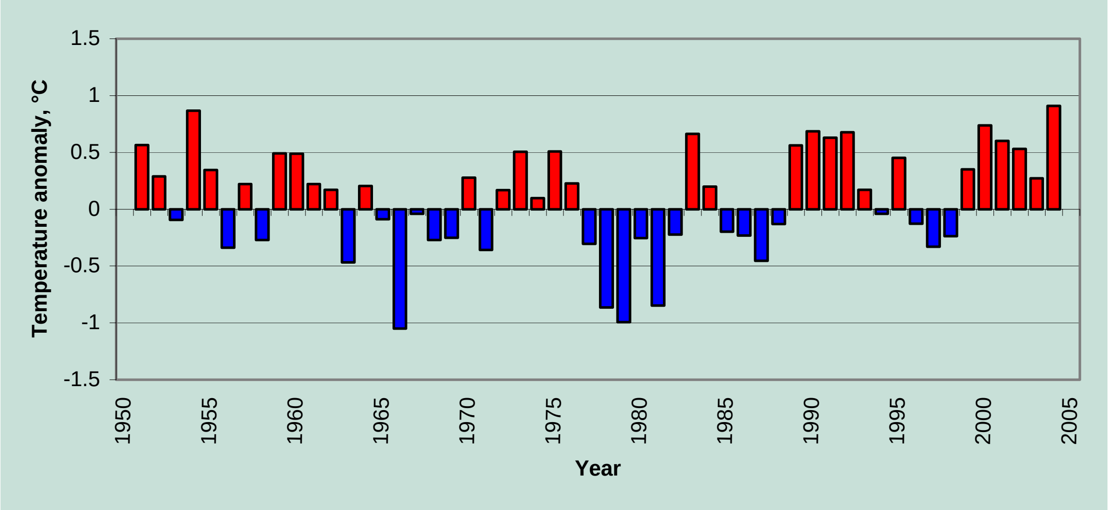

Figure 3. Mean yearly temperature anomalies in the 0–200 m layer in the Kola section in 1951–2004.

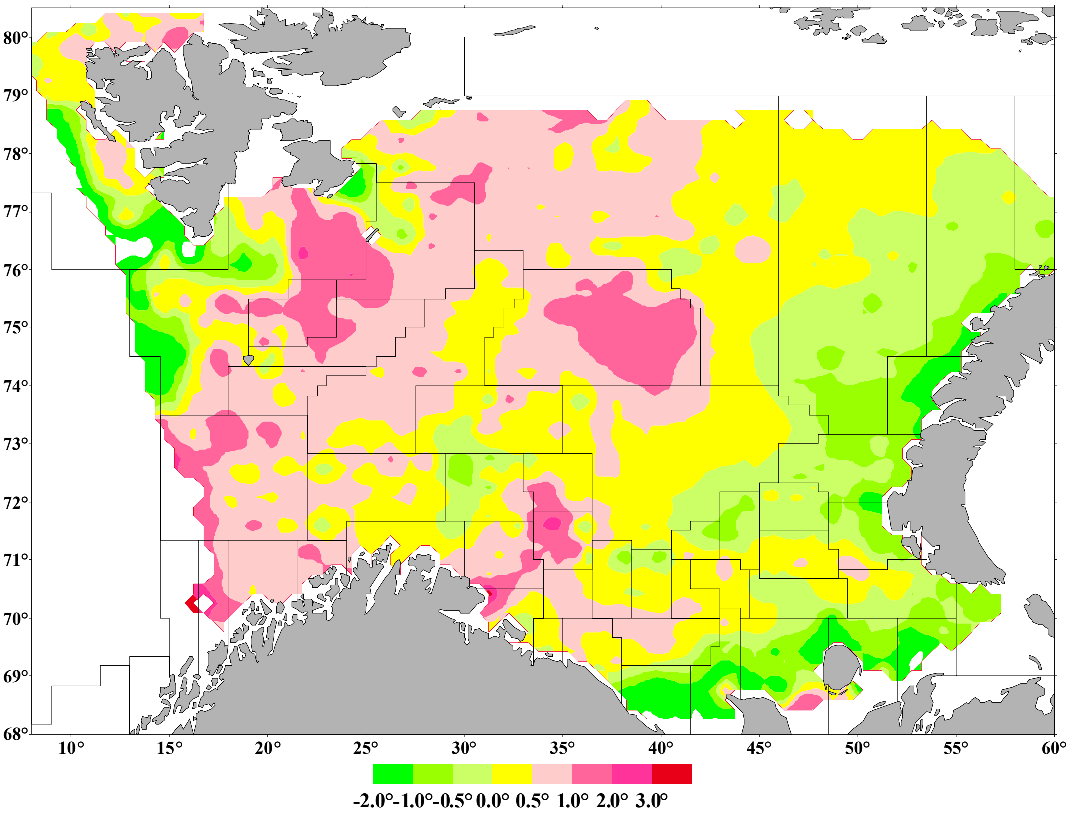

Figure 4. Bottom temperature anomalies in the Barents Sea in August–September 2004

Annex 13: Polish National Report (Area 8,10, and 11)

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Observations 2004

AREX2004 cruise of Institute of Oceanology Polish Academy of Sciences (IOPAS) vessel R.V Oceania was performed in period of 8 June–19 July 2004. 214 CTD casts along 12 sections were done (Figure 1). The SBE 9/11 device was used. Some transects were repeated two or even three times to observe the short-term variability of hydrological fields and currents. Measurements of currents were performed by means of lowered Acoustic Doppler Current Profiler (LADCP). The self-recording 300 kHz RDI device was used to profile entire water column during the standard CTD casts. During the whole cruise continuous currents measurements by the ship-mounted ADCP, RDI 150 kHz were conducted.

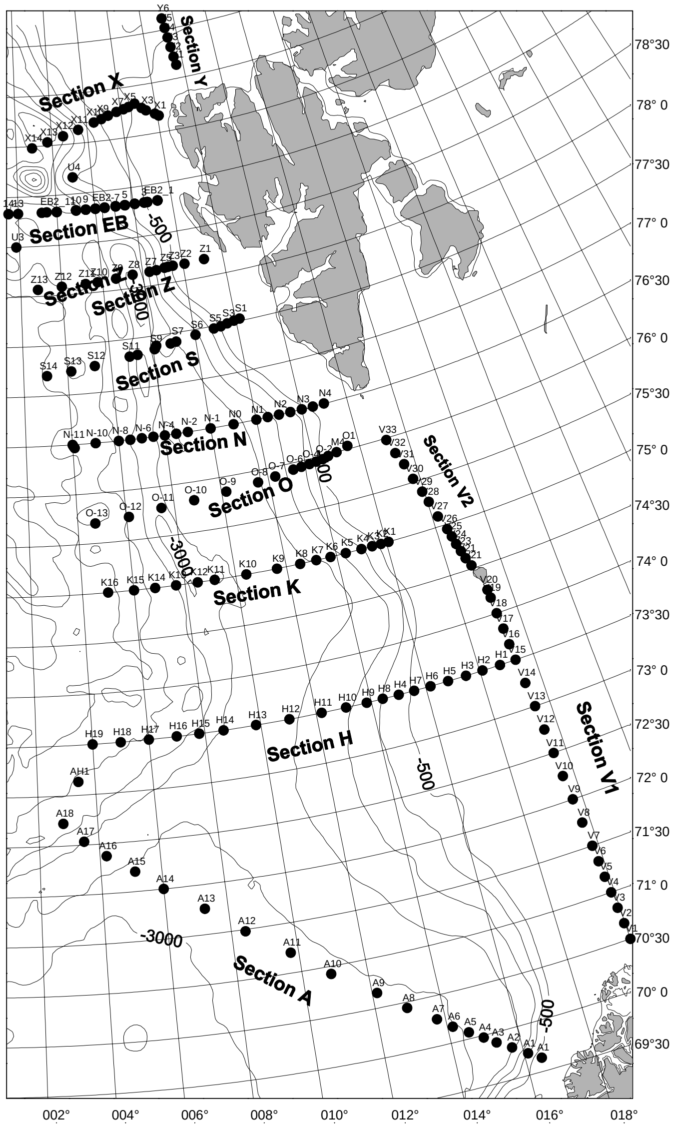

Figure 1 Stations grid performed during R.V 'Oceania' cruise, summer 2004.

Hydrographic conditions

In June/July 2004 temperature and salinity in the upper layer of investigated region (Fig 2) was higher than observed in summer 2003 and higher than mean properties for summers 2000-2004 (Figure3). Also measurements at standard sections show much higher then usually temperature and salinity of inflowing Atlantic Water.

