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Report of the Working Group on Oceanic Hydrography (WGOH)

1–3 April 2014

Hamburg, Germany

ICES International Council for the Exploration of the Sea

CIEM Conseil International pour l'Exploration de la Mer

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Contents

Executive summary

The WGOH meets yearly to review oceanographic conditions in the ICES region and to report on these in the ICES Report on Ocean Climate (IROC).

Interim IROC Highlights for 2013

Interim highlights of the North Atlantic Ocean for 2013

- In Newfoundland and Labrador Shelf the conditions in 2013 was similar to 2012; warmer/fresher than normal but a decreasing trend in temperature.
- Wet weather ended the recent high salinity anomalies in the Bay of Biscay and the temperature and salinity values were in 2013 back to average values.
- The upper salinities in the Rockall Trough was notably low, and this change has been observed in other time series in the eastern subpolar North Atlantic
- Temperature and salinity of Atlantic Water in the Norwegian Sea declined with values about average and above average, respectively.
- The Barents Sea was considerable warmer than normal.
- Low sea ice extent in the Barents Sea and ice-free during late summer in 2013 similar as in 2012.
- Unusually cold March gave maximum ice record late in the Baltic Sea.

Interim highlights of the North Atlantic atmosphere in winter 2012/2013

- The winter NAO index was strongly negative (-1.97).
- Cold air over much of northwestern Europe and warm air over the Labrador Sea.
- Weakened wind speed across the Nordic Seas, Rockall Trough, North Sea and central subpolar gyre and strengthened winds at the latitude of the Azores.

Winter 2013/14 had conditions indicating strong positive NAO index with warmer air over the Nordic Seas, Europe and Greenland, and strengthened winds over eastern North Atlantic.

The WGOH also fulfils the Terms of Reference for the group including strengthening the role of WGOH and physical oceanography within ICES, exploring areas of mutual interest with international climate monitoring programmes and providing expert knowledge and guidance to ICES Data Centre.

Approach taken at the meeting

A structured agenda was used for this WGOH meeting that was hosted by the Bundesamt für Seeschifffahrt und Hydrographie (BSH), Hamburg (see Annex 2). A mini-symposium was held on the first day of the meeting which included a combination of talks from the host institution and invited WGOH members. Within the meeting, most of the time was spent reporting findings from the different ICES areas. The combined area reports are included as Annexes 5–14 to this report. The remainder of the meeting was spent working through the other ToRs for the WGOH.

Description of the structure of the report

This report describes the discussion and outcomes relating to the individual terms of references of the WGOH. The bulk of the report is contained in the area reports (included as Annexes 5–14 to the report), which in turn forms the major contribution to the ICES Report on Ocean Climate (IROC). Solid progress towards the WGOH Terms of Reference was made during this meeting. The IROC 2013 will be submitted to ICES shortly where many of the Expert Group's key findings are presented.

Key recommendations

- WGOH recommends that the IROC report continues.
- WGOH recommends the continuation of the printed version of the IROC report.
- WGOH recommends modification of the IROC report with more recent information.

1 Opening of the meeting

The Working Group on Oceanic Hydrography, chaired by Stephen Dye (UK) and Kjell Arne Mork (Norway), met at the Bundesamt für Seeschifffahrt und Hydrographie (BSH), Hamburg, 1–3 April 2014.

19 WGOH members and 3 chair invited members attended (Annex 1) representing 14 ICES nations. Local host Holger Klein welcomed all WGOH participants to the meeting and provided all relevant logistical information to those present.

2 Adoption of the agenda and key discussion points

2.1 Membership and introduction

Member introductions took place and the agenda was formally adopted. New members in the group are Randi Ingvaldsen and Øystein Skagseth, both from the Institute of Marine Research (Norway).

2.2 IROC updates

Stephen Dye gave an introduction of the IROC report and mentioned the widely use of the report, and that the report has been cited numerous times.

The reference period for the IROC data series changed, last year, from 1971–2000 to 1981–2010 to mirror common practice in global climate programmes. Contributors were reminded to use the new reference period. Unfortunately the IROC will this year have lesser figures with Argo synthesis. However, a new configuration over the North Atlantic with higher resolution and that include the Baltic and Irish seas and including more data will developed and ready for the next year IROC report.

2.3 ICES Data Centre (Hjalte Parner)

Hjalte Parner at the Data Centre provided information about the IROC web page, and it has been a success after it was official released in December 2013. Since last time there is now an acknowledgement of the data provider and a reference to an IROC publication when plotting and downloading the data. A key reference for the time series can also be included in the data file. Some improvements were discussed but it was agreed to keep it simple. The format of the IROC data files used on the web was also discussed. At present, a common format of the representation of the data series and text for the different data files is missing. The Data Centre will cooperate with the WGOH to agree on a more appropriate format that can be used for all data files.

2.4 Review of the 2013–2014 Atmospheric conditions

Stephen Dye presented the atmospheric conditions for winter 2013 and 2014. In winter 2013 was the North Atlantic Oscillations strongly negative with a cooling in the North Europe and warmer over Greenland. In winter 2014, there was negative winter SLP anomaly centred over Iceland/the Faroese with warmer air over the Norwegian Sea, North and East Europe, and North Greenland.

2.5 Area reports (latest results from standard sections and stations)

The following members of the WGOH presented their respective area reports:

Boris Cisewski, Stephen Dye, Hedinn Valdimarsson, Cesar González-Pola, Glen Nolan, Karin M. Larsen, Holger Klein, Karin Borenäs, Kjell Arne Mork, Alexander Trofimov, Ilona Goszczko

Area reports are included as Annexes 5–14 to this report.

2.6 Help to develop the framework for regional integrated ecosystem advice

This was proposed by Mark Dickey-Collas, SSGEF and ACOM. ICES has constructed "Ecosystem Overviews" which describe the trends in pressures and state of regional ecosystems. ICES plans for this advice to be operational, by which it means having a clearly defined business process that outlines the roles, operators, methodologies, timetables and agreed deliveries of services/products that constitute the advice mechanism. These advice processes will require regular inputs of monitoring information on the oceanography and hydrology of the regions. These will be called Operational Oceanographic Products and Services (OOPS).

The WGOH together with WGOOFE are involved in the process before and after the call, mainly by emails and video/web conferences.

2.7 Update on the Marine Strategy Framework Directive

Several from the WGOH (e.g. Cesar Gonzalez-Pola, Glenn Nolan, Stephen Dye) are directly or indirectly involved in the MSFD. The MSFD includes a descriptor devoted to the hydrographical environment across the European marine regions (Descriptor 7, "Permanent alteration of hydrographical conditions does not adversely affect marine ecosystems"). The main focus of the descriptor is on the direct effect of large human infrastructures at sea and/or the effects of the continuous alteration of the coastline. However, large-scale hydrographical variability either natural or caused by ongoing climate change (i.e. anthropogenic) strongly affects all ecosystem components, thus influencing most of MSFD descriptors and potentially forcing to review the indicators periodically.

The monitoring programmes design has to be defined and implemented by nations before the end of 2014 and it is yet to be decided whether or not the MSFD would request large-scale hydrographical monitoring of some marine regions.

In any case, the analyses performed every year by the WGOH based on running hydrographical time-series match with the need of the MSFD of having a robust knowledge of interannual large-scale hydrographical variability. Maintaining the current programs and alongside the Argo array may be enough to fit the MSFD needs.

The WGOH did not receive any new updated information about the role of WGOH in MSFD before the meeting.

2.8 Relations with international climate monitoring programmes/projects

The EU BG-8 (*"Developing in-situ Atlantic Ocean Observations for a better management and sustainable exploitation of the maritime resources"*) proposal "AtlantOS" was introduced by J.

Karstensen (GEOMAR Helmholtz Centre for Ocean Research Kiel, Kiel, Germany). AtlantOS is a research and innovation project that proposes the integration of ocean observing activates across all disciplines for the Atlantic, considering European as well as non-European partners (referencing to "The Galway Statement on Atlantic Ocean Cooperation [1]", May 2013). The proposal applies the "Framework for Ocean Observing [2]" to the observing of the Atlantic. The overarching goal of AtlantOS is the integration of the so far loosely-coordinated set of existing ocean observing activities to a sustainable, efficient, and fit-for-purpose Integrated Atlantic Ocean Observing System (IAOOS). The IAOOS is to form the ocean in-situ observing backbone of the Copernicus Marine Monitoring system, which is the marine part of the European Earth Observation Programme[3]. ICES is a partner in the AtlantOS proposal contributing to the research on defining the observational requirements, collaborating on joint data sharing and product generation, and working on the System evaluation. The first stage proposal was submitted on 12. March (second stage deadline 26. June) and, if funded, the project will start early 2015. AtlantOS is coordinated by the GEOMAR Helmholtz Centre for Ocean Research Kiel, Kiel, Germany.

Kjell Arne informed about the development of the Argo program. There are now more focus on regional and high latitude regions and biogeochemical sensor. Prototype of floats that can go down to 6000 m do now exist, which are of importance among other to estimate the global and basin heat content below 2000 m.

Unfortunately Detlef Stammer, co-chair of the CLIVAR Scientific Steering Group could not attend the meeting and present the CLIVAR program.

2.9 Discussion on the contributions to the Science Plan

Regarding the ICES Science Plan, the multi-annual portfolio of WGOH addresses the climate change and the long-term monitoring of physical parameters in the ocean. The work of the WGOH increases our understanding of how the physical component of the ecosystem is functioning. Within the Science Plan the WGOH addresses particular the element: *Ecosystem Processes and Dynamics*, and its objective "Describe and quantify the state of North Atlantic Ocean regional systems", but also the element: *Integrated Ecosystem Observation and Monitoring*, and its objective "Identify and prioritize ICES monitoring and data collection needs".

The WGOH reports annually the status and trends of the ocean climate variability through updating several time series in the North Atlantic. The oceanographic and atmospheric conditions in the ICES region are reviewed and reported in the ICES Report on Ocean Climate (IROC). The processes responsible for the variability are discussed and reported as well.

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[1] http://europa.eu/rapid/press-release_IP-13–459_en.htm

[2] http://www.oceanobs09.net/foo/

[3] http://www.copernicus.eu/

2.10 Strengthening the role of WGOH within ICES and contribution to other ICES groups

Several WGOH members also participate in other ICES groups:

Holger Klein is the link between the WGOH and the WGOOFE ('Working Group on Operational Oceanographic Products for Fisheries and Environment'). The most important terms of Reference for WGOOFE are to identify oceanographic products that can be realistically regularly delivered from the group or individual members and to refine and evaluate this list of products to the needs of the users, including format and timing, and identify gaps in the products available.

Kjell Arne Mork contributed to the Working Document from a post cruise meeting in June 2013 on the Working Group on International Pelagic Surveys/Working Group on Widely distributed Stocks.

Three new groups are now established that will work on the integrated assessments for the Norwegian, Barents, and North Sea. Øystein Skagseth and Alexander Trofimov are involved in the groups; Working Group on the Integrated Assessments of the Norwegian Sea (WGINOR) and Working Group on the Integrated Assessments of the Barents Sea (WGIBAR), respectively. They informed the WGOH about the work done so far. Both groups focus now on to identify relevant parameters/available time series that can in best manner describe the ecosystem and used in the analysis. Both two groups will perform integrated analysis of multi-disciplinary data and report on the annual status of the ecosystem. Anna Akimova is involved in the third group; Working Group on Integrated Assessments of the North Sea (WGINOSE), but unfortunately she could not attend the meeting.

The Working Group on Northwest Atlantic Regional Sea (WGNARS) is an expert group formed under the ICES Parent Steering Group on Regional Sea Programmes. The group is working to coordinate marine science in the Northwest Atlantic to provide the infrastructure for an integrated approach to ecosystem science and management. Work of WGNARS has set the stage for development of Integrated Ecosystem Assessments (IEAs) for the northwest Atlantic continental shelf system, including reviewing information available from existing monitoring programs and ecosystem surveys, developing a comprehensive draft set of indicators and thresholds intended to provide relevant information about drivers and responses in the NW Atlantic region and discussing interactions of processes at different spatial scales. In upcoming years, WGNARS will strive to develop an initial integrated assessment for the NW Atlantic region, with priority activities including evaluating risks of various ocean use impacts and evaluating indicator performance relative to ecosystem drivers. WGNARS continually seeks to coordinate its activities with other IEA-relevant activities in ICES. Paula Fratantoni will keep the WGOH updated regarding the progress of the WGNARS.

2.11 ASC theme session

The WGOH submitted a theme session for the ASC 2014 ("Circulation and water masses variability in the temperate North Atlantic" by C. González-Pola, F. Gaillard and A. Lavin). The theme sessions was accepted but merged together with another theme session(s) submitted by Ecosystem Studies of Subarctic Seas (ESSAS) and SICCME. The name of the merged theme session is “Physical and biological consequences of North Atlantic circulation patterns” with conveners Ken Drinkwater, Cesar Gonzalez-Pola, Ólafur S. Ástþórsson, and Seth Danielson.

2.12 WGOH website

The WGOH web site at the ICES is:

http://www.ices.dk/community/groups/Pages/WGOH.aspx. Links to the IROC reports and the IROC web page have now been included. A new photo should be included.

2.13 New chair

No new chair was elected at the meeting, but afterwards both Karin M. Larsen and Sarah Hughes were positive to be co-chairs for the next three years period (2015–2017). The formal election of the new chair will be done in the start of the next meeting (March 2015).

2.14 Next meeting

Victor invited the WGOH to the AZTI-Tecnalia in Pasaia (near San Sebastian), Spain for the 2015 meeting. The WGOH participants accepted this and suggested the dates 24–26 March for the meeting in 2015 which was also fine with the host. WGOH thanked Holger Klein at the BSH for hosting the meeting, excellent preparations and splendid dinner.

Annex 1: List of participants

Name	Email	Country
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Annex 2: Agenda

Day 1, Tuesday 1th April

Start at 0900 (Coffee break 10:30)

1. General information, Membership and Introductions
2. IROC (Stephen Dye)

    IROC 2012 review

    Review IROC and IROC web page

    Suggestions for improvements and any new time series or products

    Initial overview of contents and contributions received so far

3. ICES Data Centre (Hjalte Parner)

    Update the data series on the web

    Review of recent activities and future plans

4. Review of 2013 Atmospheric conditions (Stephen Dye)
5. Area reports (latest results from standard sections and stations)

Lunch: 12:30

1400–1700 Mini-symposium

1400: Birgit Klein: Sea level trends and variability in the North Sea

1420: Nikesh Narayan, Birgit Klein and Holger Klein: Future evolution of stratification and thermodynamics of the North Sea: the effect of North Atlantic Oscillation.

1440: Claudia Denker: Water mass variability observed at the Mid-Atlantic Ridge in the sub-polar North Atlantic

1500: Coffee break

1530: Øystein Skagseth: Transport of Arctic Water from the Iceland Sea to the Norwegian Sea

1550: Bogi Hansen: Is the overflow across the Iceland-Faroe Ridge coupled to the Atlantic inflow across the Ridge?

1610: Victor Valencia: "Heavy rainfall and river flows in 2013. A new shift in salinity distribution?"

1630: John Mortensen: ”Coastal time series”

1830 Joint dinner (Restaurant Porto - Ditmar-Koel-Straße 15)

Day 2, Wednesday 2th April

Start at 0900 (Coffee breaks 10:30 & 1500, Lunch 12:30)

5. Continue area reports

Day 3 (morning only), Thursday 3th April

Start at 0900 (Coffee breaks 10:30)

6. ICES Matters

- Help to develop the framework for regional integrated ecosystem advice (ToR: e).

  (input from Mark Dickey-Collas; links to WGINOR, WGIBAR, WGEAWESS?)

- Support and guidance to SCICOM and other Expert Groups (SCICOM: Marine Strategy Framework Directive, WKOOI, ToR: f)

7. Relations with international climate monitoring programmes/projects (e.g., CLIVAR, AtlantOS, Argo, etc.)

8. ASC 2014 (A Coruña, Spain), Theme sessions in 2014. ASC 2015?

9. IROC highlights and key issues from the national reports

10. WGOH website

11. New chair and multi annual Terms of References

12. Next Meeting

13. AOB

Annex 3: WGOH terms of reference for the 2014 meeting

2013/2/SSGEF06 The **Working Group on Oceanic Hydrography** (WGOH), chaired by Stephen Dye, UK, and Kjell Arne Mork, Norway, will meet in Hamburg, Germany, 1–3 April 2014 to:

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

b) Consolidate inputs from Member Countries to, and continue development of the ICES Report on Ocean Climate (IROC); work with ICES Data Centre to develop web based presentation of IROC data including full meta-data;

c) Explore areas of mutual interest with international climate monitoring programmes;

d) Provide expert knowledge and guidance to ICES Data Centre (possibly via subgroup) on a continuous basis;

e) Help develop the framework for regional integrated ecosystem advice, advise on best temporal and spatial scales and spatial partitioning for descriptors of trends and variability of each ICES Ecoregion (for temperature, Salinity, water column structure, connectivity/flows, freshwater run-off/ice cover/salinity events, regional scale atmospheric forcing) and design a "briefing sheet" detailing the current state of the physical and biological environment in each ecoregion;

f) Provide expert knowledge, support and guidance to SCICOM and other Expert Groups requiring information on oceanic hydrography, and working to strengthen the role of physical oceanography within ICES in conjunction with groups such as WGOOFE, including: i) Support SCICOM regarding elements of the EGs' work that are relevant to Marine Strategy Framework Directive activities,

ii) Contribute to WKOOI to ensure Oceanic Hydrology is considered in the overall ICES framework for observing needs;

g) Prepare contributions for the 2013 SSGEF session during the ASC on the topic areas of the Science Plan.

WGOH will report by 30 April 2014 (via SSGEF) for the attention of SCICOM and ACOM.

Supporting information

Priority	The activities of this Group are fundamental to the work of the SSGEF.
Scientific justification	ToR a) This is a repeating task established by the Working Group to closely monitor the ocean conditions in the ICES area.. ToR b)The Working Group recognises the need for disseminating climate information in a timely and appropriate manner. This agenda item will allow WGOH members to prepare the document during the meeting, thus avoiding delays in the dissemination of the information. We will review proposed new developments in IROC content. ToR c) 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. ToR d) An ongoing ToR supporting a request from the ICES Data Centre ToR e) Proposed by Mark Dickey-Collas, SSGEF and ACOM: ICES is developing region ecosystem overviews. The will be an ongoing and iterative process and it must become operational within the ICES advice process. WGOH documents variability and trends in the oceanic hydrography for most ecoregions. The ICES Integrated Assessment Expert groups have also provided analysis of variability and trends. This information from different sources needs to be synthesized and build into a comprehensive description of the state of the regional seas and the Atlantic Ocean. Part of the process will be ensuring that knowledge from WGOH is taken up by the integrated assessment groups. ICES requires an agreed approach on the potential scales (both spatial and temporal) that best describe the regional variability. In addition it requires agreement on the partitioning of time-series by area. In other words, is it appropriate to describe temperature of the North Sea with one metric per year, or should the North Sea be split into 2 or 3 areas (as proposed by the integrated assessment groups) and/or should winter temperatures be described separate from summer temperatures? Scientists often want to split at finer and finer scales, but at what scales do the dominant oceanographic processes occur which have a regional impact? This ToR requires a preliminary list to be developed for each Ecoregion. This list can be fine-tuned in the coming years, but WGOH is being requested to use expert judgement, based on their extensive knowledge of the oceanographic systems, to create an initial list at their next meeting. This list will also be used to stimulate debate in WGOOFE, to look into the operationalization of the provision of the time-series. This TOR also addresses a proposal by WGIPEM for all integrated assessment working groups to provide a list of any relevant hydrographic indicators of community-level changes within their region, working with WGOOFE and WGOH. Finally, it addresses a request by HAWG or the annual creation of a “briefing sheet” detailing the current state of the physical and biological environment in the ecoregions that it covers as an aid to generating advice. ToR f) To follow up on the ICES General Secretary’s suggestions for increasing the visibility of oceanography within ICES. To improve communications between working groups under the ICES system. This also responds to a request from Adi Kellerman via WGOOFE and a request for ongoing support from the SCICOM Chair in 2011. ToR g) This is in response to a request from SSGEF.
Resource requirements	No extraordinary additional resources
Participants	WGOH members; Chair of SSGEF
Secretariat facilities	None.
Financial	No financial implications.
Linkages to advisory committees	ACOM
Linkages to other committees or groups	Publications Committee
Linkages to other organizations	IOC, JCOMM, CLIVAR

Annex 4: Recommendations

Recommendation	For follow up by:
1. WGOH recommends that the IROC report continues.	
2. WGOH recommends to continue the printed version of the IROC report.	
2. WGOH recommends modification of the IROC report with more recent information	

The **ICES Report on Ocean Climate**, edited by Agnieszka Beszczynska-Möller (Germany) & Stephen Dye (UK), as reviewed and approved by the Chair of the Steering Group on Ecosystems Functions (SSGEF), will be published annually in the *ICES Cooperative Research Report* series. The estimated number of pages is 80.

The Working Group on Oceanic Hydrography (WGOH) agrees to submit the final draft of the proposed publication by mid-year of the intended year of publication.

Supporting information

Priority:	This draft resolution continues the development of the IROC, and makes it an official, regular and citable ICES product.
Scientific justification:	The Cooperative Research Report series offers a good vehicle for this recurring publication of the IROC. These reports represent assessments made annually for five years, which can support the advisory function by providing regionally-based assessments of ocean climate in the ICES area.
Resource requirements:	Editorial support.
Participants:	
Secretariat facilities:	Help with document preparation / publication. Final editing.
Financial:	Cost of production and publication of each a 80-page CRR
Linkages to advisory committees:	Advisory Committee (ACOM)
Linkages to other committees or groups:	Publications Group (PUBCOM), SCICOM Steering Group on Ecosystems Functions (SSGEF)
Linkages to other organizations:	IOC, OSPAR

Annex 5: Regional report – West Greenland 2013 (Area 1)

Boris Cisewski

Thünen Institute of Sea Fisheries, Germany

The water mass circulation off Greenland comprises three main currents: Irminger Current, West Greenland and East Greenland Currents (Figure 1). The East Greenland Current (EGC) transports ice and cold low-salinity Surface Polar Water (SPW) to the south along the eastern coast of Greenland. On the inner shelf the East Greenland Coastal Current (EGCC), predominantly a bifurcated branch of the EGC, transports cold fresh Polar Water southward near the shelf break (Sutherland and Pickart, 2008). The Irminger Current (IC) is a branch of the North Atlantic Current. Figure 2 reveals warm and salty Atlantic Waters flowing northward along the Reykjanes Ridge. South of the Denmark Strait (DS) the current bifurcates. While a smaller branch continues northward through the DS to form the Icelandic Irminger Current, the bulk of the current recirculates to the south and transports salty and warm Irminger Sea Water (ISW) southward along the eastern continental slope of Greenland. It makes a cyclonic loop in the Irminger Sea. South of Greenland both currents bifurcate and spread northward as a single jet of the West Greenland Current (WGC). The WGC carries the water northward and consists of two components: a cold and fresh inshore component, which is a mixture of the SPW and melt water, and a saltier and warmer Irminger Sea Water (ISW) offshore component. The WGC transports water into the Labrador Sea, and hence is important for Labrador Sea Water formation, which is an essential element of the Atlantic Meridional Overturning Circulation. The dynamics of the current is monitored yearly in autumn at two standard ICES/NAFO oceanographic sections across the slope off West Greenland (Figure 3). The German groundfish survey off Greenland is conducted since 1981, aiming at monitoring groundfish stocks in particular of cod and redfish, collecting environmental data and performs ecosystem studies in the area. The monitoring is carried out by the Thünen-Institute of Sea Fisheries (TI-SF) from board of RV 'Walter Herwig III' and reveals significant interannual and long-term variability of both components of the WGC.

Atmospheric conditions

The variability of the atmospheric conditions over Greenland and the Labrador Sea is driven by the large scale atmospheric circulation over the North Atlantic, which is normally described in terms of the North Atlantic Oscillation (NAO). During a positive NAO strong northwest winds bring cold air from the North American continent and cause negative anomalies of the air temperatures over Greenland, Labrador Sea and Baffin Bay (Hurrell and Deser, 2010). During a negative NAO the westerlies slacken and the weather is normally milder over the whole region. According to ICES standards, I use in this study the Hurrell winter (DJFM) NAO index, which is available at *http://www.cgd.ucar.edu/cas/jhurrell/indices.html*.

In winter 2012/2013, the NAO index was negative (-1.97) describing weaker winds, and milder weather over the North Atlantic Ocean (Figure 4). Figure 5a shows the winter sea level pressure (SLP) averaged over 30 years (1981–2010), mainly dominated by the Iceland Low and the Azores High. In winter 2012/2013, the average SLP field had a fairly typical pattern compared to the long-term mean, however both the Iceland Low and the

Azores High were weaker than in the mean pattern (Figure 5b). The resulting positive anomalies in the north and the negative in the south reveal a negative NAO character (Figure 5c).

Air temperature at Nuuk was used to characterize the atmospheric conditions in 2013. Annual and monthly mean values were obtained from the Danish Meteorological Institute (Cappelen, 2013). In 2013, the monthly mean air temperatures were higher than the long-term mean for the first four months, while for the rest of the year the monthly temperatures were close to their long-term mean (Figure 6). The resulting annual mean temperature at Nuuk was 1.1°C above the long-term mean (Figure 7).

Hydrographic Conditions

Here a short overview of the hydrographical condition west off Greenland during autumn 2013 is presented. The core properties of the water masses of the WGC are formed in the western Irminger Basin where the EGC meets the Irminger current (IC). The EGC transports fresh and cold PSW of Arctic origin. The IC is a northern branch of the Gulf Stream, which makes a cyclonic loop in the Irminger Sea and carries warm and saline ISW. After the currents converge, they turn around the southern tip of Greenland, form the WGC and propagate northward along the western coast of Greenland. During this propagation considerable mixing between two water masses takes place and ISW gradually deepens (Clarke and Gascard, 1983; Myers *et al.*, 2009).

There is more than one definition of the water masses carried by the WGC (Clarke and Gascard, 1983; Stein, 2005; Schmidt and Send, 2007; Myers *et al.*, 2009). Here we consider the upper layer down to 700 m water depth and define SPW and ISW following the nomenclature of Myers *et al.*, 2009 (Table 2). The annual sea surface temperature (NOAA OI SST) anomalies for 2013 indicate positive anomalies of the SST in the Northwestern Atlantic and around Greenland (Figure 8). Negative anomalies were observed only along the southeastern coast of Greenland and associated with the East Greenland current.

CTD profiler casts were conducted with a Sea-Bird 911plus sonde attached to a 12-bottle water sampler. The hydrographic database consisted of 35 hydrographic stations sampled between October 13 and October 31, 2013, from R.V. 'Walther Herwig III'. Study area and station locations are shown in Figure 3. For in-situ calibration, salinity samples were analyzed with a Guildline Autosal-8400A salinometer immediately after the cruise. The collected data was interpolated to a 1 m grid in the vertical. If data was missing at the top of a profile, we assumed constant properties from the first measurement (normally 2–5 m) up to the surface.

Standard Cape Desolation and Fyllas Bank sections span across the shelf and the continental slope off West Greenland. The Cape Desolation section is situated 300 km northwest from the southern tip of Greenland. At this section a strong surface front separates PSW on the shelf from ISW offshore (Figure 9). In autumn, the temperature of the upper layer is well above zero (θ_{Min} = 1.58°C) due to the summer heat accumulation, and hence only the salinity can be used as a tracer of the SPW (Figure 9a). A salinity of less than 32 was observed at station 792 (Figure 9b). The most offshore station of the section done in 2013 (Station 787) corresponds to the standard Cape Desolation Station 3, which was reported in ICES WGOH since 2001 (Stein, 2010). In 2013, no SPW was apparent at this station. Moreover, the water temperature of the upper 100–120 meters was higher than its long-term mean (Figure 10a). The salinity of the upper 200 meters also reveals high positive anomalies (Figure 10b).

In 2013, the water temperature and the salinity in the 75–200 m layer at Cape Desolation Station 3 was 5.84°C (Figure 11a) and 34.97 (Figure 11b), which was 0.12°C and 0.05 above the long-term mean, respectively. This finding agrees with previous studies e.g. Myers *et al.*, 2009 who used summer observations off West Greenland. The observed warming of the ISW in the WGC coincides with a temperature increase at other locations within Subpolar Gyre (e.g. Irminger Current south of Iceland, see Hátún *et al.*, 2005) and is believed to be cause by weakening of the Subpolar Gyre started a decade and a half ago (Häkkinen and Rhines, 2004; Hátún *et al.*, 2005; Hátún *et al.*, 2009).

The properties of the North Atlantic Deep Water in the deep boundary current west of Greenland are monitored at 2000 m depth at Cap Desolation Station 3. The temperature and salinity of this water mass underwent strong interannual variability during the 1980s (Figure 12). Since the beginning of the 1990s, both characteristics were decreasing and reached their minimum values in 1998 and 1997, respectively. After that, positive trends were observed until 2007. In 2007 the temperature of the North Atlantic Deep Water started to decrease and its salinity stagnated. This decrease of the water temperature continued till 2010. Between 2010 and 2012, the temperature and salinity increased again. In 2013, the temperature and salinity decreased, but were 0.08°C and 0.01 above the long-term mean (Figures 12a and b).

The Fyllas Bank section is situated further to the north over the broad shallow Fyllas Bank that affects strongly the structure of the West Greenland Current (Myers *et al.*, 2009). In 2013, fresh PSW was seen in uppermost 100 m over the entire section (Figure 13) and it spread at least 100 km away from the shelf. The core of ISW (θ >5 °C, S>34.9) was found between 199 and 730 m water depth at station 814, which corresponds to standard Fyllas Bank Station 4 (e.g. ICES, 2002; ICES, 2004). In 2013, this station can be characterized by a negative potential temperature anomaly within the uppermost 200 to 300 m and a positive temperature anomaly between 300 and 700 meter water depth and high negative salinity anomalies within the upper 500 m (Figures 14 a and b). The water properties between 0 and 50 m depth at Fyllas Bank Station 4 are used to monitor the variability of the fresh Polar Water component of the West Greenland current. In 2013, the temperature of this water was 0.37°C below the long-term mean (Figure 15a). The salinity anomaly of the Polar Water reveals a positive trend between 2008 and 2011 (Figure 15b). However, in 2012 the salinity decreased and was 0.45 below its long-term mean and stagnated on the same level in 2013.

Tables

Table 1. Details on the times series, analysed in this study.

Name	Lat (°N)	Lon (°W)	Type	Source

Nuuk (4250)[4]	64.17	51.75	Weather station	DMI
Nuuk airport (4254)[1]	64.20	51.68	Weather station	DMI
Cape Desolation Station 3	60.47	50.00	Oceanographic station	TI-SF
Fyllas Bank Station 4	63.88	53.37	Oceanographic station	TI-SF

Table 2. Water mass characteristics in the study area.

The water masses in the area	Potential temperature (θ)	Salinity (S)
Surface Polar Water (SPW)	$\theta \leq 0$	$S \leq 34.4$
Irminger Sea water (ISW)	$\theta \geq 4.5$	$S \geq 34.95$

[4] In recent years, Nuuk air temperature was taken from the Nuuk airport synop station 04254 due to a failure on Nuuk synop station 04250 (Cappelen, 2013).

Figures

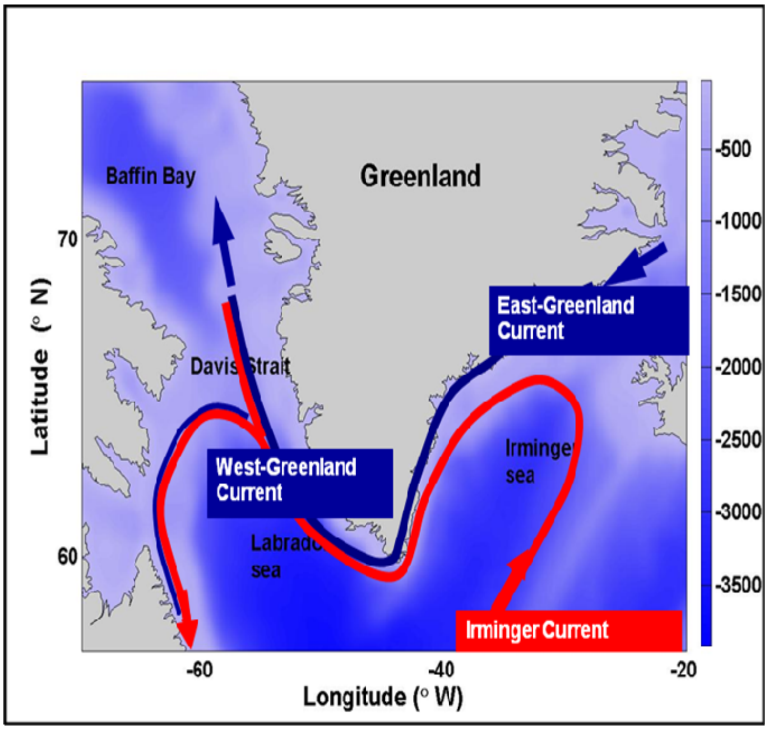


Figure 1. Scheme of the upper ocean circulation in the study area. Red and blue curves show the trajectories of warm Irminger Sea Water and cold Surface Polar Water, respectively.

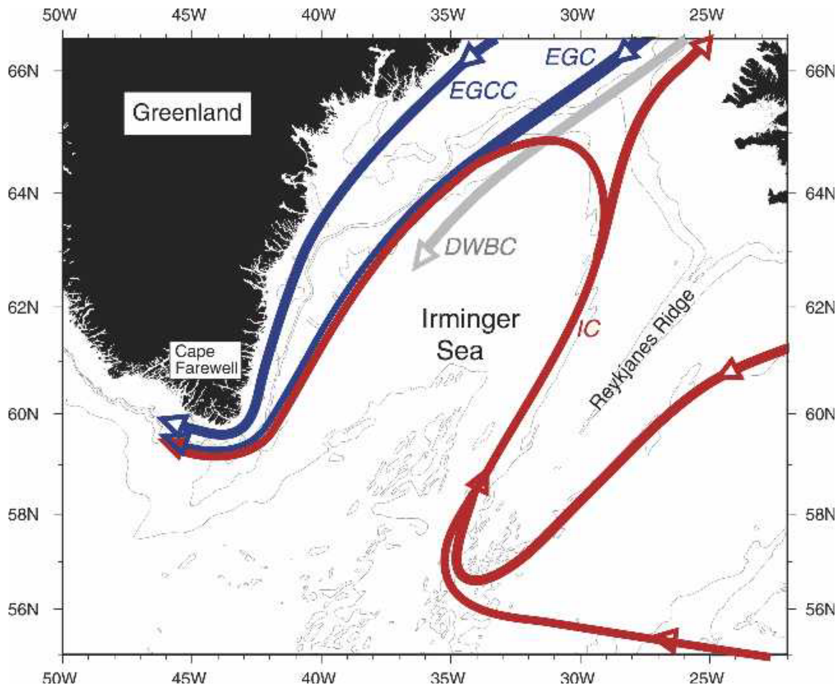


Figure 2. Schematic of the boundary currents of the Irminger Sea (depicted from Pickart *et al.*, 2005)

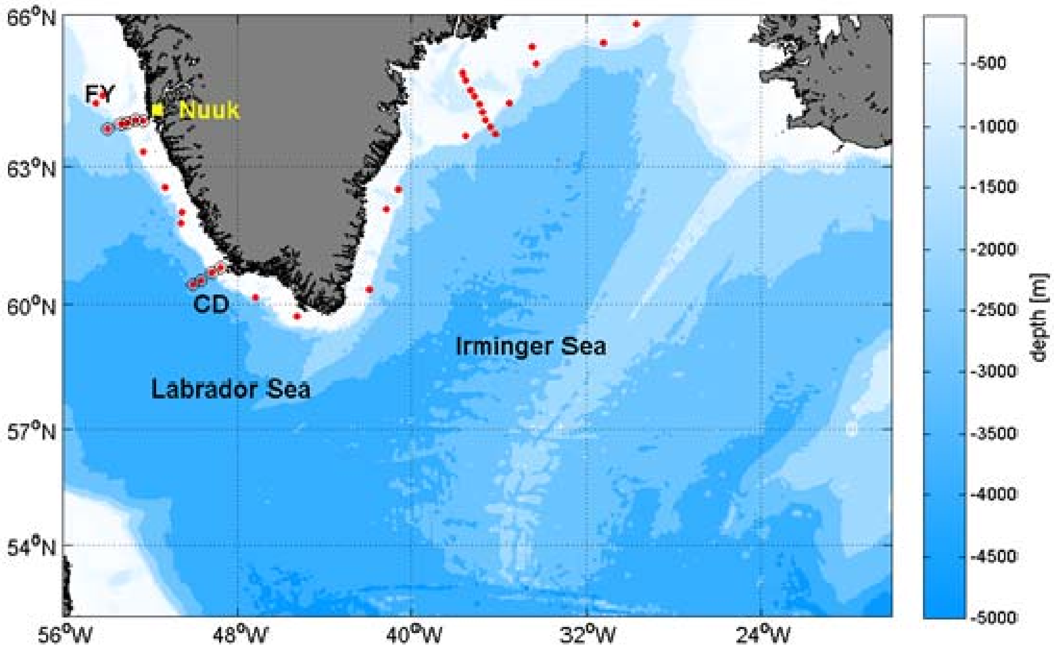


Figure 3. Map and bathymetry of the study region. Meteorological station location is shown in yellow. Red dots show the location of the hydrographic stations, conducted during the survey in 2013. Gray edged dots show the two ICES/NAFO standard sections (CD – Cape Desolation section, FY – Fyllas Bank Section; geographic coordinates are given in table 1).

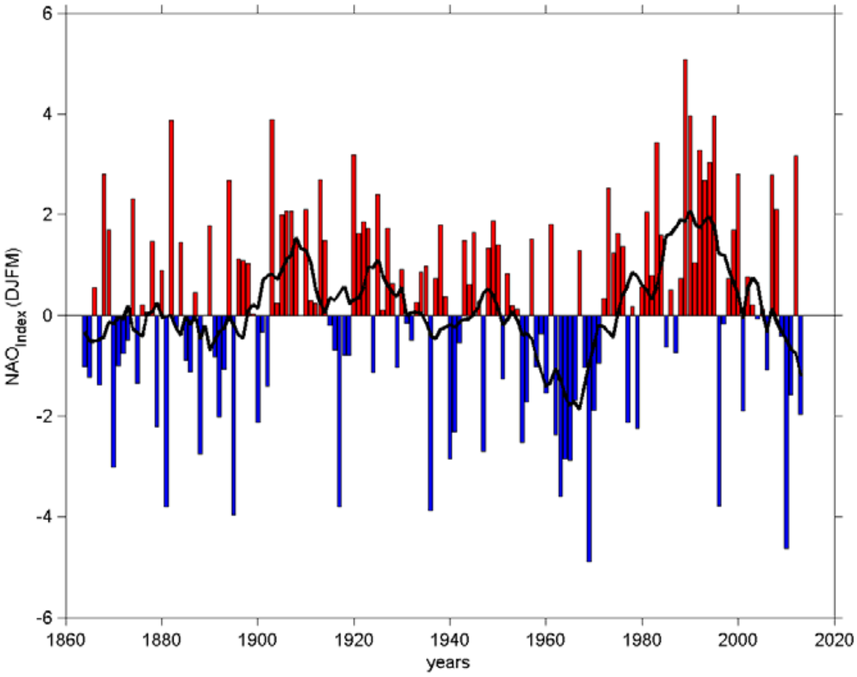


Figure 4. The Hurrell winter (DJFM) NAO index with a 5-year running mean (black curve). Data source: http://www.cgd.ucar.edu/cas/jhurrell/nao.stat.winter.html.