Measurements at the section ‘N’ along the 76° 30’ N parallel, from latitude 004°E to 015°E has been performed from the board of R.V. ‘Oceania’ every summer since 1996. For entire section in 2004, mean temperature at 200 dbar was 3.30°C, salinity 35.047 in comparison to 2.18°C and 35.00 in 2003. Between latitudes 009–011°E mean temperature and salinity at 200 dbar was in 2004 respectively 3.37°C and 35.06 in comparison to 2.63°C and 35.04 in 2003. The Atlantic Water core salinity and temperature reached in summer 2004 the highest ever observed by R.V. “Oceania” values (Figure 4).

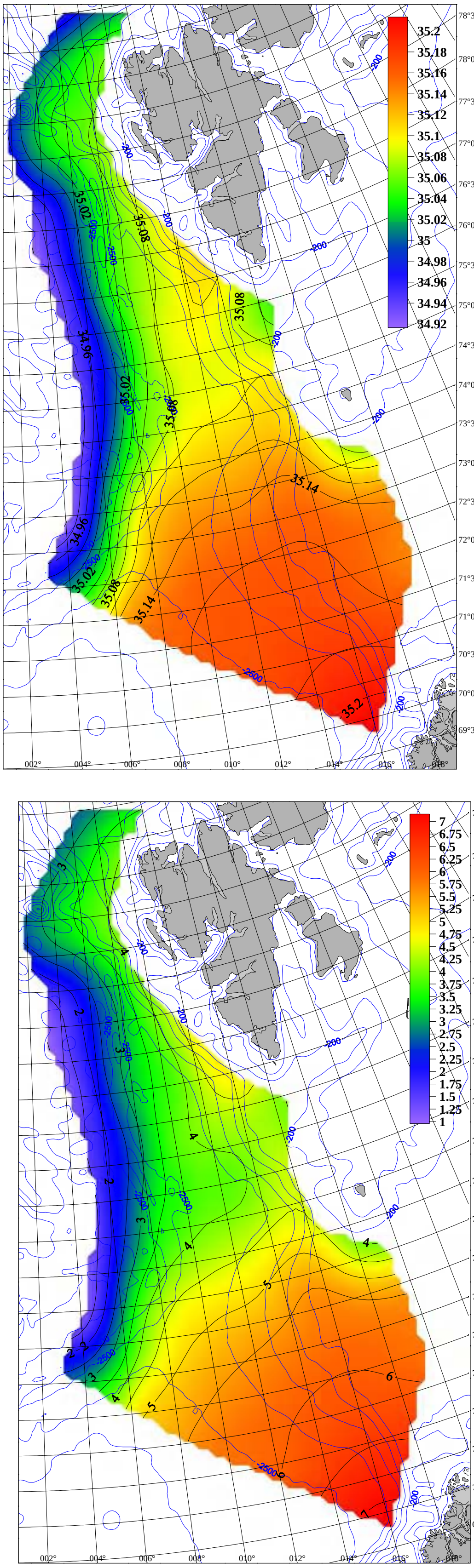

Figure 2. June–July 2004. Mean salinity (left panel) and temperature for layer 100-300 dbar.

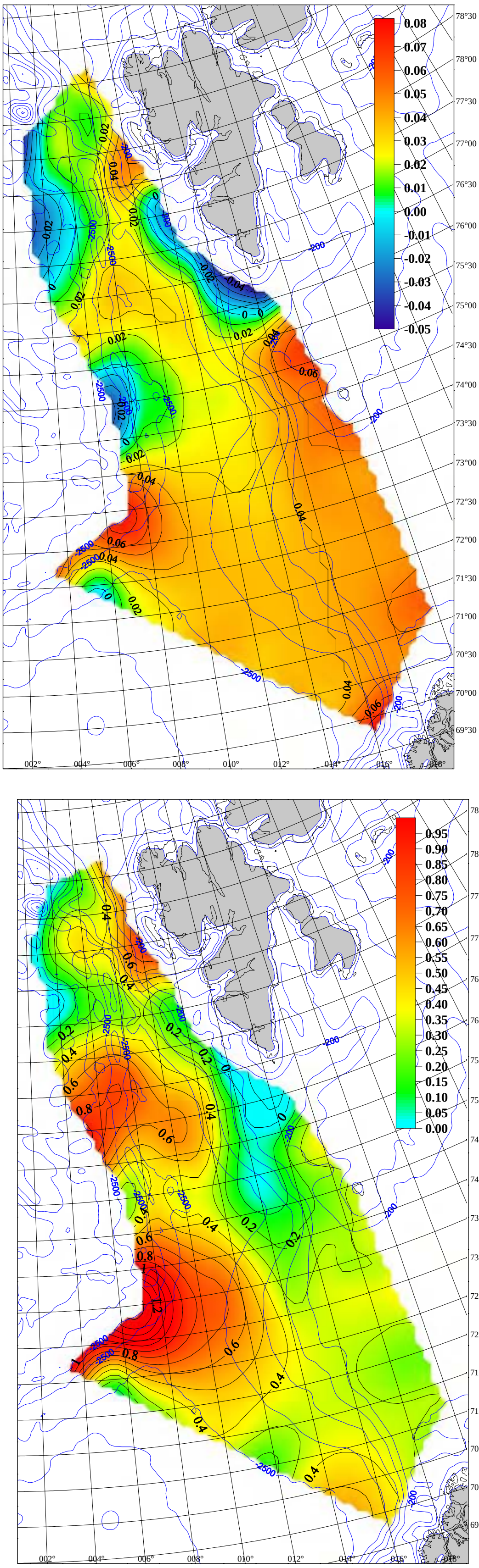

Figure 3. June-July 2004. Anomaly of salinity (left panel) and temperature at 100 dbar.

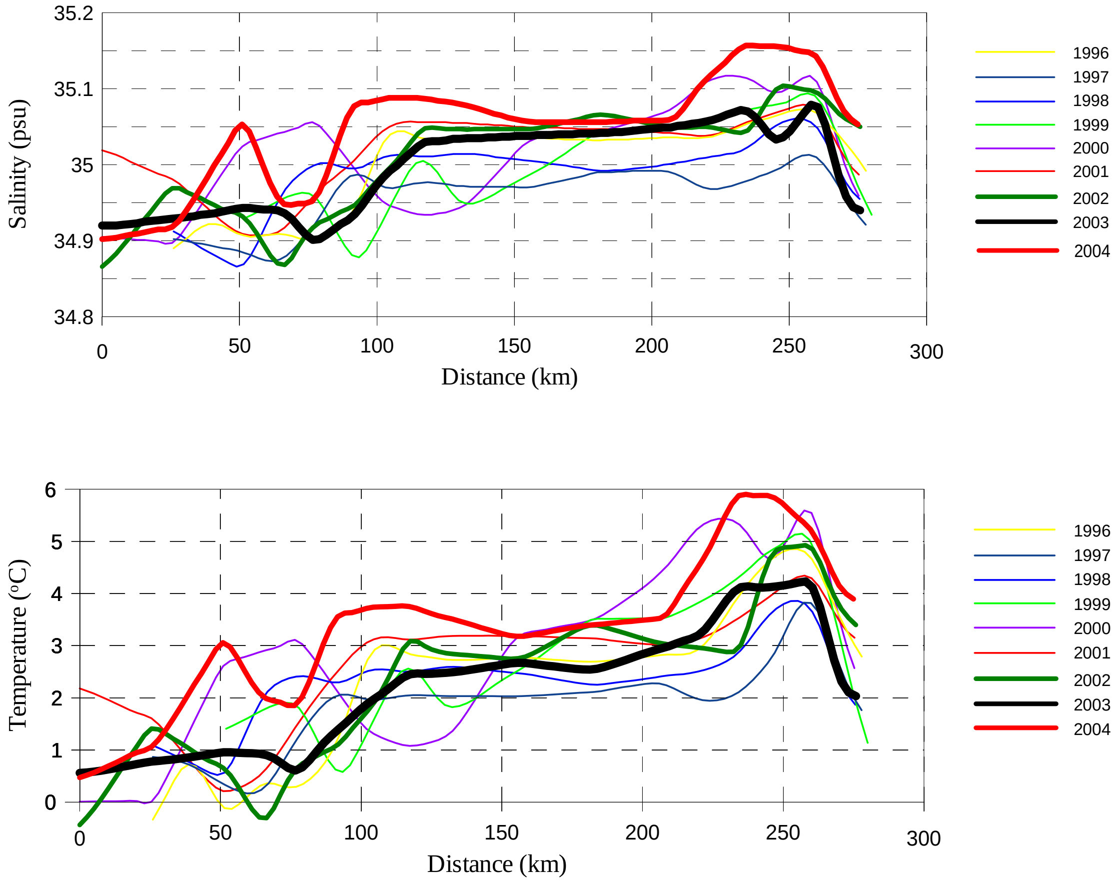

Figure 4. Salinity (upper panel) and temperature at section 'N' along 76°30' N parallel at 200 m.