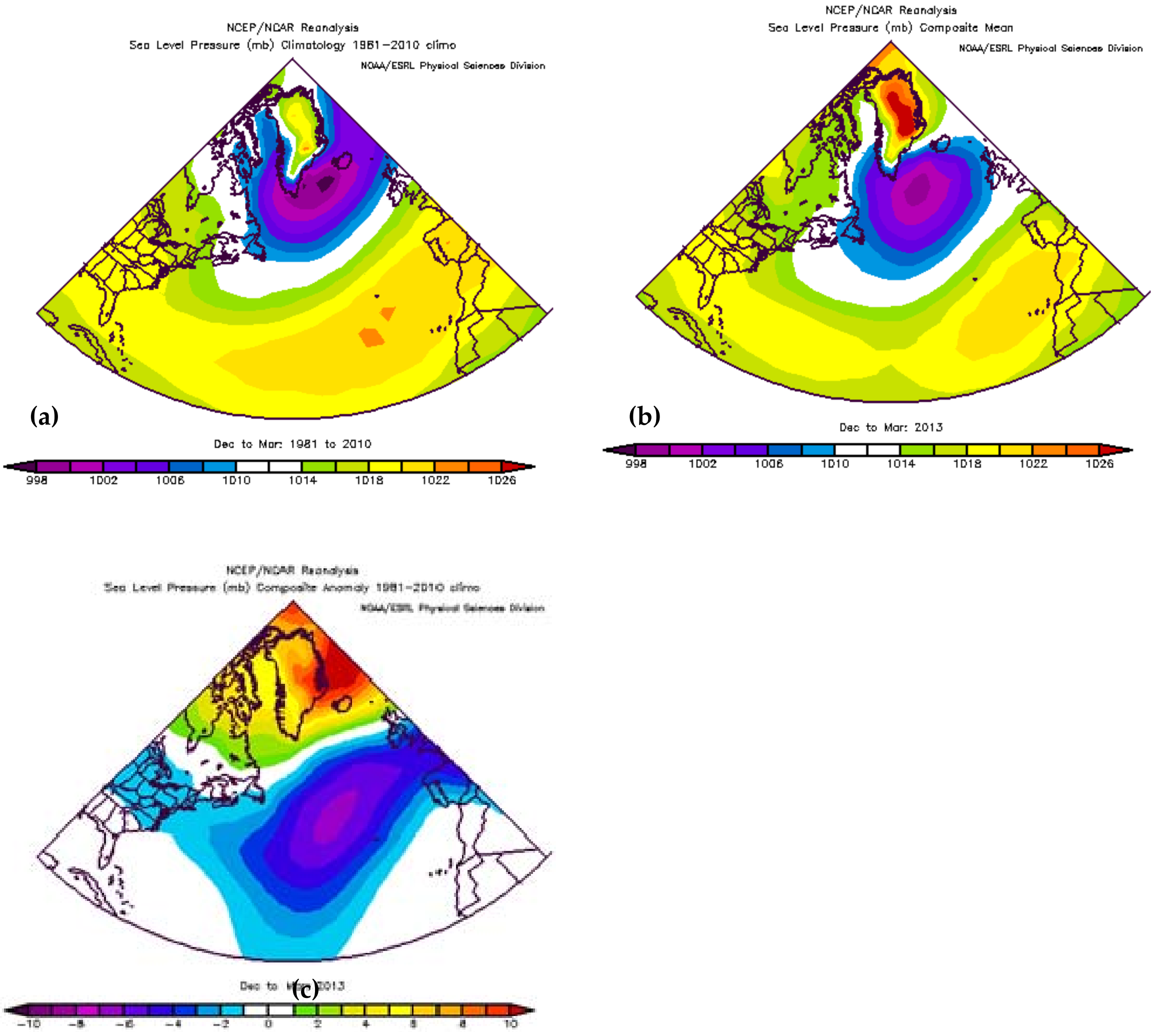


Figure 5. Maps of winter 1981–2010 (DJFM) mean sea level pressure (SLP) (a), winter 2013 SLP (b), and resulting SLP anomaly (c) over the North Atlantic. ***Images are provided by the NOAA/ESRL Physical Science Division, Boulder, Colorado***

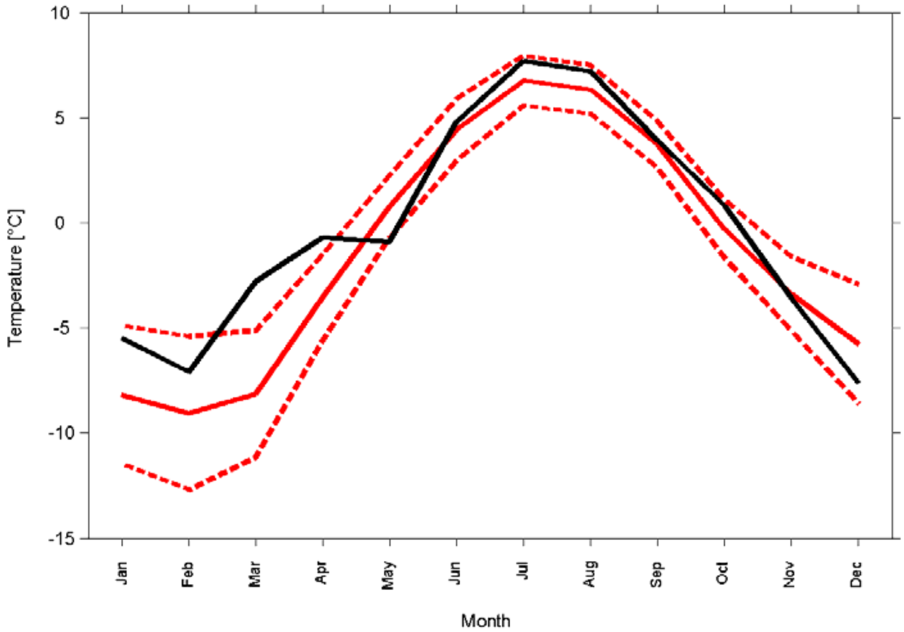


Figure 6. Monthly mean temperature at Nuuk station in 2013 (black line), long-term monthly mean temperature (red solid line) and one standard deviation (red dashed lines) are shown. Reference period is 1981 to 2010. Data source: Danish Meteorological Institute (DMI)

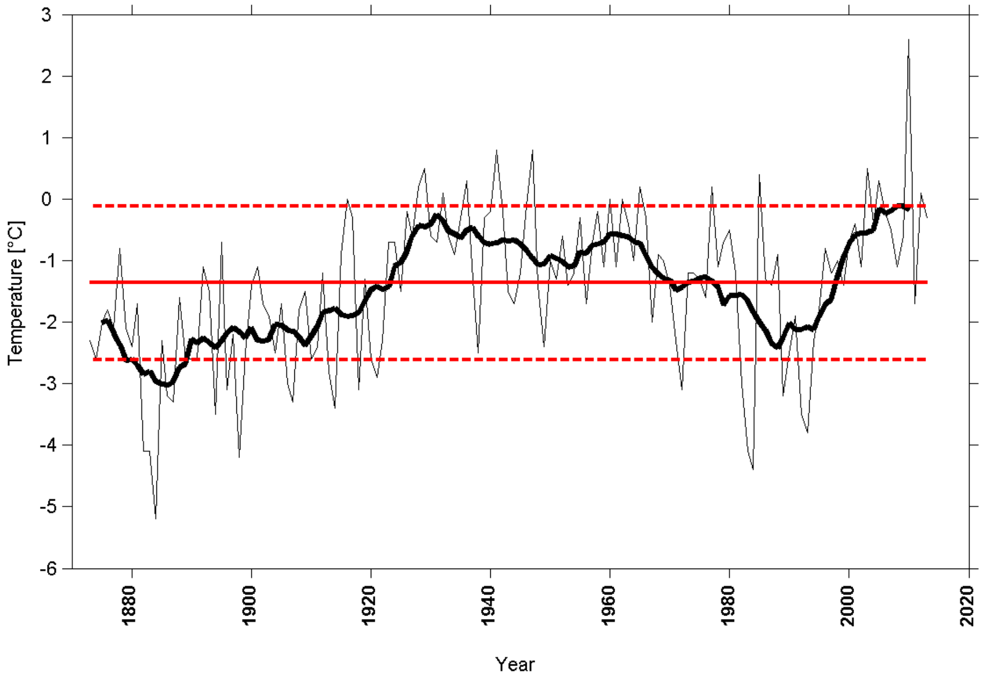


Figure 7. Annual mean air temperature at Nuuk station. Thick black line shows the 5-year smoothed data. Red solid line indicates the long-term mean temperature, referenced to 1981–2010. Dashed red lines mark corresponding standard deviations. Data source: Cappelen, J. (ed.), 2013: Greenland - DMI Historical Climate Data Collection 1873–2012 – with Danish Abstracts. DMI Technical Report 13–04. Copenhagen.

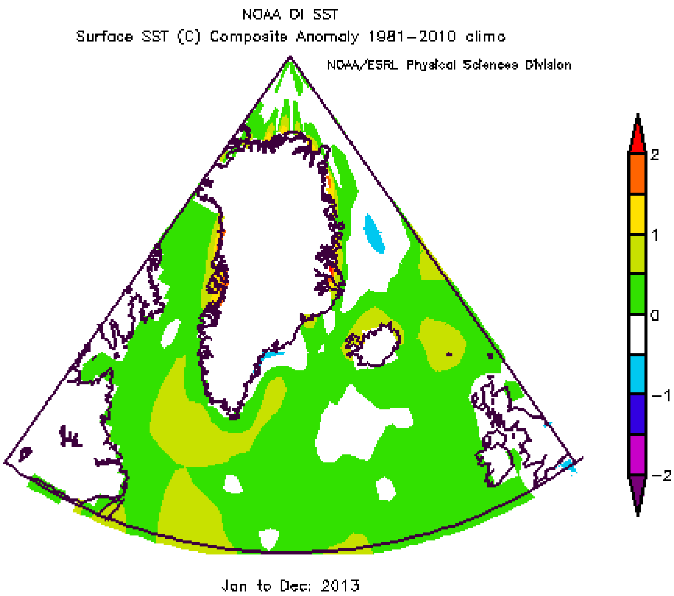
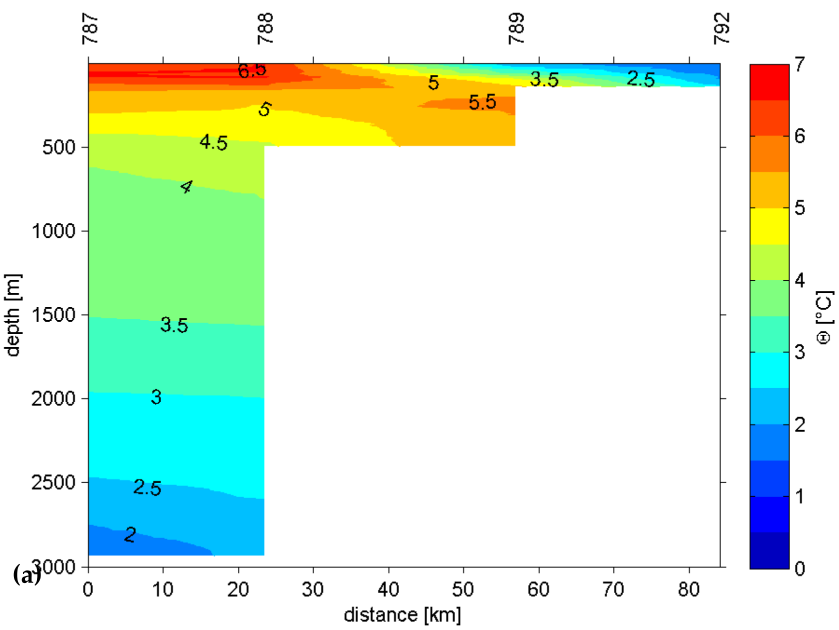


Figure 8. Map of 2013 annual sea surface temperature (NOAA OI SST) anomalies in the study region. The long-term mean corresponds to 1981–2010. *Image is provided by the NOAA/ESRL Physical Science Division, Boulder, Colorado*



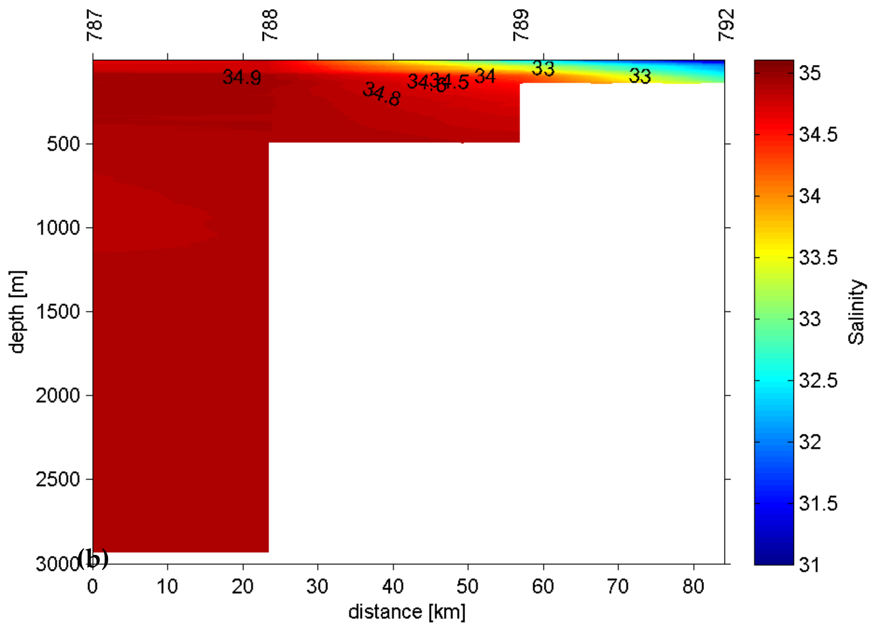
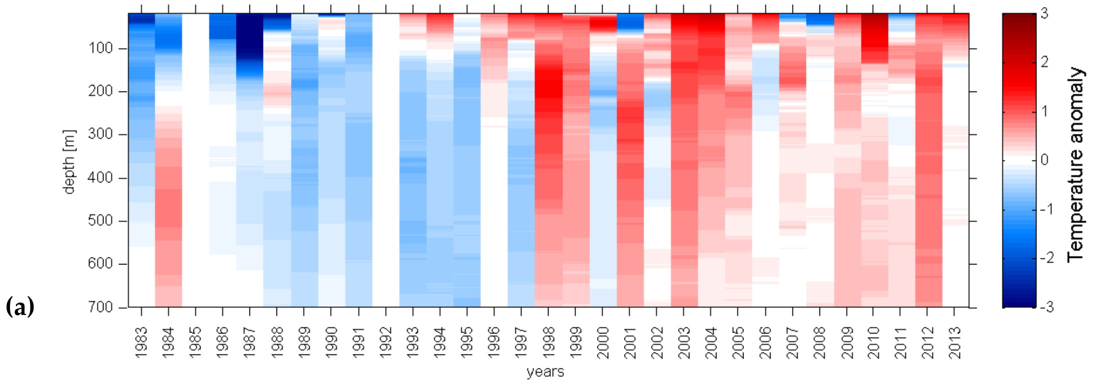


Figure 9. Vertical distribution of potential temperature (a) and salinity (b) along the Cape Desolation section in 2013.



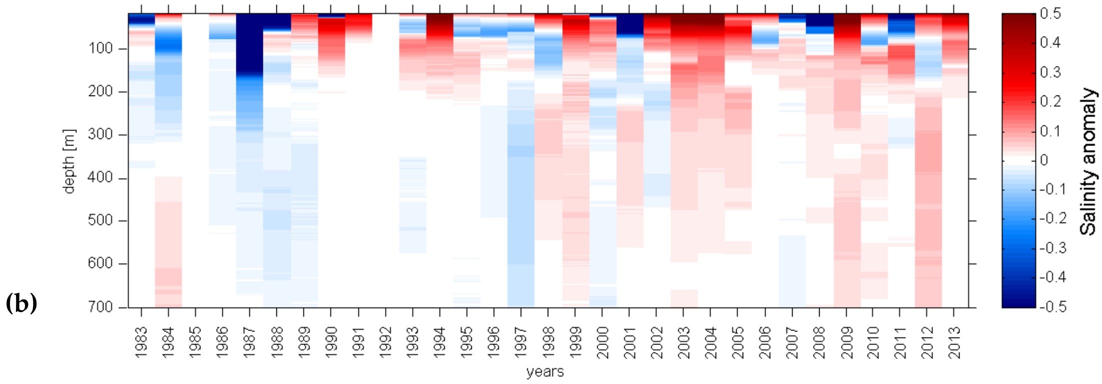


Figure 10. Hovmoeller diagram of the potential temperature anomalies (a) and salinity anomalies (b) in the upper 700 m at Cape Desolation Station 3. Reference period is 1983–2010.

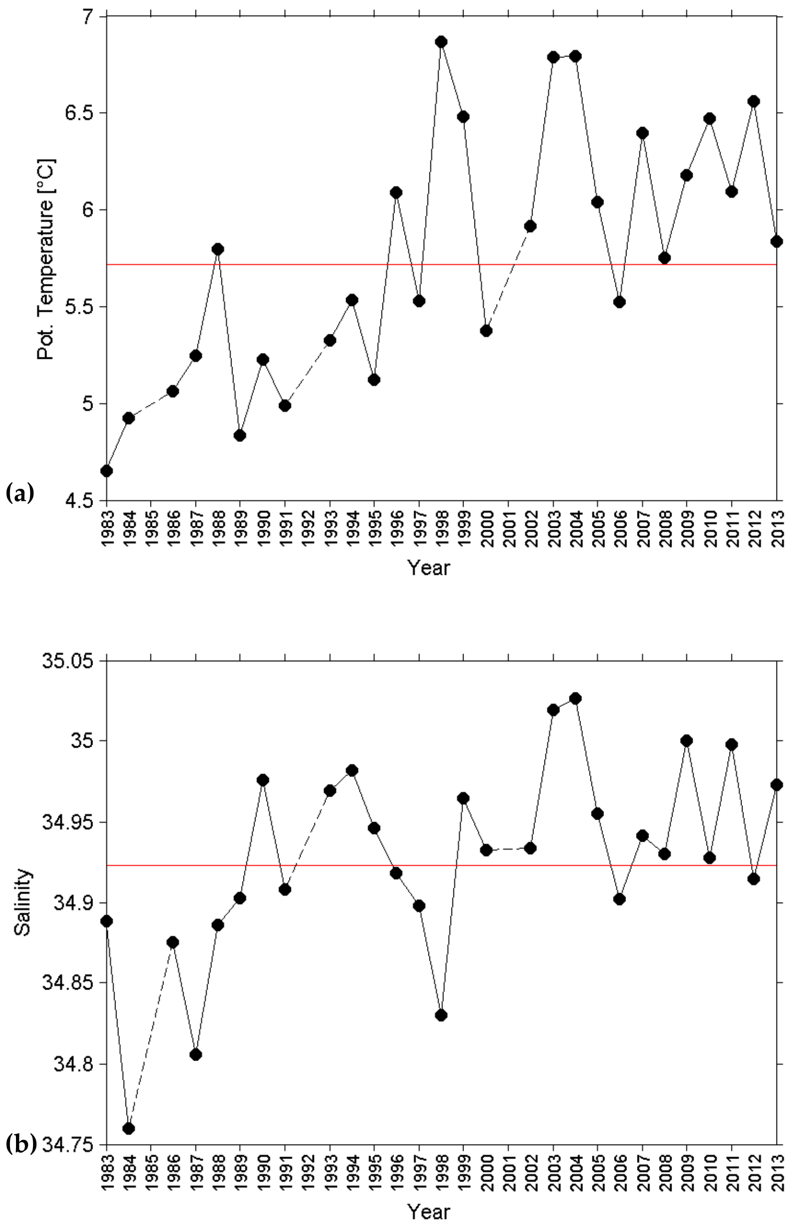


Figure 11. Potential temperature (a) and salinity (b) in 75–200 m water layer at Cape Desolation Station 3 (60.47°N, 50°W). Red lines indicate the long-term mean potential temperature and salinity, referenced to 1983–2010.

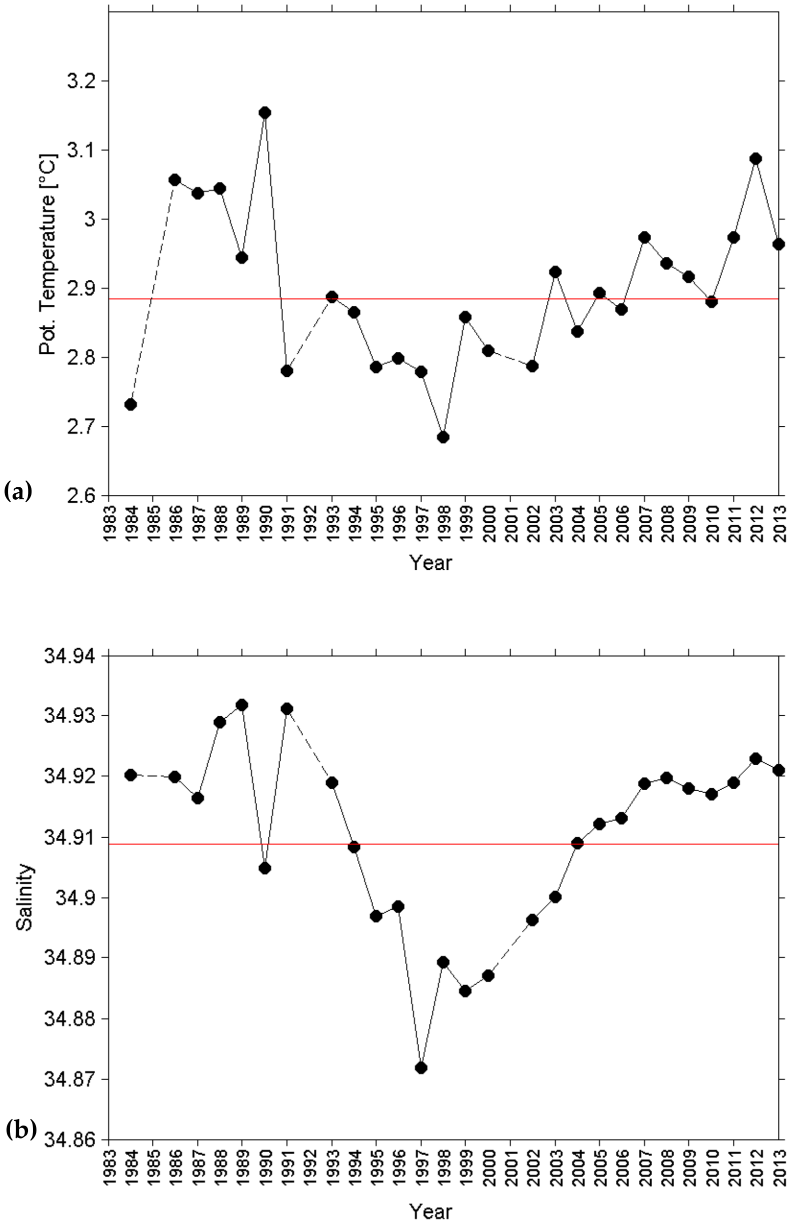


Figure 12. Potential temperature (a) and salinity (b) at 2000 m water depth at Cape Desolation Station 3 (60.47°N, 50°W). Red lines indicate the long-term mean potential temperature and salinity, referenced to 1983–2010.

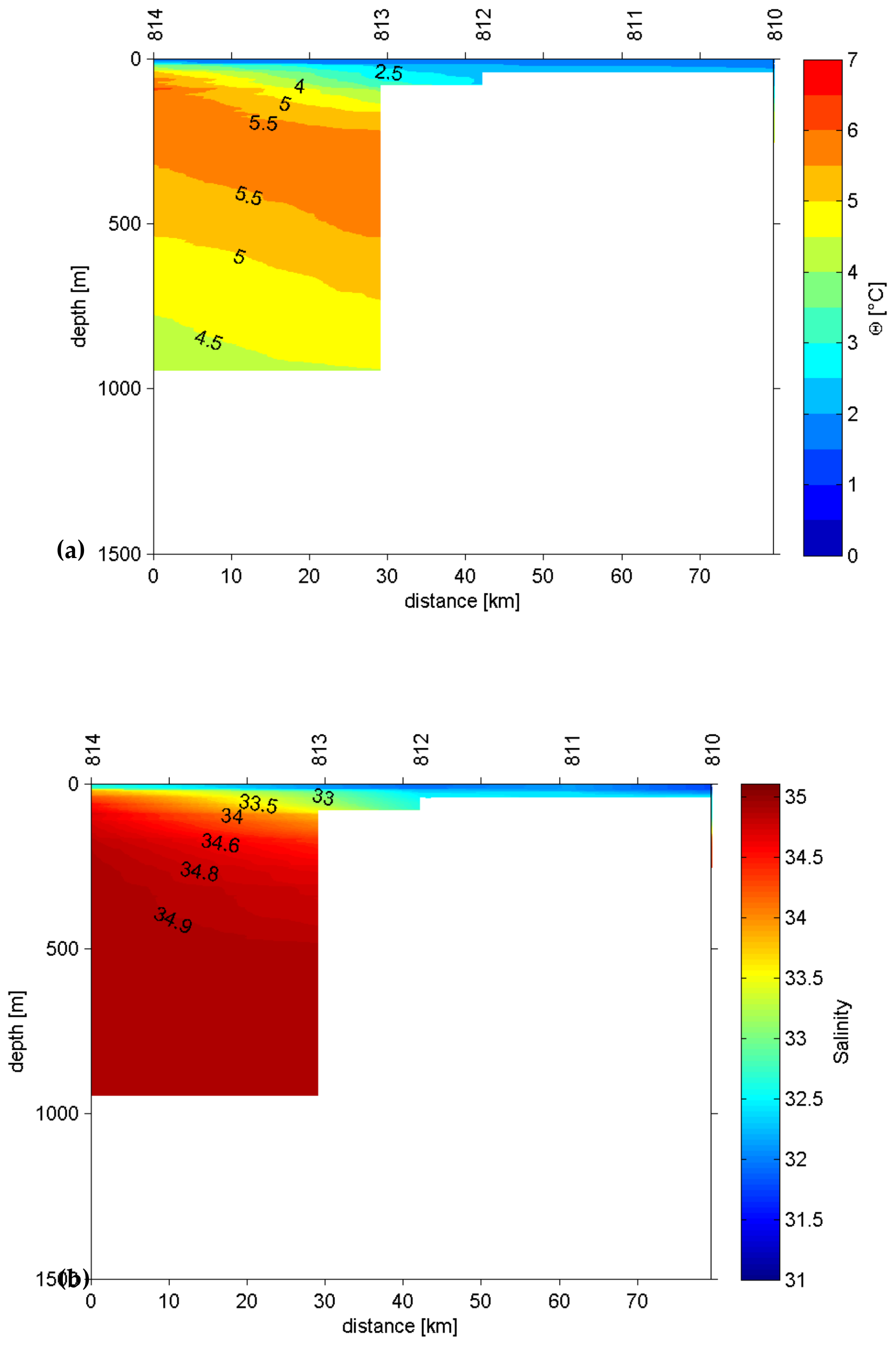


Figure 13. Vertical distribution of potential temperature (a) and salinity (b) along Fyllas Bank section (Figure 8) in 2013.

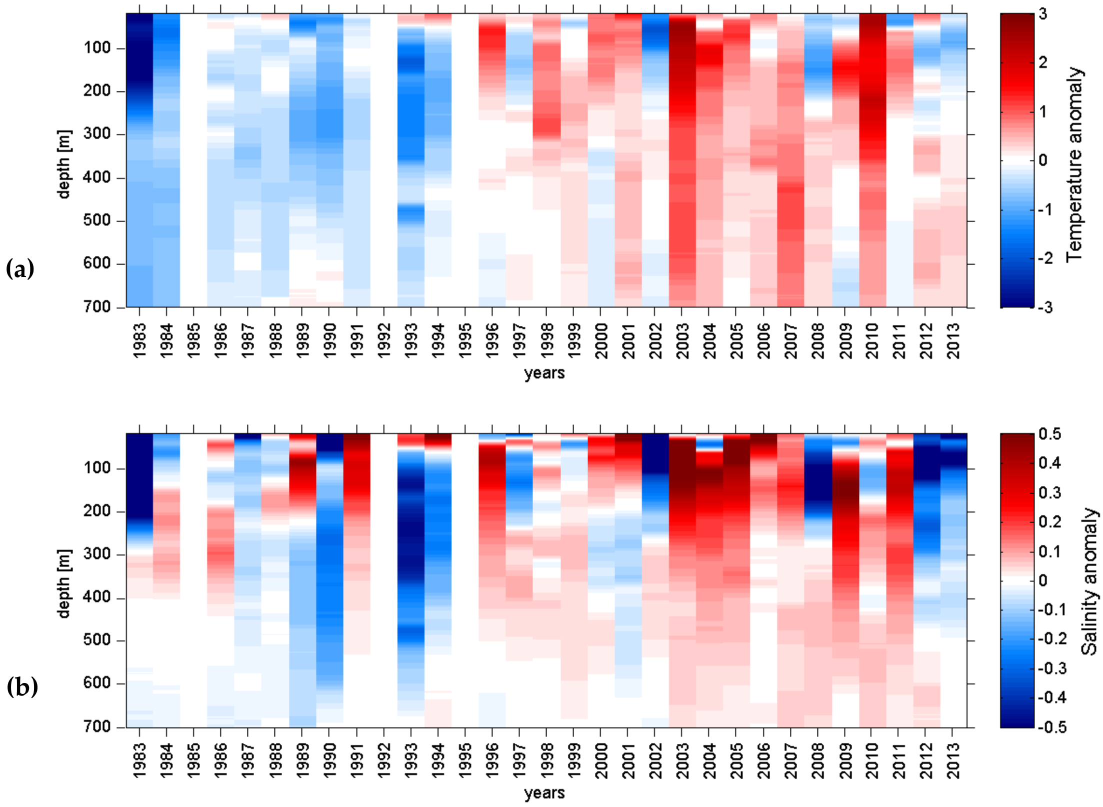


Figure 14. Hovmoeller diagram of the potential temperature anomalies (a) and salinity anomalies (b) in the upper 700 m at Fyllas Bank Station 4. Reference period is 1983–2010.

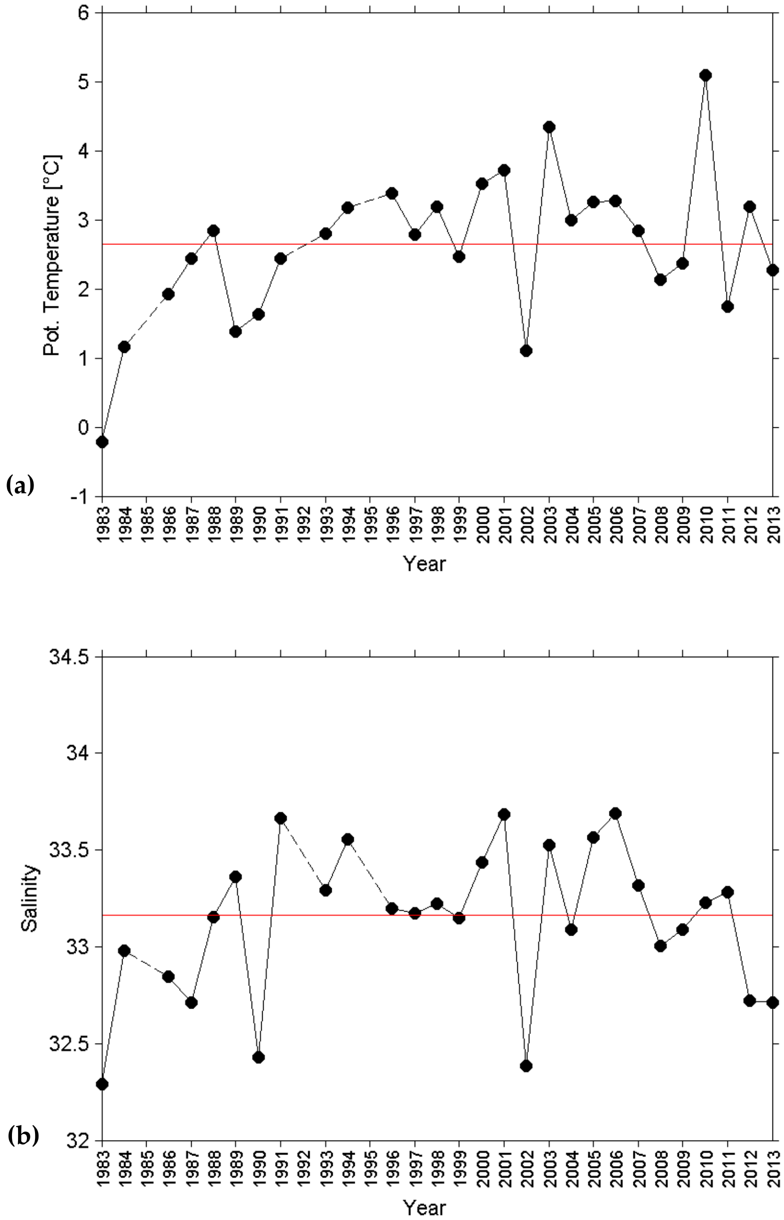


Figure 15. Mean potential temperature (a) and salinity (b) in the 0–50 m water layer at Fyllas Bank Station 4 (63.88°N, 53.37°W). Red lines indicate the long-term mean potential temperature and salinity, referenced to 1983–2010.

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Annex 6: Regional report – Icelandic waters 2013 (Area 3)

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Iceland is at a meeting place of warm and cold currents (Fig. 1), which meet in an area of submarine ridges (Greenland-Scotland Ridge, Reykjanes Ridge, Kolbeinsey Ridge), which form natural barriers against the main ocean currents. From the south flows the warm Irminger Current which is a branch of the North Atlantic Current (6–8°C), and from the north flow the cold East Greenland and East Icelandic Currents (-1 to 2°C).

Deep and bottom currents in the seas around Iceland are principally the overflow of cold water from the Nordic Seas and the Arctic Ocean over the submarine ridges into the North Atlantic.

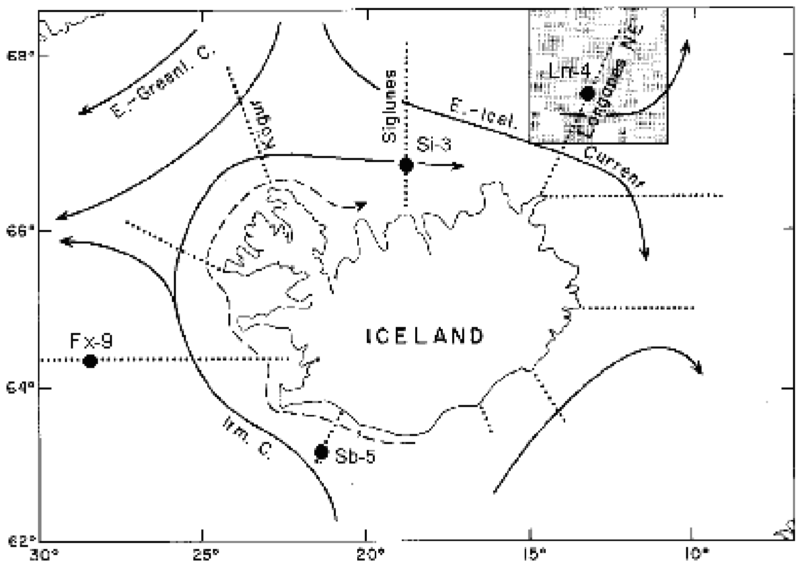

Figure 1. Main currents and location of standard hydrographic sections in Icelandic waters. Selected areas and stations dealt with in this report are indicated.

Hydrographic conditions in Icelandic waters are generally closely related with the atmospheric or climatic conditions in and over the country and the surrounding seas, mainly through the Iceland Low and the high pressure over Greenland. These conditions in the atmosphere and the surrounding seas have impact on biological conditions, expressed through the food chain in the waters including recruitment and abundance of commercial fish stocks.

In 2012 mean air temperature in the south (Reykjavik) and north (Akureyri) were above long time average (Fig 2a).

The salinity and temperature in the Atlantic water from the south remained at high levels similar to previous years (Fig 3.b and 5), with the highest salinity in almost fourty years occurring in 2009, slightly lower in 2011 to 2014. The salinity in the East Icelandic Current in spring 2012 was well above average and temperature was above long term mean (Fig 3a).

Extremely cold conditions were observed in the northern area 1995, warming in the years 1996 to 2001. With a slight decrease in first half of 2002 (Fig. 2b) and were then followed by the mild conditions for all seasons in 2003 and 2004. Lower temperatures were seen in the north and east areas in 2005 and 2006 increasing again after that. However south and west of Iceland temperatures and salinities have remained high since 1997 and this continued through 2010, lowered some in 2011 to 2014 . In winters 2011 to 2014 mid layer (Atlantic inflow) temperatures were around and above long term mean in the north throughout the year as salinity of same layers lowered below long term mean except for 2013 (Fig. 4).

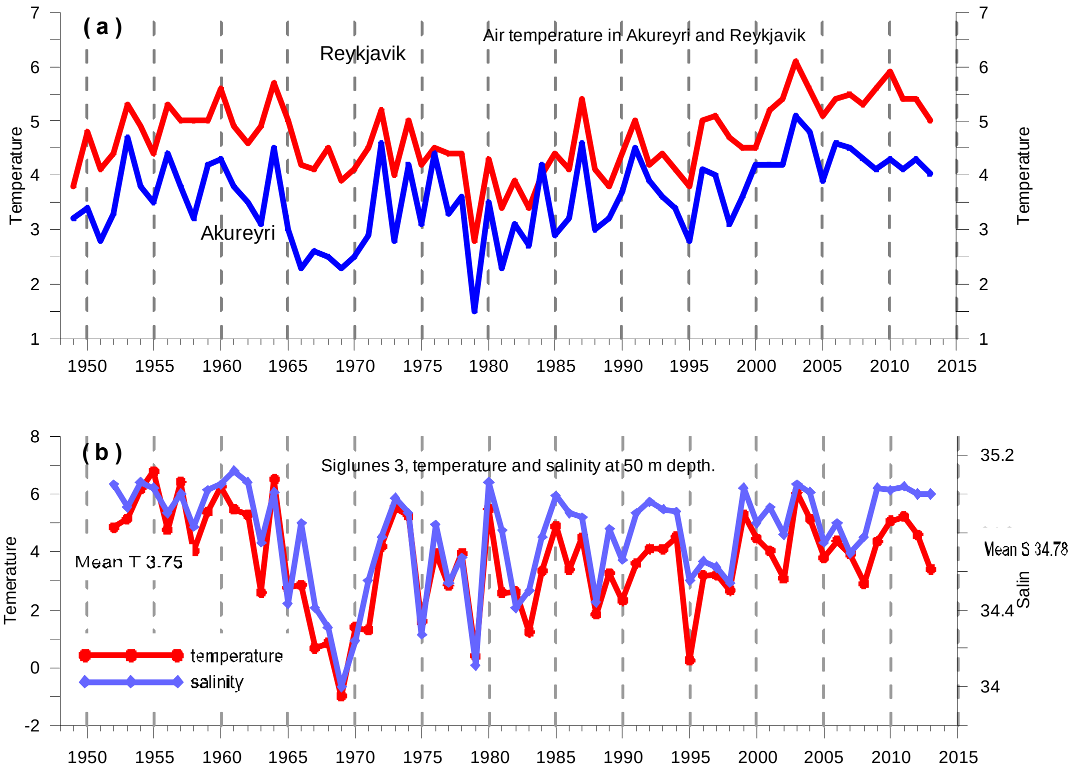

Figure 2.

a. Mean annual air-temperatures in Reykjavík and Akureyri 1949–2013. Data from Icelandic Met Office, Reykjavík.

b. Temperature and salinity at 50 m depth in spring at Station Si-3 in North Icelandic waters 1952–2013

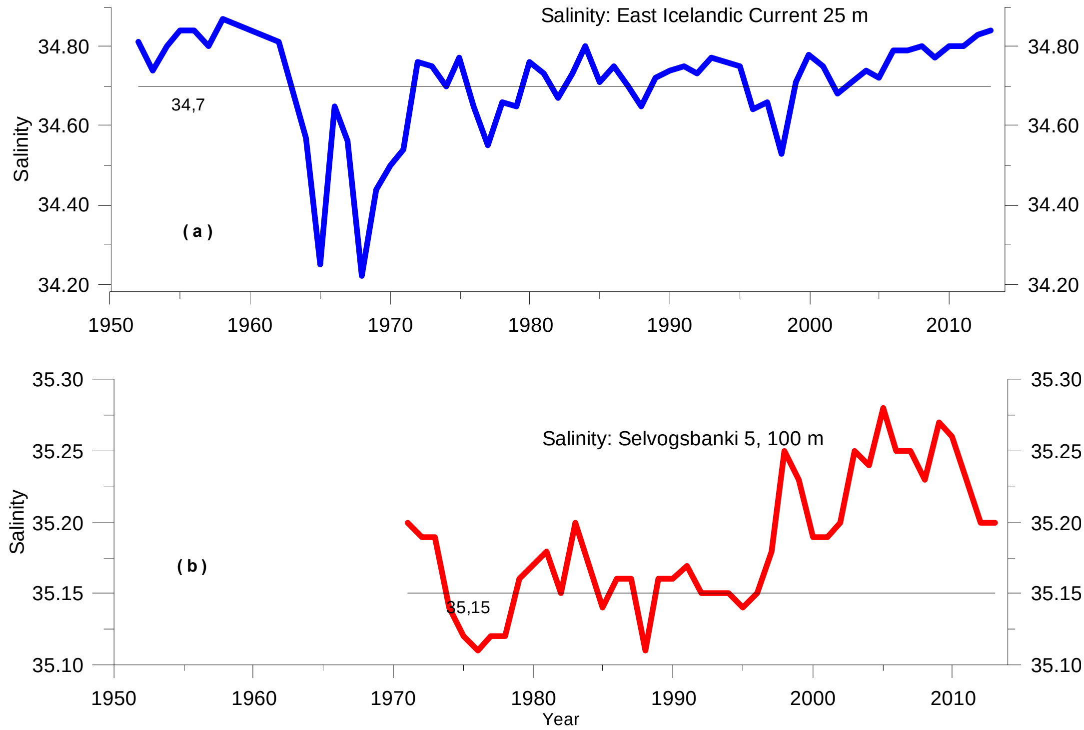

Figure 3. Salinity in *spring* at

a. 100 m depth in the Irminger Current south of Iceland (Sb-5) 1971–2013.

b. 25 m depth in the East Icelandic Current north-east of Iceland 1952–2013, mean of stations crossing the East Icelandic Current NE of Iceland.

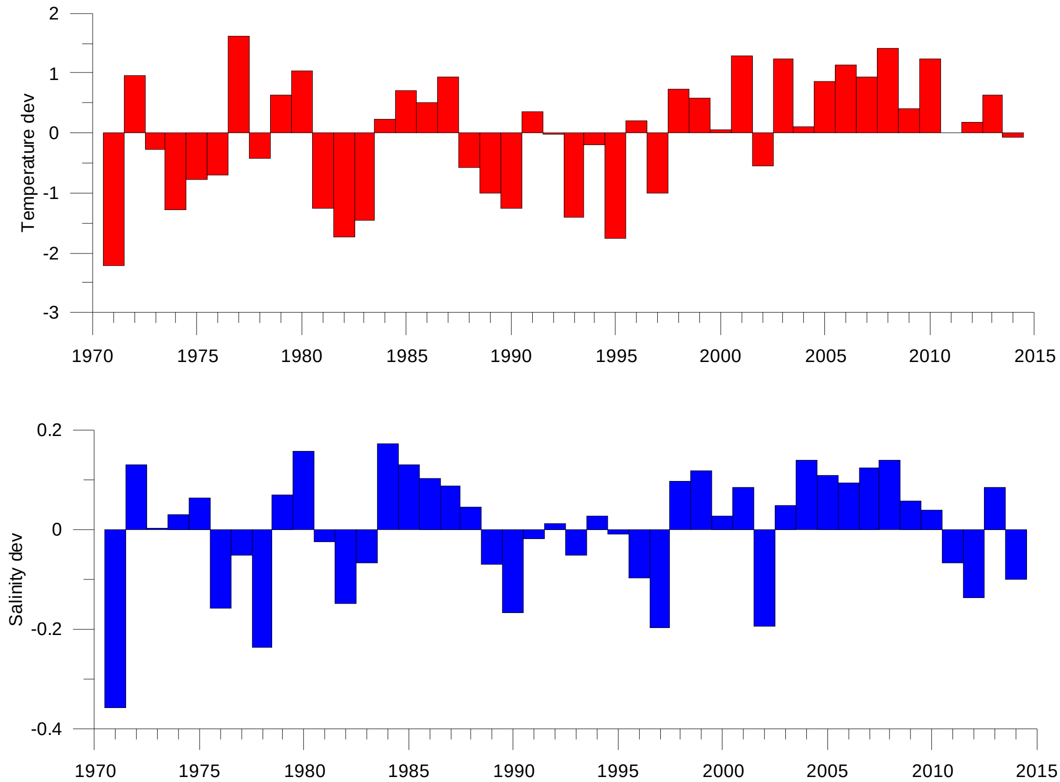

Figure 4. Temperature (upper) and salinity (lower) in winter on Siglunes section,north of Iceland, 1971–2014, stations 2–4 depth averaged over 50 -150 m. Deviation from mean for the measuring period.

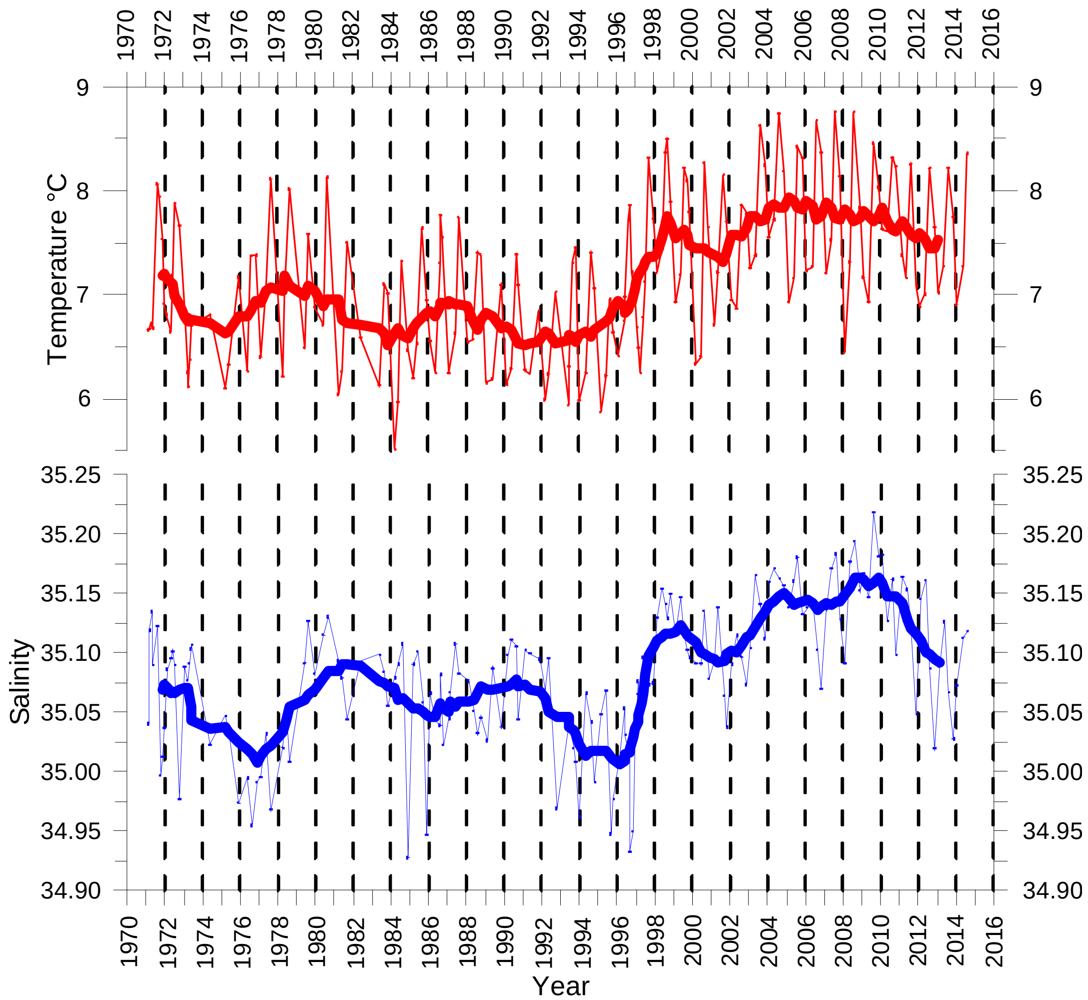

Figure 5. Mean temperature 0–200 m at the shelf brake west of Iceland, 1971–2014. Combined data from stations RE8 (1971–1984) and FX9 (1984–2013), 20 nm apart. Thick line is approx. 3 yrs running mean.

Annex 7: Spanish Standard Sections 2013 (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 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 1986 (Figure 1).

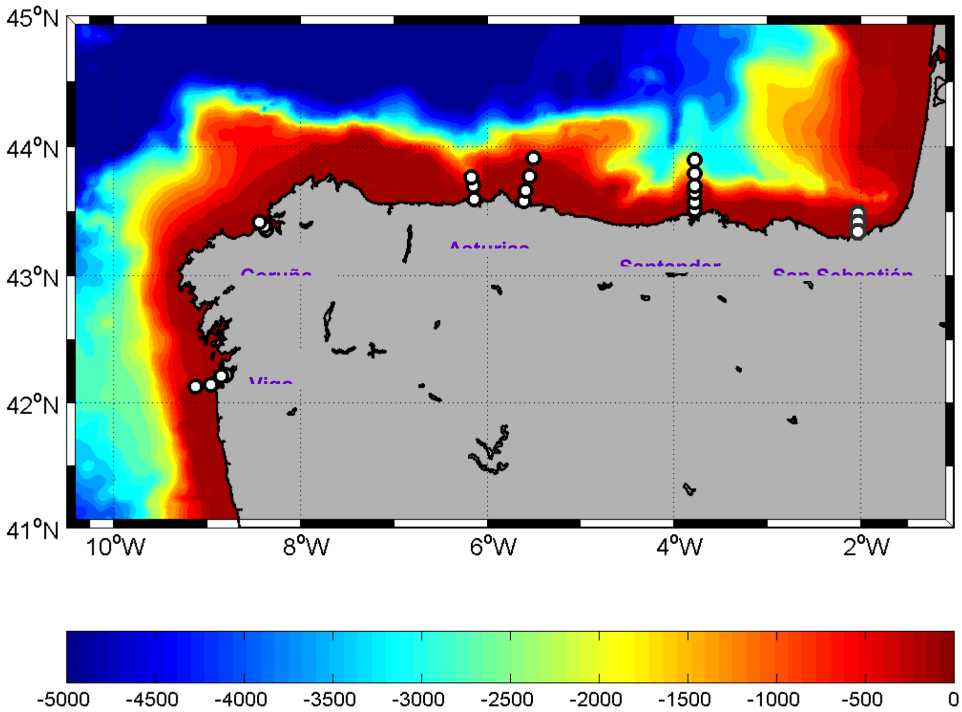


Figure 1. Spanish Standard Sections from the 'Instituto Español de Oceanografía' (Vigo, Coruña, Asturias, Santander) and from AZTI (San Sebastián).

The Bay of Biscay, located in the eastern North Atlantic at the NE edge of the subtropical anticyclonic gyre, is almost an adjacent sea with weak anticyclonic circulation (1–2 $cm \cdot s^{-1}$). Shelf and slope currents are important in the system, characterized by coastal upwelling events in spring-summer and the dominance of a geostrophic balanced poleward flow (known as the IPC) in autumn and winter.

In the SE corner of the Bay of Biscay, relatively strong continental influence modifies both the temperature and salinity of the shelf waters. Nevertheless, the changes in salt and heat content in the water column, over the continental shelf and slope, cannot be explained fully by the local modification of the water masses (e.g., the increase of the heat content in the shelf waters, from summer to early autumn, as opposed to the atmospheric and sea surface cooling, should be explained by accumulation and downwelling of warm waters into the shelf area).

Meteorological Conditions

Atmospheric temperature

Meteorological conditions in the north of the Iberian Peninsula in 2013 indicate that it was an average year relative to the long-term period reference (1981–2010) with a very similar value than 2012. Annual mean air temperature was 14.5º C in Santander (43º30′N, 3º47′W). Towards the easternmost part of the Bay of Biscay, the annual air temperature average in 2013 at the Igeldo Meteorological Observatory (San Sebastian, 43°18.5′N, 02°2.37′W) was 13.32º C, 0.3º C below the 1986–2013 average.

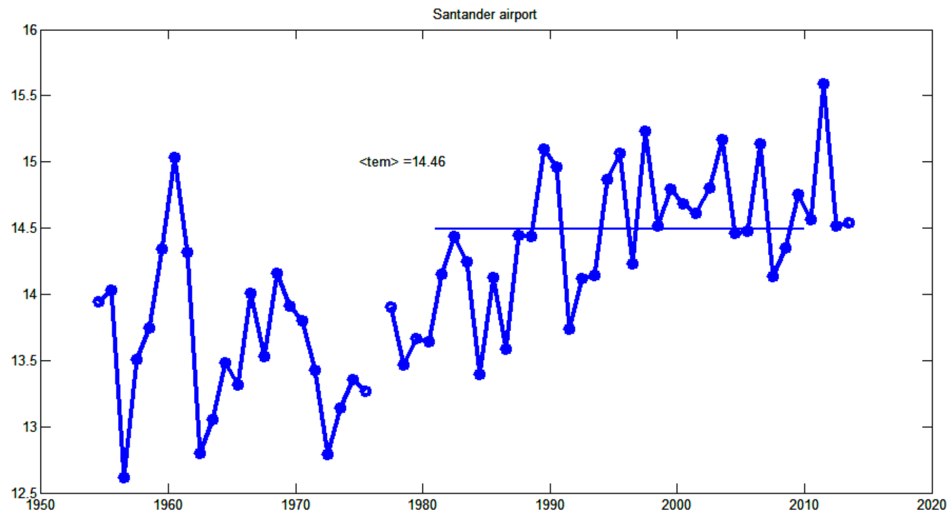
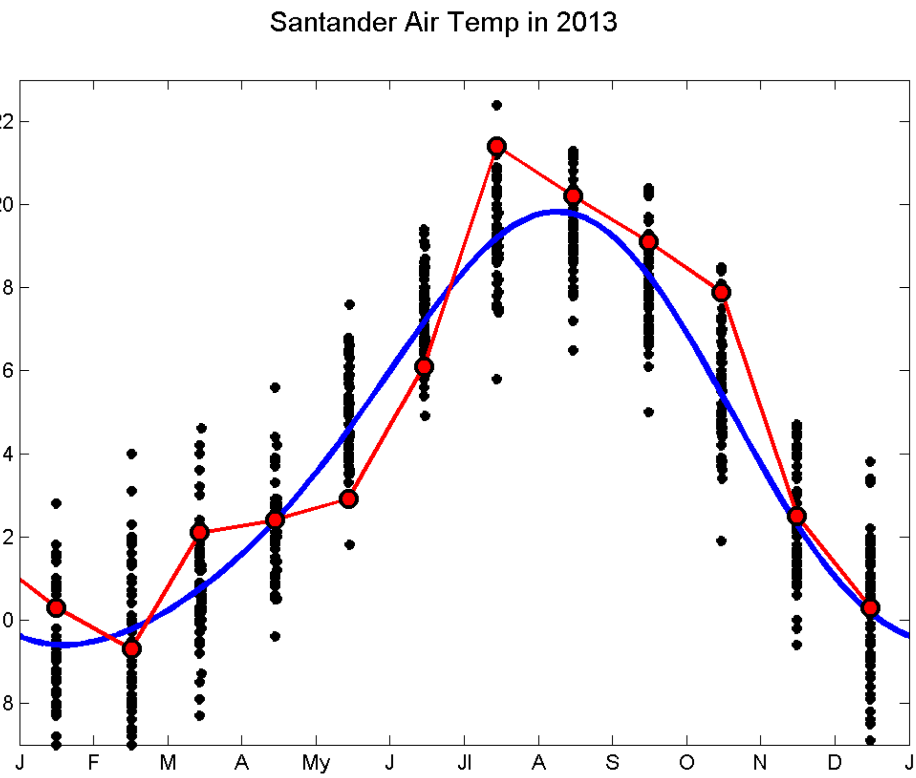


Figure 2. Air temperature in Santander meteorological station.

The seasonal cycle was characterized by strong asymmetry, colder than usual in the first half of the year (especially in spring) and warmer than usual in the second half (especially September-October) (Figure 3).



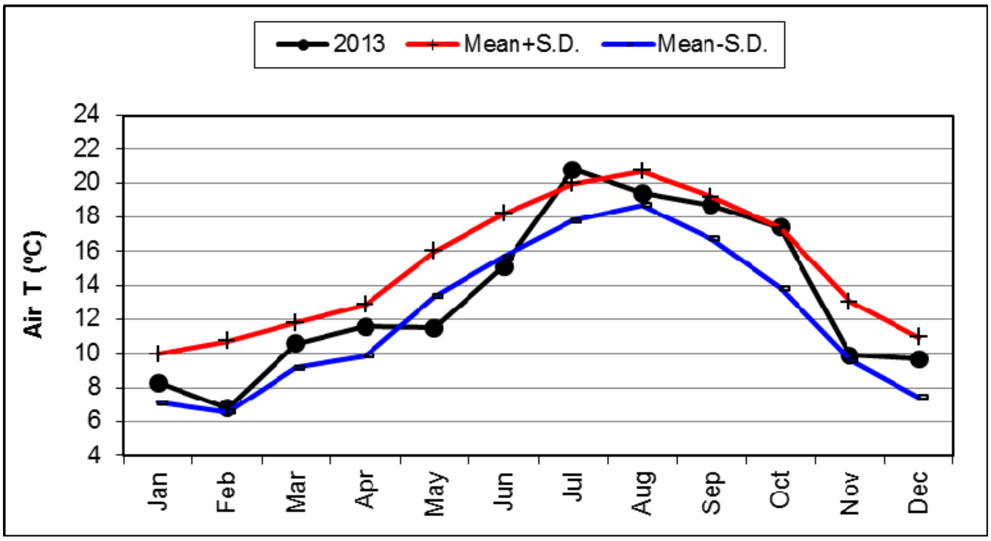


Figure 3. Monthly mean air temperature (°C) in in Santander (43º30′N, 03º47′W,upper) and San Sebastián (43°18.5′N, 02°2.37′W, lower) in 2013 compared with the mean ± standard deviation for the period 1986–2013. Courtesy of the 'Agencia Estatal de Meteorología.

Precipitation and evaporation

2013 can be characterised for being very wet year concerning the precipitation regime. Thus, winter and spring were very wet, around the average or above the average plus standard deviation for the period 1986–2013. Conversely, summer and autumn were dry, with the exception of November which was above the mean plus standard deviation for the period 1986–2013 (Figure 4). The annual mean precipitation was 179 mm, 53 mm above the 1986–2013 average (126 mm).

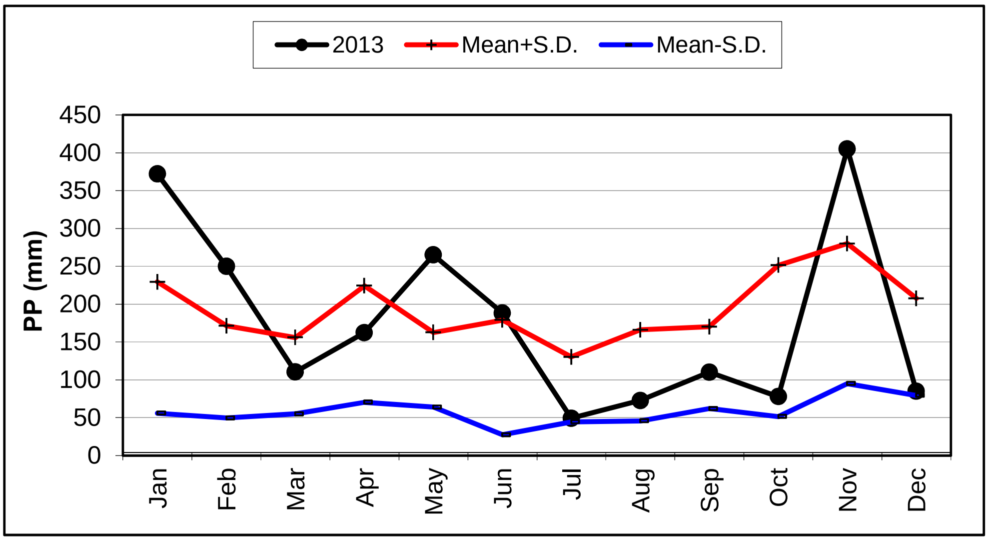


Figure 4. Monthly precipitation (mm) in San Sebastián (43°18.5′N 02°2.37′W) in 2013 compared with the mean ± standard deviation for the period 1986–2013. Data Courtesy of the 'Agencia Estatal de Meteorología'.

With regard to water balance, the year 2013, within the context of the previous years, shows an increasing trend in the precipitation, in terms of accumulated anomalies (Figure 5a). Also, the precipitation minus evaporation balance shows an increasing trend, in terms of water balance (Figure 5b).

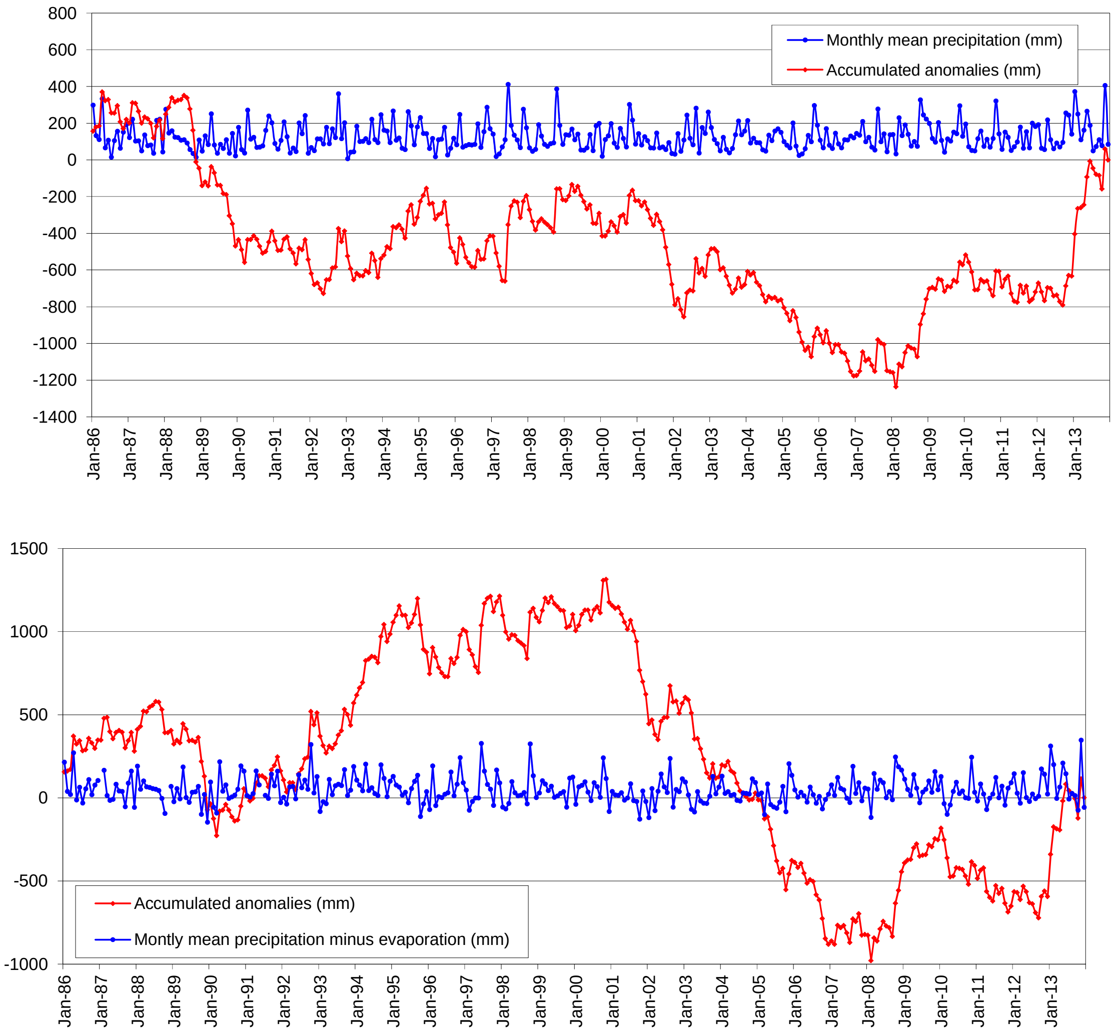


Figure 5. a) Monthly precipitation (mm) in San Sebastián (43°18.5′N 02°2.37′W) in 1986–2013 and accumulated anomalies.b) Same as (a) for precipitation minus evaporation (mm). Data Courtesy of the 'Agencia Estatal de Meteorología'.

Continental runoff

The Gironde river runoff values represent well the water inputs of continental origin 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 other small Cantabrian Rivers incoming into the SE Bay of Biscay (Table 1).

Table 1. Correlation matrix for the Gironde river flow, precipitation in San Sebastián (PP) and precipitation minus evaporation balance (PP-EV) in San Sebastián in a quarterly basis, for the period 1986–2013. NS: not significant; *P=0.01; **P=0.005 ***P=0.001.

	FLOW WINTER	FLOW SPRING	FLOW SUMMER	FLOW AUTUMN
PP WINTER	0.65***			
PP-EV WINTER	0.62***			
PP SPRING		NS		
PP-EV SPRING		NS		
PP SUMMER			0.44*	
PP-EV SUMMER			0.50**	
PP AUTUMN				0.47*
PP-EV AUTUMN				0.52**

The Gironde River flow in 2013, 1073 $m^3 \cdot s^{-1}$, was 248 $m^3 \cdot s^{-1}$ above the 1986–2013 average. On a monthly basis, the flow was around or above the average for the period 1986–2013, only with the exception of September, October and December where the flow was below monthly average for the period 1986–2013. In this context, the Gironde River flow is in agreement with the precipitation in San Sebastián (Fig. 5).

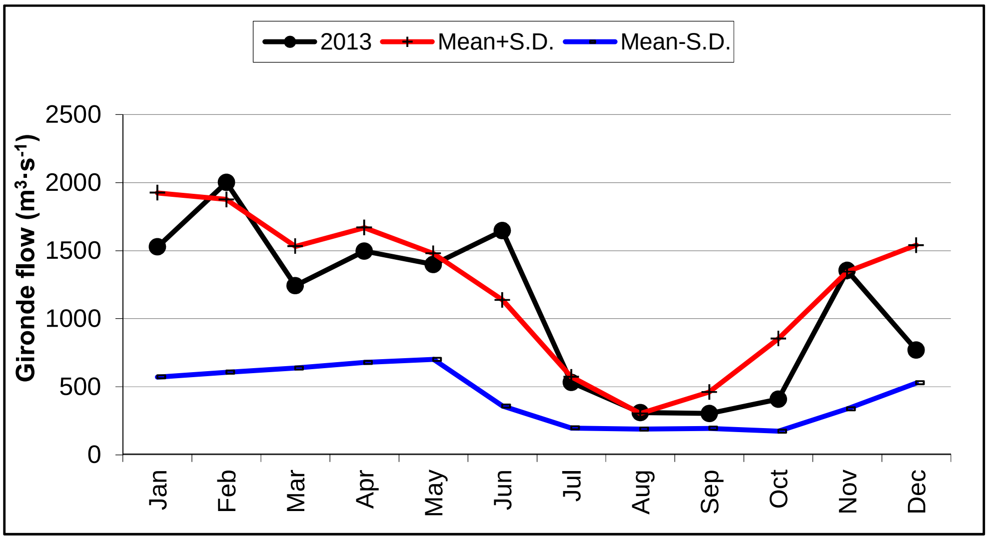


Figure 6. Monthly mean flow (m^3 s^{-1}) of the Gironde River in 2013 compared with the mean ± standard deviation for the period 1986–2013. Data Courtesy of the 'Bordeaux Harbour Authority'.

Hydrography

Coastal and shelf waters

Coastal and shelf waters properties are modulated by the combination of local air-sea forcing, the development shelf currents and the river runoff. All these forcings have a strong seasonal character with regional differences:

- Seasonal warming/cooling cycle is enhanced towards the south-eastern Bay of Biscay due to the continental effect.
- The effect of shelf-slope currents is enhanced at the western Iberian margin (Galician area). This happens for both the upwelling in summertime and the IPC in wintertime.
- Precipitation peaks during autumn-winter periods in the whole area. However, river runoff at the main French rivers (influencing the eastern Cantabrian Sea) is dominated by spring snowmelt at the Pyrenees, while there is no significant snow accumulation in north Spanish mountains. Therefore the salinity surface minimum is delayed as we move towards the east (Fig.7).

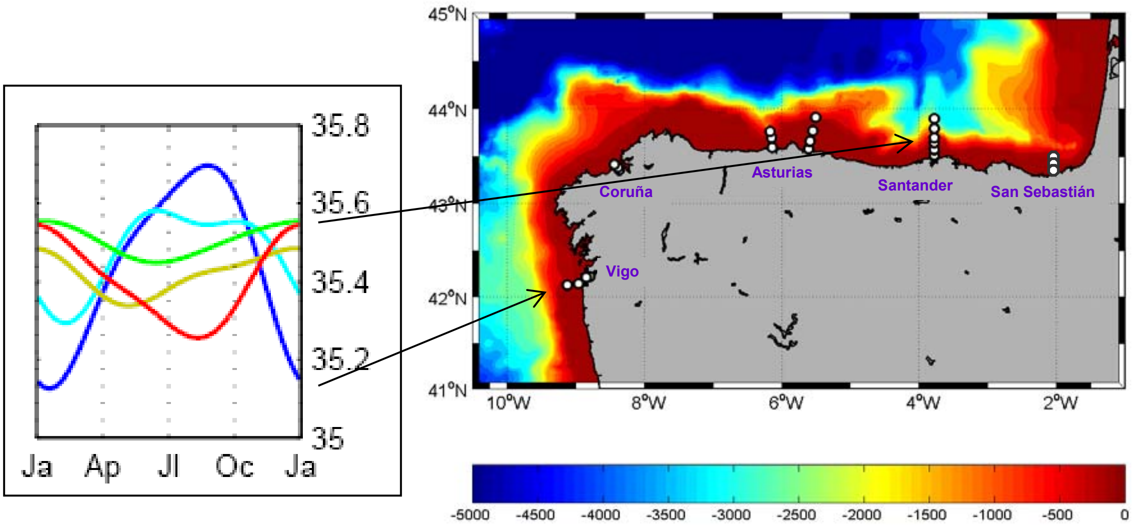


Figure 7. Surface salinity seasonal cycle at the shelf along the western Iberian margin and the Cantabrian Sea.

Contours of temperature and salinity (over the shelf, 100 m depth) in the Santander section are shown in Figure 8. The main characteristic of 2013 is that the subsurface structure was much fresher than in the two previous years, returning to the long-term average. Temperature has also dropped to average values after the previous two warm years. This behaviour is a combination of the atmospheric mild conditions plus enhanced rainfall together with a lack of strong signature of the Iberian Poleward Current. The overall combination of these features results, for the upper-ocean influenced by the mixed layer development (0–300dbar), in a year with the average values of salinity and temperature. This is an end of the high salinity anomaly that developed in 2011 and 2012.

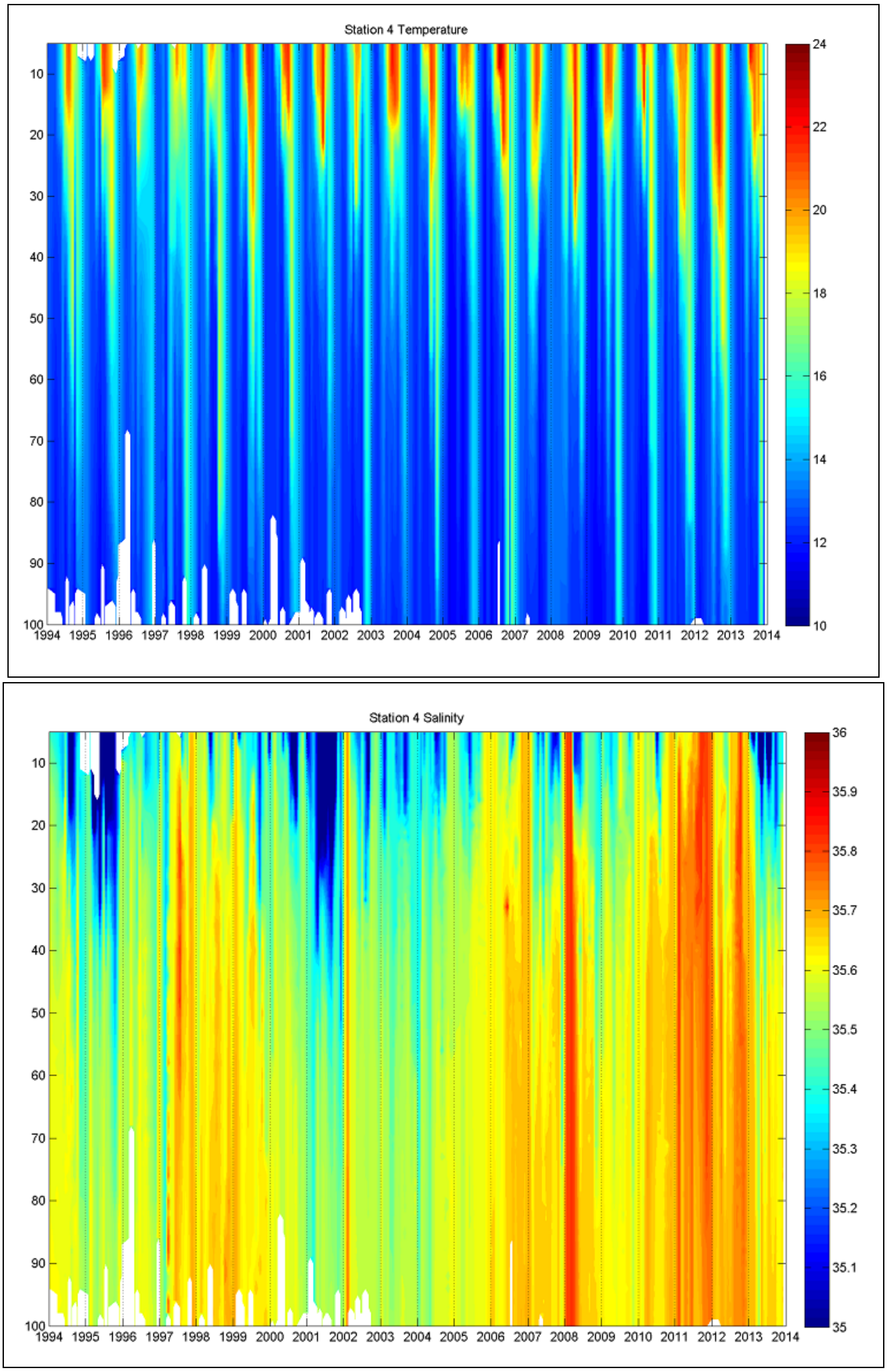
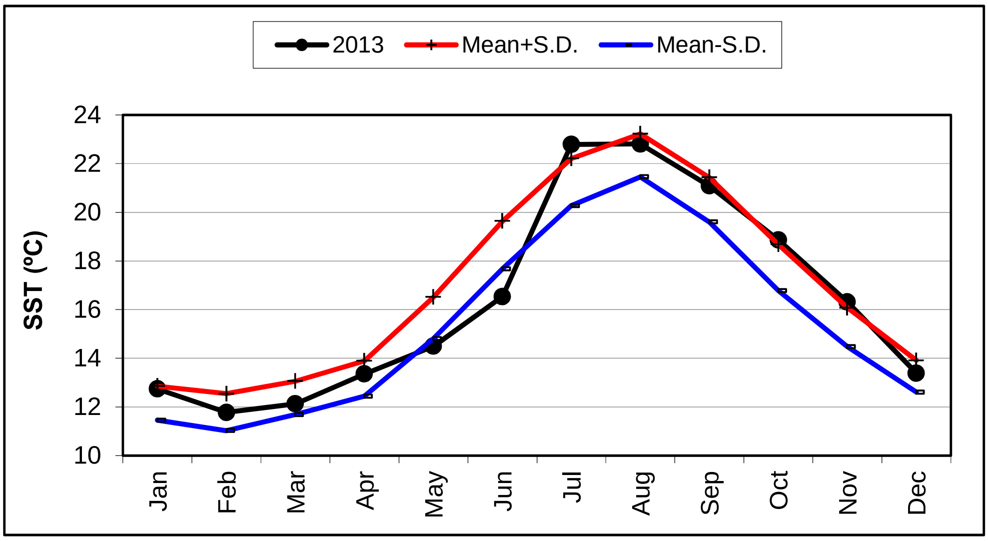


Figure 8.Time-series of temperature (upper) and salinity (lower) at the shelf at Santander (43º35′N,3º47′W).

Figure 9 shows the evolution of the monthly averaged sea surface temperature (SST) in 2013 in a station close to the coast (on the basis of a time-series obtained from the Aquarium of the Sociedad Oceanográfica de Gipuzkoa). Average sea surface temperatures can be observed in winter and cold SST in spring (with a few exceptions in January and April). Summer and autumn can be characterised for being very warm in terms of SST, around the mean plus the standard deviation for the period 1986–2013. Annual mean SST in 2013 was 16.36º C, 0.18º C above the 1986–2013 average.



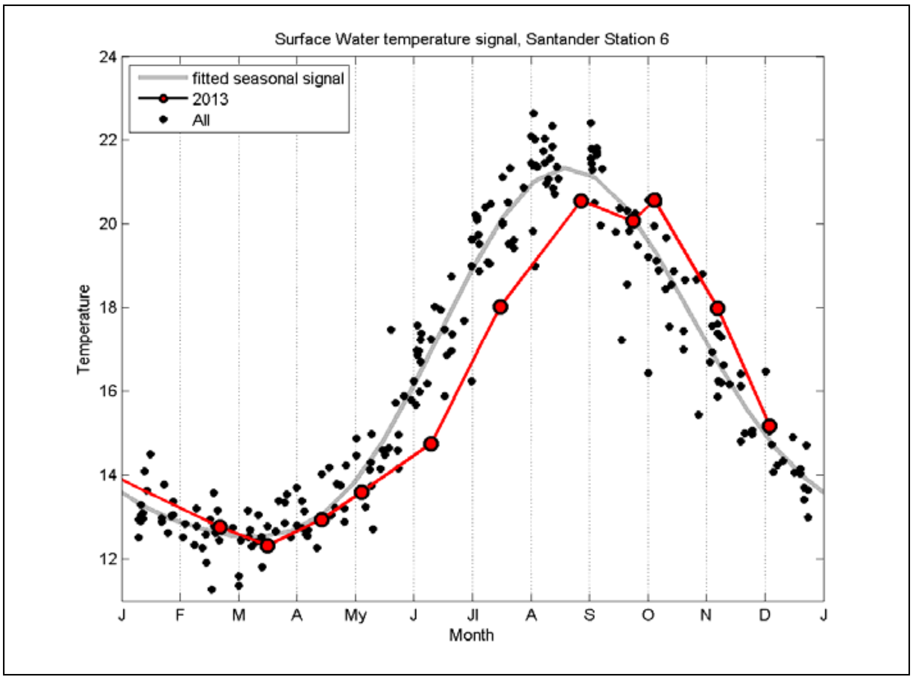


Figure 9. Monthly averaged sea surface temperature (°C) in San Sebastián (43°20′N 02°00′W) in 2013 in comparison with the mean ± standard deviation for the period 1986–2013 period. Data Courtesy of the 'Sociedad Oceanográfica de Gipuzkoa'. Lower panel is SST at station 6 in Santander (43° 42.6'N, 3° 47' W).

A detailed view of hydrographic conditions in 2013 at the southeasternmost Bay of Biscay can be summarised from TS diagram representing the waters over the continental shelf (43°30′N, 02°00′W) as shown in Figure 10.

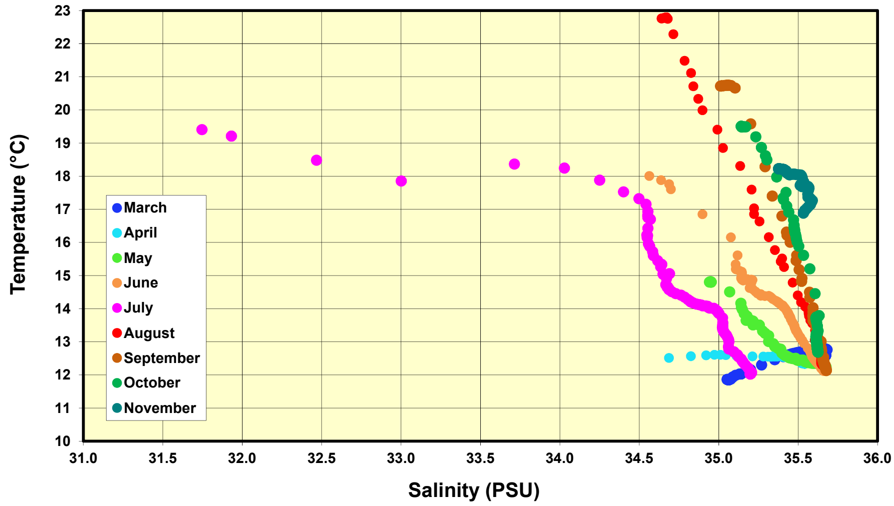


Figure 10. TS diagram of the waters over the continental shelf of the SE Bay of Biscay (43°30′N 02°00′W) in 2013.

As a result of the high precipitation (Figure 5), the TS diagram is characterised by a thermal inversion in March. Again, April is characterised by haline stratification due to the presence of waters of continental origin. The thermal stratification develops between May and October. The TS diagram shows that the period between June and July is characterised by termohaline stratification due to the contribution of the spring warming and the presence of waters of continental origin. The prevalence of thermal stratification is observed in the period August-October. Finally, the TS diagram is characterised by a relatively high haline and thermal content of the water column in November. This is consistent with the prevalence of downwelling and convergence in the area.

Table 2. Hydro-meteorological data in the shelf waters of San Sebastián (43°30′N 02°00′W) in 2013. Mean temperature and salinity calculated for the upper 100 m.

2013	**Air T (°C)**	**PP (mm)**	**Gironde flow ($m^3 s^{-1}$)**	**SST (ºC)**	**SSS (PSU)**	**Mean Temp. (ºC)**	**Mean Salinity (PSU)**	**Bottom Temp. (ºC)**	**Bottom Salinity (PSU)**	**14 ºC isotherm depth (m)**
January	8.30	371.9	1527	12.74		14.62	35.595			
February	6.80	249.8	1999	11.78		13.55	35.543			
March	10.60	110.4	1242	12.13	35.054	12.47	35.490	12.59	35.673	<14
April	11.60	162.4	1496	13.36	34.688	12.46	35.425	12.34	35.543	<14
May	11.50	265	1398	14.49	34.943	12.86	35.440	12.24	35.673	13
June	15.10	188.2	1646	16.54	34.563	13.97	35.364	12.19	35.648	52
July	20.80	49.2	532	22.79	31.747	14.24	34.779	12.03	35.200	53
August	19.40	72.6	310	22.81	34.641	15.19	35.391	12.30	35.653	37
September	18.70	110	303	21.08	35.012	14.52	35.514	12.15	35.677	33
October	17.40	77.8	408	18.86	35.144	14.76	35.520	12.81	35.621	37
November	9.90	405.1	1354	16.32	35.378	18.03	35.450	17.26	35.590	>14
December	9.70	84.8	769	13.39						

Slope and Oceanic waters

Contours of temperature and salinity over the shelf-break (600 m depth) in the Santander section are presented in Figure 11. The fresh patch seen at the shelf is also evident out at the slope but constrained to the surface (no insights of freshening on modal water so far). Figure 12 shows average TS values for the upper-ocean influenced by the mixed layer development (0–300 dbar) highlighting the return to normal values.