Dynamics

Figure 5 presents the distribution of temperature, σ_Θ and baroclinic currents at 100 and 300 dbar (currents calculated for the reference level of 1000 m.) during summer 2004. Atlantic Water (AW) is defined as water with $\Theta > 2$°C and $27.7 < \sigma_\Theta < 27.97$ (white bold lines). Considerable part of AW flowing along the Norwegian coast proceeds eastward into the Barents Sea. Strict description of currents pattern in the southern part of polygon is impossible due to the spare data distribution. The rest of AW inflow continues northward as two separated branches. The branch related to the Barents Sea slope is warmer and more saline. The stream bifurcates at 78° 30' N, AW partly recirculates westward, partly inflows into the Arctic Ocean via Fram Strait as separated warm eddies. The mesoscale activity along the shelf-break, especially along the Spitsbergen's shelf is pronounced. Also jet-streams of Arctic Front, which form the western branch, create mesoscale meanders and eddies. The western branch recirculates westward between 78º-79ºN.

The baroclinic calculations show in 2004 more intensive inflow of AW across the Fram Strait than in summer 2003. This inflow of warmer than usually water caused that in region of north-western Spitsbergen, the ice margin was in July 2004 shifted 65 Nm north-eastward in comparison to 2003.

The flow structure obtained from LADCP measurements is similar to those from hydrography-based calculations, however velocities of measured currents and calculated transports were much higher.

The high temporal currents variability was observed directly this year. Currents changes seem to be related to wind direction and induced by barotropic flows.

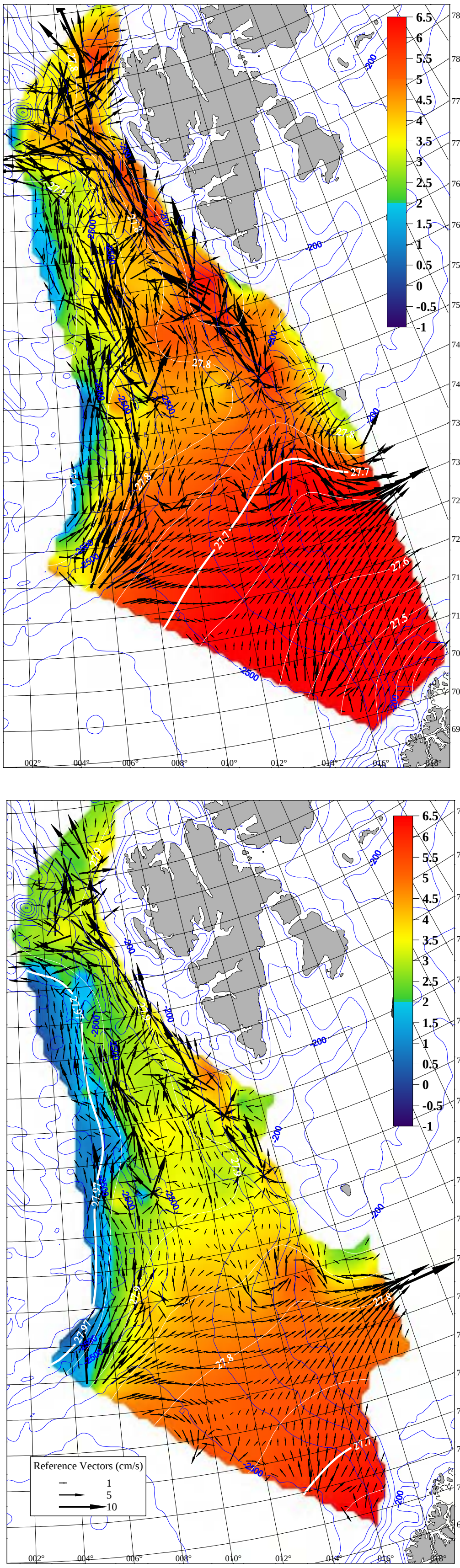

Figure 5. June-July 2004. Temperature distribution (colour scale), σΘ (white lines) and baroclinic currents at 100 m (left panel) and 300 m. Reference level 1000 m.

Annex 14: Hydrographic conditions in the Greenland Sea and Fram Strait (Area 12)

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In summer 2004 the hydrographic measurements in the Greenland Sea (section along 75°N) and in Fram Strait (section along 78°50'N) were continued by Alfred Wegener Institute. These two sections allow to monitor the northward flow of Atlantic Water in the eastern part of the investigated area as well as the return flow located farther to the west.

Bottom water renewal in the Greenland Sea by deep convection in interplay with ice coverage and atmospheric forcing is a major element of the water mass modification in the Arctic Mediterrean. It influences both the waters of the central Arctic Ocean and the overflow waters in the North Atlantic. However, since the hydrographic observations became more frequent in 1980s no bottom water renewal by winter convection took place. Furthermore, the doming structure in the Greenland Gyre, as observed in the mid-80s, was superseeded by the essentially two layer water mass arrangement with a marked density step, presently at about 1800 m.

The oceanic fluxes enter the Arctic Ocean either through the Barents Sea or through Fram Strait. However, the Fram Strait represents the only deep connection between the Arctic Ocean and Nordic Seas. The transfer of heat and freshwater is affected by the different ocean-atmosphere interaction over the deep passage of Fram Strait and shallow Barents Sea and the spreading of Atlantic water into the different pathways affects the climatic conditions in the Arctic. The Atlantic water inflow has a strong influence on the stratification and internal circulation in the Arctic Ocean and the outflow from the Arctic Ocean is either transferred south by the East Greenland Current or enters and affects the water mass modification in the Nordic Seas. The complicated topographic structure of the Fram Strait leads to a splitting of the West Spitsbergen Current into at least three branches. One part follows the shelf edge and enters the Arctic Ocean north of Svalbard. This branch has to cross the Yermak Plateau, passing over the sill with a depth of approximately 700 m. A second part flows northward along the north-western slope of the Yermak Plateau and the third branch recirculates immediately in Fram Strait at about 79°N. The size and strength of the different branches largely determine the input of oceanic heat to the inner Arctic Ocean. The East Greenland Current, carrying water from the Arctic Ocean southward has a concentrated core above the continental slope, west of Greenland.

In the central Greenland Sea a long-term zonal CTD section at 75°N was performed in summer 2004 with a regular station spacing of 10 Nm. In addition, a long lived submesoscale coherent vortex was investigated to reveal its role in the increasing of the winter convection depth. In July and August 2004 a hydrographic section with a high spatial resolution was carried out aross Fram Strait at 78°50'N. The CTD and ADCP measurements were combined with recovery and redeployment of 12 moorings in the eastern and central part of the strait.

The obtained time series of temperature and salinity in the Greenland Sea and Fram Strait were compiled from the AWI sections combined with the earlier data sets to describe the long-term variability of different water masses. Time series of the currents, temperature and salinity were also provided by recovering 12 moorings, deployed in autumn 2003. Since 1997 the year-round measurements at the array of moorings have been carried out in Fram Strait with the aim to estimate mass, heat and salt fluxes between the Nordic Seas and Arctic Ocean. Until 2000 the observations were done in the framework of the VEINS project. Since 2003 the work has been carried out as a part of international programme ASOF-N (Arctic-Subarctic Ocean Fluxes-North). The moorings array covers the entire deep part of Fram Strait from the eastern to the western shelf edge. Altogether 17 moorings are deployed along 78°50'N and twelve of them are maintained by AWI. The Norwegian Polar Institute operates the remaining 5 moorings in the western part of the strait. In 2003-2004 the measurements at the array augmented with two new moorings in the recirculation area and an additional level of instruments at the AW lower boundary (ca 700 m) were continued.

The general situation at the section in the Greenland Sea at 75°N was characterized by summer conditions with a low salinity surface layer. The subsurface layer was only marginally influenced by Atlantic Water as the salinites hardly exceed 34.9. At about 70 m depth cold temperatures (below -1° C) are encountered around 3° E, while the majority of the profiles shows temperatures warmer than -0.75° C at that depth due to summer heating. It is difficult to determine the exact depth to which winter convection has proceeded, and this has to be analyzed later. At first sight, convection seems to have affected only the upper 1000 m. The temperature maximum at intermediate depth descended by about 100 m again, which contrasts the previous winter but is in accord with the long term development. The bottom water temperature increase continued, and amounts again to about 0.01°C between spring 2003 and summer 2004. This temperature increase was observed throughout the whole layer below the temperature maximum.