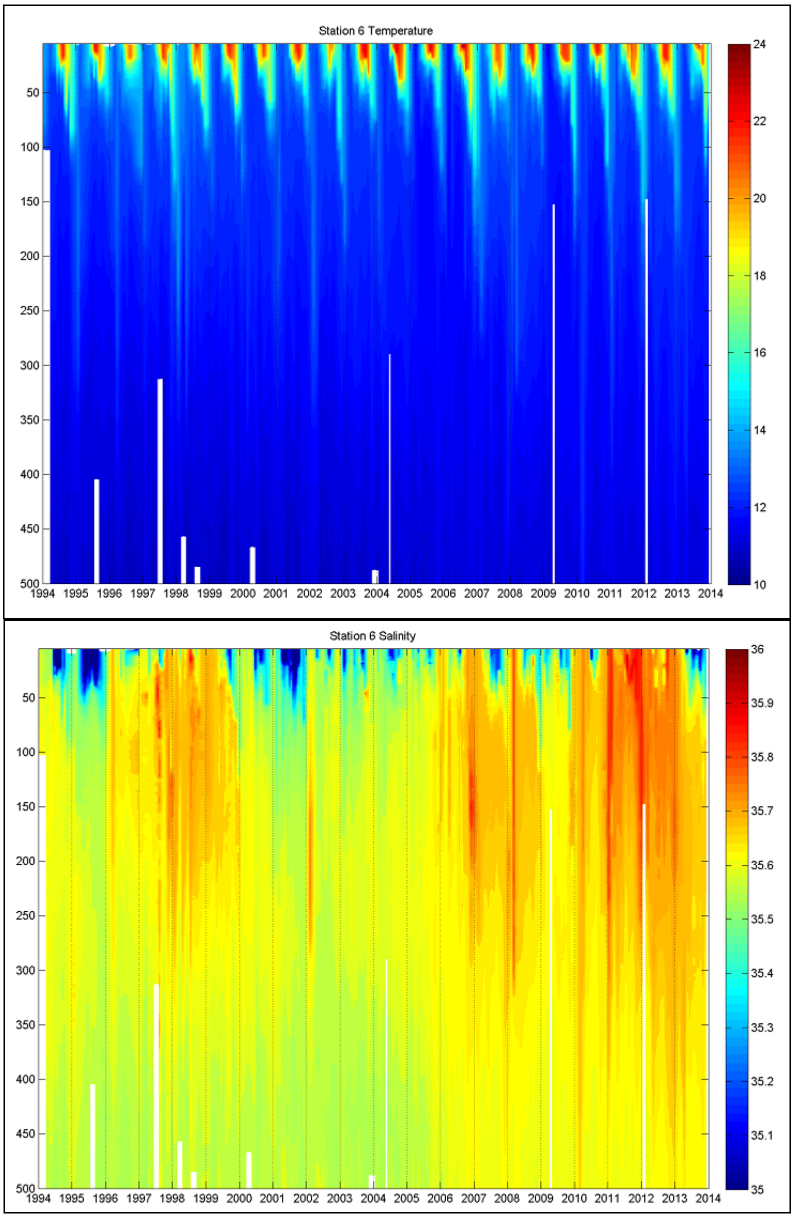
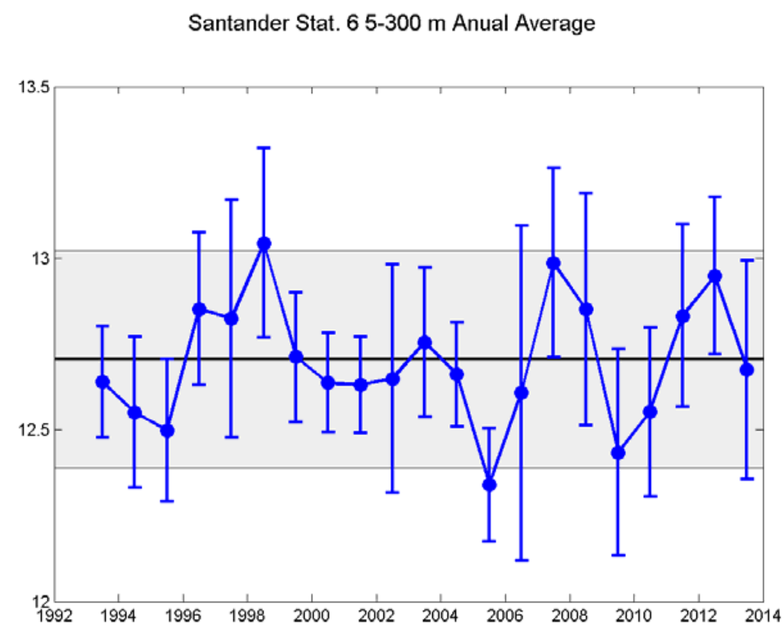


Figure 11.Time-series of temperature (up.) and salinity (low) at the slope at Santander (43º42'N,3º47'W).



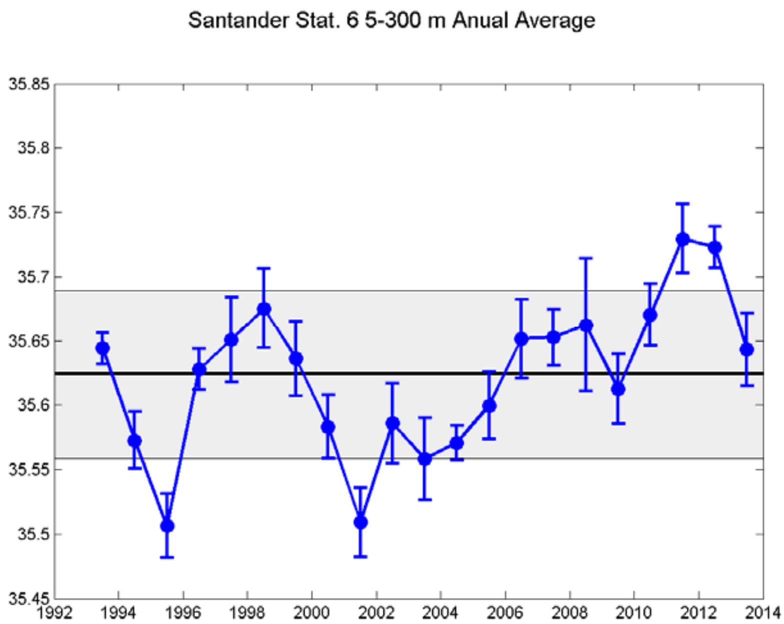


Figure 12.Temperature (up.) and salinity (low) averagesfor the upper 300 m. at the slope at Santander *(43º42′N,3º47′W).*

Deeper Water Masses

Figures 13–15 show the TS diagram and hydrographic series at isobaric levels from 200 to 1000 m depth over the slope in Santander (St 7). Overall warming trends are evident at most layers, corresponding to the East North Atlantic Central Water (200–600) and upper

Mediterranean Water (600–1000). Salinity also shows a notable increase along the whole series but less smooth than temperature. The water masses evolution is strongly influenced by a strong shift in salinity at lower ENACW (~400 m) in 2005 after the occurrence of very strong winter mixing.

In 2013, central waters continue the long-term warming trend and salt-increase. ENACW modal waters are at the highest values of the series. Since the start of the intermediate water series in1994 only a temporary drop was observed around 2009. Deeper at the level of the MW the water masses continues pretty stable since mid-00`s, slightly fresher at its core in 2011–2013 after peaking around 2007–2009.

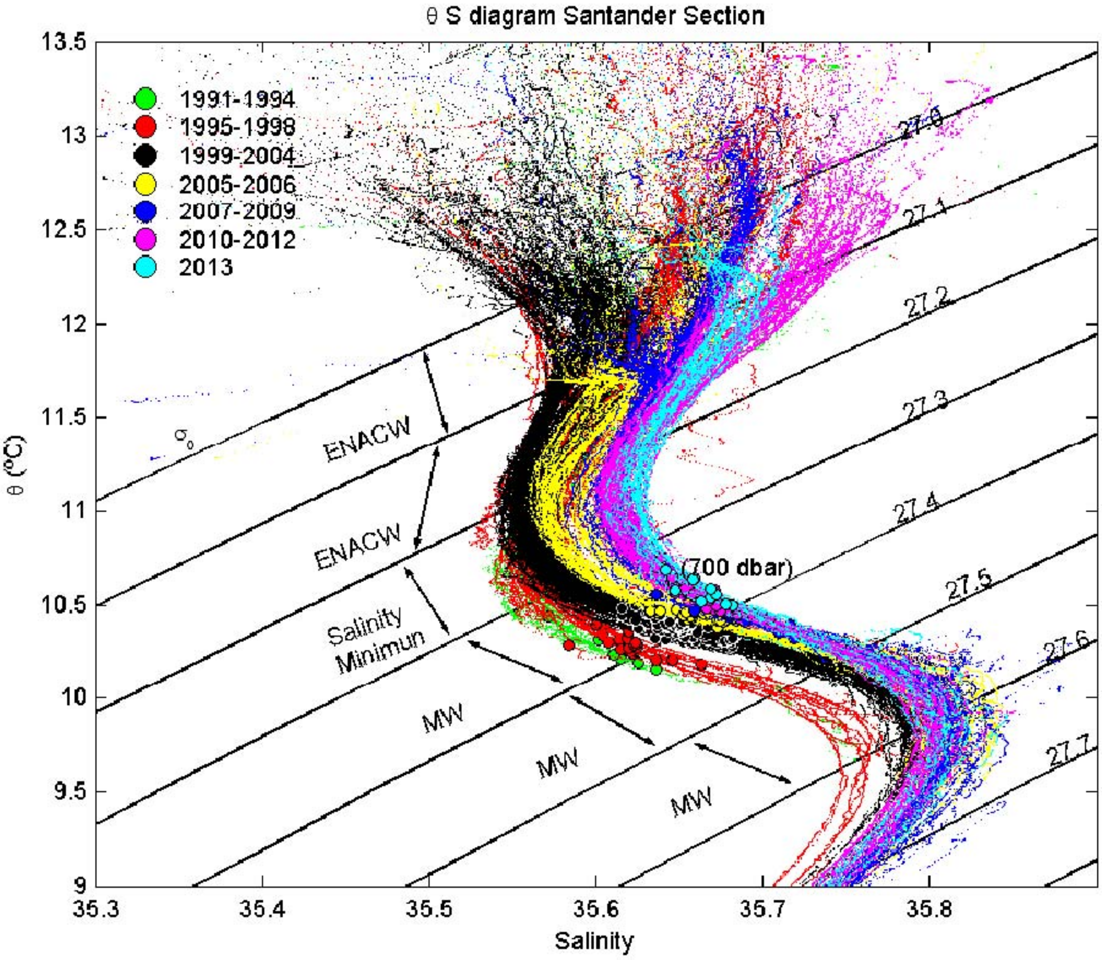


Figure 13. TS diagram of water mass properties at Santander station 7(43º 48′N, 3º 47′W) (outer slope).

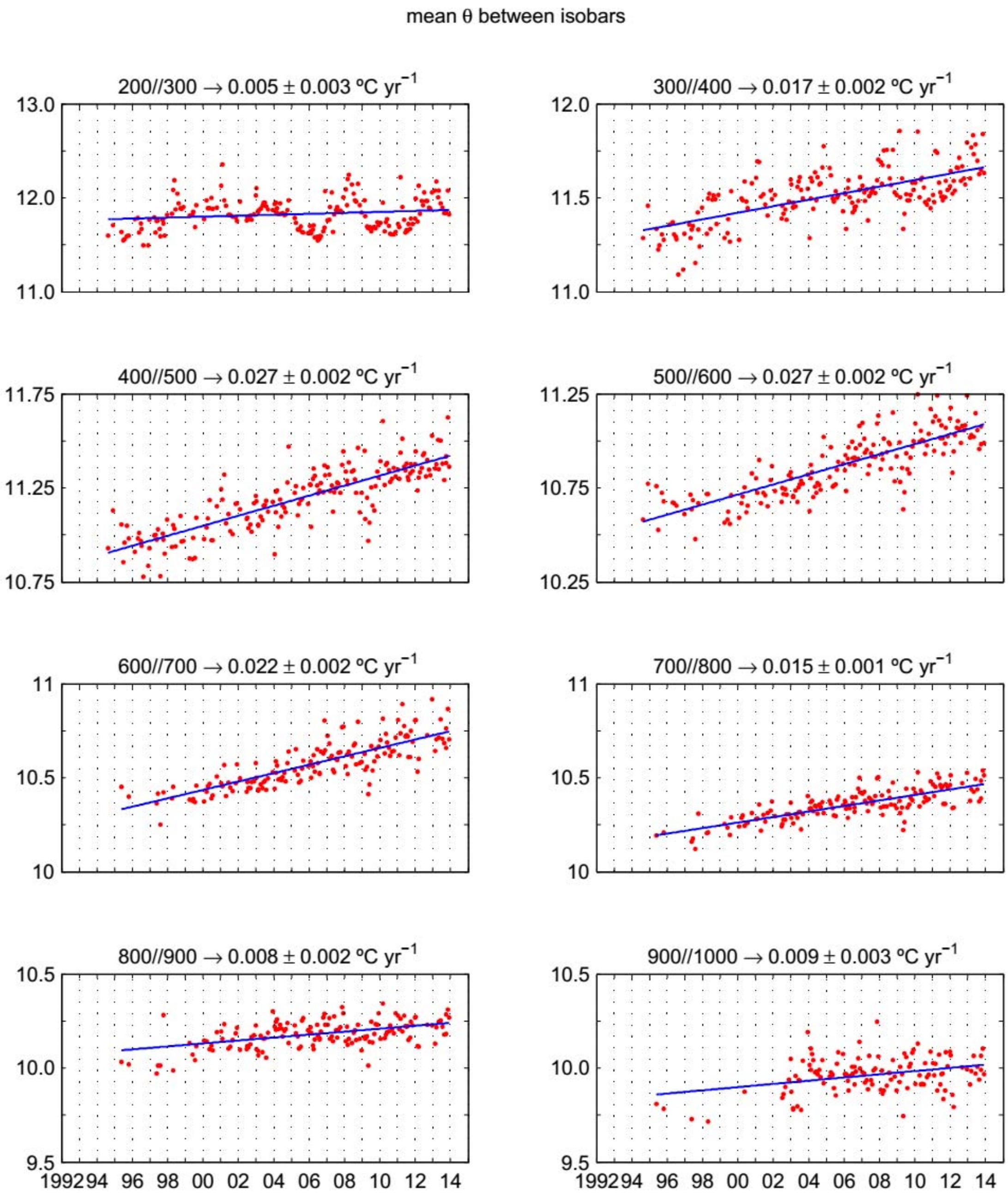


Figure 14. ENACW and MW potential temperature at Santander station 7(43º 48′N, 3º 47′W) (outer slope).

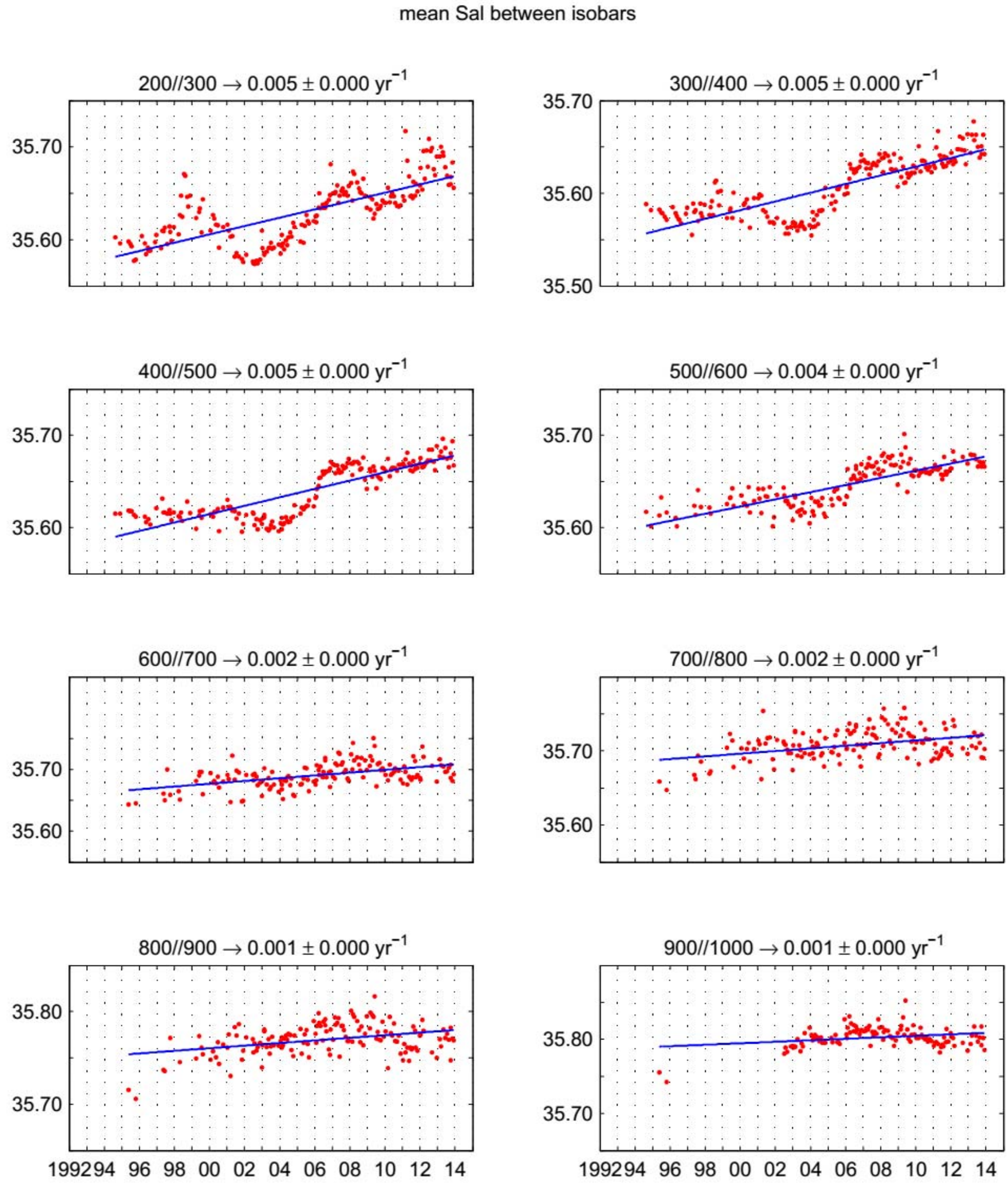


Figure 15. ENACW and MW salinity at Santander station 7(43º 48′N, 3º 47′W) (outer slope).

Annex 8: Regional report – Ellett line 2014 (Area 5)

National Oceanography Centre

Research & Consultancy Report No. 43

State of the eastern North Atlantic subpolar gyre: The Extended Ellett Line Programme Annual Report No. 2

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2014

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ABSTRACT

The Extended Ellett Line is a hydrographic section between Iceland and Scotland that is occupied annually by scientists from the National Oceanography Centre (NOC) and the Scottish Association for Marine Science (SAMS), UK. The measurement programme began as a seasonally-occupied hydrographic section in the Rockall Trough in 1975, building on early surface observations made underway from ocean weather ships. In 1996 the section was extended to Iceland, sampling three basins: the Rockall Trough, the Hatton-Rockall Basin and the Iceland Basin. This report presents a summary of data from the Extended Ellett Line programme as well as an overview of activities and analysis from the programme. Historical and recent physical data are analysed to calculate time series of temperature and salinity of the upper ocean and Labrador Sea Water in the eastern subpolar gyre. The most recent Extended Ellett Line cruise (May 2013) is shown as temperature, salinity and density sections.

KEYWORDS:

ISSUING ORGANISATION **National Oceanography Centre**
University of Southampton Waterfront Campus
European Way Southampton SO14 3ZH UK

PDF available at http://nora.nerc.ac.uk/

1. Introduction

The Extended Ellett Line is a hydrographic section between Iceland and Scotland that is occupied annually by scientists from the National Oceanography Centre (NOC) and the Scottish Association for Marine Science (SAMS), UK. The measurement programme began as a seasonally-occupied hydrographic section in the Rockall Trough in 1975, building on early surface observations made underway from ocean weather ships. In 1996 the section was extended to Iceland, sampling three basins: the Rockall Trough, the Hatton-Rockall Basin and the Iceland Basin (Figure 1). These three basins form the main routes though which warm saline Atlantic water flows northwards into the Nordic Seas and Arctic Ocean. The section crosses the eastern North Atlantic subpolar gyre; as well as the net northward flow there is a large recirculation of the upper layers as part of the wind-driven gyre. During its passage through the region, the warm saline water is subjected to significant modification by exchange of heat and freshwater with the atmosphere. The two deep basins (Rockall Trough and Iceland Basin) contain southward flowing dense northern overflow waters, and Labrador Sea Water in the intermediate layers.

This report presents a summary of temperature and salinity data from the Extended Ellett Line programme, alongside a review of recent and current research, and details of the impact of the research. The historical data set is analysed to calculate time series of temperature and salinity of the upper ocean and Labrador Sea Water in the eastern subpolar gyre. The most recent Extended Ellett Line cruise (May 2013) is shown as temperature, salinity and density sections.

The Extended Ellett Line programme is jointly led by Penny Holliday at NOC and Stefan Gary at

SAMS. For more detailed information visit the website: projects.noc.ac.uk/ExtendedEllettLine/

2. Current Research

In 2013 a peer-reviewed summary of the history of, and discoveries from, the Extended Ellett Line programme was published in Oceanography, the magazine of The Oceanography Society (Holliday and Cunningham, 2013). The article summarised research since sampling started in the region in 1948. It concludes with the message that while the time series can be supplemented with additional data from autonomous vehicles such as floats and gliders, only ship-based surveys can provide the high quality physical, chemical, and biological data that are necessary for understanding the changing environment in all depths of the ocean. The ship-based observations are also required for calibrating data from autonomous vehicles; without ship-based surveys the data from the floats and gliders become less valid.

A study of changing nutrient concentrations in the upper waters of the Rockall Trough (Johnson *et al.* 2013) showed that the declining values from 1996 to the mid-2000s was a direct result of the decreasing proportion of subpolar water masses reaching the basin. The decline in subpolar water was associated with a weakening subpolar gyre circulation. Since the mid-2000s the upper water properties have been more stable, and small changes likely the result of changes in the source regions for the warm water.

Meanwhile, a number of strands of new research are underway, including deriving a mean full depth velocity section from nearly 20 years of LADCP measurements (Elizabeth Comer, masters student at NOC), understanding interannual to deadal variability in carbon storage (Matthew Humphries, PhD student at NOC), long-term changes the volume transport through the section, and quantifying the long-term variability and uncertainty in physical properties from the section.

3. Impact

The Extended Ellett Line programme regularly provides advice to the public, government and policymakers through the media of climate status reports. The two most prominent reports are the annual ICES Report on Climate (IROC, Beszczynska-Moller and Dye, 2013), and the Annual Report Card of the Marine Climate Change Impacts Partnership, (MCCIP, http://www.mccip.org.uk, MCCIP 2013, Dye *et al.* 2013a, Dye *et al.* 2013b). Both use the Extended Ellett Line data along side other time series to build a picture of the ocean conditions over time. The main conclusions of the 2013 IROC (data from 2012) were that temperatures and salinity in the eastern subpolar region decreased to levels seen in early 2000s, while temperatures in the Norwegain and Barents Seas were above average, and upper layers of the northwestern subpolar region were warm in summer 2012. Salinity was high in the Greenland Sea and along the path of the East Greenland Current, but the surface waters of the subpolar gyre appeared to be freshening. The MCCIP ARC has as one of its key findings that ocean temperatures continue to show an overall upward trend despite short-term variability; they cite the example of the average coastal sea surface temperature that was lower in

2008–2012 than in 2003–2007, and this is also seen in the records from the Extended Ellett Line (see below).

Extended Ellett Line analyses have contributed to the enormous body of literature used to form the AR5 report by Working Group I of the Intergovernmental Panel on Climate Change (IPCC, http://www.ipcc.ch and www.climatechange2013.org, IPCC *et al.* 2013). Holliday *et al.* (2008) forms part of the evidence that the upper ocean of the North Atlantic is vigorously variable in salinity, and that changes in the subpolar region are advected into the Arctic. The report notes that while it is clear that there are times when more subtropical water is advected into the subpolar region, there is some debate about the causal mechanisms, and what the role of cross-equatorial transport of salt is.

4. Collaborative Work

The Extended Ellett Line forms part of the design for the international OSNAP array (Overturning in the Subpolar North Atlantic Programme www.ukosnap.org). The OSNAP array was designed to segue into the eastern part of the Extended Ellett Line in order to optimise sampling and to make use of existing observations and knowledge. OSNAP will use gliders and moorings to measure volume and heat flux through the subpolar region including the Iceland Basin, the Hatton-Rockall Basin and the Rockall Trough, and both programmes will benefit from this co-ordinated approach. The OSNAP observations programme begins in summer 2014.

The 2014 Extended Ellett Line survey (June-July) will be a joint cruise between this project, UK OSNAP, and RAGNARoCC (Radiatively Active Gases from the North Atlantic Region and Climate Change), a NERC-funded project. By scheduling surveys for all these programmes together we are maximising the resources available for shiptime, as well as optimising potential for analysis.

The Extended Ellett Line is a partner in GO-SHIP (Global Ocean Ship-based Hydrographic Investigations Programme www.go-ship.org) which is an organisation that "brings together scientists with interest in physical oceanography, the carbon cycle, marine biogeochemistry and ecosystems ... to develop a sustained global network of hydrographic sections as part of the Global Ocean / Climate Observing System". GO-SHIP has document the fact that "despite numerous technological advances over the last several decades, ship-based hydrography remains the only method for obtaining high- quality, high spatial and vertical resolution measurements of a suite of physical, chemical, and biological parameters over the full water column. Ship-based hydrography is essential for documenting ocean changes throughout the water column, especially for the deep ocean below 2 km (52% of global ocean volume not sampled by profiling floats)".

The Extended Ellett Line programme devotes significant resources to training students (undergraduate, masters levels and PhD). The extensive historical data resources is held in matlab form to be instantly accessible by students, and is used for several projects and dissertations each year. Each cruise has several berths set aside for students who come to learn new skills, collect data for a project or test their new sensors and techniques. Since 1996 students from 25 different universities and centres have benefitted from free places on Extended Ellett Line cruises; in 2013 we hosted students from University of Liverpool, University of Bristol, University of Southampton and University of Highlands and Islands.

5. The May 2013 Iceland–Scotland hydrographic section

The 2013 Iceland-Scotland section was carried out on RRS *James Cook* cruise JC086 in May. Colin Griffiths (SAMS) was principle scientist and details of the full suite of data collected can be found at

www.bodc.ac.uk/data/information_and_inventories/cruise_inventory/report/13389/. The cruise enjoyed good weather throughout and the section was completed without interruption. Figure 2 shows the potential temperature, salinity and potential density for the full section.

6. Temperature and salinity time series for the upper ocean

The Extended Ellett Line upper ocean data are presented as time series of potential temperature and salinity (Table 1 and Figure 3). The Rockall Trough time series is well-established (e.g. Holliday *et al.* 2000, Beszczynska-Moller and Dye, 2013); the "upper ocean" is calculated as an average of data from 30–800 dbar between Rockall and the outer Scottish continental shelf (black dots in Figure 1). The 800 dbar limit is selected because it marks the top of the permanent thermocline, or the base of the dominant water mass, the Eastern North Atlantic Water. By ignoring the very surface layer we hope to reduce temporal aliasing. However it should be noted that the upper ocean is subject to a seasonal cycle in properties (deep winter mixing to 600–800m depth, and spring/summer surface warming), and some aliasing of the seasonal cycle is inevitable. The Rockall Trough part of the Extended Ellett Line began in 1975 (black dots in Figure 1); present day conditions are warm and saline in the upper ocean compared to the long-term mean despite a recent decline in both parameters (black lines in Figure 3). Between 1975 and 1995 the mean temperature of the upper ocean in the Rockall Trough was 9.2±0.3 °C. A warming trend from 1995 to 2005 reached a peak of 10.1°C before cooling to 9.3°C in 2013. Upper ocean salinity in the Rockall Trough was at a minimum in the late 1970s (35.27) during the Great Salinity Anomaly, rose to a maximum around 1983 (35.37), decreased in the 1990s, then rose again to a maximum of 35.41 in 2010. Salinity in 2013 was notably low, and this change has been observed in other time series in the eastern subpolar North Atlantic (IROC 2013, in prep).

The upper ocean in the Hatton-Rockall Bank (red dots in Figure 1) is defined in the same way (30–800 dbar) because the permanent thermocline is found at similar depths (Figure 2). The shorter time series shows a similar pattern of variability as the Rockall Trough though the amplitude of the interannual variability is higher (red lines in Figure 3). In the Iceland Basin (blue dots in Figure 1), the upper ocean is defined as 30–600 dbar since the permanent thermocline is shallower here (Figure 2). Different water masses are present in the Iceland Basin, and the region is an area of active modification of mode waters. The time series of temperature and salinity show similar patterns of variability as the other two basins, but the multi-year trend is less clear (blue lines in Figure 3).

7. Temperature and salinity time series for intermediate waters

The intermediate layers of the two deep basins, the Rockall Trough and Iceland Basin, are filled with Labrador Sea Water (LSW). The core of the LSW can be identified by a layer of well mixed, low- stratification water; the signature of its origins as a surface water mass subjected to very deep convective mixing in winter. Formally this can be detected as a minimum in potential vorticity calculated at the two deepest stations, Station M in the Rockall Trough (57.30°N 10.38°W) and at station IB12 in Iceland Basin (60.0°N 20.0°W). The evolution of the LSW properties in the two basins is rather different (Table 2 and Figure 4); in the Rockall Trough, temperature and salinity has been rather stable over the past 15 years, and both remain low compared to the early part of the time series. In the Iceland Basin, there is a slight trend of increasing temperature and salinity of LSW since the late 1990s.

Table 1. Time series of temperature and salinity of the upper ocean in the Rockall Trough (30–800 dbar), Rockall-Hatton Basin (30–800 dbar) and Iceland Basin (30–600 dbar).

Date	Rockall Trough		Hatton-Rockall Basin		Iceland Basin	
	Potential Temp °C	Salinity	Potential Temp °C	Salinity	Potential Temp °C	Salinity
1975.34	8.84	35.304				
1975.51	9.14	35.284				
1975.86	9.50	35.303				
1976.25	8.96	35.271				
1976.39	9.02	35.269				
1977.29	8.83	35.281				
1977.35	8.78	35.274				
1977.64	9.22	35.280				
1978.30	8.84	35.297				
1978.43	8.89	35.301				
1978.61	9.14	35.288				
1978.69	9.24	35.322				
1978.85	9.54	35.307				
1979.39	8.88	35.309				
1979.71	9.54	35.344				
1979.83	9.33	35.340				
1980.34	8.98	35.338				
1981.08	9.14	35.364				
1981.30	9.14	35.347				
1981.53	9.50	35.331				
1981.79	9.56	35.334				
1983.40	9.22	35.363				
1983.63	9.35	35.373				
1984.90	9.52	35.357				
1985.07	9.25	35.368				
1985.36	9.06	35.353				
1985.64	9.46	35.352				
1987.03	9.17	35.329				
1987.33	8.87	35.341				
1988.47	9.30	35.332				
1989.07	9.32	35.322				
1989.35	8.81	35.297				
1989.60	9.18	35.321				
1989.90	9.52	35.339				
1990.49	9.08	35.320				
1990.67	9.29	35.308				
1992.74	9.26	35.314				
1993.37	9.09	35.313				
1993.69	9.38	35.305				
1994.21	8.85	35.320				
1994.35	8.60	35.298				
1994.63	9.10	35.303				
1994.90	9.42	35.321				
1995.58	9.35	35.338				
1996.75	9.12	35.277	8.46	35.194	8.75	35.210
1997.70	9.72	35.358	9.01	35.272	8.76	35.218
1998.40	9.38	35.369	9.07	35.320	8.66	35.263

1999.70	9.65	35.370	9.07	35.288	8.93	35.226
2000.11	9.56	35.372				
2000.38	9.28	35.353				
2001.35	9.26	35.350	8.62	35.263	8.11	35.207
2003.30	9.60	35.401				
2003.56	9.91	35.407				
2004.54	9.88	35.402	9.41	35.332	8.96	35.265
2005.80	9.93	35.391			8.67	35.237
2006.82	10.13	35.390	9.70	35.332	8.97	35.227
2007.66	10.02	35.396	9.57	35.333	8.92	35.243
2008.39	9.90	35.409				
2009.46	9.77	35.411	9.16	35.344	8.44	35.261
2010.38	9.63	35.412	9.02	35.313	8.28	35.230
2011.42	9.56	35.401	9.05	35.311	8.49	35.246
2012.59	9.68	35.374	9.37	35.290	9.03	35.230
2013.37	9.38	35.369	9.05	35.267	8.06	35.180

Table 2. Time series of temperature and salinity of the Labrador Sea Water in the Rockall Trough (Station M, 57.30°N 10.38°W) and Iceland Basin (Station IB12 60.0°N 20.0°W).

Date	Rockall Trough		Iceland Basin	
	Potential Temp °C	Salinity	Potential Temp °C	Salinity
1975.34	3.76	34.983		
1975.51	3.63	34.967		
1975.86	3.71	34.986		
1976.25	3.96	34.981		
1976.39	3.55	34.951		
1977.29	3.54	34.967		
1977.35	3.59	34.965		
1977.64	3.71	34.953		
1978.30	3.48	34.972		
1978.61	3.61	34.962		
1978.69	3.99	34.999		
1978.85	3.80	34.971		
1979.39	3.86	35.001		
1979.71	3.62	34.981		
1980.34	3.47	34.991		
1981.08	3.89	34.974		
1981.30	3.44	34.979		
1981.79	3.37	34.978		
1983.63	3.45	34.972		
1985.36	3.67	34.944		
1985.64	3.81	34.946		
1987.03	3.46	34.952		
1987.33	3.48	34.952		
1988.47	3.67	34.961		
1989.07	3.93	34.968		
1989.35	3.70	34.971		
1989.60	4.02	34.974		
1989.90	3.64	34.955		
1990.49	3.61	34.947		
1990.67	3.47	34.917		
1992.74	3.24	34.942		
1993.37	3.42	34.941		
1993.69	3.67	34.925		
1994.21	3.51	34.940		
1994.35	3.38	34.943		
1994.63	3.73	34.931		
1994.90	3.81	34.937		
1995.58	3.61	34.931		
1996.75	3.49	34.932		
1997.70	3.46	34.927	3.45	34.888
1998.40	3.62	34.936	3.22	34.891
1999.70	3.39	34.931	3.42	34.898
2000.11	3.31	34.926		
2000.38	3.15	34.931		
2001.35	3.27	34.924	3.11	34.890
2003.30	3.38	34.924		
2003.56	3.33	34.929		

2004.54	3.37	34.912	3.46	34.894
2005.80	3.23	34.940		
2006.82	3.30	34.923	3.54	34.908
2007.66	3.21	34.927		
2008.39	3.88	34.942		
2009.46	3.47	34.931	3.55	34.912
2010.38	3.53	34.930	3.56	34.910
2011.42	3.53	34.929	3.80	34.918
2012.59	3.27	34.924	3.70	34.914
2013.37	3.74	34.946	3.78	34.916

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Figures

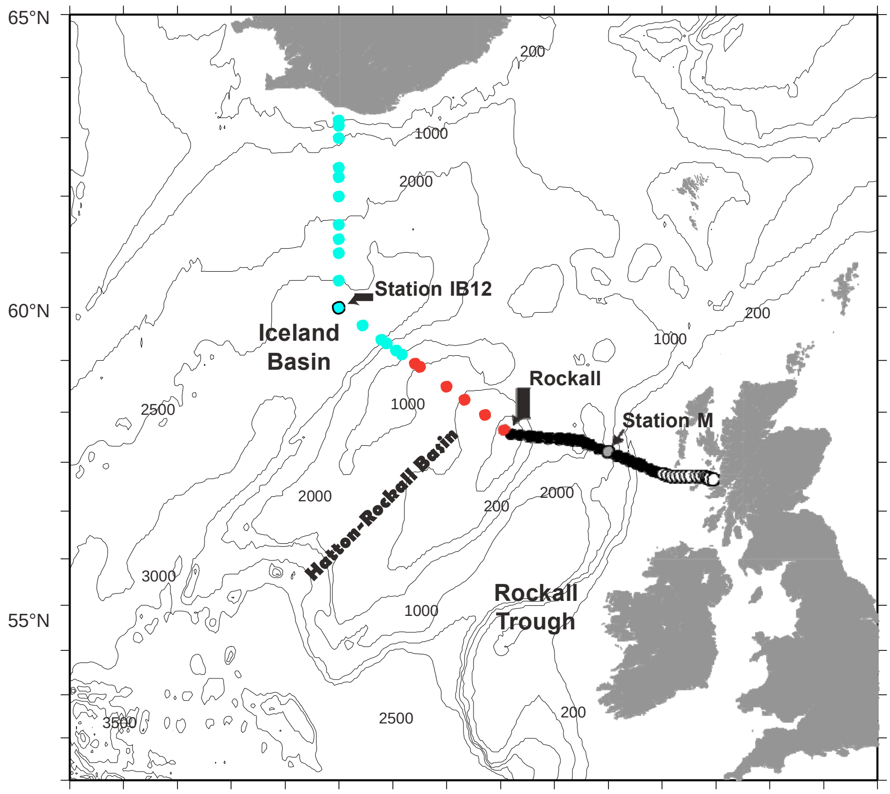

Figure 1. **Location of the Extended Ellett Line, a hydrographic section between Iceland and Scotland. Each dot represents the position of a standard station, and the different colours indicate the stations used in calculating the time series shown here. Open circles are continental shelf stations, filled black dots are Rockall Trough stations, red dots are Hatton-Rockall Basin stations, blue dots are Iceland Basin Stations. Stations M and IB12 are labelled; these are the deep stations where Labrador Sea Water properties are examined. Bathymetry contours are labelled in metres (200, 1000, 2500, 3000, 3500m).**

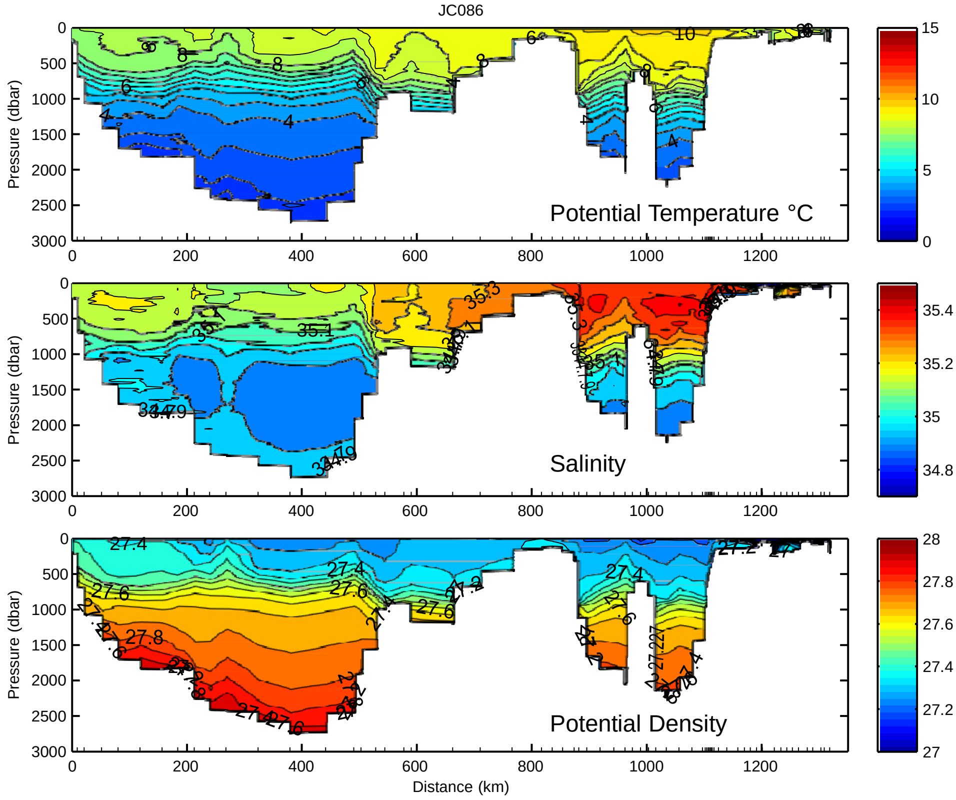

Figure 2. Temperature, salinity and density of the eastern North Atlantic subpolar gyre; the Extended Ellett Line in May 2013. The section runs north to south, horizontal axis given in kilometres from the first station off the Iceland coast, last station is on the Scottish continental shelf.

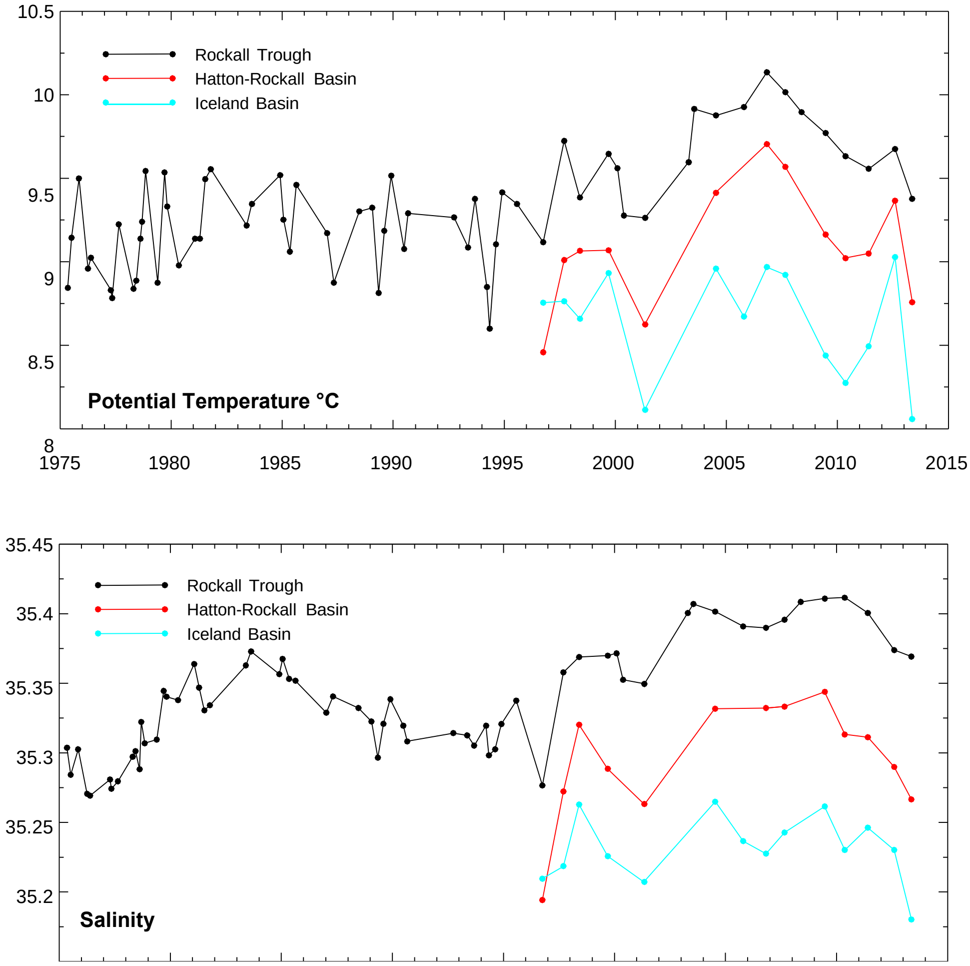

Figure 3. Temperature (top panel) and salinity of the upper ocean in the Rockall Trough (black), Hatton-Rockall Basin (red), and Iceland Basin (blue). Upper ocean defined as 30–800m in Rockall Trough and Hatton-Rockall Basin, and as 30–600m in Iceland Basin. Continental shelf stations are not included in this figure (see Figure 1).

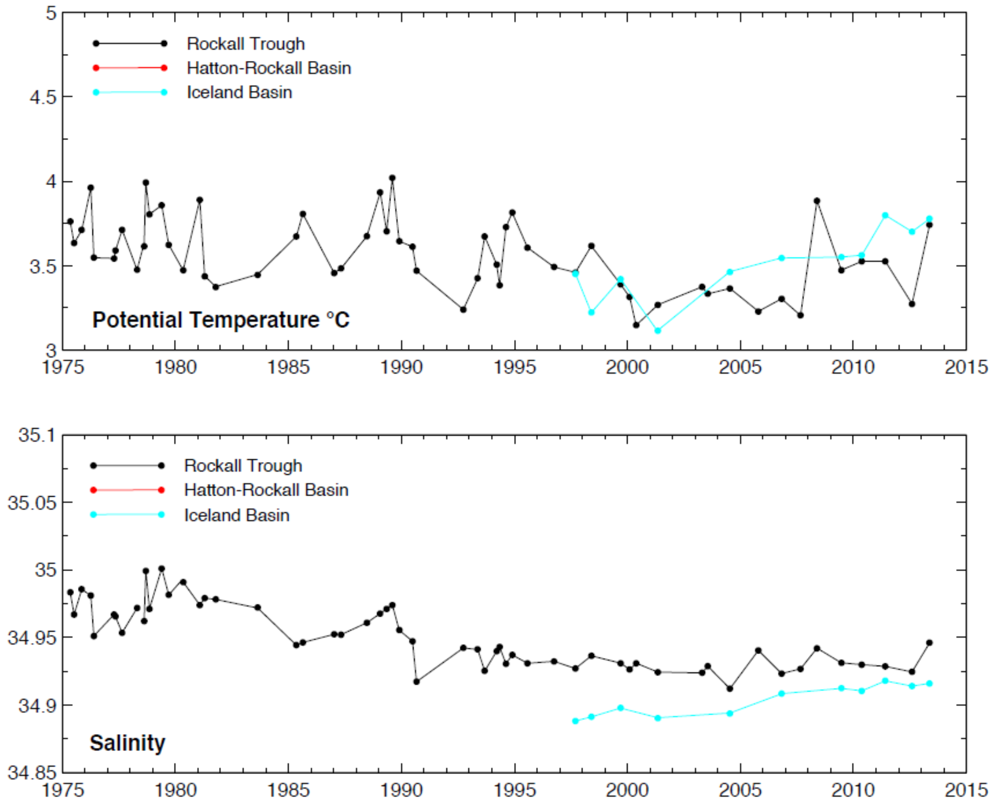

Figure 4. Temperature (top panel) and salinity of the Labrador Sea Water in the Rockall Trough (black) and Iceland Basin (blue). Properties extracted from deep (1800–2000 dbar) potential vorticity minimum at station M in Rockall Trough (57.30°N 10.38°W) and at station IB12 in Iceland Basin (60.0°N 20.0°W). The Hatton-Rockall Basin is too shallow to contain LSW.

Annex 9: Regional report – Norwegian Waters 2013 (Areas 8–11)

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Main summary

The temperatures of the inflowing Atlantic water were in 2013 close to the long-term means (1981–2010), except in the Barents Seas where it was considerable warmer than normal. In the North Sea and Skagerrak, the heat content reduced mainly due to reduced inflow of Atlantic Water. The observed transport of Atlantic water to the Norwegian and Barents Sea has been stable and normal since 2007. The Barents Sea was ice free during late summer 2013 as in 2012.

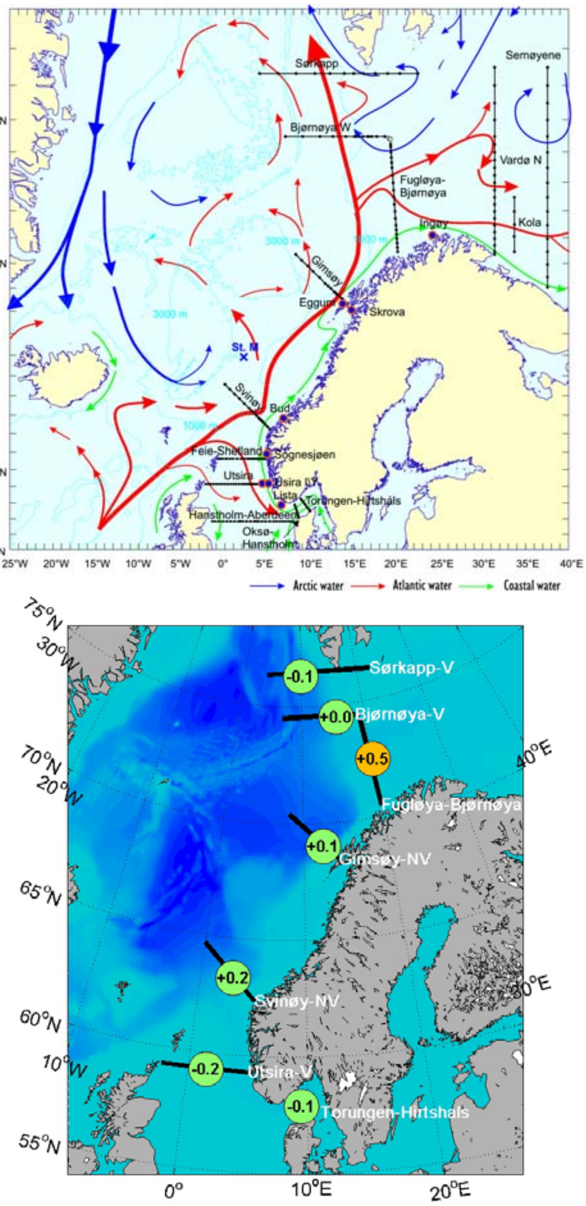

Figure 1. Standard sections and fixed oceanographic station worked by Institute of Marine Research, Bergen. The main surface currents are also shown. Right: Annual temperature anomalies (50–200 m) relative to 1981–2010 at the standard sections for 2013.

The Norwegian Sea

Kjell Arne Mork

Summary

- The temperatures in the Atlantic water along the Norwegian continental shelf were in 2013 close to normal
- The salinity was in 2013 lower than 2012 but still above the long-term mean
- In the southern Norwegian Sea, Northeast of the Faroese and Iceland, the temperatures in the spring were considerable higher than normal, up to 1°C above the long-term mean.
- The areas of Atlantic and Arctic waters in the southern Norwegian Sea were relatively high and low, respectively
- The volume transport of Atlantic water to the Norwegian Sea was in 2013 equal to the long-term mean

The hydrographic condition in the Norwegian Sea is characterized by relatively warm and salt water in the east due to the inflow of the Atlantic water from the south. In the west, however, the hydrographic condition is also influenced by the fresher and colder Arctic water that arrive from the Iceland and Greenland Seas (Fig. 1.)

Fig. 2 shows the development of temperature and salinity in the core of Atlantic Water for the sections in the eastern Norwegian Sea during 2013 (Fig. 1). At the Svinøy section, the temperature was near or above the normal throughout 2013. Compared with last year, the temperature was lower in the spring but higher later in the year. On average the temperature was for 2013 at the Svinøy section 0.2°C above the normal. Further north, the temperatures were lower and higher than normal in the spring and the summer, respectively. The temperatures were there also significantly lower in 2013 compared to 2012. The salinity in the sections was in 2013 lower than in 2012 but still higher than normal.

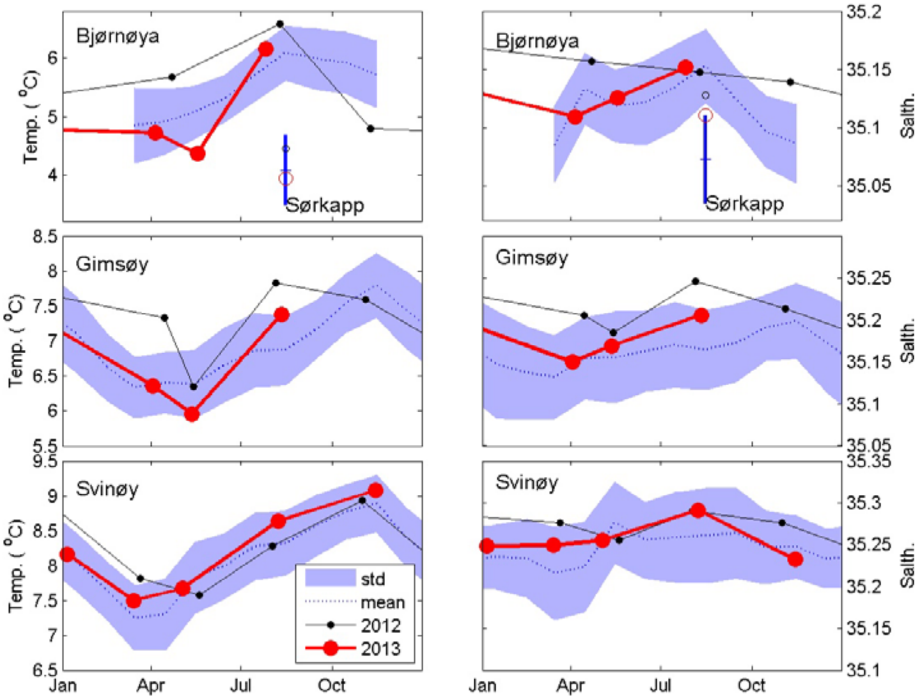

Figure 2. Temperature (left) and salinity (right) in the core of Atlantic water), averaged between 50 and 200 m depth, for the sections Bjørnøya-W (upper figures), Gimsøy-NW (middle figures), Svinøy section (lower figures) and Sørkapp-W section (in the upper figure, only for August) for the years 2013 and 2012.

There has been an increase of temperature and salinity in all sections from the 1970s to present where 2007 was the warmest year ever since the time-series started in 1977 (Figure 3). Then the annual mean temperatures in the sections were 0.6–0.8ºC above the long-term means. After around 2000, the annual means have usually been over the long-term means but have had several oscillations of 2–5 years duration. The temperatures seem to have a slight downward trend the recent years at all sections. The Atlantic water along the continental slope has since the mid-1990s been significantly saltier in all sections. In the recent years, however, the salinity decreased but is still above the long-term average. The large temperature and salinity increase observed since the late 1990s is mainly due to warmer and saltier inflowing water from the North Atlantic to the Norwegian Sea. In 2013, the annual temperature averages were about 0.2 ºC, 0.1 ºC, and 0.0 ºC above the long-term-means for the time series in the Svinøy, Gimsøy and Bjørnøya sections, respectively, and 0.1 ºC below the long-term-mean in the Sørkapp-W section. The salinity anomalies in the sections were above normal in 2013 for all sections.

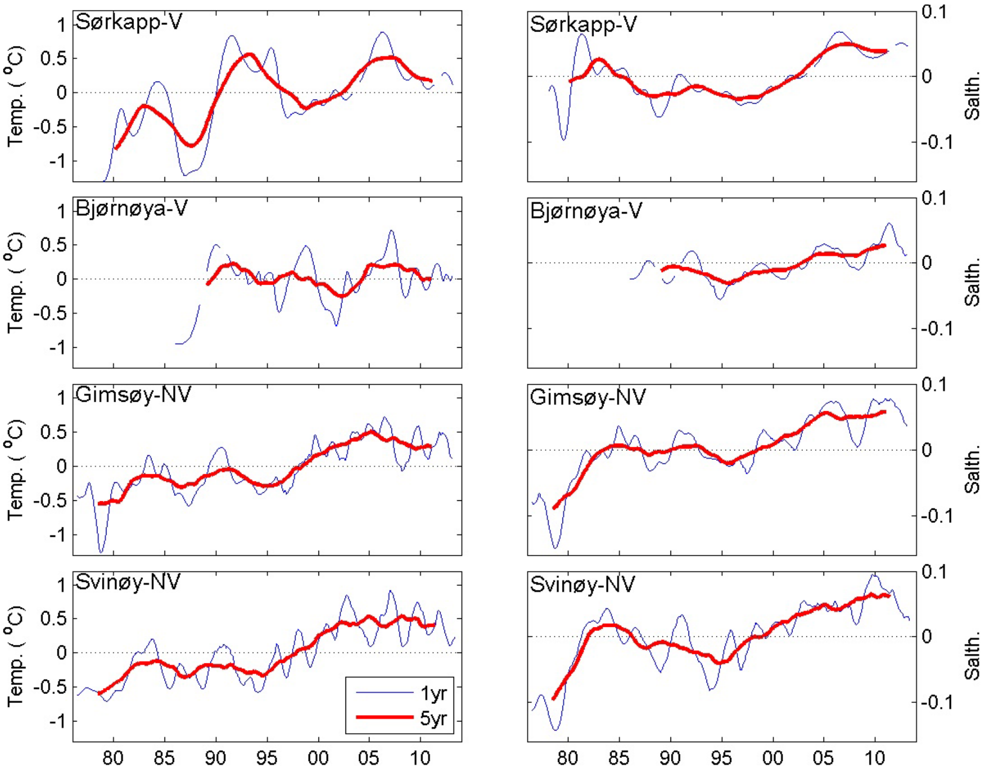

Figure 3. Temperature (left) and salinity (right) anomalies in the core of Atlantic water, averaged between 50 and 200 m depth, for the sections Svinøy-NW, Gimsøy-NW, Bjørnøya-W and Sørkapp-W. Both yearly and five years averages are shown. The anomalies are calculated relative to the 1981–2010 averages.

The volume transport in the Svinøy section in the eastern branch, the slope current along the shelf edge, has since 2007 been stable with normal values (Fig. 4), but in 2010 and 2011 the yearly averages of the inflow was approximately 0.2 Sv above the long term mean. For 2012 and 2013 the inflow was approximately equal to the long-term mean.

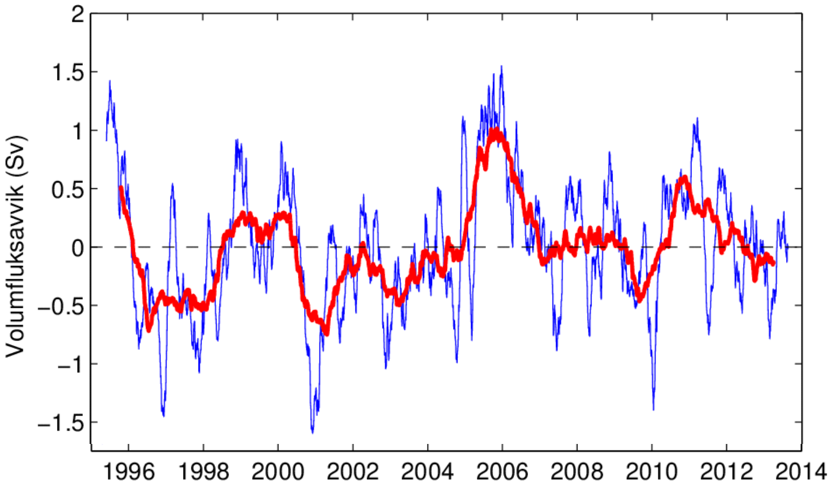

Figure 4. Volume transport anomaly in the Svinøy section. Updated from Orvik *et al.* (2001). The blue line is 3 months anomaly averages while the red line is one year anomaly averages.

In the period from the end of April to beginning of June an international coordinated pelagic cruise has been performed every year since 1995. Figure 5 shows the temperature distribution, averaged between 50–200 m depth in 2013, and the anomalies relative to the long-term mean. The increased influence of the colder and fresher East Icelandic Current in the southern Norwegian Sea is clearly visible. In the eastern areas, near the continental slope, the temperatures in 2013 were near or slightly below the normal. Northeast of the Faroe Islands and north of the Island, however, the temperatures were significant higher than normal, up to 1°C above the long-term average.

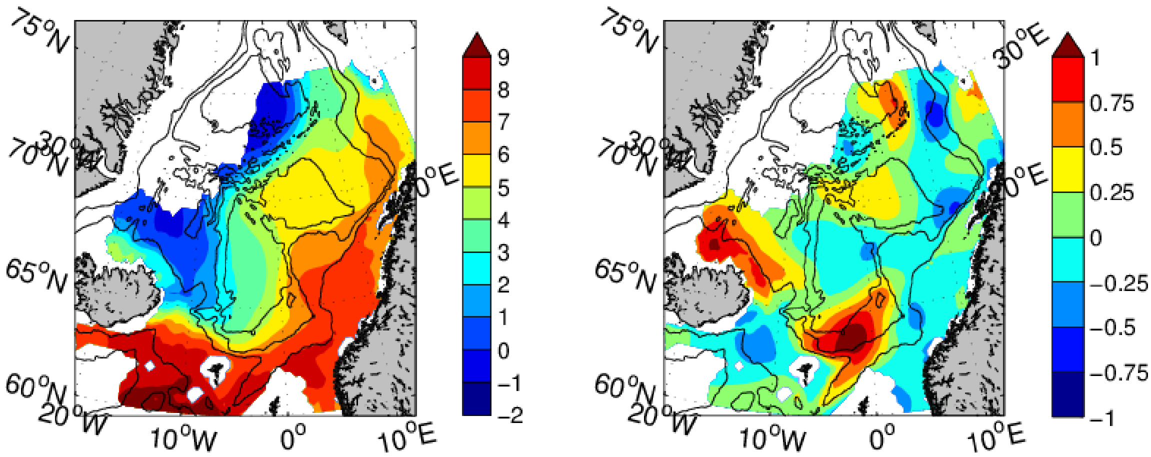

Figure 5. Left: Temperature, averaged over 50–200 m depth, in May 2013. Right: temperature anomalies, averaged over 50–200 m depth, relative to a 1995–2013 mean.

The area of total occupied Atlantic Water in the Svinøy section is shown in Figure 6. After a relatively low extension of AW in the first half of the 1990s the area of AW has increased. In 2013 the area was considerable above the long-term mean for both the spring and summer. In the spring it was also the highest ever in the time series. The averaged temperature in the occupied AW has increased linearly since 1978 and has, during the whole period, become 0.7°C and 0.8°C warmer for spring and summer, respectively. In 2013 the temperatures slightly increased from 2012, and were 0.3°C higher than the long term means for both spring and summer.

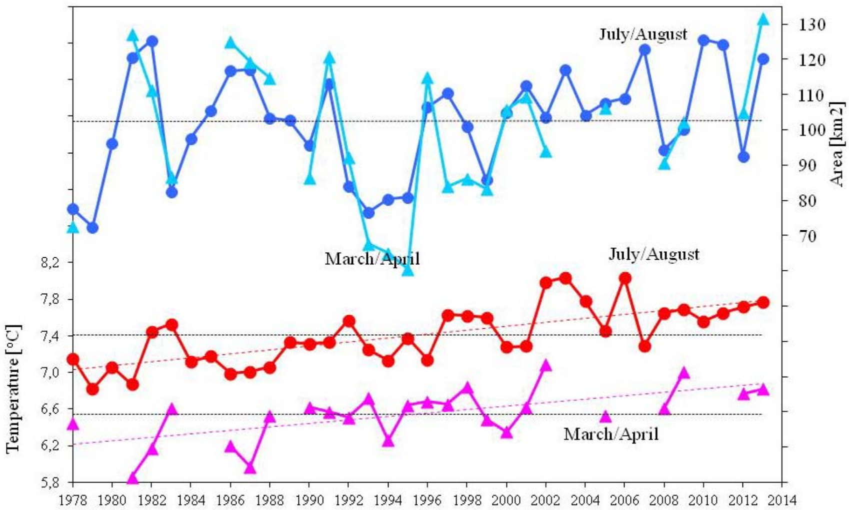

Figure 6. Area of Atlantic water and averaged temperature of AW in the Svinøy section for spring (March/April) and summer (July/August).

The variability of the inflow of Arctic water from the Iceland and Greenland Sea to the Norwegian Sea has potentially large climate and ecosystem effects because the temperature and salinity properties are very different from the Atlantic water. The amount of Arctic water is measured several times per year in the Svinøy section and once per year in the Norwegian Sea. Figure 7 shows that the amount of Arctic water has varied largely since the 1970s. It was high in the late 1970s and from the early 1990s to the early 2000s. In the late 1980s and after the 2000s the amount was small. In 2013, the amount of Arctic water in both the Svinøy section and over the larger area in the Norwegian Sea was at a very low level.

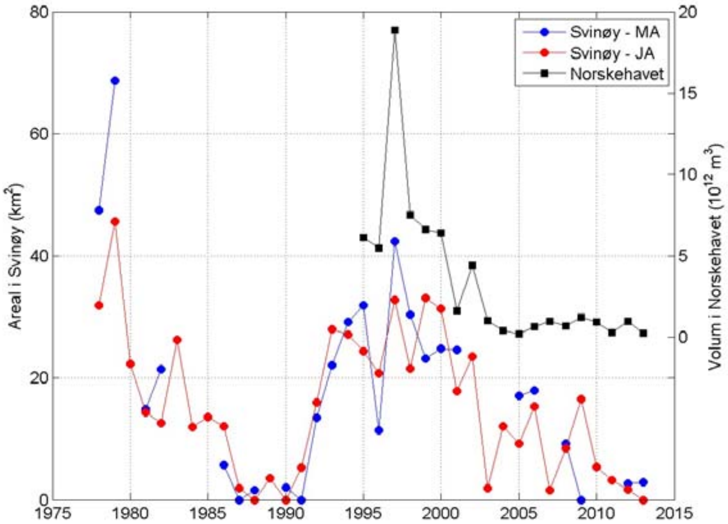

Figure 7. Amount of Arctic water (salinity<34.9) at the four westernmost stations in the Svinøy-NW section at 50–500 m depth in spring (March-April, MA) and summer (July-August, JA), and in the southern Norwegian Sea (62–68 N, 150–300 m depth).

The Barents Sea

Randi Ingvaldsen

Summary

- The temperature in the Barents Sea is lower than in 2012 but still above the long-term mean, and warmest was in the eastern Barents.
- During winter there was slightly more ice in 2013 compared to 2012, and the Barents Sea was ice free in late summer for both 2012 and 2013.
- The inflow to the Barents Sea has since 2007 been close to the long term mean, but was slightly higher in 2013 compared to the previous year.

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 observations, and in addition, current measurements have been carried out in the Fugløya-Bear Island section continuously since August 1997.

The Fugløya-Bear Island Section, which capture all the Atlantic Water entering the Barents Sea from south-west, showed temperatures of 0.3–0.71 °C above the long-term mean in during 2013. (Figure 8). This is lower than was observed last year.

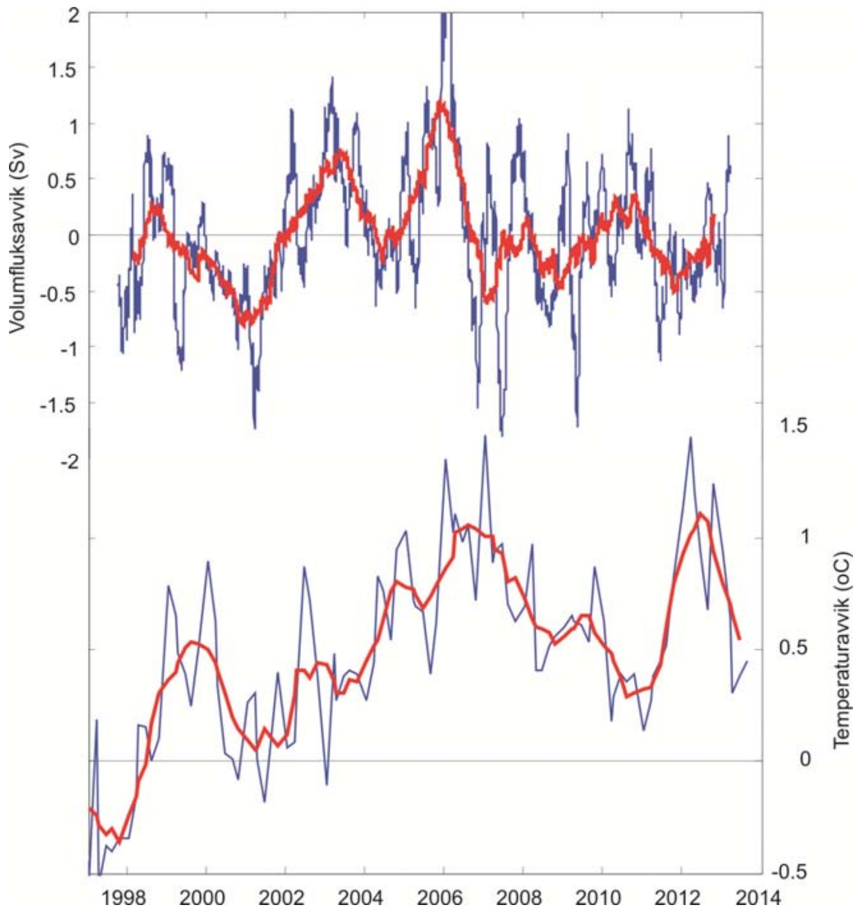

Figure 8. Temperature and volume flux anomalies in Fugløya-Bear Island Section.

The volume flux of Atlantic Water flowing into the Barents Sea has been monitored with current measurements in the section Fugløya-Bjørnøya since 1997. The inflow is predominantly barotropic, with large fluctuations in both current speed and lateral structure. In general, the current is wide and slow during summer and fast, with possibly several cores, during winter. The volume flux resembles the velocity field and varies with season due to close coupling with regional atmospheric pressure. Southwesterly wind, which is predominant during winter, accelerates flow of Atlantic Water into the Barents Sea; whereas, weaker and more fluctuating northeasterly wind common during summer, slows the flow. The mean transport of Atlantic Water into the Barents Sea for the period 1997–2010 is 2 Sv (Sv = 10^6 m^3s^{-1}) with an average of 2.2 Sv during winter and 1.8 Sv during summer. During years in which the Barents Sea changes from cold to warm marine climate, the seasonal cycle can be inverted. Moreover, an annual event of northerly wind causes a pronounced spring minimum inflow to the western Barents Sea; at times even an outward flow.

The volume flux into the Barents Sea varies with periods of several years, and was significantly lower during 1997–2002 than during 2003–2006 (Figure 8). During 2006 the volume flux was at a maximum during winter and very low during fall. After 2006 the inflow has been relatively low. In fall 2011 and winter 2012 there was a particular low inflow, but thereafter the inflow increased towards spring 2013. The data series presently stops in summer 2013, thus no information about the fall and early winter 2013 is yet available.

Hydrographic observations during late summer 2013 show record high temperatures at surface in 2013, in particular in the eastern parts (Figure 9). This was related to extremely high air temperatures in the region during summer 2013. Below surface, the temperatures were more close to normal, and in the 50–200 m depth layer the temperatures were between 0 and 0.5°C warmer than the long term mean. This is lower than has been observed in the last years. However, in the eastern parts, temperatures up to 2°C above the long term mean were observed.

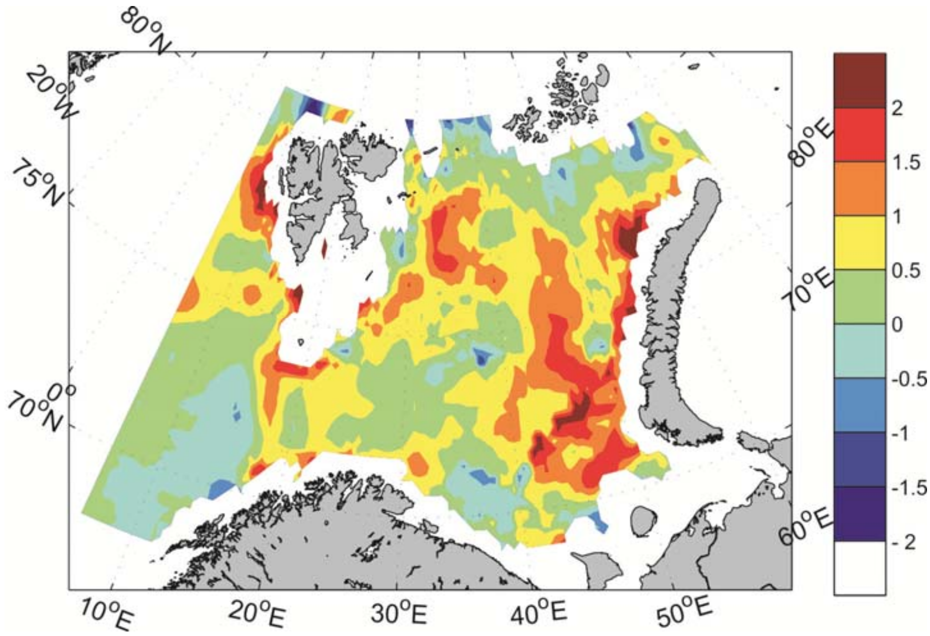

Figure 9. Temperature anomalies at 100 m depth in August-September 2013 relative to the long-term mean (1977–2006).

The variability in the ice coverage in the Barents Sea is linked to the temperature of the inflowing Atlantic water, the wind field and the import of ice from the Arctic Ocean and the Kara Sea. The ice has a response time on temperature changes in the Atlantic inflow (one-two years), and usually the sea ice distribution in the western Barents Sea respond faster than in the eastern part. There has been a linear negative trend in the ice area, particular in the winter, the last 40 years. In 2013 there was slightly more ice for winter compared to 2012, and in late summer for both 2012 and 2013 the Barents Sea was ice free.

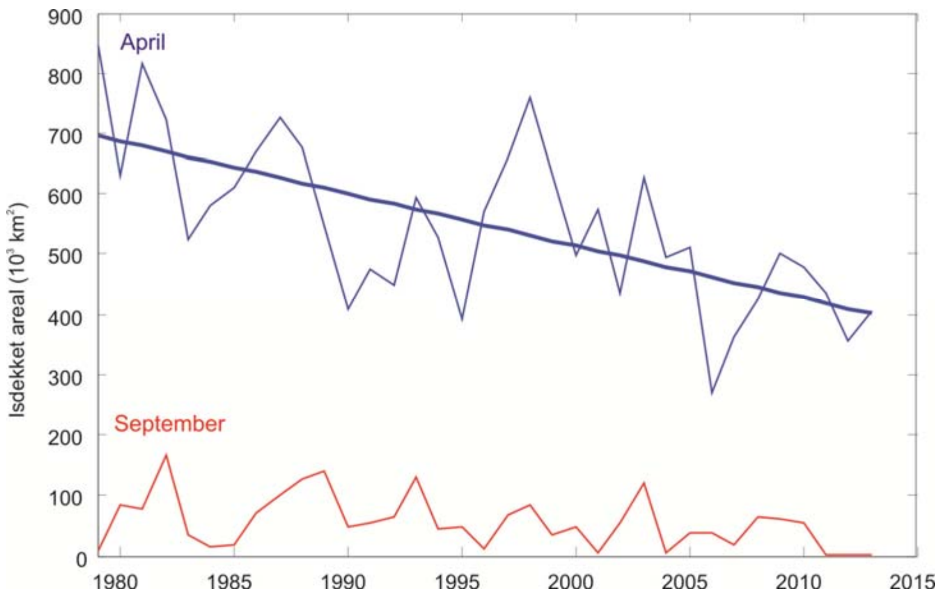

Figure 10. Ice area in the Barents Sea (10–60°E, 72–82°N) at maximum (April) and minimum (September) ice coverage. The thick blue line shows the linear trend.

The North Sea

Jon Albretsen, Solfrid S. Hjøllo and Morten D. Skogen

Summary

- The heat content in the North Sea and Skagerrak was reduced during 2013, mainly during the winter and spring, due to low near-surface temperatures and low inflow of Atlantic water.
- While the first half of 2013 was relatively cold, the period from July to December was warmer than normal.

Temperature and water masses

The sea surface temperatures in the Skagerrak were 1–2 °C below the long-term average (1970–90) throughout the winter 2013, while the North Sea had more normal temperatures in January and February. The period from March to June was cold both in the Skagerrak and the North Sea, in average 1–2 °C below the long-term average. The southern North Sea was particularly cold until June. From July and the rest of the year both the Skagerrak and the North Sea had a positive temperature anomaly of about 1–2 °C (source: BSH, Bundesamt für Seeschifffahrt und Hydrographie).

Both temperature and salinity within the Atlantic water masses in the deep water (representing the 100–200m depth range) in the Skagerrak, approx. 10km off Torungen lighthouse near Arendal, was above the 1961–90-average from January until May 2013, similar to the entire 2012. During March and April the values were particularly high. However, from June to December 2013 both temperature and salinity had about normal values, except for an increase in the salinity-anomaly in September and October (Figure 11).

After the exchange of bottom water in the Skagerrak basin during the spring 2010 (with cold North Sea water) and during the spring 2011 (with Atlantic water), there was a renewal of the basin water in March/April 2013 with inflowing Atlantic water. The exchange of bottom water led to an increase of the oxygen level and a small increase in salinity. In addition, there was observed a drop in the bottom water temperature of about 1 °C (Figure 12).

Transports and heat content

Results from the ocean circulation model NORWECOM show that the southward inflow of Atlantic water between the Orkney Islands and Utsira, Norway, was relatively low during 2013, and particularly low from January to June. According to this time series from 1985–2013, only 2010 have had lower inflow during the first half of the year. The inflow increased during the rest of 2013 with the largest transports toward the end of the year (Figure 13).

Both seasonal variations and long-term oscillations of the heat content in the North Sea are computed for 1985–2013 from the NORWECOM model simulation. The minimum and maximum heat content will reflect the degree of winter cooling and summer heating of the North Sea, respectively. The loss of heat during the winter 2013 was the third largest since 1985, only winters 1986 and 1996 lost more heat. A warm summer and autumn compensated some of the negative heat balance, but the heat budget was negative for the entire North Sea throughout 2013 (Figure 14).

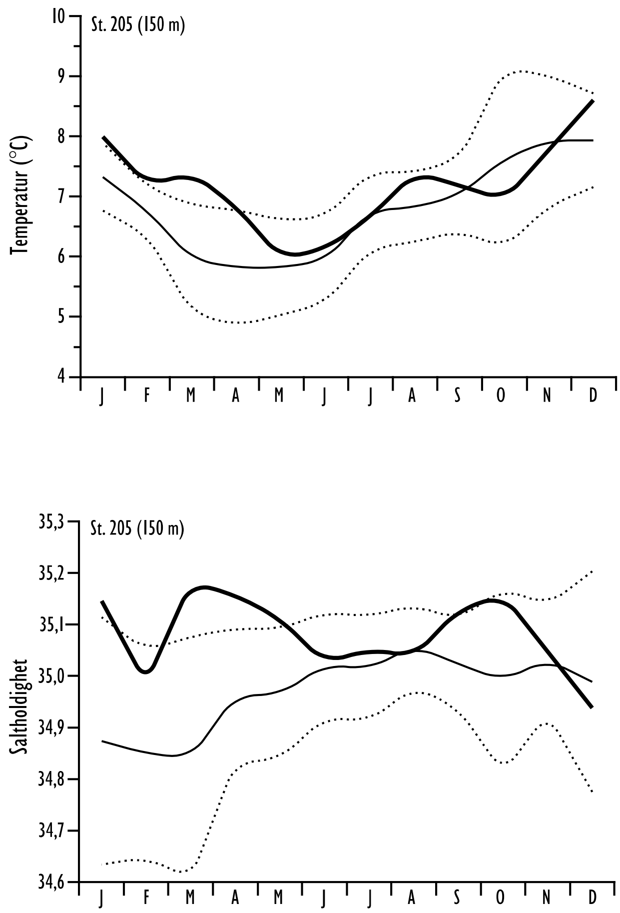

Figure 11. Temperature (upper panel) and salinity (lower panel) at 150m depth based on monthly observations in 2013 sampled approx. 10km off Torungen lighthouse near Arendal. The long-term mean (thin solid line) and the standard deviation (dotted line) are based on measurements sampled between 1961 and 1990.

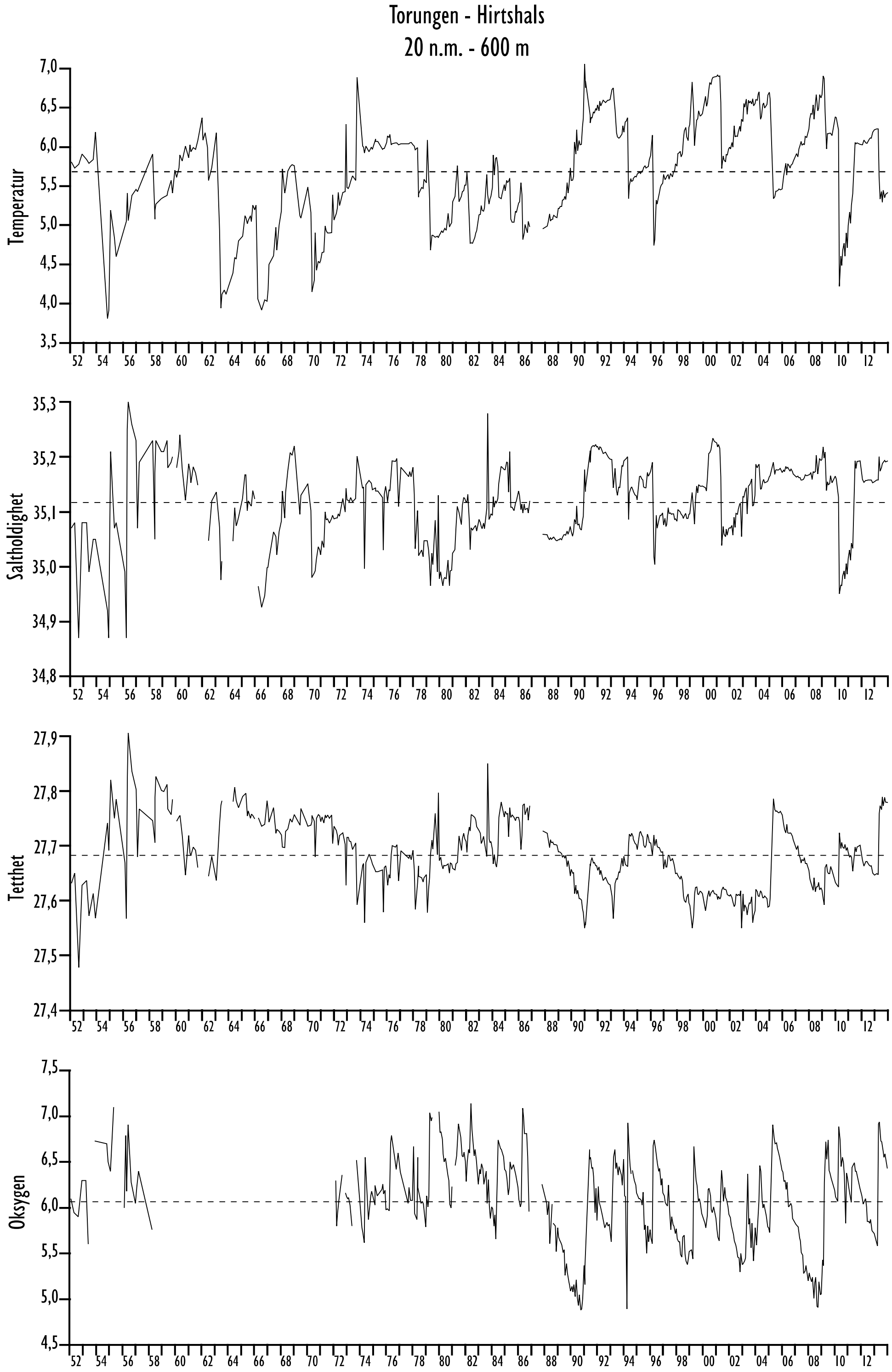

Figure 12. Temperature (°C), salinity, density (σ_t in kg/m^3) and oxygen (ml/l) at 600m depth in the Skagerrak Basin from 1952 to 2013.This location depicts the physical environment in the Skagerrak bottom water.

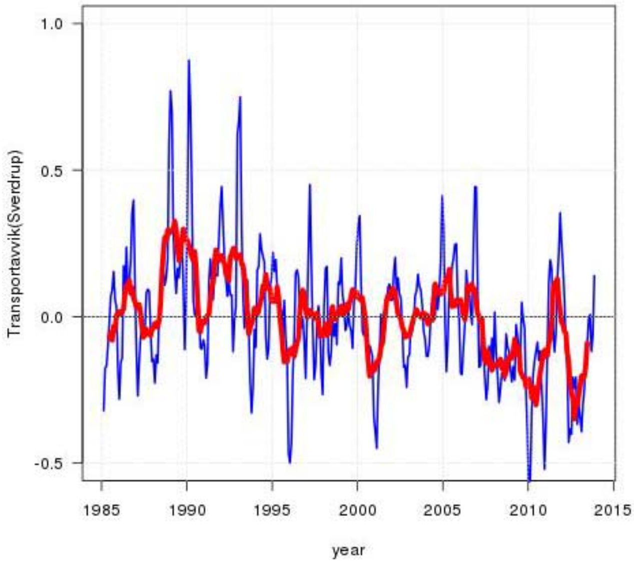

Figure 13. Time series (1985–2013) of modelled monthly mean volume transport anomalies of Atlantic water into the northern and central North Sea southward between the Orkney Islands and Utsira, Norway. The vertical axis denotes transport anomaly in Sv ($10^6 m^3 s^{-1}$). The blue and red line displays the 3 and 12 months running average, respectively.