The most outstanding single feature of the survey in the Greenland Sea was certainly the additional convective eddy, showing that two of these eddies can coexist at the same time in the central Greenland Gyre. This is remarkable, as a full region survey, performed a few weeks before our cruise, revealed no eddy in the Greenland Sea (presumably due to its coarser station spacing). These features represent the deepest convection level observed in recent years. The eddy structure we observed was broader than expected and the eddy core extended to only 2300 m, compared to 2700 m observed in the eddy the previous year. The eddy core was not vertically homogeneous but showed a vertical structure around 1500 m probably marking the convection depth of the preceeding winter.

The properties of the Atlantic Water (AW) and Return Atlantic Water (RAW) observed at the section in the Greenland Sea at 75°N have changed since last year, recovering from the extremely low values in 2003. The properties of the Atlantic Water are given as temperature and salinity averages over the depth range from 50 to 150 m of the stations between 10° and 13°E while the Return Atlantic Water is characterized by the temperature and salinity maximum below 50 m averaged over 3 stations west of 11.5°W. In both domains temperature increased strongly as compared to 2003 and reached the long term mean. A significant rise of mean salinity was also found in the AW domain together with a bit weaker increase in the RAW area. In the RAW domain the long-term decreasing trend in temperature, which had been observed for at least last eight years was interrupted in 2004.

In Fram Strait three characteristic areas can be distinguished in relation to the main flows: 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. In 2004 the outstanding warming and salinification were observed in the entire Fram Strait and especially in the RAC domain. The Atlantic layer in the core of the WSC was warmer by more than 1°C and up to 200m deeper than in 2003. Also maximum temperature and salinity observed in the WSC in 2004 The intermediate layer with temperature over 1.5°C was observed the farthest west in last years, reaching the edge of the east Greenland shelf. In the eastern part of the recirculation area (RAC) the amount of the AW (T>2°, S>34.92) nearly doubled as compared to 2003 and its temperature strongly increased. A temperature difference at the section between 2003 and 2004 reveals the strong warming up to 2°C in the middle part of the strait extending not only in the AW layer but much lower into the deep waters down to 1500m. In the WSC core the temperature difference is less (up to 1°C) and confined to the AW layer. Comparisons between temperature measured in Fram Strait in 2004 and available climatologies (WOA2001, EGW, PHC; picture not shown) in all cases shows the strong warming signal in 2004. Mean temperature and salinity in the layer 50-500m in three domains (WSC, RAC, EGC) were all higher than the long period average and continued the increase observed already in 2003. The strong intensification of the southward flow in the EGC was observed from mooring data together with only slightly stronger northward flow in the WSC what resulted in the southward net volume transport through the strait.

Hydrographic properties of the Atlantic water (defined as water mass with T>2°C and S>34.92) reveal the clear trend for last 7 years. While the area of the cross-section occupied by AW varied strongly between years, the mean temperature and salinity of Atlantic Water have been increasing since 1997. In 2004 the mean temperature and salinity of the AW recovered from the slight decrease in 2003 and returned to the high values from 2002. In addition to high temperature and salinity, the AW occupied exceptionally big area of the section what resulted in the largest heat content since the beginning of time series.

Time series of temperature and current velocities, recorded at the array of moorings since 1997 were used to calculate volume and heat fluxes through Fram Strait. For the last measured period, 2003-2004, the annual average of volume transport was higher than in 2003 with a net flow to the south. Despite of that the heat flux increased significantly as compared to 2003.

The mean volume transport in 2002-2004 was estimated on 0.6 Sv (1 Sv=$10^6 m^3$/s) to the south. A comparison of two winter centered means for September-July period reveals that net volume transport measured across Fram Strait was directed northward in 2002-03 (0.4 Sv) and turned to the southward one in 2003-04 (2.2 Sv). In spite of that the net heat flux was directed northward and increased from 39 TW in 2002-03 to 50 TW in the next year. The mean heat flux for the period 2002-2004 was estimated as 44 TW (Fig. 3.5).

The annual mean fluxes for separate domains show that increase of the heat flux in Fram Strait was due not only to higher northward heat fluxes in the WSC and recirculation areas but also to weakened southward heat flux in the EGC. At the same time strong increase of the southward volume flux in the EGC was also supported by prevailing southward volume transport in the middle of the strait. The monthly means of heat flux reach the highest values in late summer and, after some decrease, in late autumn and winter. The volume flux was the strongest during the winter and early spring months but another maximum was also observed during the preceding summer. The net heat flux to the Arctic Ocean was the highest in winter and decreased in spring and early summer. The summer decrease of the heat flux was much weaker in 2004 than in 2003 due to the higher than seasonal mean temperature of the Atlantic water in the core of the WSC.

The mean volume transport in 2002-2004 was estimated on 0.6 Sv (1 Sv=$10^6 m^3$/s) to the south. A comparison of two winter centered means for September-July period reveals that net volume transport measured across Fram Strait was directed northward in 2002-03 (0.4 Sv) and switched to the southward one in 2003-04 (2.2 Sv). In spite of that the net heat flux was directed northward and increased from 39 TW in 2002-03 to 50 TW in the next year. The mean heat flux for the period 2002-2004 was estimated as 44 TW.

Time series of the vertically integrated volume and heat fluxes based on daily means of measured variables suggest that the southward net volume transport in the last year was mostly due to strengthening of the southward flow in the East Greenland Current together with a change of the flow structure in the recirculation area. At the same time the heat transport northward to the Arctic Ocean did not diminish, but on the contrary, increased significantly. There are two main reasons for this discrepancy. The first one is related to the high correlations between the total net volume transport and the volume transports in the East Greenland Current (correlation coefficient r=0.53) and the recirculation area (r=0.7). Although the mean volume transport in the West Spitsbergen Current is of the similar order as the one in the East Greenland Current, it is not significantly correlated with the net volume transport through the whole section. On the other hand, the variability of the net heat transport in Fram Strait is mostly determined by its variations in the WSC domain (r=0.8). The heat flux in the recirculation area and in the EGC domain is of one order of magnitude lower and in respect to a long-term mean, nearly balanced between these two domains. In the WSC domain the annual mean of the net volume transport increased by ca. 1 Sv to the north between 2002-03 and 2003-04. At the same time an increase in the temperature of the Atlantic water was observed, reaching its maximum in the last months of measurements (spring and early summer of 2004). The observed warming is consisted with the similar event observed upstream at the Svinøy section with a time lag of *ca* 1.5 year (Ø. Skogseth, pers. comm.). Preliminary results from Fram Strait array suggest that the observed warming is less visible as an absolute value (extreme temperature) but rather as deviation from the strong seasonal cycle towards the higher temperature in spring and early summer. The full analysis of the observed feature will be possible after the recovery of the presently deployed mooring array in 2005.

List of figures:

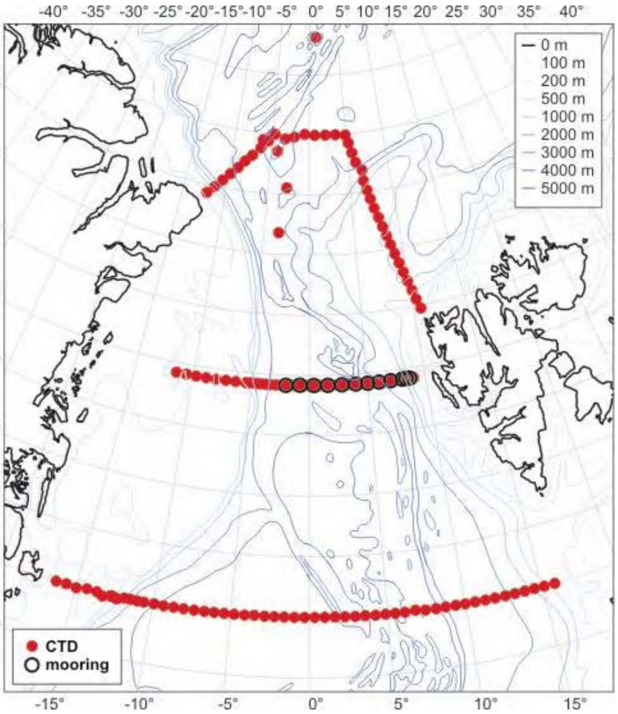

Fig. 2 Location of sections (dots - CTD stations, circles - moorings redeployed in 2004.