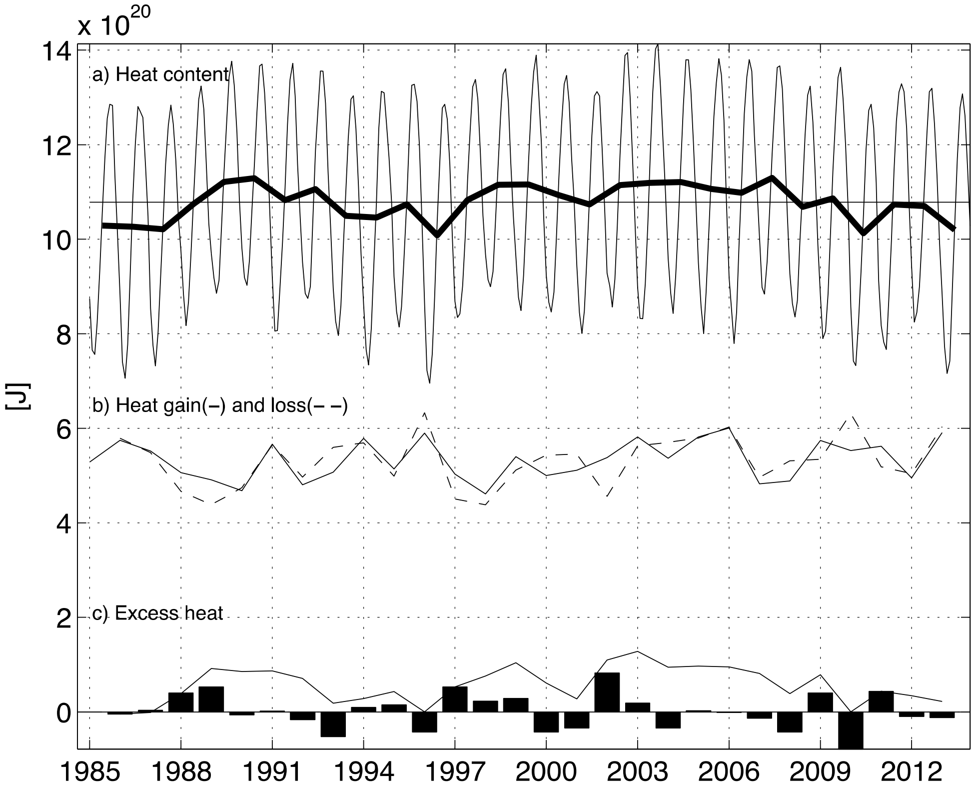

Figure 14. a) Modelled North Sea heat content for the period 1985–2013. Monthly (thin line) and annual (thick line) values are shown. b) Heat gain (solid) and loss (dashed line). Heat gain is defined as difference between heat content maximum (in August or September) and minimum (in February or March) for each year. Heat loss is defined as the absolute value of the difference between heat content minimum and maximum the year before. c) Excess heat (bars) and accumulated excess heat (line). Positive values mean a net heat gain, i.e., the North Sea summertime heat gain is larger than the heat loss the winter before.

Annex 10: Regional report – North Sea 2013 (Area 8, 9)

Holger Klein, Alexander Frohse, Peter Löwe, Birgit Klein, Achim Schulz

Bundesamt für Seeschifffahrt und Hydrographie, Hamburg, Germany

1 North Sea 2013: Annual Survey

1.1 Global Radiation

In 2013 the monthly means of global radiation at the East Frisian island of Norderney (Fig. 1.1a) had been close to means of the reference period 1981–2010. Only in April, July and August they exceeded the means and reached values close to the maxima of the reference period. The July mean is highest since 1971.

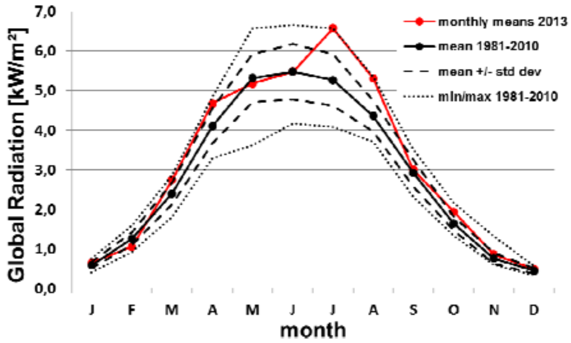

Fig. 1.1a: Red: Seasonal cycle of monthly averaged daily global radiation totals 2013 in kW/m² at Norderney. Black: Monthly means of the 1981–2010 base period ± standard deviations (broken lines) and extreme values (dotted lines). Data provider: German Meteorological Service (DWD).

The annually averages of daily global radiation totals at Norderney for the period 1971–2013 are shown in Fig. 1.1b. The data indicate a positive trend for the last three decades.

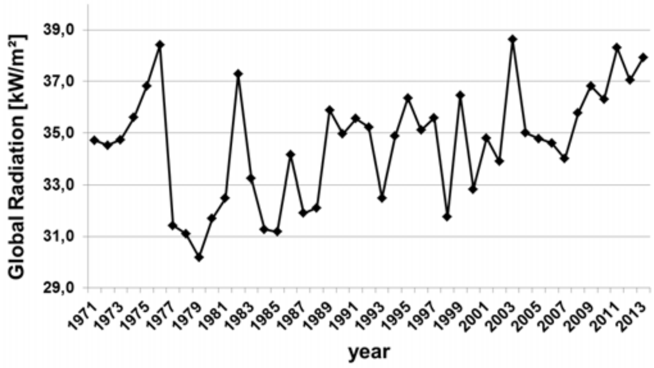

Fig. 1.1b: Annually averages of daily global radiation totals at Norderney1971–2013 in kW/m². Data provider: German Meteorological Service (DWD).

1.2 Elbe River Run-Off

Tremendous rainfalls over northern Europe during early summer caused significantly enhanced run-offs during June and July 2013 and a strong Elbe flood while the other monthly run-off volumes had been within the 95%-band. The April flood enhanced the annual run-off volume to about 33 km³/a, however, also this value is still within the 95%-band (Fig.1.2).

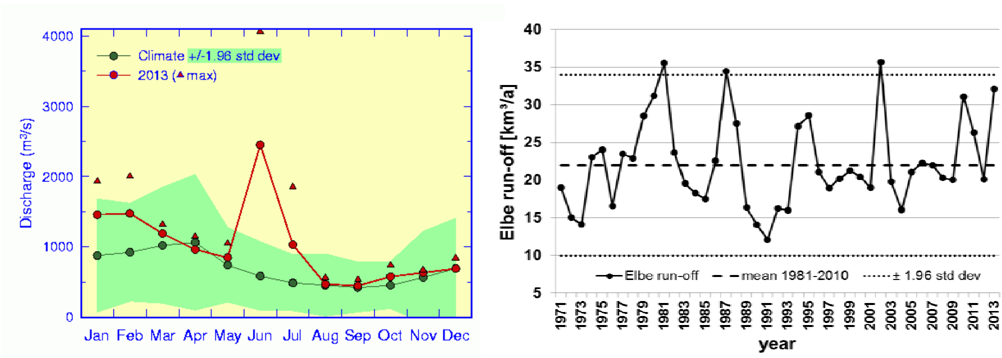

Fig. 1.2: Left: Monthly means of Elbe discharge at weir Neu Darchau in m³/s and 1971–2000 mean ±1.96 standard deviations in 2013. Right: Total annual run-off in in km³/year 1971–2013 and 1981–2010 mean ±1.96 standard deviations. Data provider: BfG / WSA Lauenburg.

1.3 North Sea SST

Monthly means of area averaged North Sea SST for 2013 are shown in Fig. 1.3a. Due to the long and cold winter 2012/2013 the first half of 2013 was colder than the reference period 1981–2010. From March to May the monthly anomalies exceeded -1.2 K. During the second half of the year the SST was slightly above the reference period with anomalies between 0.2 K and 0.5 K. The annual SST mean is 0.2 K below the reference value.

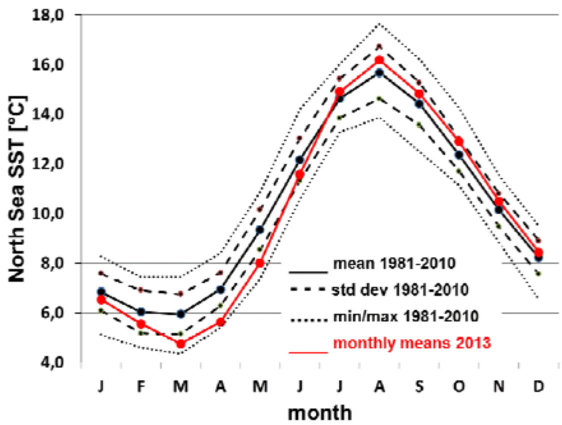

Fig. 1.3a: Monthly means of area averaged North Sea SST in °C for 2013 (red line). Black solid line: mean of reference period 1981–2010, broken lines: standard deviations of reference period, dotted lines: min/max of reference period.

The time series in Fig. 1.3b shows the annual North Sea SST means 1969–2013. The last years possibly indicate a fall-back into a cooler period.

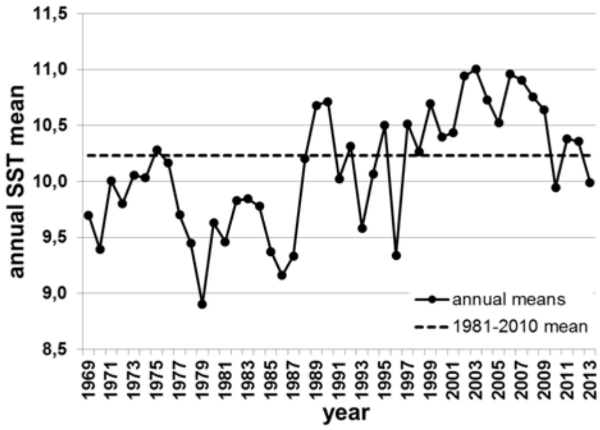

Fig. 1.3b: Annual North Sea SST means 1969–2013 in °C. Dotted line: 1981–2010 mean.

The spatial pattern of monthly North Sea SST anomalies relative to the reference period 1971–1993 are shown at:

http://www.bsh.de/de/Meeresdaten/Beobachtungen/Meeresoberflaechentemperatur/anom.jsp#SSTJ

1.4 Monthly Means of the North Sea Volume Temperature and SST

The observed monthly SSTs and the monthly mean temperatures of the total North Sea volume based on results of the operational BSH model 'BSHcmod' Version 4 are shown in Fig. 1.4 for the period 2000–2013. The pronounced warming and increasing length of the summer season observed during the last decade is no longer visible, neither in the SST pattern nor in the volume temperature.

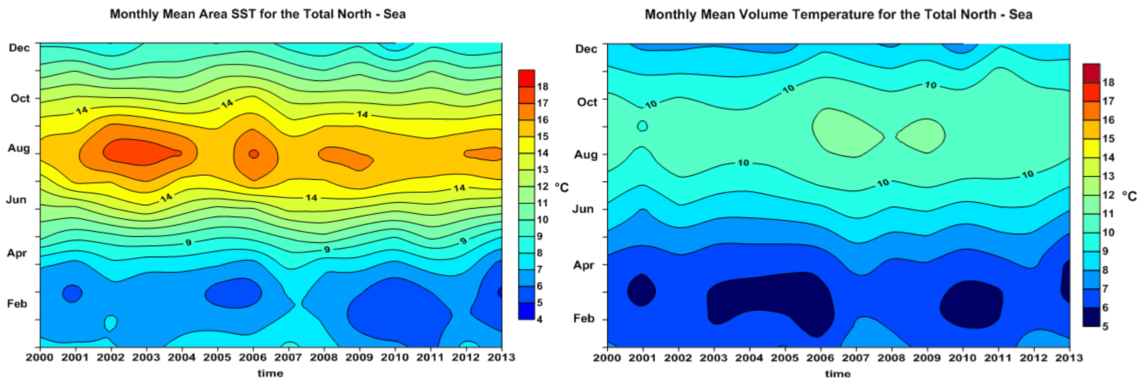

Fig. 1.4: Observed monthly and area averaged North Sea SSTs (left) and monthly mean temperature of the total North Sea volume in °C based on BSHcmod model data (right) for the period 2000–2013.

1.5 Temperatures at Light Vessel "German Bight"

The temperature conditions in the German Bight are exemplarily documented by the temperature records of the MARNET station on the unmanned light vessel *German Bight* (54° 10′ N; 7° 27′ E, water depth 38 m) between 3 and 30 m depths for the period 2011 to

2013 (Fig. 1.5). Gaps in the time series are caused by technical problems, bio-fouling or dockyard lay time for maintenance. The broken lines gives the climatological seasonal extreme values in the surface layer according to Janssen *et al.*, 1999[5] with an amplitude of about 13.5 K. In 2013 stratification started in the midst of May and broke down at the end of September due to strong winds. The difference between surface and bottom temperature reached values up to 7 K. Unfortunately there is a larger data gap during summer due to maintenance work at the light vessel.

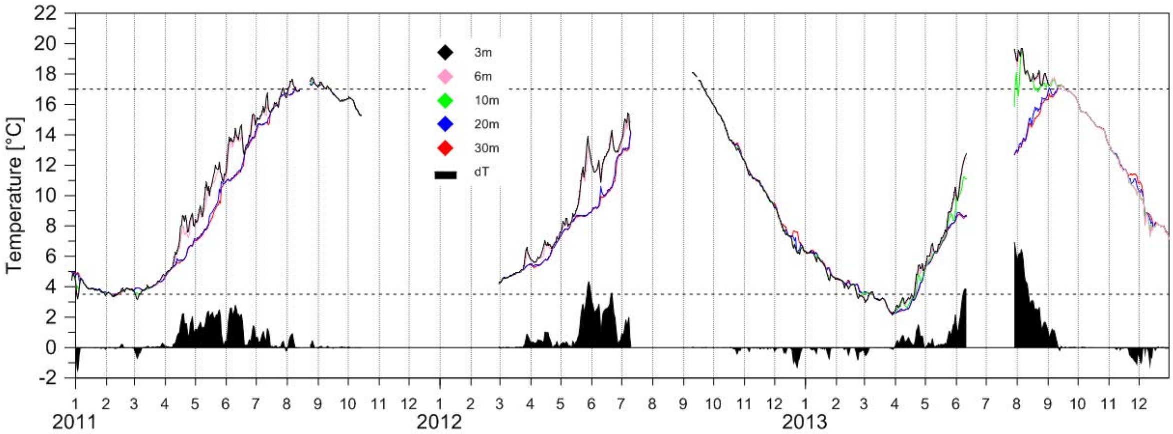

Fig. 1.5: Temperatures [°C] at light vessel "German Bight" 2011–2013. Broken lines: climatological seasonal maximum and minimum of the surface layer according to Janssen *et al.*, 1999.

1.6 Surface Salinity at Helgoland Roads

The surface salinity at Helgoland Roads shows extreme low salinities during June and July due to extraordinary fresh water supplies caused by the Elbe flood (see1.2).

[5] Janssen F., C. Schrum and J.O. Backhaus, 1999: A Climatological Data Set of Temperature and Salinity for the Baltic Sea and the North Sea, German Journal of Hydrography, Supplement 9, 245pp.

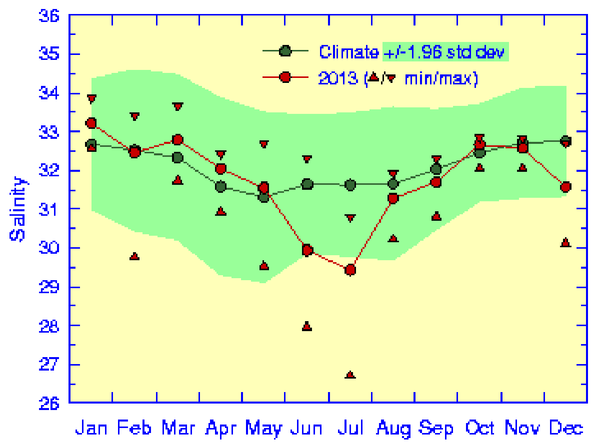

Fig. 1.6: Monthly means of surface salinity at Helgoland Roads together with intra-monthly extremes, 1971–200 base period monthly means and 95% band. Raw data courtesy of K. Wiltshire, Biologische Anstalt Helgoland/AWI.

2 North Sea Summer Status 2013

2.1 The BSH North Sea Summer Surveys

The summer state of the North Sea is determined by the BSH North Sea Summer Surveys (NSSS). BSH[6] started these annual surveys in 1998. They cover the entire North Sea with seven coast to coast East-West sections between 54° and 60°N and additional stations between 54°N and the entrance of the English Channel. The surveys were realised at a time when thermal stratification is expected to be at its maximum and phytoplankton production has passed its maximum. With the exception of the first survey in 1998 all surveys served a fixed grid of vertical CTD casts (see red dots in Fig. 2.2a). Between the fixed stations a towed CTD-system (1998–2008 the BSH *Delphin*, since 2009 an EIVA *MK2 ScanFish*) was deployed which oscillated between surface and bottom to record the distribution of relevant oceanographic parameters with high resolution in space and time (24 Hz). Both CTD-systems are sampling temperature, salinity, fluorescence (chlorophyll-a, yellow substance), and oxygen concentration. Additionally, ship-mounted temperature-, salinity- and optical sensors provided data at about 4 m depth. In order to sample the transition area between North Sea and Atlantic the survey was expanded to 62.5°N since 2010 (see Fig. 2.2a).

For the assessment of the North Sea status a 10 years reference period (RP) from 2000 to 2010 was defined which skips the 2002, because the 2002 survey was much too early in the seasonal cycle. Due to technical problems there large gaps in the ScanFish sections between 58° and 60°N in 2013. This leads to some uncertainties in the calculation of the heat and salt budgets.

[6] German Federal Maritime and Hydrographic Agency

2.2 North Sea Summer Temperature Distribution and Total Heat Content

The large scale horizontal temperature distribution in the surface is very close to the RP. Only in the area of the Fair-Isle inflow there is a small negative anomaly of -1 K. Due to the long winter over northern Europe large areas of the bottom layer are significantly colder than in previous years with negative anomalies of below -2K (Fig.2.2a) and a temperature minimum of less than 6°C.

In the central North Sea the maximum difference between surface and bottom temperature exceeds 10 K, this is more than 2 K more compared to previous years (Fig. 2.2b). The left panel of Fig. 2.2b gives the maximum of the vertical temperature gradient which varies between 0.5 and 2.7 K/m. This is a much stronger gradient compared to 2012 and corresponds to previous years with typical maxima between 2.5 and 3.0 K/m. Areas with gradients less than 0.5 K/m are not shown. The right panel gives the depth of maximum gradient, i.e. the depth of thermocline, with a maximum vertical extension of >35 m.

The vertical sections show a relative homogeneous surface layer with a strong thermocline which fades away towards the UK coast (Fig. 2.2d). In the colder deep layer there are several domelike structures where the cold near-bottom water spreads towards the bottom side of the thermocline.

Compared to 2012 the total heat content of 1.627×10^{21}J decreased slightly and is close to the reference mean of 1.631×10^{21}J (see Table 1 and Fig. 2.2c).

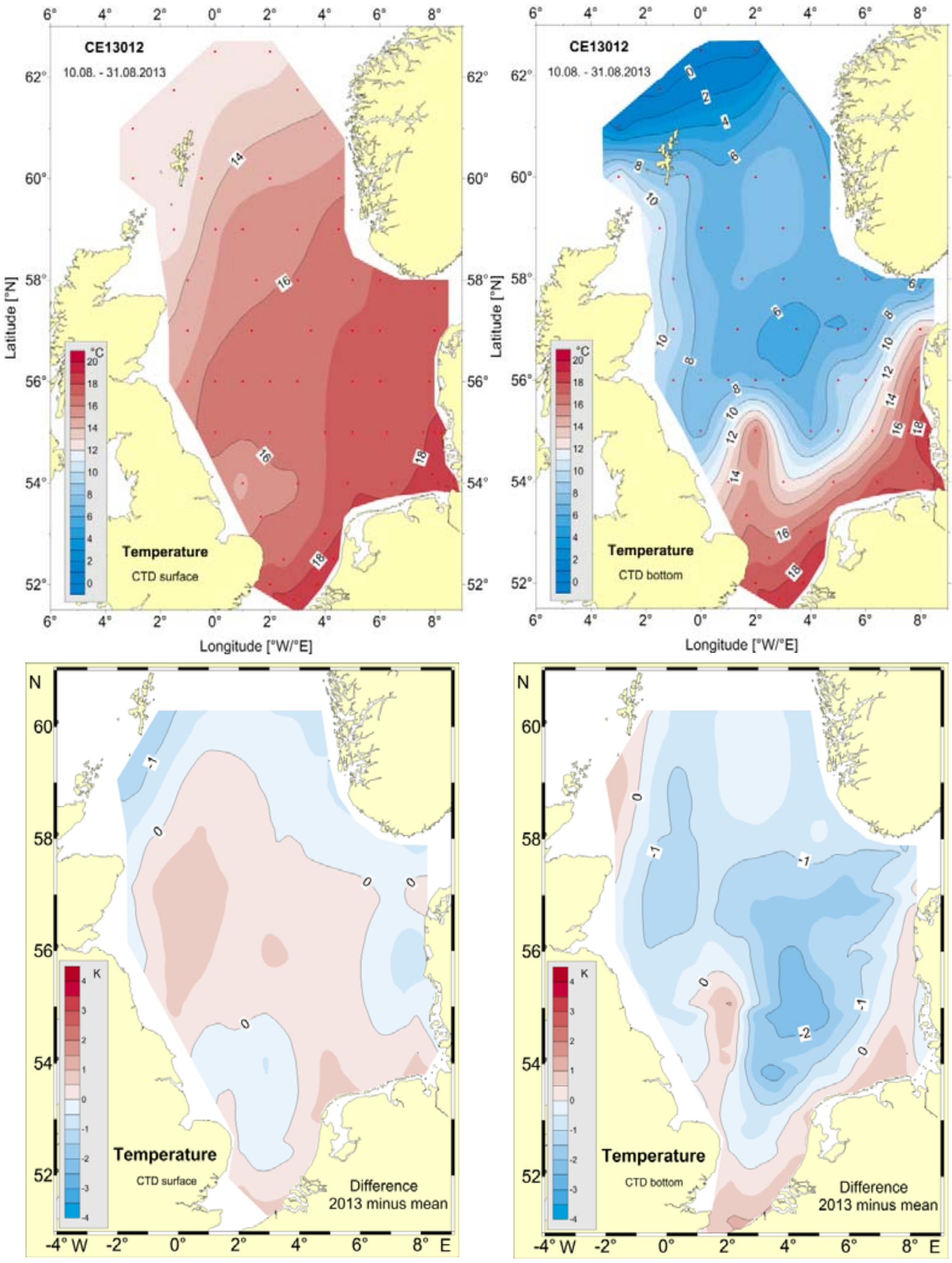

Fig. 2.2a: Top: Horizontal surface (left) and bottom (right) temperature distribution in °C. Bottom: Horizontal surface (left) and bottom (right) temperature anomalies (2013 – reference period 2000–2010) in K.

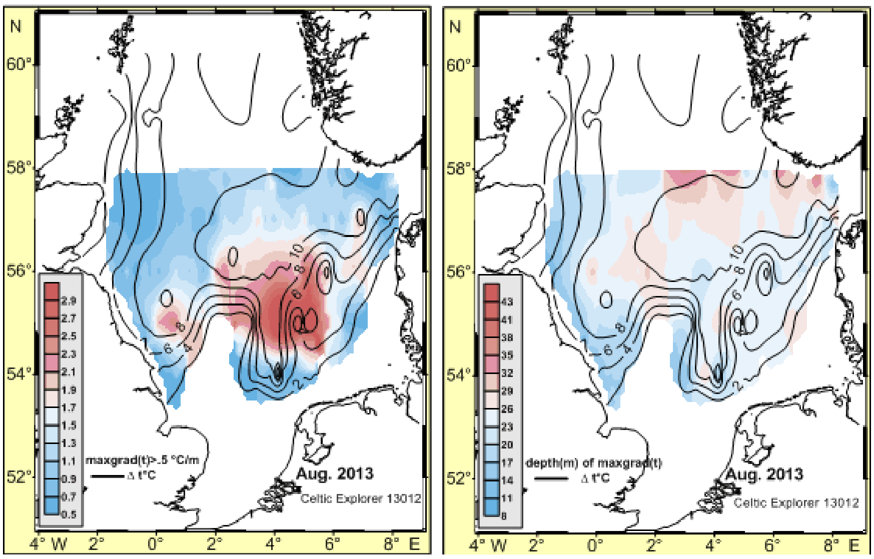

Fig. 2.2b: In both figures the isolines give the difference T_{sur}-T_{bot} in K. Colour coded: strength of maximum gradient in K/m (left) and depth of maximum gradient in m (right).

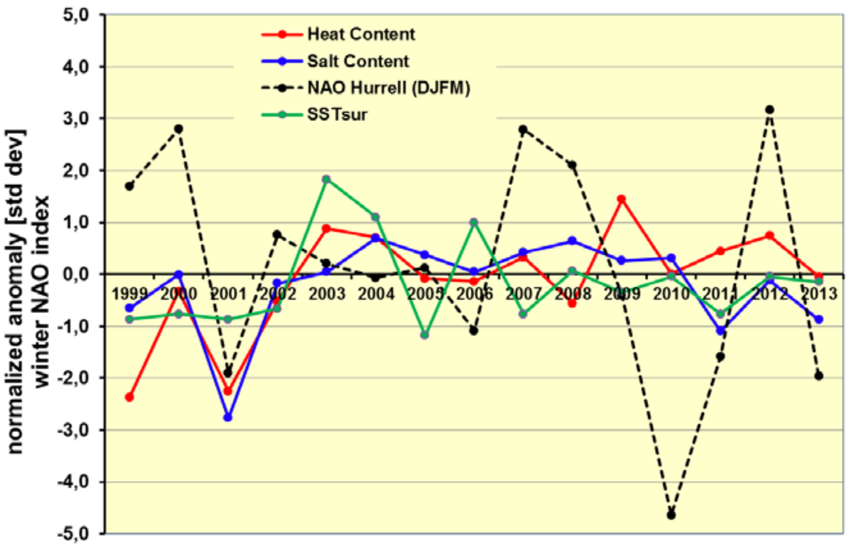

Fig. 2.2c: Normalised anomaly of total heat and salt content and mean SST of survey period in standard deviations. Broken line: Hurrell winter NAO staion index (DJFM)[7], reference period 2000–2010 but without 2002.

7 https://climatedataguide.ucar.edu/sites/default/files/climate_index_files/nao_station_djfm.txt

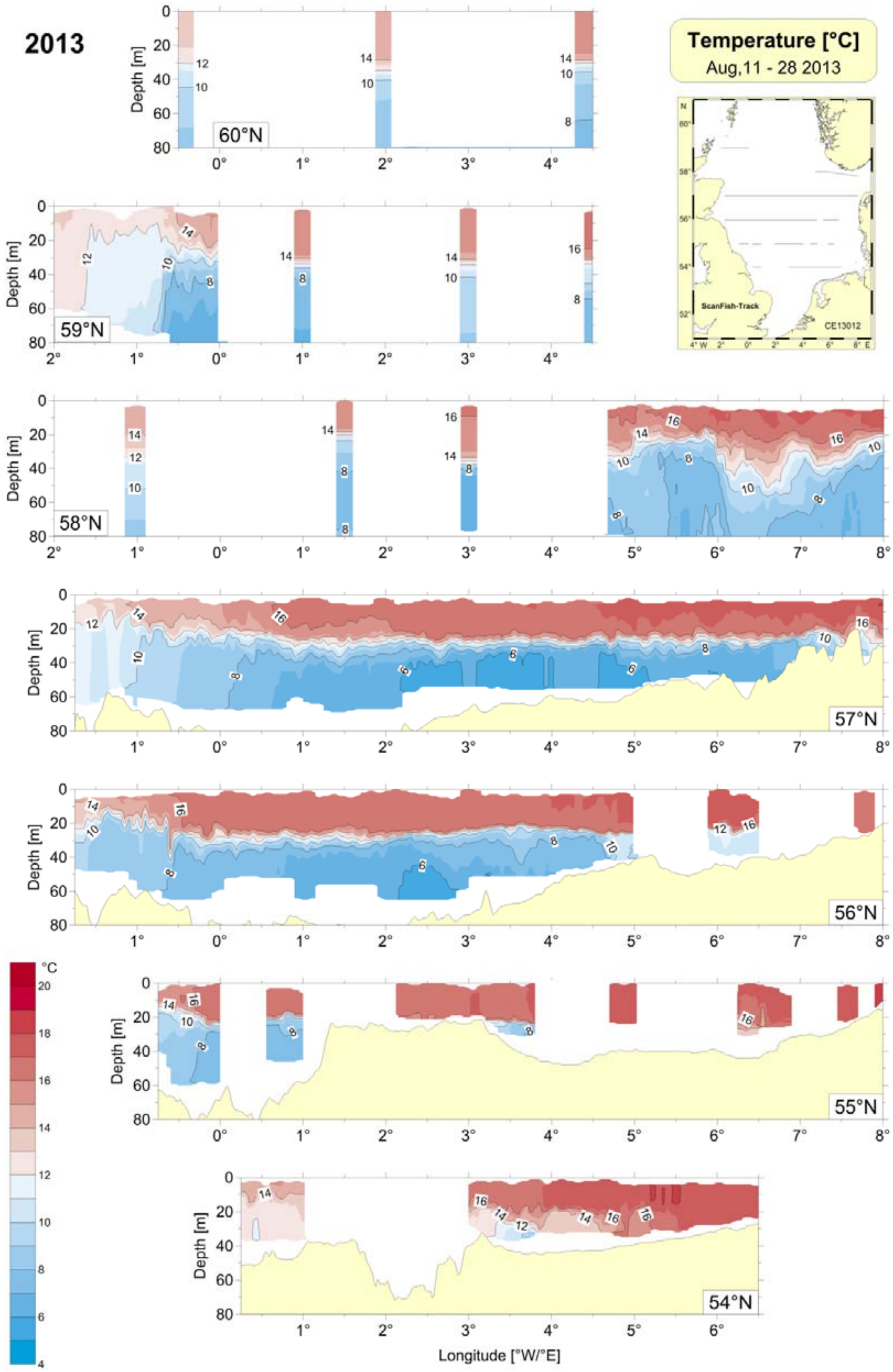

Fig. 2.2d: Temperature sections in °C.

2.3 North Sea Summer Salinity Distribution

The horizontal salinity distribution at the surface shows a positive anomaly in the north-eastern North Sea (>1 psu) and a negative anomaly (more than -1 psu) in the south-eastern North Sea along the Dutch, German and Danish coast (Fig. 2.3a-c) which is at least partly caused by enhanced river run-offs (see 1.2 and 1.6). This negative anomaly appears also in the bottom layer, whereas the other bottom areas are close to the reference period.

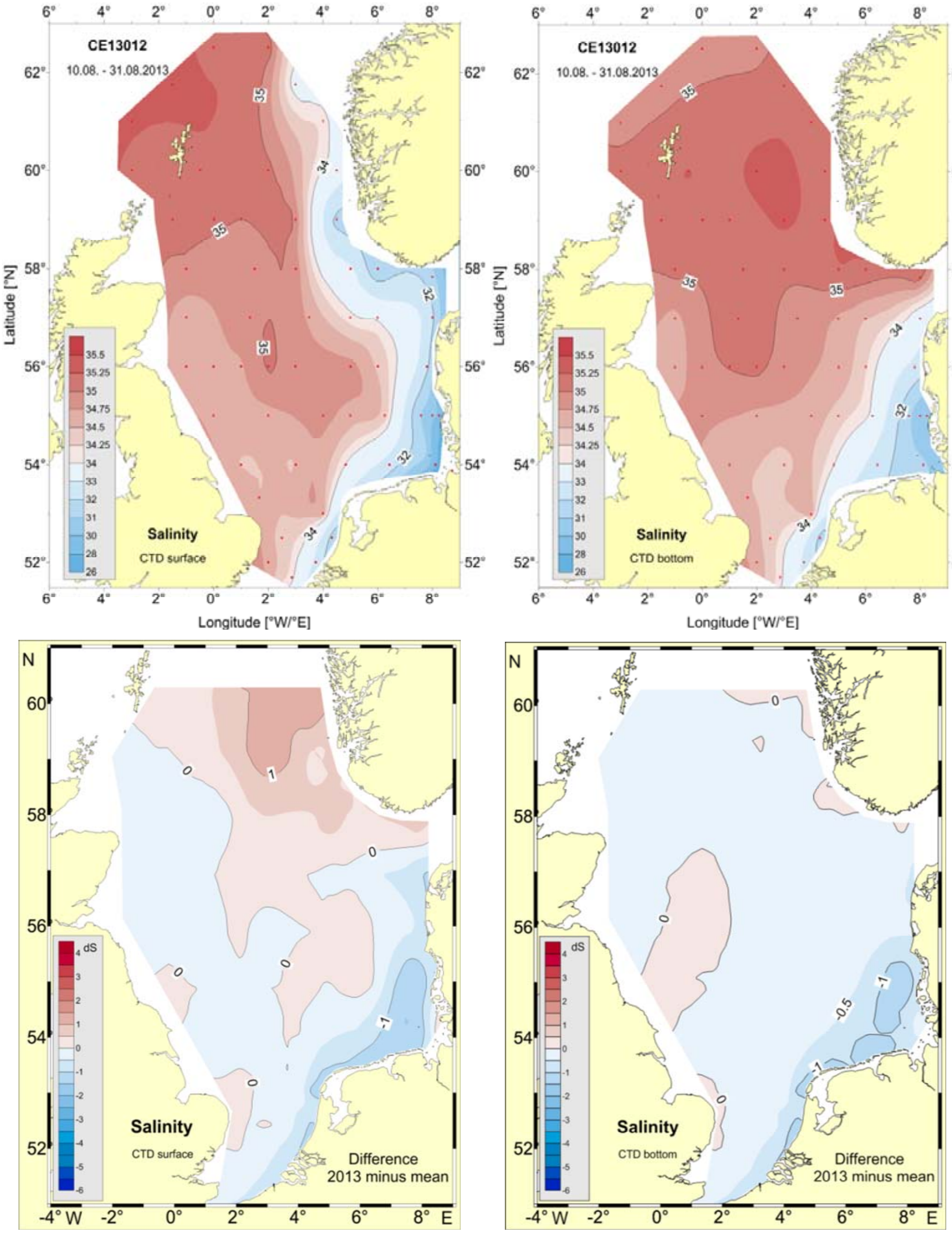

Fig. 2.3a: Top: Horizontal surface (left) and bottom salinity distribution (right). Bottom: Salinity anomalies (2013 – reference period 2000–2010), in the surface (left) and bottom layer (right).

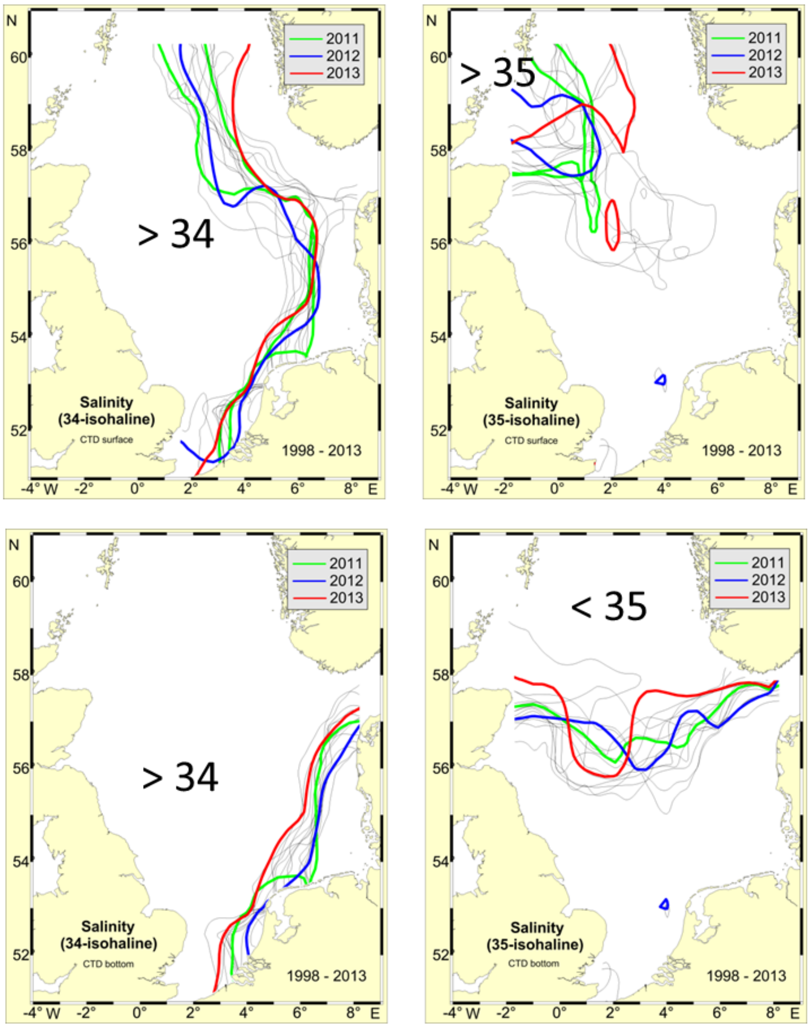

Fig. 2.3b: Position of the 34 (left) and 35 (right) isohalines 1998 – 2012. Top panel: surface layer, bottom panel: bottom layer. Red: 2013, blue: 2012, green: 2011, and grey: 1998–2010.

The vertical sections in Fig. 2.3c show a relatively small southward intrusion of AW >35 psu extending until 56°N in the central North Sea. Compared to 2012 the total salt content decreased to 1.118 x 10^{12} t which is about one standard deviation below the mean of the RP (see Fig. 2.2c and Table 1).

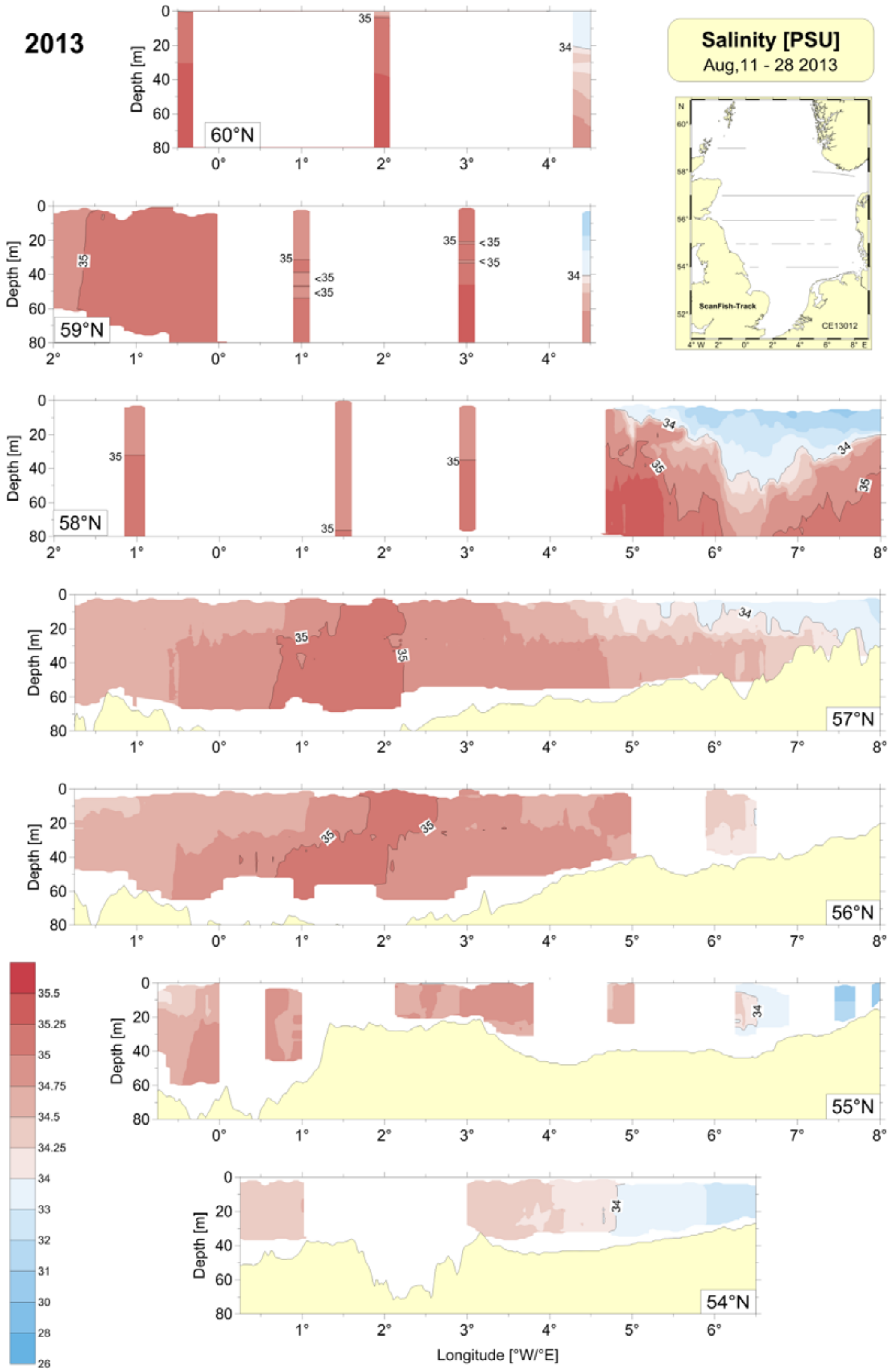

Fig. 2.3c: Salinity sections in psu.

2.4 Summer Distribution of Oxygen Saturation and pH

The oxygen saturation during late summer was uncritical, the saturation in the surface layer exceeded 100 % in the whole North Sea. At the bottom the minimum saturation was slightly below 80 % (Fig. 2.4). A saturation of 84% (~7.5 mg/l) is the lower limit of a sufficient oxygen supply. Values below 70% (~6 mg/l) can affect fish growth and values less than 50 % (~4 mg/l) can affect the metabolism of benthic animals (Weigelt-Krenz, 2013, in Löwe *et al.*, 2013[8]).

The pH distribution is very homogenous with only minor differences between surface and bottom. The pH of seawater in the euphotic zone lies in a range of 7.8 to 8.3.

[8] Loewe, P., H. Klein, S. Weigelt-Krenz (Eds.), 2013: System Nordsee – 2006 & 2007: Zustand und Entwicklungen. Berichte des BSH, Nr. 49, Bundesamt für Seeschifffahrt und Hydrographie, Hamburg und Rostock, 303pp.

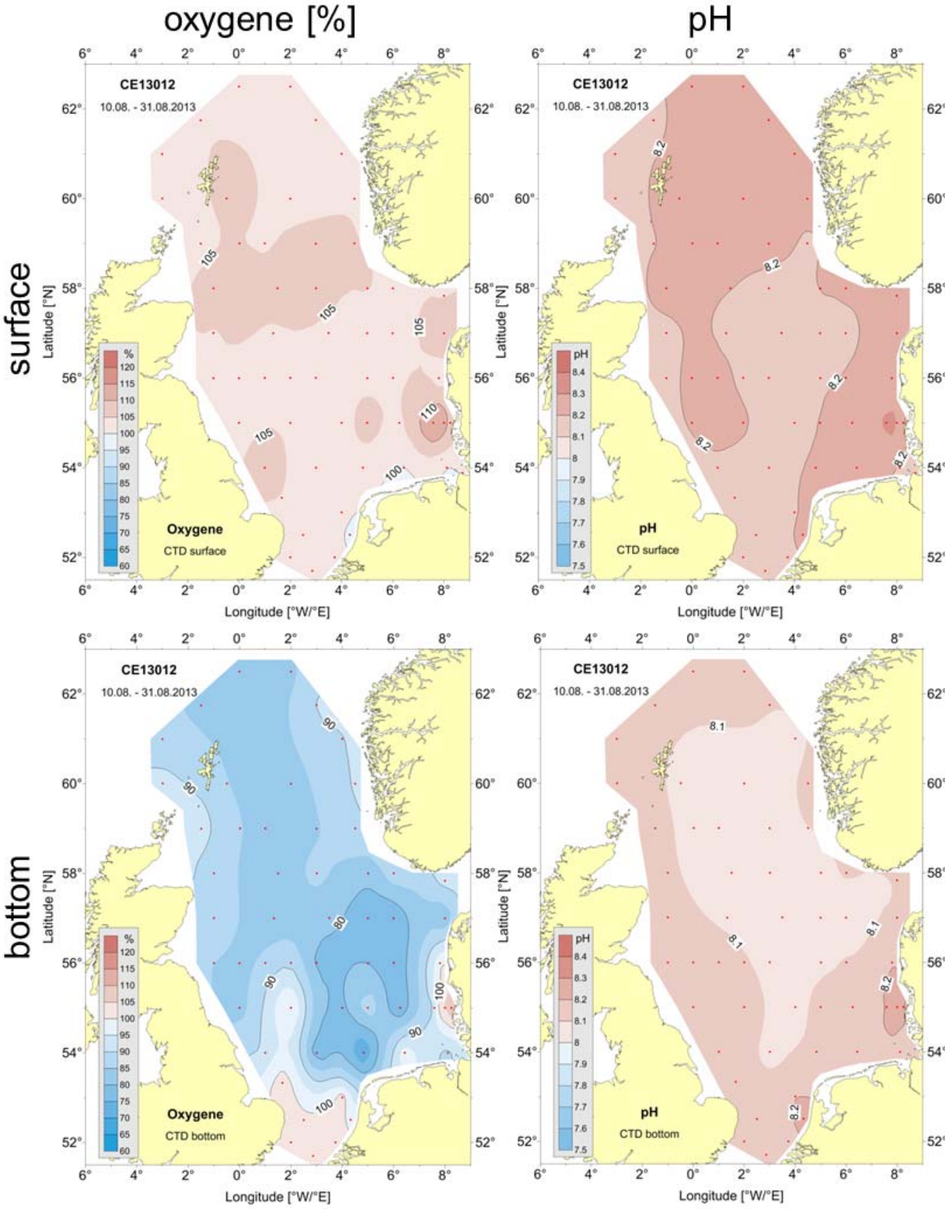

Fig. 2.4: Surface and bottom distribution of oxygen saturation in % and pH.

2.5 Summer Secchi-Depth

The Secchi-Depth shows a large maximum in the central North Sea with depths up to 20 m. One reason for this high value is, like in 2012, the very calm weather during the cruise which reduced the intrusion of air bubbles into the surface layer significantly. Secchi-Depth measurements can be taken only during daylight time. Therefore, not all stations could be sampled.

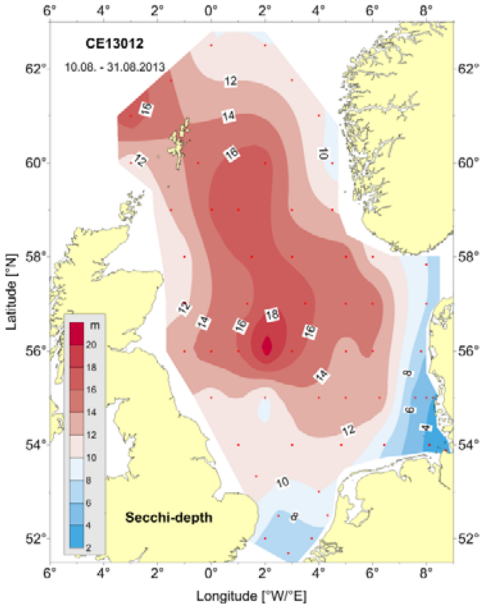

Fig. 2.5: Secchi-depth in m.

3 Summary of North Sea Conditions 1999 – 2013

		Annual Means				North Sea Summer Survey Data					
year	NAO Winter Index 1)	SST_{annual} [°C]	ΔSST [std dev]	Elbe Run-off [km³/a]	ΔERO_r [std dev]	SST_{sur} [°C]	ΔSST_{sur} [std dev]	Total Heat Content [x 10^{21} J]	ΔTHC [std dev]	Total Salt Content [x 10^{12} t]	ΔTSC [std dev]
1999	1.70	10.69	0.84	21.22	-0.12	15.2	-0.87	1.427	-2.38	1.122	-0.66
2000	2.80	10.40	0.31	20.41	-0.25	15.3	-0.77	1.603	-0.33	1.134	-0.01
2001	-1.90	10.44	0.37	18.99	-0.48	15.2	-0.87	1.438	-2.25	1.083	-2.77
2002	0.76	10.94	1.29	35.69	2.24	15.4	-0.66	1.587	-0.52	1.131	-0.17
2003	0.20	11.00	1.40	19.79	-0.35	17.8	1.83	1.707	0.88	1.135	0.04
2004	-0.07	10.73	0.91	16.03	-0.97	17.1	1.10	1.692	0.71	1.147	0.69
2005	0.12	10.52	0.53	21.08	-0.14	14.9	-1.18	1.624	-0.08	1.141	0.37
2006	-1.09	10.96	1.32	22.29	0.05	17.0	1.00	1.619	-0.14	1.135	0.04
2007	2.79	10.91	1.23	21.98	0.00	15.3	-0.77	1.659	0.32	1.142	0.42
2008	2.10	10.75	0.95	20.25	-0.28	16.1	0.06	1.583	-0.56	1.146	0.64
2009	-0.41	10.64	0.74	20.06	-0.31	15.7	-0.35	1.755	1.44	1.139	0.26
2010	-4.64	9.95	-0.52	31.08	1.49	16.0	-0.04	1.632	0.01	1.140	0.31
2011	-1.59	10.38	0.28	26.30	0.71	15.3	-0.77	1.669	0.44	1.114	-1.09
2012	3.17	10.36	0.23	20.12	-0.30	16.0	-0.04	1.695	0.74	1.132	-0.12
2013	-1.97	9.99	-0.44	32.11	1.66	15.9	-0.15	1.627	-0.05	1.118	-0.88
reference period	-	1981-2010		1981-2010		2000-2010		2000-2010		2000-2010	

1) J. Hurrell NOA winter station based index (DJFM)

anomaly [std dev]	≤ -2	≤ -1	≤ 0	> 0	≥ 1	≥ 2

Table 1: Winter NAO (DJFM), annual and area averaged North Sea SST, annual Elbe run-off (ERO), area averaged SST of the survey periods (SST_{sur}), total summer heat (THC) and salt content (TSC), and normalised anomalies in standard deviations (Δ) 1999–2013.

Annex 11: Regional report – Northern Baltic Sea 2013 (Area 9)

Pekka Alenius

Finnish Meteorological Institute

Meteorological conditions in 2013

The year 2013 was exceptionally warm in Finland and in the middle of the country more rainy than on the average. Mean temperature was 1–2°C higher that the long-term average (average of 1981–2010). In the observation era there has been only five warmer years, latest of which was 2011.

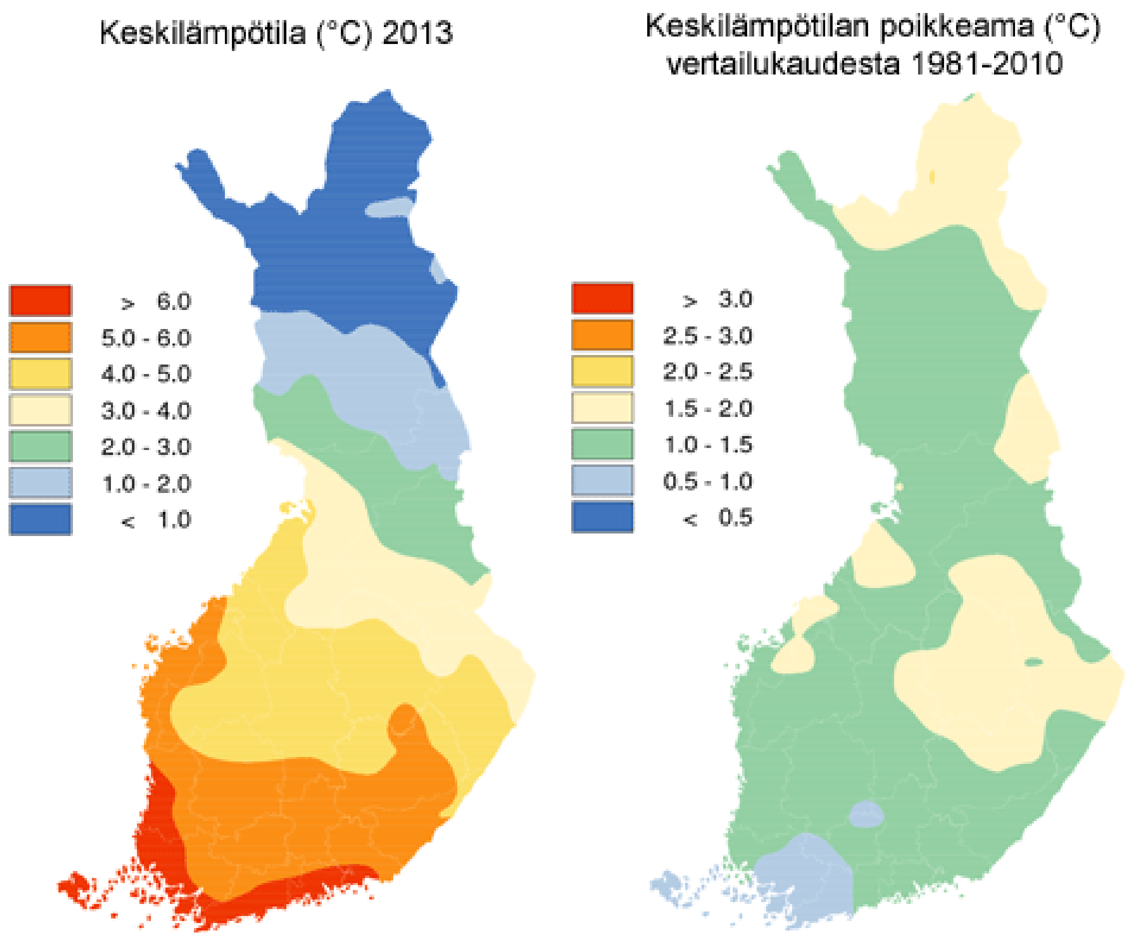

Figure 1. On the left there is the annual mean temperature and on the right the deviation of 2013 from the average conditions in 1981–2010 (Figure courtesy of FMI, taken from www.fmi.fi). The annual course of air temperature showed above average conditions in February, late spring-early summer and in autumn.

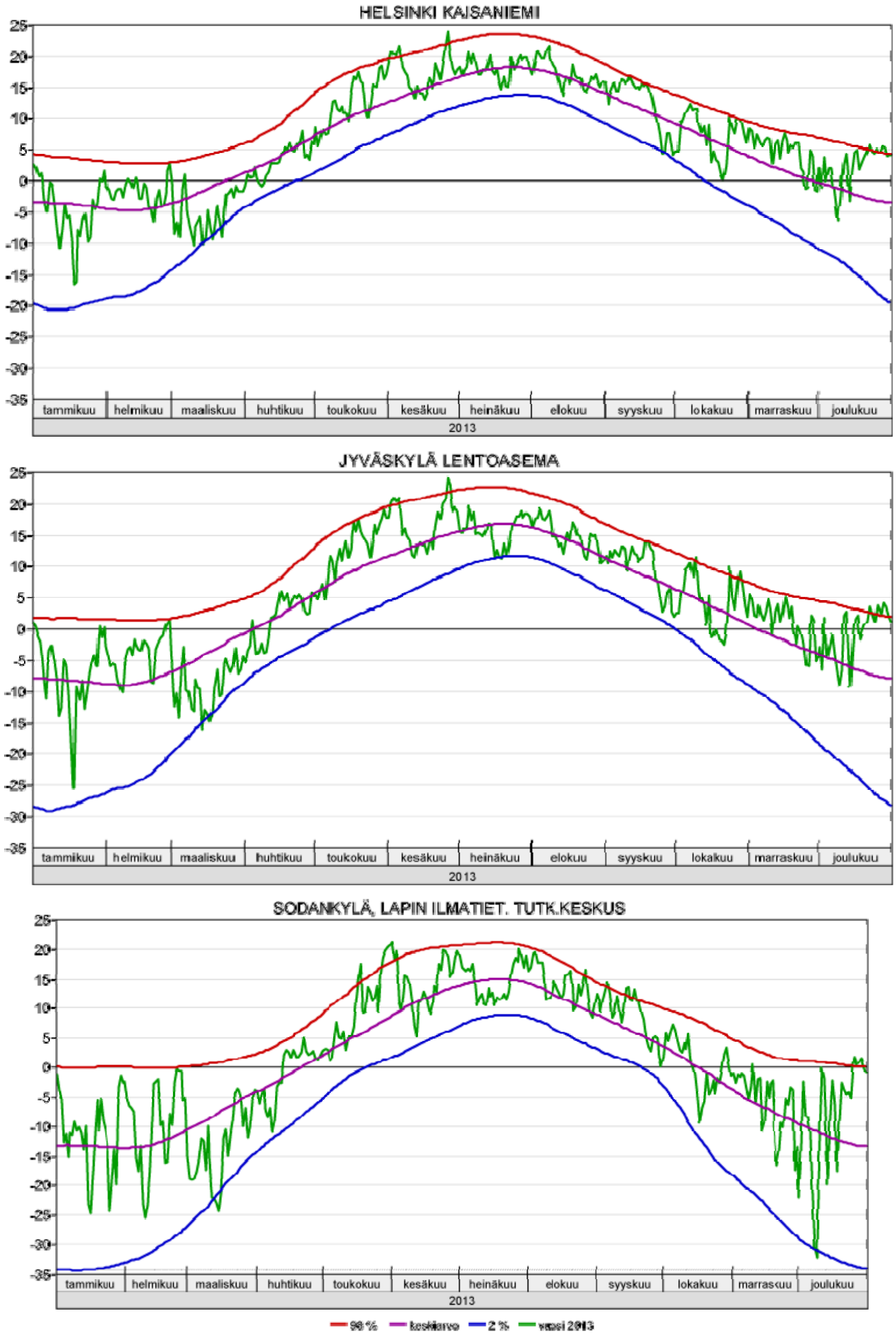

Figure 2. Annual course of air temperature in 2013 in comparison to statistical values in Southern, Middle and Northern Finland (Figure(s) courtesy of FMI taken from www.fmi.fi).

Sea surface temperature behaved similarly to the air temperature. Early summer and early autumn had especially warm sea surfaces. In July and August heavy upwelling events mixed the water and cooled the surface layer for several days.

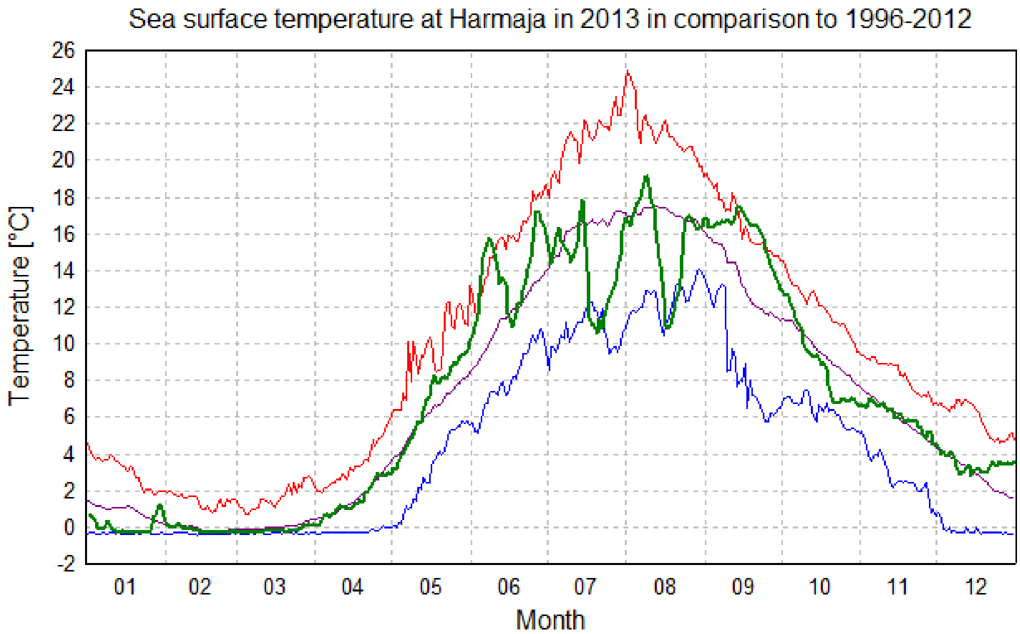

Figure 3. Annual course of sea surface temperature near to Helsinki in 2013 (green thick line) in comparison to statistical values 1996–2012.

Ice conditions in 2012

The ice winter 2012/2013 was almost similar to the previous year in ice extent. The maximum annual ice extent was 177 000 km², which is among normal winters and slightly more than on the average in 2000s.

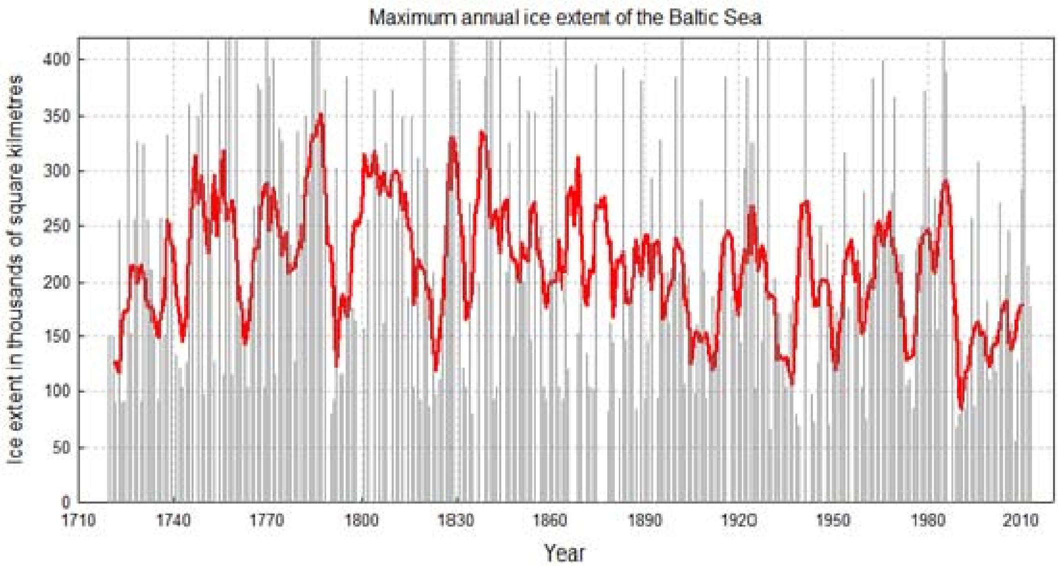

Figure 4. Annual maximum ice extent of the Baltic Sea since winter 1719/1720. The solid line is five years moving average.

Deep-water salinity and temperature

The deep waters have cooling trend after 2008 after slight warming since 2004. Salinity was lower than in some recent years.

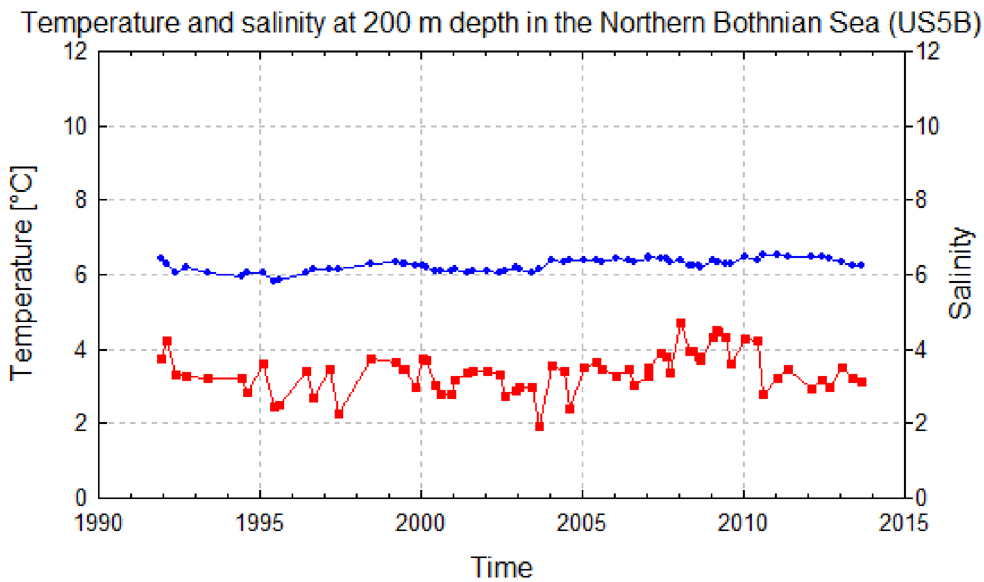

Figure 5. Deep-water salinity and temperature in the Northern Bothnian Sea in 1991–2013. The temperature cooling has stopped and salinity is remaining on the general level.

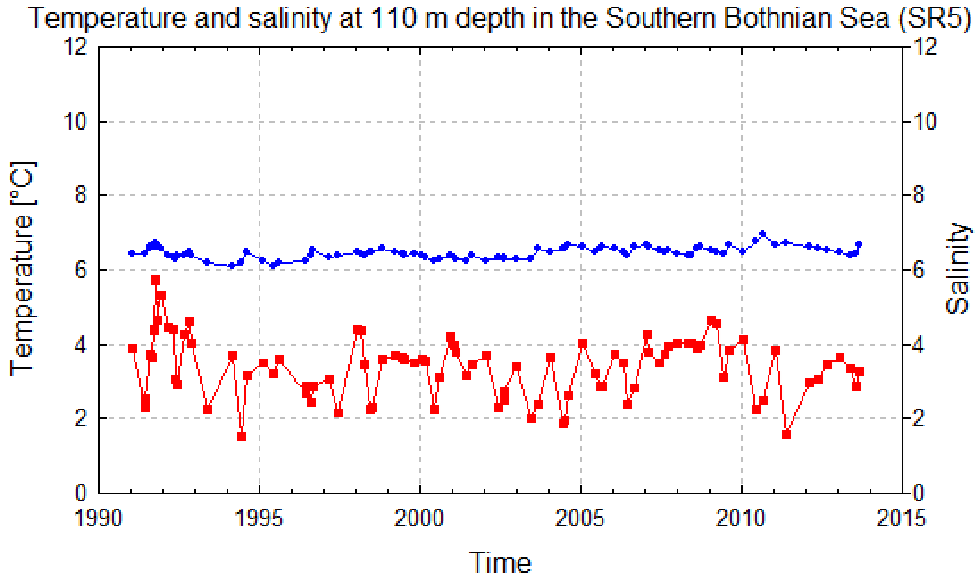

Figure 6. Deep-water salinity and temperature in the Southern Bothnian Sea in 1991–2013. The temperature has returned to ardinary level but salinity is rraising.

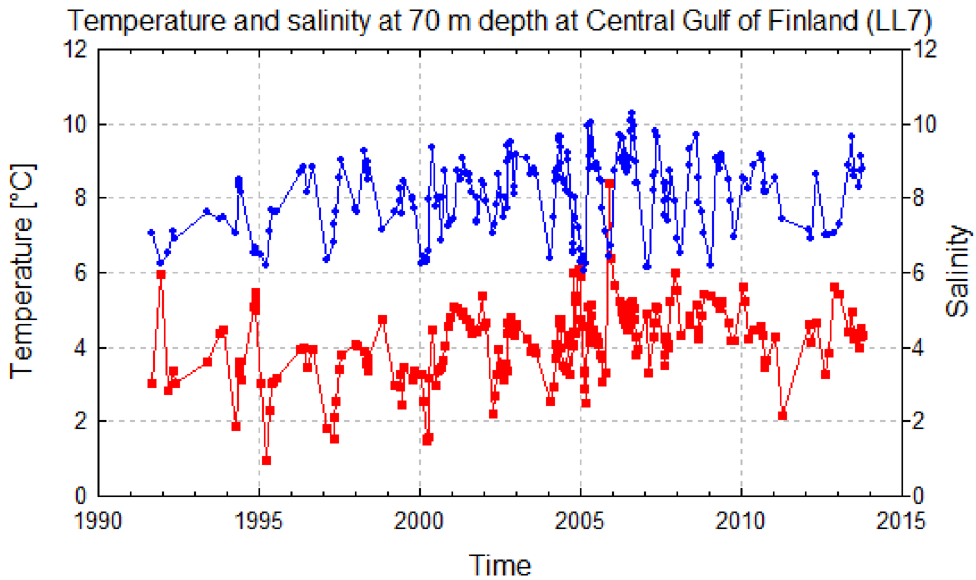

Figure 7. Deep-water salinity and temperature in the Central Gulf of Finland in 1991–2013. The temperature and salinity are in the same level as in previous year.

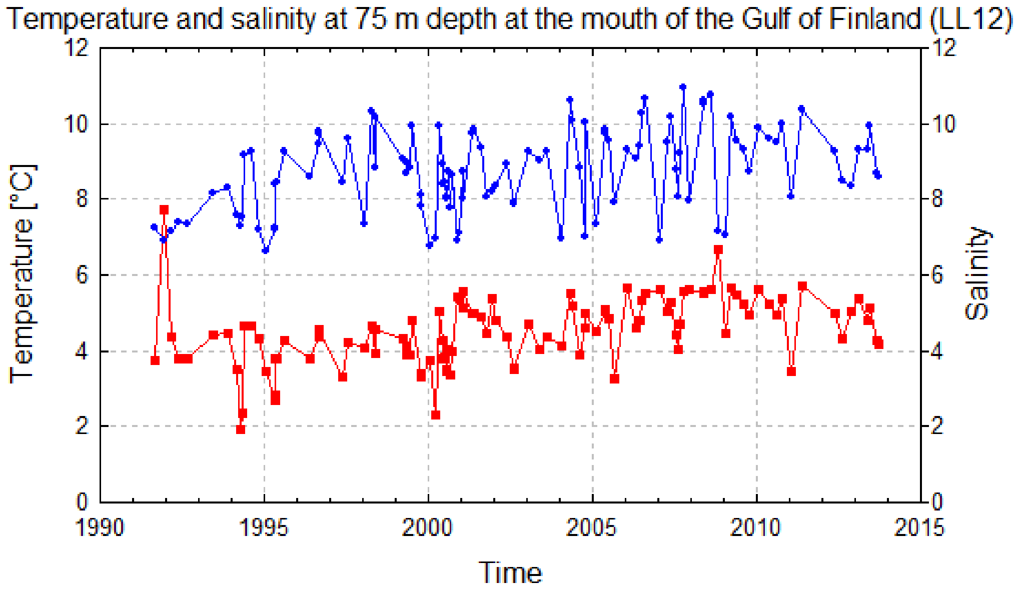

Figure 8. Deep-water salinity and temperature at the entrance of the Gulf of Finland in 1991–2013. The temperature is still cooling and salinity is going down, but still on the overall levels of the last 25 years.

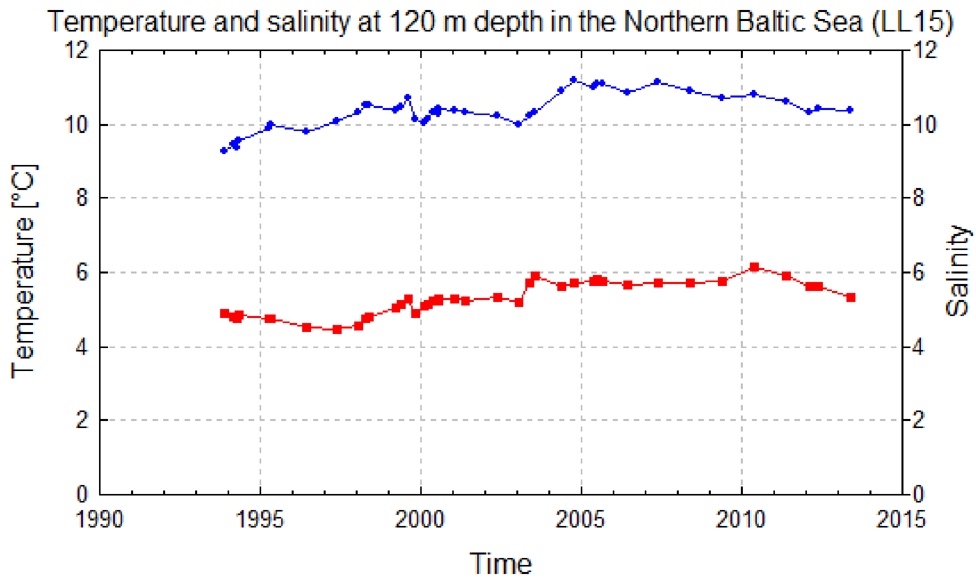

Figure 9. Deep-water salinity and temperature in the Northern Baltic Sea in 1991–2013. The temperature is cooling but salinity is staying at the same level as previous year.

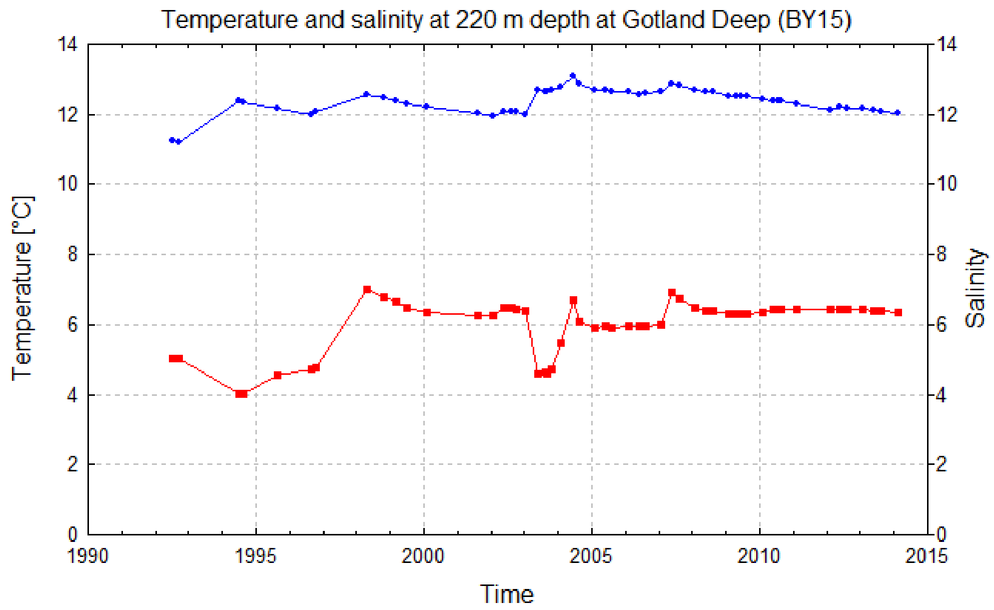

Figure 10. Deep-water salinity and temperature in the Gotland Deep in 1992–2013. The temperature is remaining but salinity may be slowly decreasing.

Salinity and temperature stratification

In August 2013 the halocline was higher than typical in the Northern Bothnian Sea but salinity below halocline was at average level.

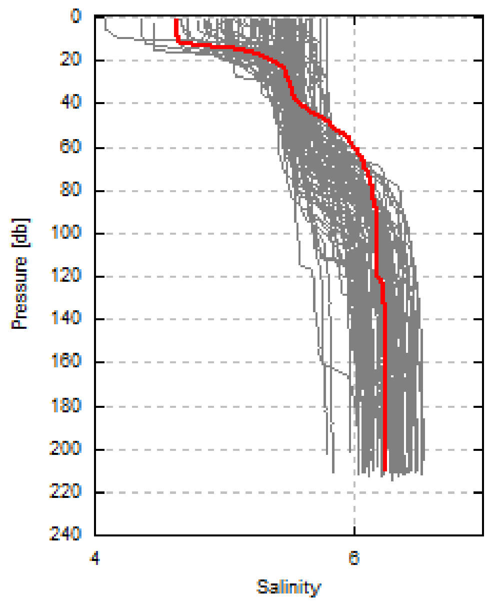

Figure 11. Salinity stratification in August in the Northern Bothnian Sea in 1991–2013. The red profile is from August 2013 and the grey ones are from 1991–2013.

The late summer temperature stratification seemed to be rather typical to the area in the Northern Bothnian Sea.

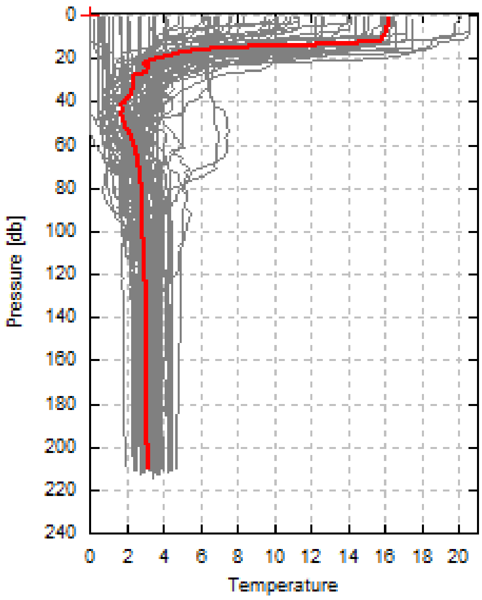

Figure 12. Temperature stratification in the Northern Bothnian Sea in 1991–2013. The red profile is from August 2013 and the grey one are from 1991–2013.

In the Southern Bothnian Sea (SR5) the halocline was rather high, too. The stratification seems to have been stronger than on the average.

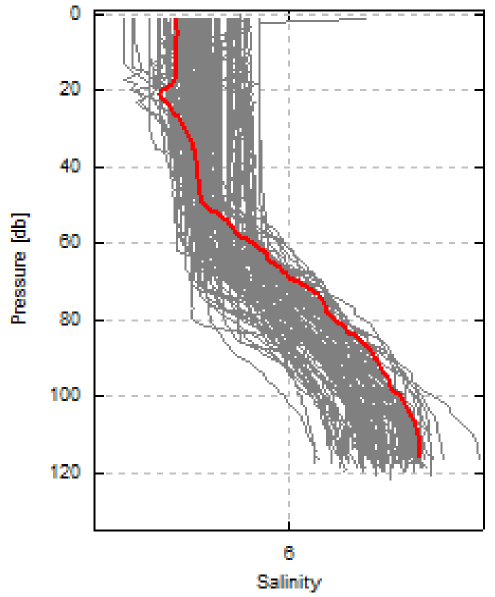

Figure 13. Salinity stratification in the Southern Bothnian Sea in 1991–2013. The red profile is from August 2013 and the grey ones are from 1991–2013.

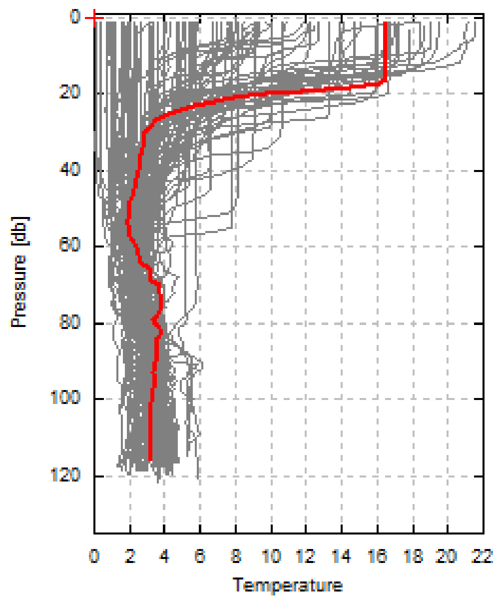

Figure 14. Temperature stratification in the Southern Bothnian Sea in 1991–2013. The red profile is from August 2013 and the grey ones are from 1991–2013.

Gulf of Finland

The salinity stratification in the Central Gulf of Finland was rather typical to the area in 2013.

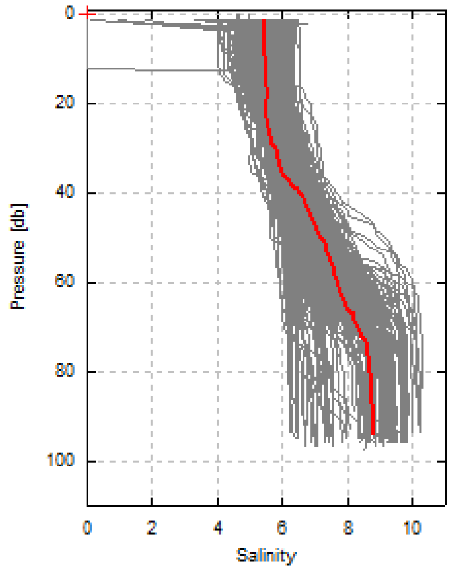

Figure 15. Salinity stratification in the Central Gulf of Finland in 1991–2013. The red profile is from August 2013 and the grey ones are from 1991–2013.

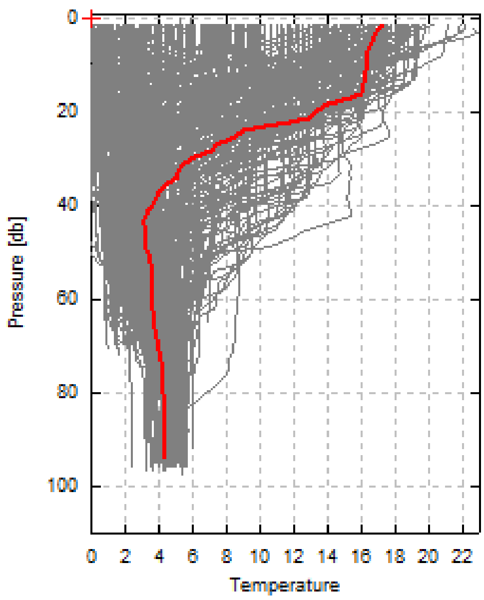

Figure 16. Temperature stratification in August in the Central Gulf of Finland in 1991–2013. The red profile is from August 2013 and the grey ones are from 1991–2013.

Baltic Sea Proper

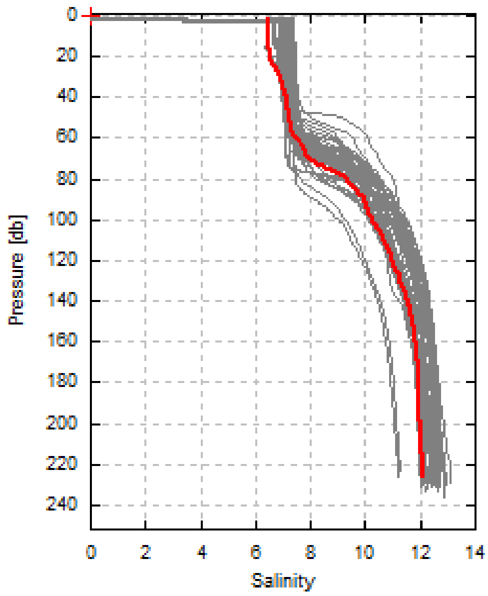

Figure 17. Salinity stratification in the Baltic Sea Proper (Gotland Deep) in 1991–2013. The red profile is from August 2013 and the grey ones are from 1991–2013.

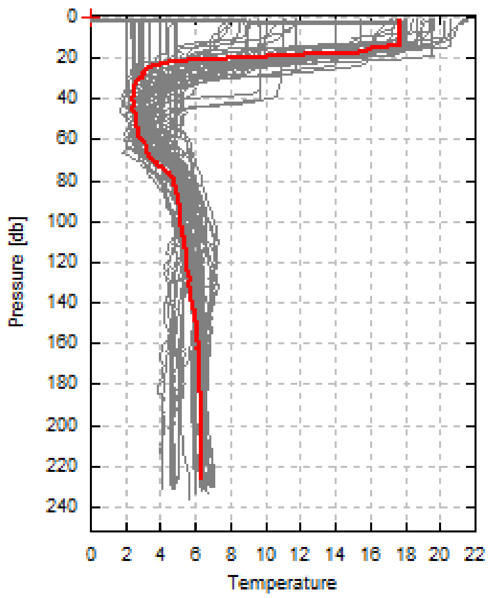

Figure 18. Temperature stratification in the Baltic Sea Proper (Gotland Deep) in 1991–2013. The red profile is from August 2013 and the grey ones are from 1991–2013.

Oxygen conditions in the Baltic Sea Proper and the Gulf of Finland in 2013

Deep-water oxygen conditions in the Baltic Sea in 2013 were worse than in 2012. The area with oxygen depletion had somewhat increased.