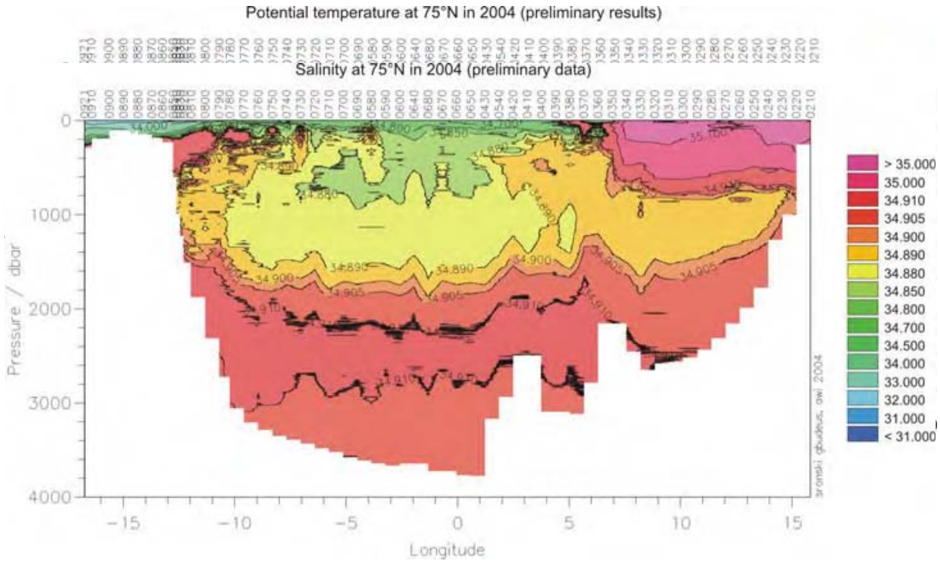

Fig. 2 Distributions of potential temperature (upper fig.) and salinity (lower fig.) at the section across the Greenland Sea measured in summer 2004 (G. Budeus, S. Ronski).

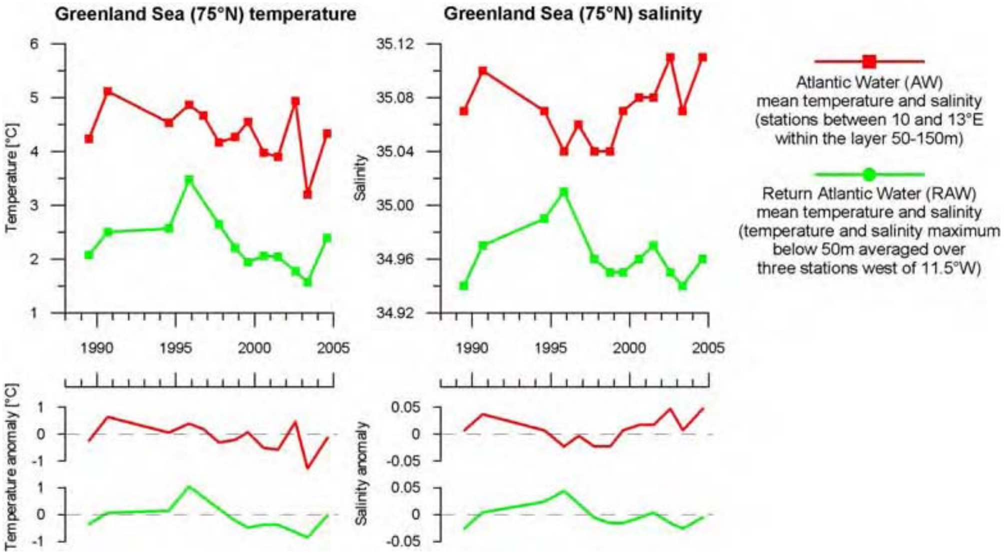

Fig. 3 Properties of the Atlantic Water (AW) and Return Atlantic Water (RAW) in the Greenland Sea observed at the section along 75°N in 2004 (G. Budeus, S. Ronski). Anomalies from the long term averages (1989-2000) shown at the bottom plots.

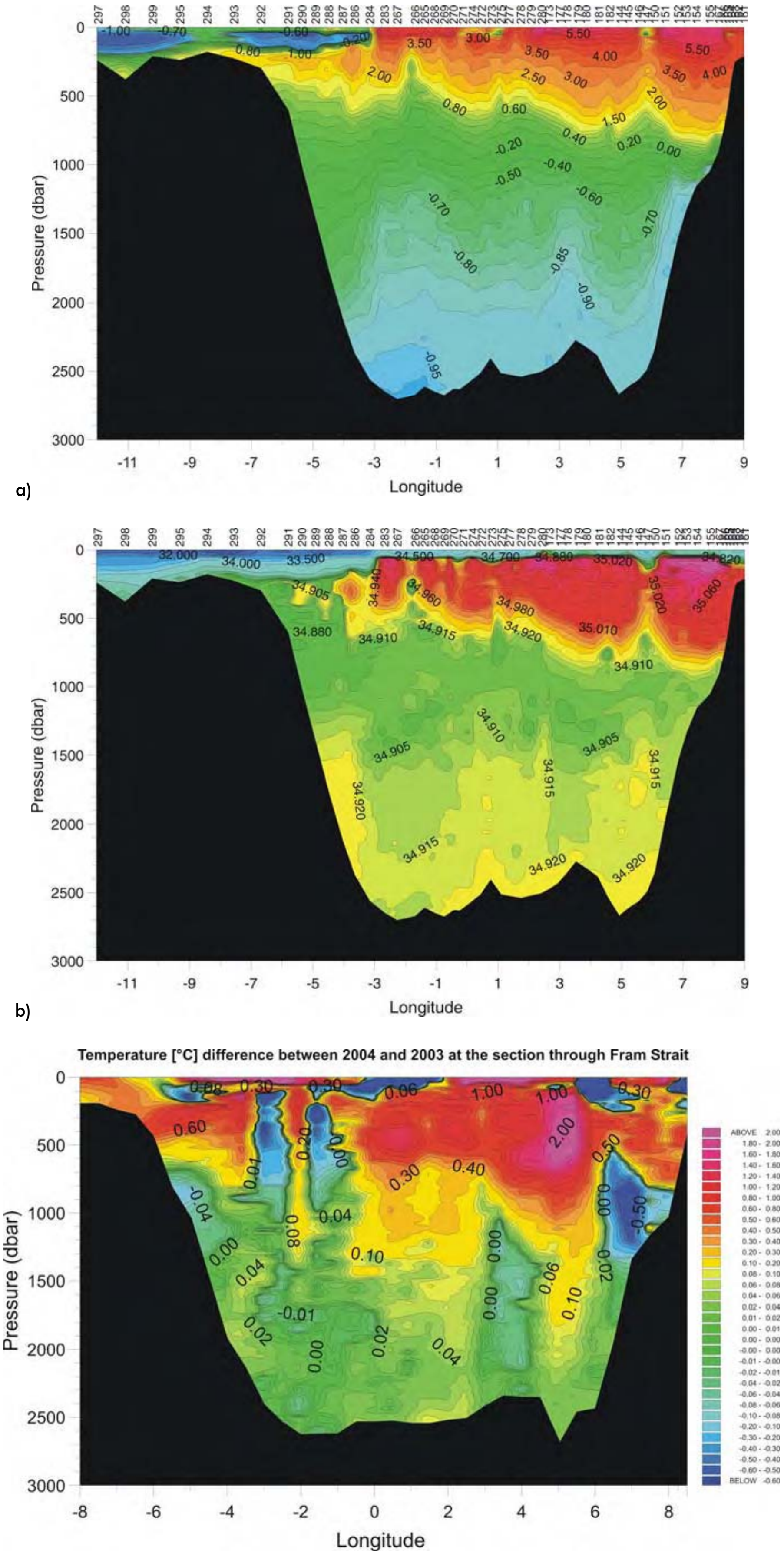

Fig. 4 Vertical distribution of (a) potential temperature and (b) salinity at the section through Fram Strait at 78°50'N measured in 2004 and (c) temperature difference between 2003 and 2004.

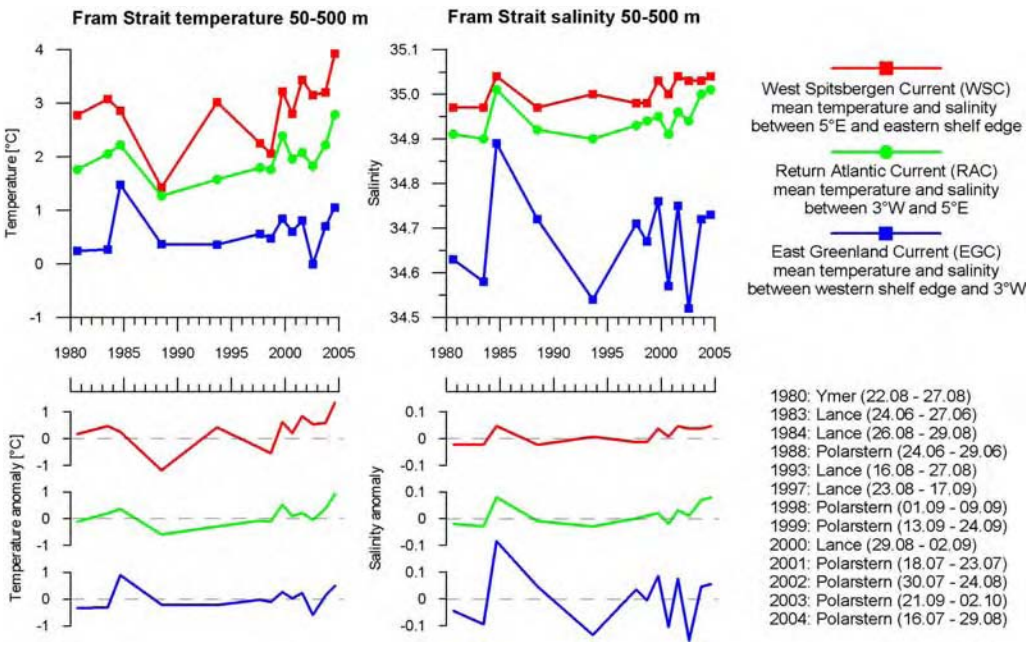

Fig. 5 The variations of the mean temperatures and salinities in Fram Strait in the West Spitsbergen Current (WSC), Return Atlantic Current (RAW) and East Greenland Current (EGC) in the layer 50-500m. Anomalies from the long term averages (1980-2000) shown at the bottom plots.

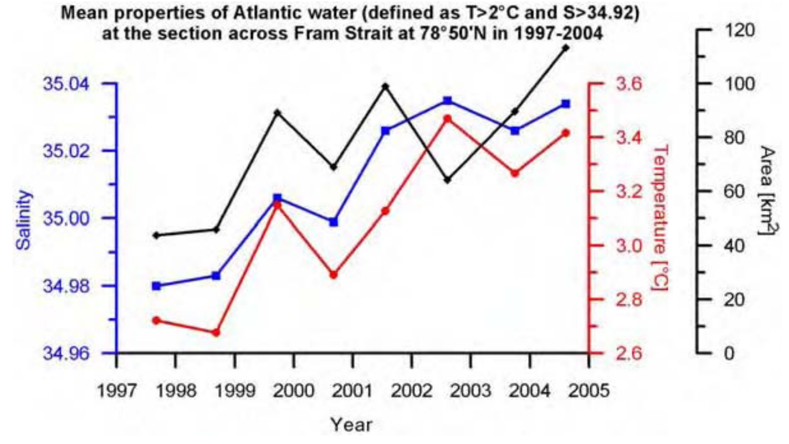

Fig.6 Mean properties of Atlantic Water (T>2°C, S>34.92) based on CTD sections in 1997-2004.

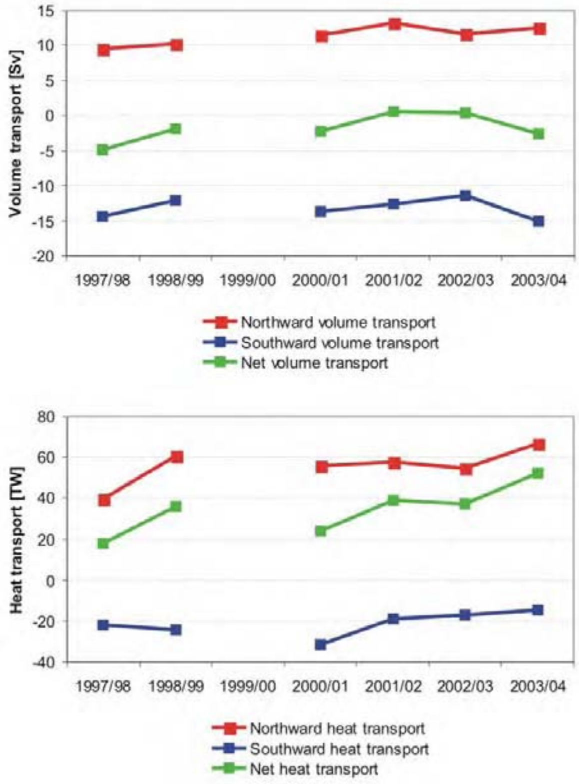

Fig.7 Annual averages of the northward, southward and net volume (left. fig) and heat (right fig.) fluxes through Fram Strait based on results from the array of moorings in 1997-2004.

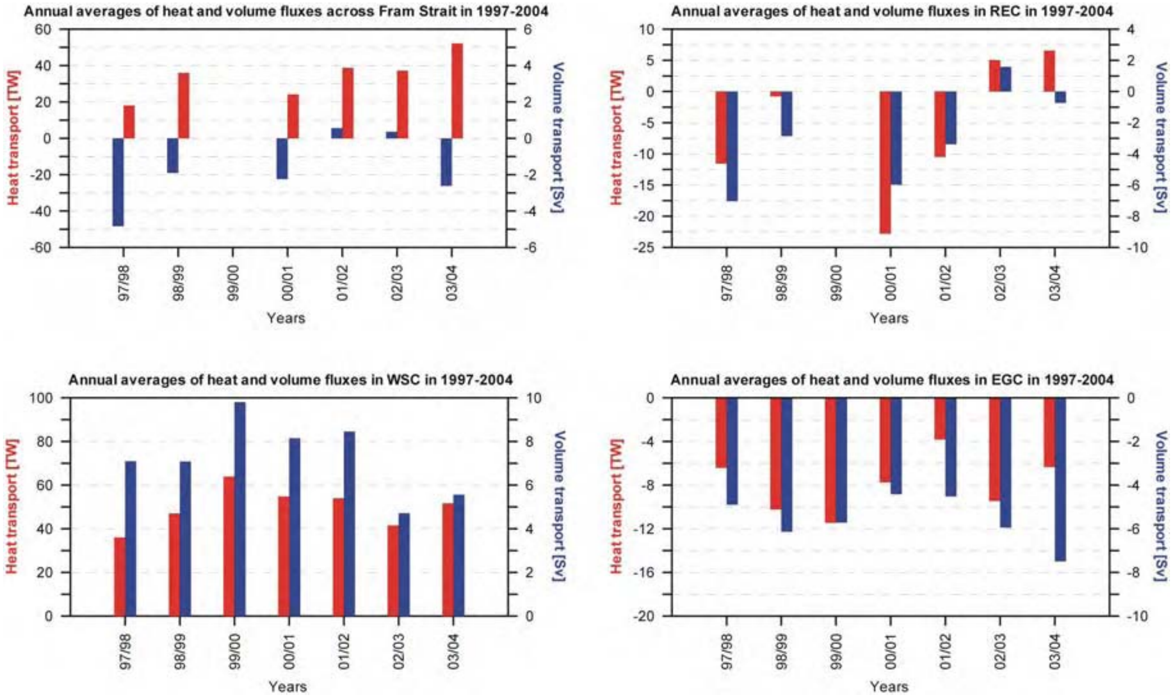

Fig. 8 Annual averages of net volume and heat fluxes through Fram Strait (upper left fig.) and separately in three domains: WSC (lower left fig.), RAC (upper right fig.) and EGC (lower right fig.) based on results from the array of moorings in 1997-2004.

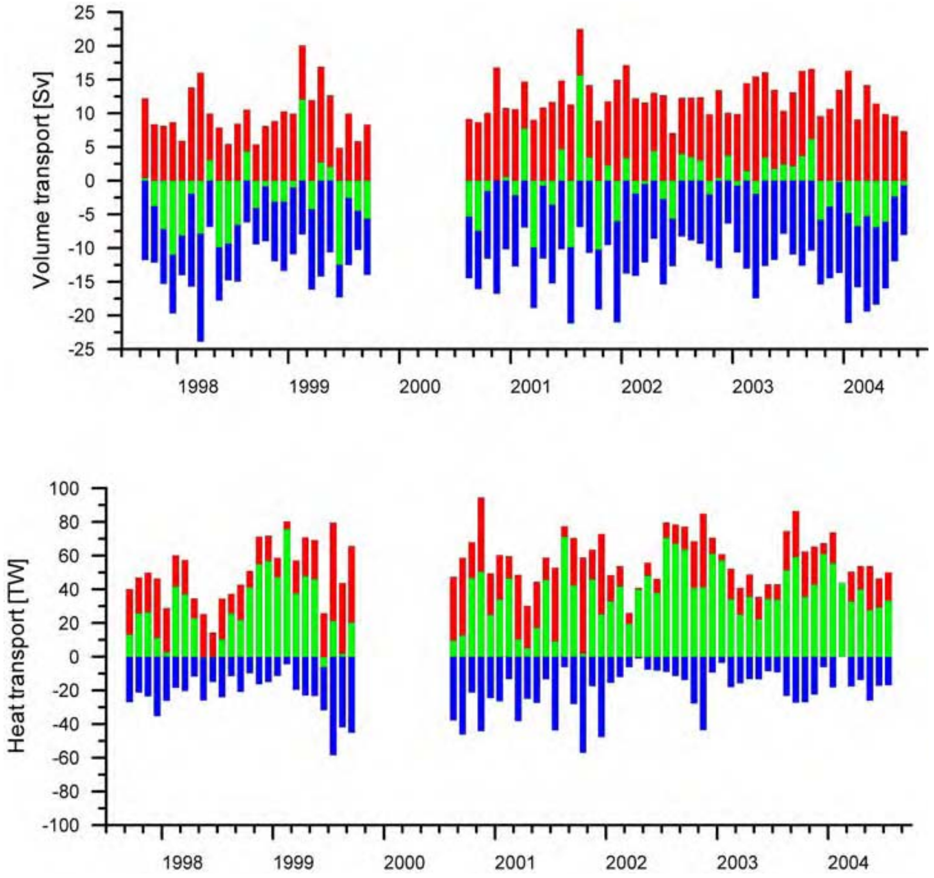

Fig. 9 Monthly means of the northward, southward and net volume (upper fig.) and heat (lower fig.) fluxes through Fram Strait based on results from the array of moorings in 1997-2004.

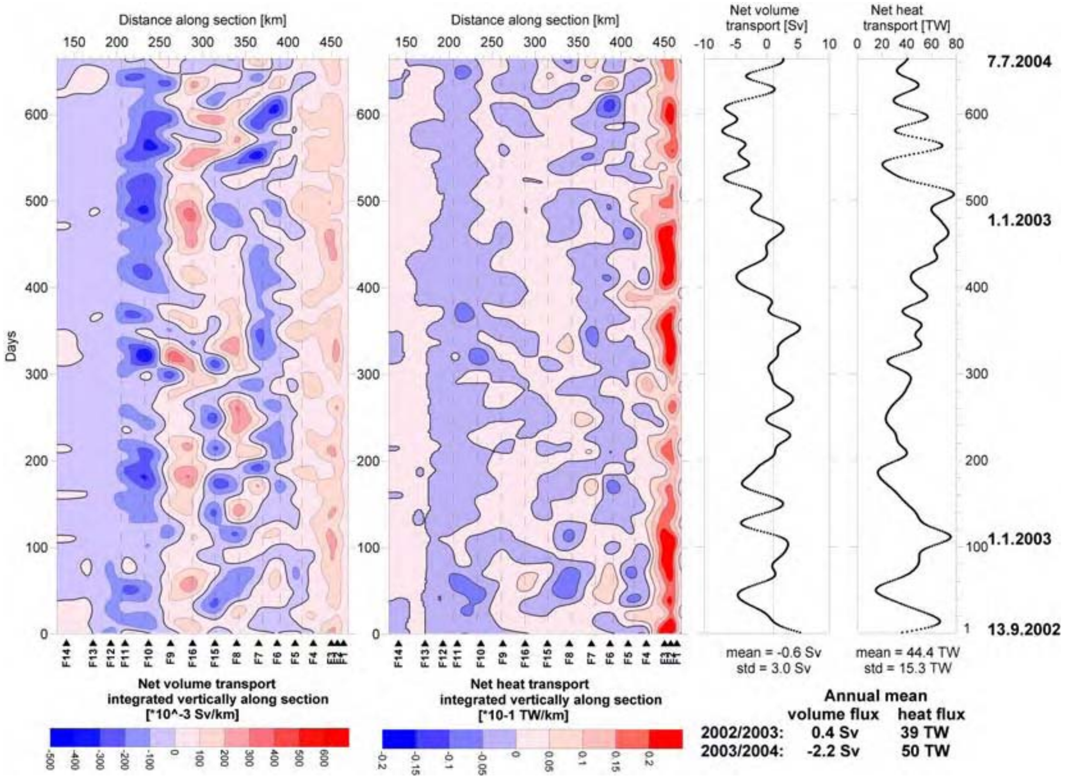

Fig. 10 Net volume and heat fluxes integrated vertically along the section (two left plates) and integrated over the entire section (two rigth plots) based on daily means of temperature and current velocity measured in 2002-2004.

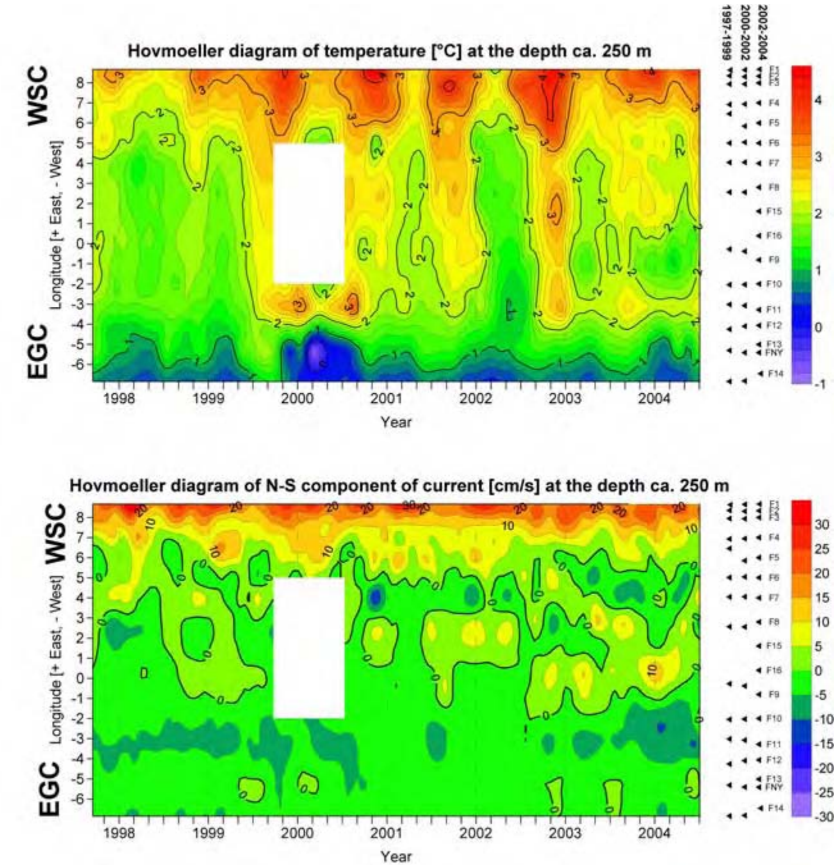

Fig. 11 Hovmöller diagrams of temperature (upper fig.) and meridional component of current (lower fig.) in the AW layer at the depth 250m in 1997-2004. Monthly means of the measured values used.

Annex 15: Initiative to strengthen the monitoring of supporting environmental factors as physical and hydrodynamic aspects, and climatic/weather conditions (e.g. flushing, temperature, salinity, light availability) and transboundary transports in region II: Greater North Sea

Background

Scientific knowledge of the seas is the indispensable basis for all marine management (OSPAR 2003 Strategy for a joint Assessment and Monitoring Programme; Reference number 2004/17). A general assessment of the quality of the OSPAR maritime area or its sub-regions is defined as: a statement of the whole part of the current knowledge of the health of the environment of a defined maritime area and its coastal margins. The monitoring data and information generated by OSPAR through its co-ordinated environmental monitoring activities (CEMP) form the baseline for OSPAR`S thematic and holistic assessments of the quality status of the OSPAR maritime area. A complete statement includes an analysis of the regions hydrodynamics, chemistry, habitats and biota with an evaluation of the impact of humans over space and time against this background of natural variability. Regarding the monitoring of supporting environmental factors (physical and hydrodynamic aspects, and climatic/weather conditions, e.g. flushing, temperature, salinity, SPM, light availability and transboundary transports) the specification and execution of information collection programmes have to be developed further or adopted to make available and sustain this kind of data for the holistic assessments.

The 2003 Strategy for a Joint Assessment and Monitoring Programme highlights the need for marine research to study further:

a) The basic processes of the marine environment (physics, chemistry and biology) on different scales

b) Causes of long-term changes identified by monitoring programmes;

c) Cause-effect relationships

To investigate these topics integrated research programmes, long-term monitoring data and appropriate numerical models are the necessary tools. It is evident that these tools are not availaible.

Information collection

Taking into account the resources available to perform these tasks it seems necessary to strenghten and to coordinate the monitoring of supporting environmental factors.

OSPAR 2004 concluded that, in the light of the work required to prepare for the QSR 2010, a long term work programme for ICES was necessary. OSPAR examined and agreed on the long term work programme for ICES (EUC 05/10/1-E), Annex 2. The issues at Annex 2 have been identified as priorities for input from ICES in the period up until the QSR 2010. The various elements at Annex 2 have been divided into two types, those for which specific requests might be included in future on the annual ICES Work Programme (and towards which OSPAR would contribute financially), and those for which information might arise through the ICES science programme without a specific request for advice from OSPAR.

The items to be suggested for the ICES science programme contain two aspects of marine ecosystems

(iii) distribution and abundance of marine species in relation to hydrodynamics and temperature;

(iv) quantification of natural climate variability

which highlight the need and use of oceanographic data and monitoring programmes. Within the ICES community the yearly International Bottom Trawl Surveys, oceanographic monitoring data (temperature, salinity, nutrients) contribute to these items. However, the station and data distribution of the North Sea IBTS is not sufficient to fulfil all quality assurance demands. National monitoring activities within OSPAR dealing with chemical and biological data mainly. The Nutrient Monitoring Programme only asks for supporting environmental factors. Other ICES science programmes or EU funded research projects miss the long term components and can therefore not granted to serve these requirements. The causes of long-term changes in the environment cannot be found with the availaible data sources. Due to the reduction of resources of the OSPAR contracting parties, data sources and added value knowledge in the field of supporting environmental factors have decreased during the last decade. It is time to start supporting environmental data monitoring programmes.

Background

The annual cycle is the dominant mode of variability within the North Sea; the second important mode of variability is the NAO winter index probably. The inflow of water of Atlantic origin into the North Sea varies to a large extent depending on the NAO. The amount of nutrients transported with the Atlantic water depends on the strength of the inflow. The riverine input is on average 25 % only of the total amount of the Atlantic inflow nutrient input into the North Sea. Small changes in the amount and/or ratio of the Atlantic inflow will change the eutrification status in the non-problem and also in the potential problem areas. Therefore the monitoring frequency of about every three years during winter is not sufficient to resolve the interannual variability. The long-term SST time series from the North Sea point to system shifts within a few months, which can not be seen or explained by sampling intervals of years. Models show increased transports of salt and nutrients into the North Sea after 1994/95. However, the validation of the model results by open North Sea monitoring data is scarce. The correlation of the seasonal stratification/heat content of the North Sea water column with the annual area averaged SST confirm the model results, but do not explain the causes for system jumps.

The North Sea is not a static shelf sea area; the North Sea is highly variable and experiences system shifts, which might strongly influence antropogenic changes. The quantification of natural climate variability and their influence upon eutrification must be investigated, especially in the light of anthropogenic caused climate change.

Germany in 1998 started a programme to monitor the North Sea in summer, when the heat content of the North Sea is at maximum level and the thermal stratification is strongest. These measurements are carried out by using high performance, high speed towed instruments supported by station data (nutrients, oxygen, organic pollutants, heavy metals, chlorophyll). The monitoring cruises are aimed to

- to support the German monitoring programme of the German Bight by background data
- to get information about the oxygen conditions in the German Bight and the central North Sea during maximum stratification
- to calculate the heat content of the North Sea
- to gain data for the annual German Status Report for the German Bight and the North Sea
- to support the ICES Annual Climate Status Report
- to build a data basis for model verification

- to get data to validate remote sensing data (ENVISAT/MERIS – chlorophyll, yellow substance, SPM, Secchi depth)

Action requested

Taking into account the decreasing resources of the OSPAR contracting parties, any effort has to be made

- to develop guidlines on frequencies and spatial coverage not only for nutrient data, but also for supporting environmental parameters
- to really integrate the existing national monitoring programmes
- to identify gaps in knowledge to implement the 2003 Strategy for a Joint Assessment and Monitoring Programme

Annex 16: Action Plan Progress Review 2005

Year	Committee Acronym	Committee name	Expert Group	Reference to other committees	Expert Group report (ICES Code)	Resolution No.		
2004/2005	**OCC**	**Oceanography**	**WGOH**		2004:\C:06	2C06		
Action **Plan**	**Action Required**	**ToR's**	**ToR**	**Satisfactory Progress**	**No Progress**	**Unsatisfatory Progress**	**Output (link to relevant report)**	**Comments** **(e.g., delays, problems, other types of progress, needs, etc.**
No.	**Text**	**Text**	**Ref. (a, b, c)**	**S**	**0**	**U**	**Report code and section**	**Text**
1.2, 1.3, 1.6	Please see Action Plan items below this table	Update and review results from Standard Sections and Stations	a)	S			5, Annexes 5, 6, 7, 8, 9, 10, 11, 12,	
1.2, 1.3, 1.6	Please see Action Plan items below this table	Consolidate inputs from Member Countries and NORSEPP into the ICES Annual Ocean Climate Status Summary (IAOCSS)	b)	S			6	WGOH requests that ICES continue its efforts to ensure that the IAOCSS is widely distributed.
1.7	Please see Action Plan items below this table	Review national monitoring programmes and OSPAR's Coordinated Environmental Monitoring Programme (CEMP), in order to improve climate monitoring activities	c)	S			7	WGOH strongly recommends that the Oceanography Committee and ACME should encourage the measurements of standard physical oceanography parameters in the Co-ordinated Environmental Monitoring Programme (CEMP) of the OSPAR.
5.14	Please see Action Plan items below this table	Review and improve relations with international climate monitoring programmes;	d)	S			8	The WGOH requests that ICES consider supporting the publication of an issue of CLI-VAR Exchanges dedicated to WGOH-related activities.
1.2, 1.10	Please see Action Plan items below this table	Undertake an isopycnal analysis of *in situ* data	e)	S			9	The WGOH agrees that this analysis should be continued and debelo-ped for different areas, ma-inly in the Nordic Seas.
1.8	Please see Action Plan items below this table	WGOH will provide summary datasets on the physical properties of the North Sea (to include salinity, temperature, tidal vectors, peak surface, mid-and bottom currents, maximum annual and 50 year significant wave heights). The data should be time averaged (annual average, seasonal cycles and annual peaks) for the period of 1984 to 2004 (where available) and spatially	f)	S			10	TheWGOH found that the REGNS assessment process required commitment of con-siderable time and resources and would request consider the sustai-nability of this approach.
5.13.4		Discuss requirements for data management in ICES and provide input to SGMID;	g)	S			11	The WGOH agreed to provide advice to the data centre manager with regard to the provision of
		Review website developments.	h)	S				

Action Plan items related to WGOH

1.2	Increase knowledge with respect to the functioning of marine ecosystems. This will be achieved through continued basic research on the biological, chemical, and physical processes of marine ecosystems and specific activities directed at improved understanding of observed and potential variability in the marine environment due to physical forcing and biological interactions.
1.3	Increase knowledge of the effects of physical forcing, including climate variability, and biological interactions, on recruitment processes of important commercial species.
1.6	Assess and predict impacts of climate variability and climate change, on scales from populations to marine ecosystems, including impacts on commercially important fish stocks.
1.7	Play an active role in the design, implementation, and execution of global and regional research and monitoring programmes, in collaborations between the ICES and other international oceanographic research or monitoring programmes such as GOOS and GLOBEC.
1.8	Implement a North Sea-oriented monitoring programme that incorporates oceanographic and fisheries data.
1.10	Develop better tools and training opportunities for monitoring and observation of physical, chemical and biological properties of marine ecosystems.
5.13.4	Contribute expertise and know-how for the development of modern marine data management systems and maintain such systems that are of relevance to ICES activities.
5.14	Establish more consistent mechanisms such as joint working groups, co-sponsored symposia, and cross-attendance at meetings, for regular exchange of information and progress with other marine scientific organisations with which ICES does not have a formal Memorandum of Understanding, such as ICLARM, CCAMLR, the NAFO Scientific Council, the Arctic Council, the European Science Foundation Marine Board, and the World Fisheries Council.