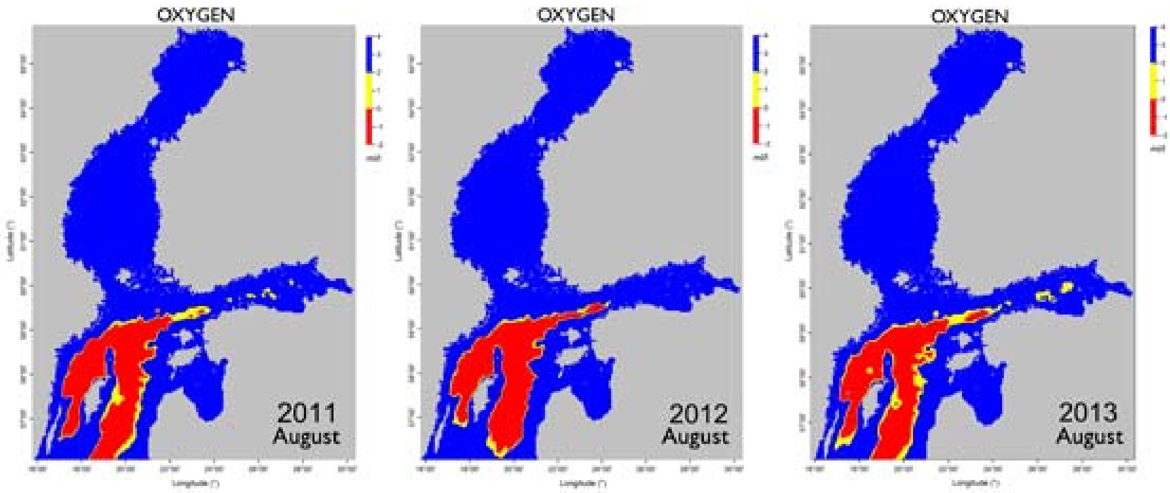

Figure 19. Areas on deep-waters with oxygen depletion in 2011, 2012 and 2013 (Figure courtesy of Finnish Environment Institute is taken from the Baltic Sea Portal http://www.itameriportaali.fi/en/ajankohtaista/itameri-tiedotteet/2013/en_GB/meren_tila/.

Annex 12: Regional report – Skagerrak, Kattegat and the Baltic 2013 (Area 9)

Karin Borenäs

Swedish Meteorological and Hydrological Institute (SMHI), Sweden

Owing to its central location relative to the Skagerrak, Kattegat, and Baltic, the weather in Sweden can be taken as representative for the area. The year 2013 was warmer than normal everywhere in Sweden, especially in the north. The yearly mean temperature was around 1°C above the long term mean (1961–1990). March was, however, several degrees below normal in the whole country with a mean temperature below zero. March was also very dry and sunny and at some locations there was no precipitation at all this month. For the whole year the precipitation was somewhat higher than normal in the north and lower than normal in the south. A record-long period (594 days) without any storms was broken at the end of October when the first of several storms hit the country.

Annual cycles of sea surface temperature and salinity

A large number of hydrographic stations are regularly visited in the Baltic Sea, Kattegat and Skagerrak, as exemplified in Figure 1. From five of these stations the annual cycles of surface temperature and salinity are presented in Figure 2.

The sea surface temperatures in Skagerrak and Kattegat were normal for most of the year except for the spring months when it was well below normal (cf. stations Å17, P2 and Anholt E in Figure 2). In the Baltic Proper the temperature was also below normal in the spring but the anomaly was smaller. For the rest of the year the sea surface temperatures in the Baltic Proper were close to normal.

The low spring temperatures in Skagerrak and Kattegat were linked to very low values of the surface salinity. From satellite SST images it was clearly visible that warmer, and more saline, water of North Sea origin did not enter the Skagerrak and Kattegat region during this cold period. Instead a long-lasting high pressure situation with north-easterly winds gave rise to large outflows of fresher water from the Baltic Sea.

The salinities in the Baltic Proper were normal for most of the year. However, a noticeable freshening of the surface water in the eastern parts of the Gotland Basin was observed during the fall (see station BY15 in Figure 2). This period was preceded by a summer with large fresh water transports, possibly entering the Riga Bight and then spreading into the Gotland Basin.

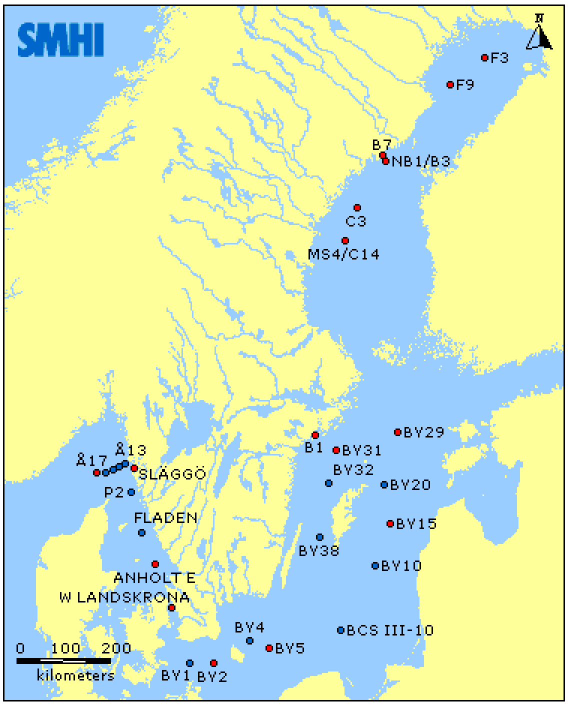

Figure 1. Position of stations visited on a regular basis. Stations marked with red pertain to the Swedish National Monitoring Programme while stations in blue are additional stations sampled by SMHI.

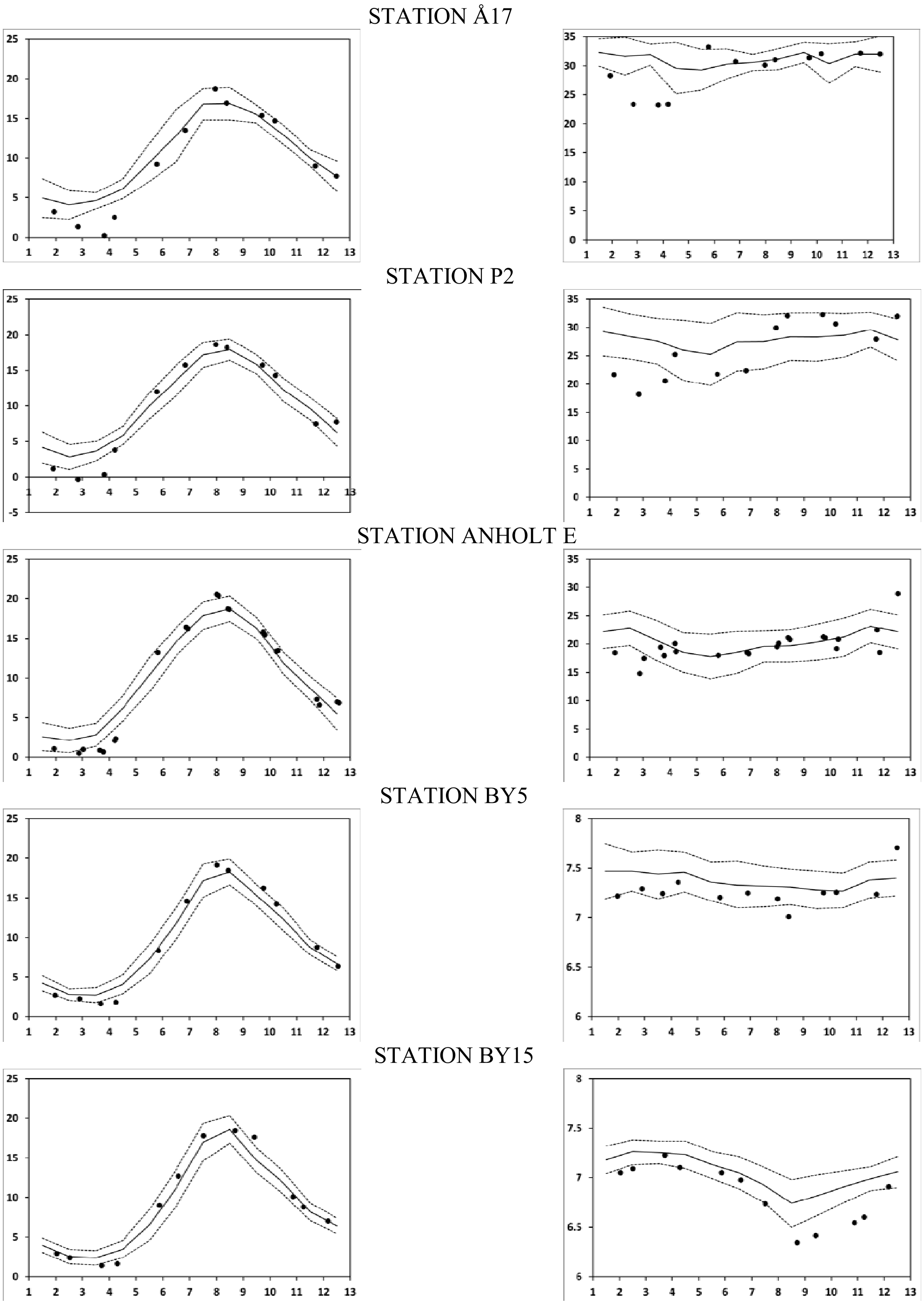

Figure 2. Annual cycles of sea surface temperature (left column) and salinity (right column), see Figure 1 for station positions. Solid line shows the mean for the period 1996–2010 and filled circles the 2013 observations. Dotted lines indicate ± 1 standard deviation (SMHI).

Long term observations at BY15

At station BY15, east of Gotland, the yearly mean surface temperature was somewhat higher than 2011, see Figure 3 upper panel (the temperature value for 2012 is missing due to problems with vessels that year). The anomaly was 0.6 °C above the 1990–1999 mean temperature. The yearly mean surface salinity at BY15 showed a drop due to, as previously mentioned, the low salinities found in the area during the fall (Figure 3, lower panel).

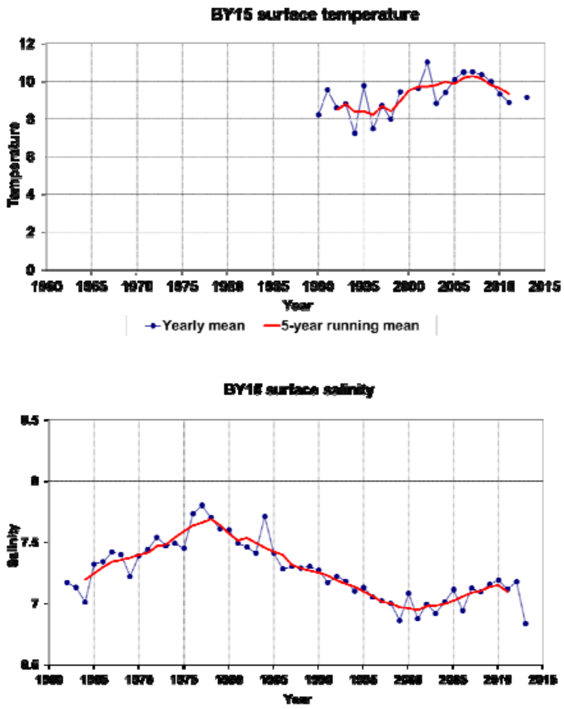

Figure 3. Sea surface temperature (upper panel) and salinity (lower panel) at BY15 (see Figure 1) in the Baltic Proper. Yearly mean (blue curve) and 5-year running mean (red curve). SMHI

Water exchange

The accumulated outflow from the Baltic Sea in March was the highest since 1977, caused by high sea levels in the Baltic Sea and a long-lasting high pressure situation with northeasterly winds. A minor inflow to the Baltic took place in January but, due to the lack of storms, it was the only inflow observed up to the end of October. Then the storm Simone caused an inflow of 40 km^3 through the Sound (not including the Danish Straits) which was followed by a smaller inflow in the beginning of December. These inflows improved the oxygen situation in the southern part of the Baltic Proper.

Inflows have to exceed 100 km^3 through the Sound to be considered as a major. The last time such a large inflow took place was in 2003.

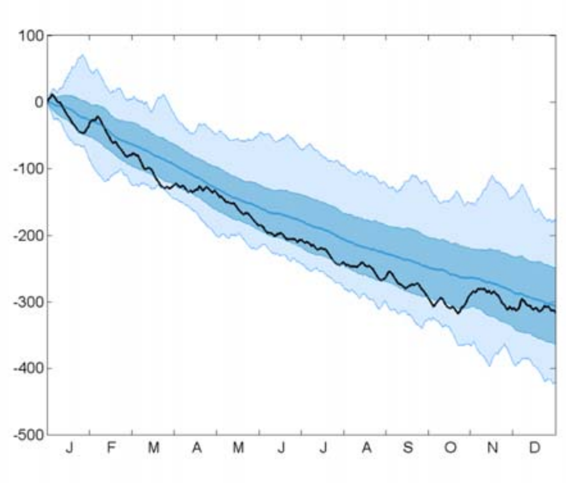

Figure 4. Accumulated inflow (km^3) through the Öresund into the Baltic in 2013 (black line) compared to 1977–2013 (blue line). The darker blue area delimits ±1standard deviation and the lighter blue area maximum and minimum values.

Ice condition

In all, the ice season 2012/2013 was considered as normal, starting off in late November, and in late December most of the Bay of Bothnia was ice covered. Around New Year windy conditions and high temperatures broke up the ice cover and it was not re-established until mid-January. The ice growth continued in the Bothnian Sea, the Gulf of Finland and in the archipelagos of the Baltic Sea, but the cover was temporarily broken up again at the end of February. Due to the unusually cold March the maximum ice extent, 176 000 km^2, was reached as late as 29 March, which is a record, see Figure 5.

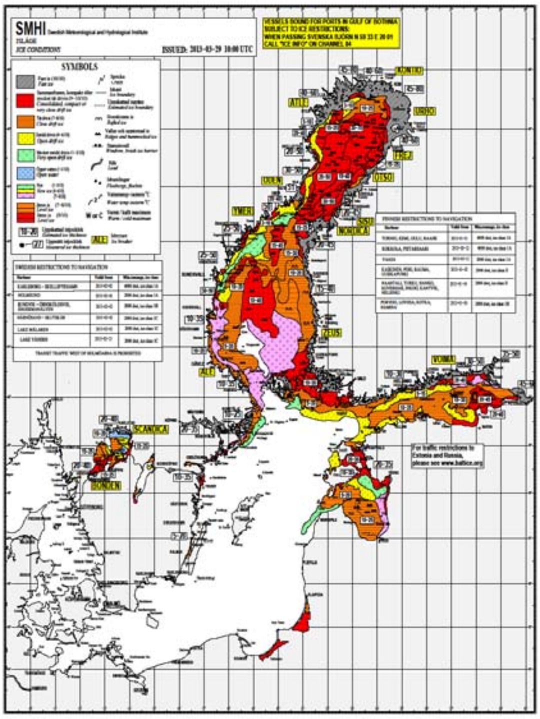

Figure 5.The maximum ice extent in the Baltic Sea during the winter 2012/2013. The map was constructed by the Ice Service at SMHI.

In Figure 6 the maximum ice extent in the Baltic is plotted for the period 1957–2013. The value for 2012/2013 was about the same as for the preceding ice season.

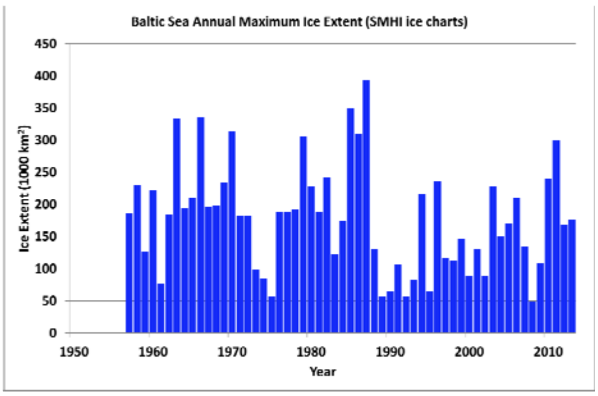

Figure 6. The maximum ice extent in the Baltic starting from 1957 (Graph constructed by Lars Axell, SMHI).

Oxygen conditions

Extensive surveys of the oxygen conditions in the Baltic Proper is regularly carried out in the fall. The 2013 survey showed that the situation in the deep water continues to be serious. In the Baltic Proper, Gulf of Finland and Gulf of Riga approximately 15% of the bottom areas was affected by anoxia and around 30% by hypoxia (<2ml/l).

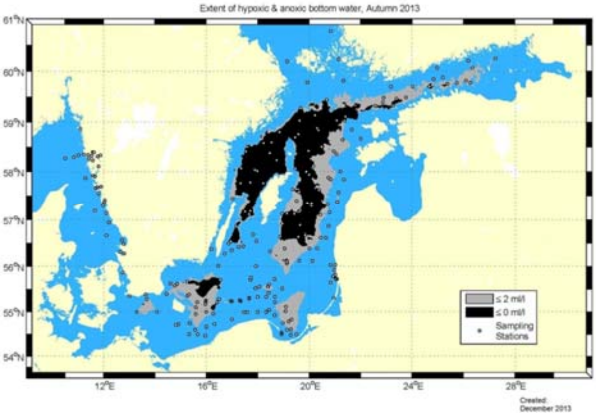

Figure 7. The preliminary oxygen situation in the Baltic Proper in autumn 2013. The map is based on measurements carried out by SMHI, together with data from Poland, Finland, Estonia, Latvia and Lithuania.. Visited stations (grey dots), hypoxia (grey) and anoxia (black).

Annex 13: Regional report – Atlantic domain of the Nordic Seas 2013 (Areas 10, 11, 12)

Ilona Goszczko, Agnieszka Beszczyńska-Möller, Waldemar Walczowski

Institute of Oceanology, Polish Academy of Sciences (IOPAS), Poland

Observations

During the AREX2013 expedition aboard R/V Oceania the oceanographic survey was conducted over a grid of stations consisting of standard sections repeated annually since 2000, as well as along new sections located north of Svalbard. The arrangement of the oceanographic sections is shown in Fig. 1. During the cruise 242 full-depth CTD casts were performed, providing profiles of temperature, salinity, dissolved oxygen and fluorescence (as proxy for chla). A standard CTD system Seabird 9/11+ was equipped with double pairs of temperature and conductivity sensors and pressure sensor. Additionally, the CTD system carried two oxygen sensors, fluorescence sensor and altimeter. The CTD system was mounted on a SeaBird bathymetric rosette (carousel) equipped with 9 Nansen bottles, 12 l each. Preliminarily the data were processed almost in real time, while the final data set will be available after the post-cruise calibration of sensors.

The water samples were collected from a deep layer of small vertical gradients of hydrographic properties for calibration of conductivity sensor. Additionally, 203 water samples at 40 stations were taken and frozen at -20°C for post-cruise lab analysis of nutrients. During the entire cruise the underway survey of sea currents in the upper ocean was performed with use of the Vessel Mounted Acoustic Doppler Current Profiler.

CTD casts were distributed along a total number of 14 hydrographic sections. The standard section EB along 78°50′N had to be shortened due to unfavorable ice conditions (ice edge at 2°E). Only a half of the planned length of section Y was covered due to sudden change of weather (high waves).

In addition to CTD casts, four high-resolution hydrographic sections (about 10 hours each) down to 300 m were measured with a towed scanfish CTD system. The scanfish system is equipped with the CTD Seabird SBE49 built into a frame constructed at IOPAS. The CTD data are received and recorded in real-time. Two scanfish sections (1HP and 2HP) were measured at the continental slope and shelf beside the Hornsund outlet. Another two scanfish sections (1NB and 1 WB) were surveyed in the southern Nansen Basin, from the deep basin towards the shelf north of Svalbard. The arrangement of all the scanfish sections is shown in Fig. 1 as well.

Hydrographic conditions

In general, the thermal conditions of the West Spitsbergen Current in summer 2013 were similar to these observed in 2012. The northern limit of 5°C isotherm at 100 m in June reached the 76°N which was comparable to the situation from the previous summer (Fig. 2).

The standard section N (76°30′N) stretching westward off Sørkapp, represents the longest time series of the IOPAS hydrographic survey and provides data for studying long-term variability of the Atlantic Water hydrographic properties. In 2013 the AW at whole section N (Fig. 3) was slightly colder and less saline than in 2012. While the AW in the core of the West Spitsbergen Current (WSC) was warmer in 2013, temperature in the lower AW layer decreased as compared to 2012.

The time series of mean AW properties at level 200 m of standard section N (between 9°E and 12°E) shows decreasing of temperature by 0.51°C (Fig. 4a). Salinity also decreased in comparison to 2012 by 0.03 (Fig. 4b). According to the IOPAS time series (mean value for the period 1996–2013), in summer 2013 temperature anomaly (section N between 9°E and 12°E, 200 m) was negative while salinity anomaly was positive; normalized temperature anomaly was equal to -0.055 and normalized salinity anomaly was equal to 0.697 (Fig. 5).

Deep water monitoring

The deep water has been monitored since 1997 at the stations located closely to each other in the deep tectonic rift, being a part of the Knipovich Ridge (~78°N, 7°E). For the last 17 years temperature between 2500 and 2850 dbar increases almost monotonically by the value close to 0.11°C (Fig. 6). This may be explained by the gradual advection of the deep water originating from the Arctic Ocean (Eurasian Basin Deep Water) to the Greenland Sea and decreased amount of the colder deep water from the Greenland Sea forming by the deep convection (Greenland Sea Deep Water). Simultaneously, there is no trend observed in the salinity at this particular location. Instead of that, annual salinity values show high interannual variability. It may be explained by existence of additional salt source namely dense water plumes cascading from the Barents Sea's shelf and other local processes which very likely have an effect on the deep water masses composition.

Dynamics

In 2013 the western boundary of the West Spitsbergen Current was strongly pronounced in the frontal zone, where significant sloping of isopycnals implied stronger geostrophic flow. The front between the warm and saline AW and the cold and fresher coastal waters in the Sørkapp Current was on the other hand much less outstanding than a year before.

Distribution of baroclinic currents and temperature at 100 dbar (calculated for the reference level of 1000 m) in summer 2013 is presented in Fig.7. As in the previous year, baroclinic inflow into the Barents Sea concentrates in the southern part of the Barents Sea Opening, close to the Norwegian coast. Part of this flow is linked with the Norwegian Coastal Current. Flow into the Fram Strait direction was slightly more intensive than in summer 2012.

Moored instruments

For the purpose of quasi-continuous year-long oceanographic survey, two shallow water moorings were recovered and one mooring was deployed during the AREX2013 cruise. Positions of all the moorings are shown in Fig. 1.

Two mooring systems deployed by the IOPAS personnel in September 2012 north of Svalbard (the Svalbard Branch of the West Spitsbergen Current, bottom depth ~800 m, not shown on the map) were recovered during the R/V Lance cruise organized by WHOI and NPI in September 2013. One McLane Moored Profilers (MMP) mooring was redeployed for the next year.

Future plans for monitoring

In summer 2014 IOPAS is going to continue measurements at the standard sections in the WSC area. There are plans to recover and re-deploy the MMP mooring north of Svalbard (autumn cruise of R/V Lance). In addition to that, the second deep water mooring should be deployed in summer 2014 (AWI cruise aboard the R/V Polarstern). Deployment of two ARGO float is planned under the Euro-Argo E-AIMS project, as well.

References

Walczowski W., Piechura J., Goszczko I., Wieczorek P., 2012, *Changes of the Atlantic Water properties as an important factor of the European Arctic marine climate*, ICES J. Mar. Sci., doi: 10.1093/icesjms/fss068

Walczowski W., 2013, *Frontal structures in the West Spitsbergen Current margins*, Ocean Sci., 9, 957–975, doi:10.5194/os-9–957–2013, 2013

Figures

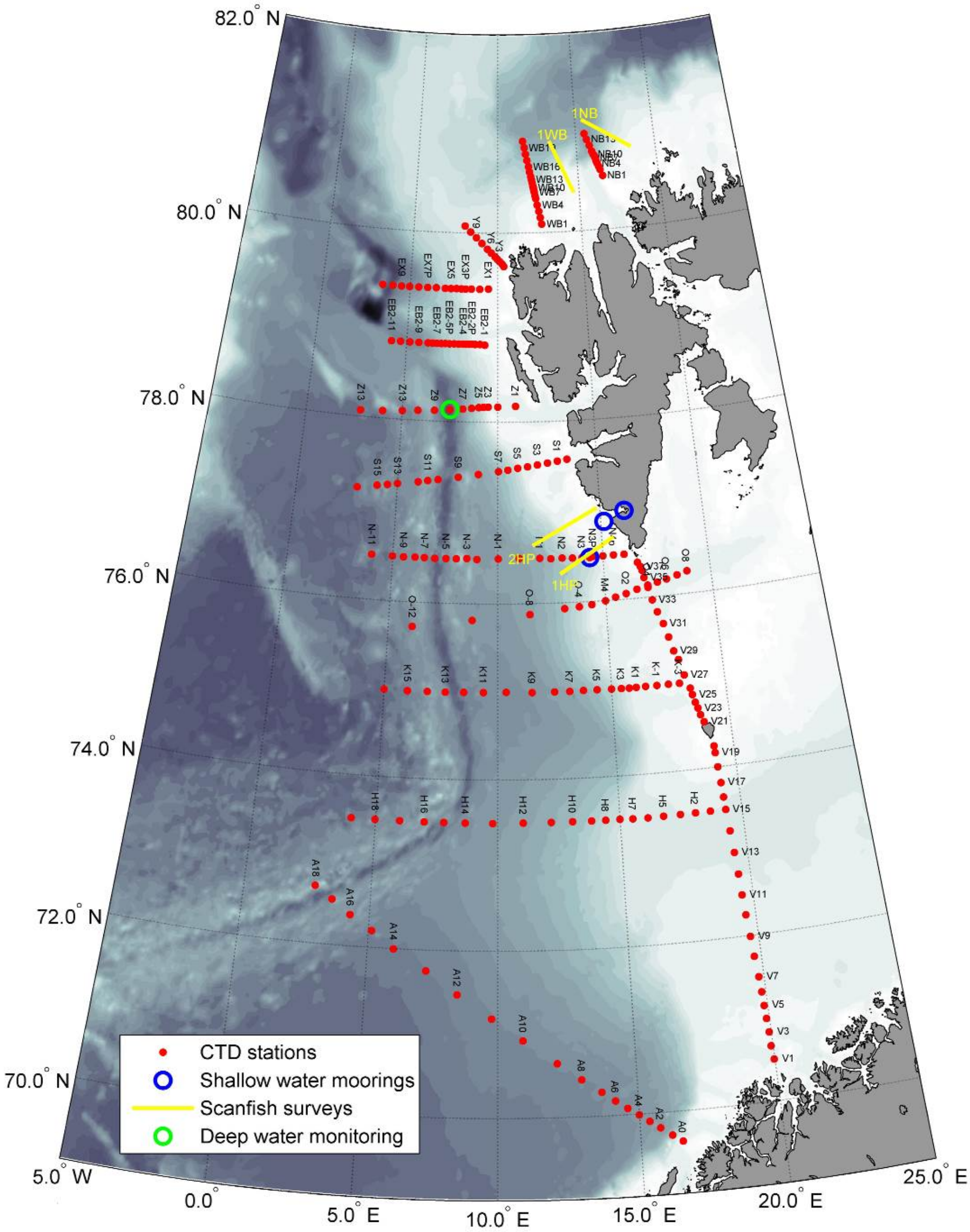

Figure 1: CTD/LADCP stations grid performed during IOPAS Arctic cruise AREX2013 aboard R/V 'Oceania' in summer 2013.

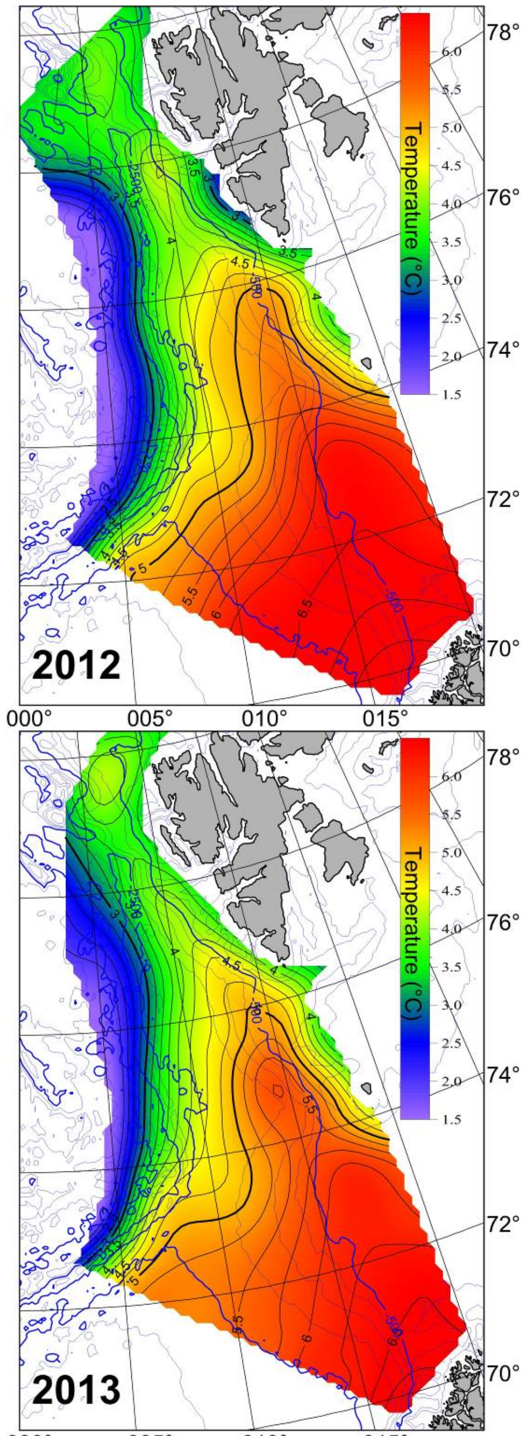

Figure 2: Temperature at 100 m in summers 2012 and 2013. Isotherm 5°C in bold.

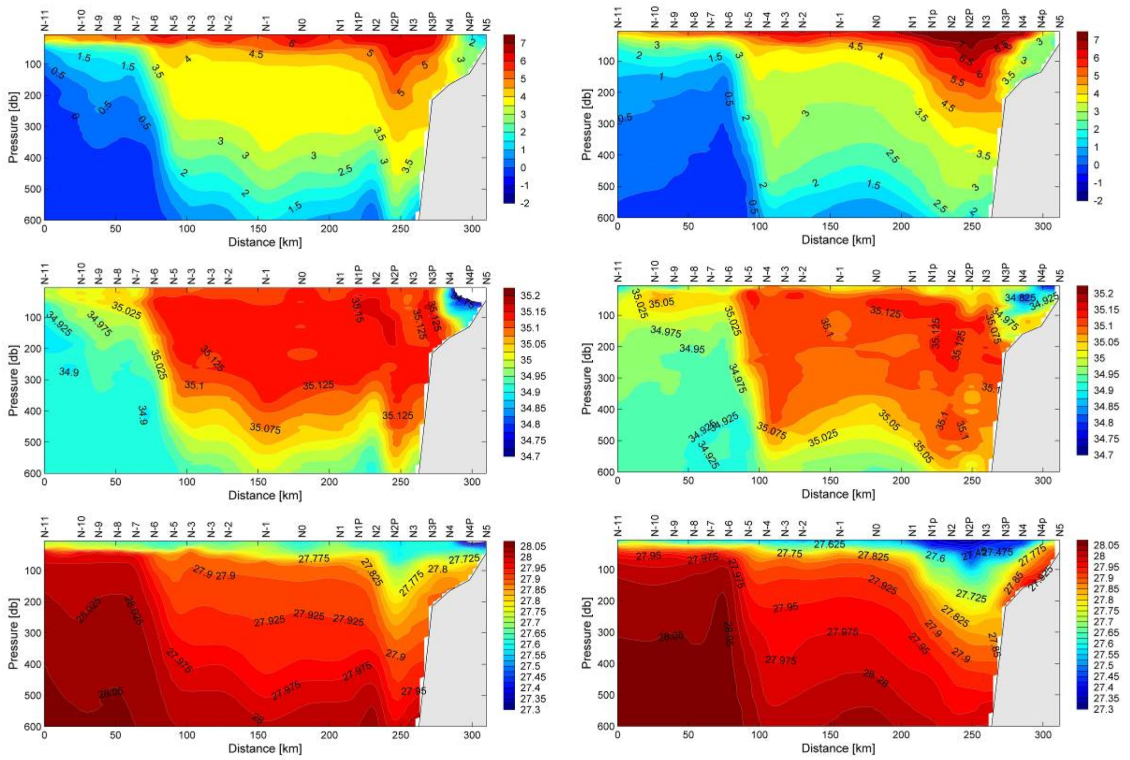

Figure 3: Potential temperature, salinity and potential density distribution along standard section 'N' (along the 76°30'N parallel) in June 2012 and 2013.

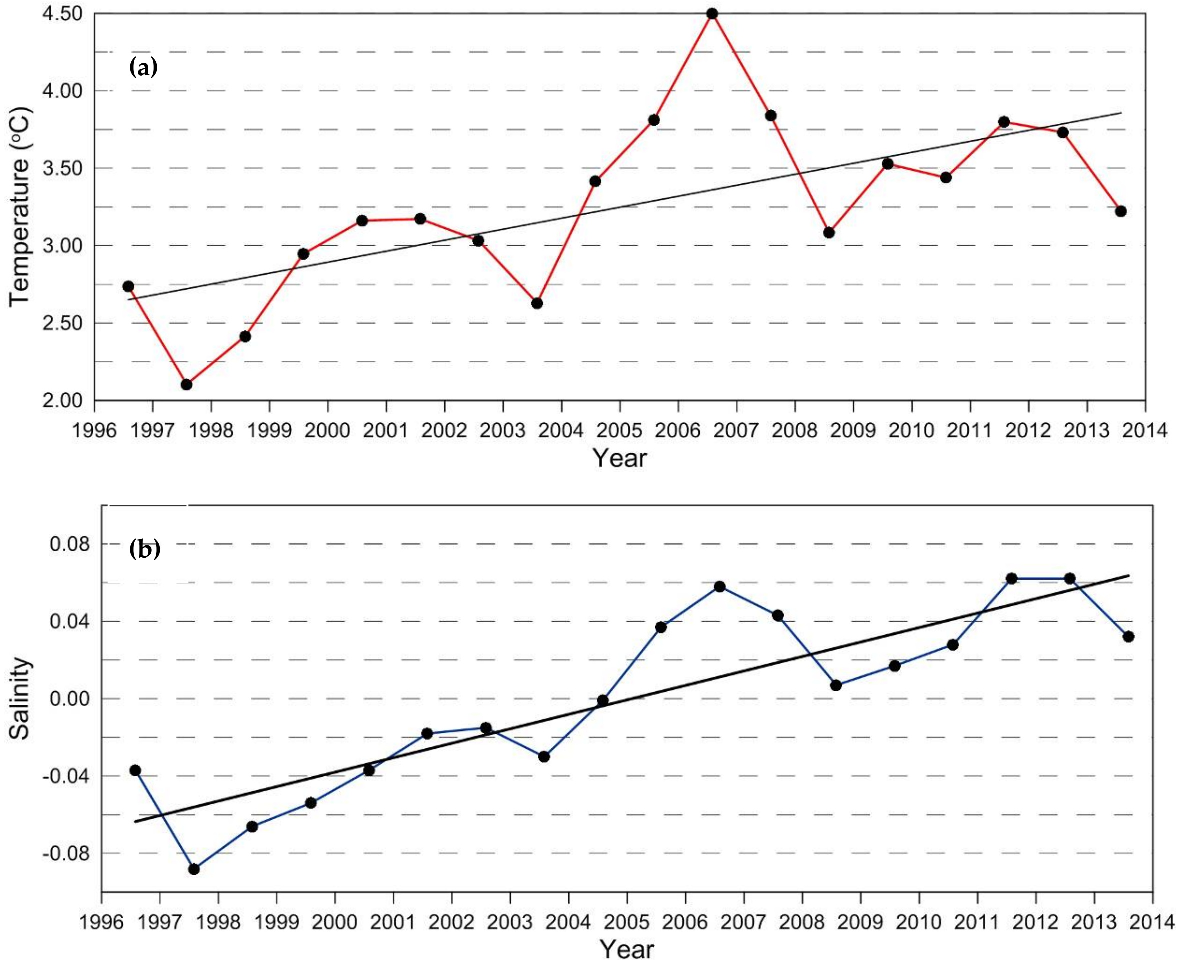

Figure 4: Time series of mean AW temperature (a) and salinity (b) at 200 m depth of the standard section 'N' (76°30'N, between 9°E and 12°E). Linear trends are marked.

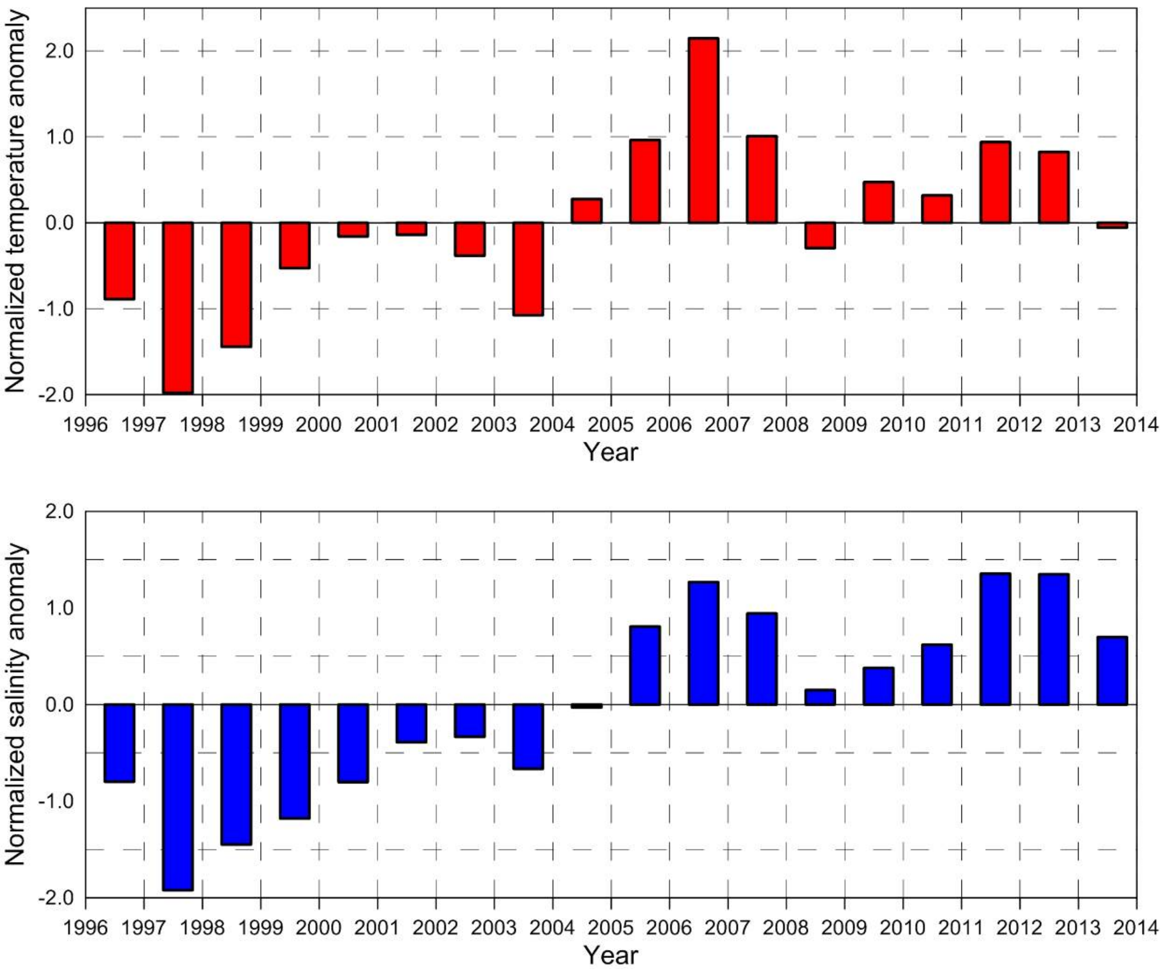

Figure 5: Normalized anomalies of AW (a) temperature and (b) salinity at level 200 of the standard section N (76°30′N, between 9°E and 12°E).

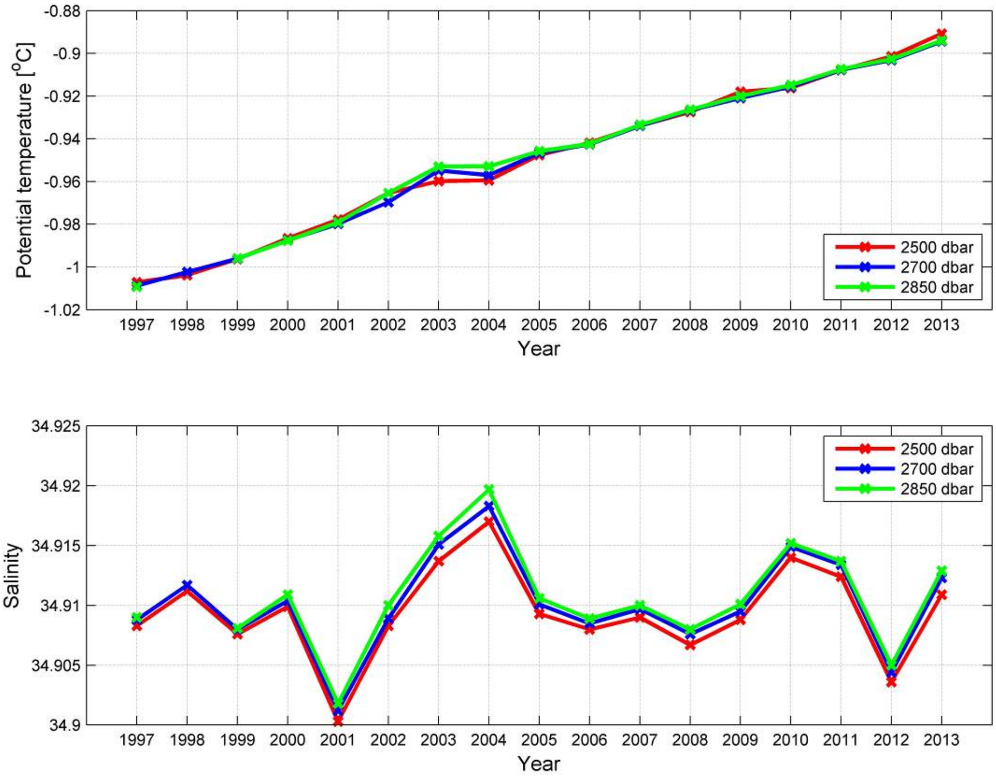

Figure 6. Annual values of temperature and salinity at three depth levels below 2000 m collected at the station in the northern part of the Greenland Sea.

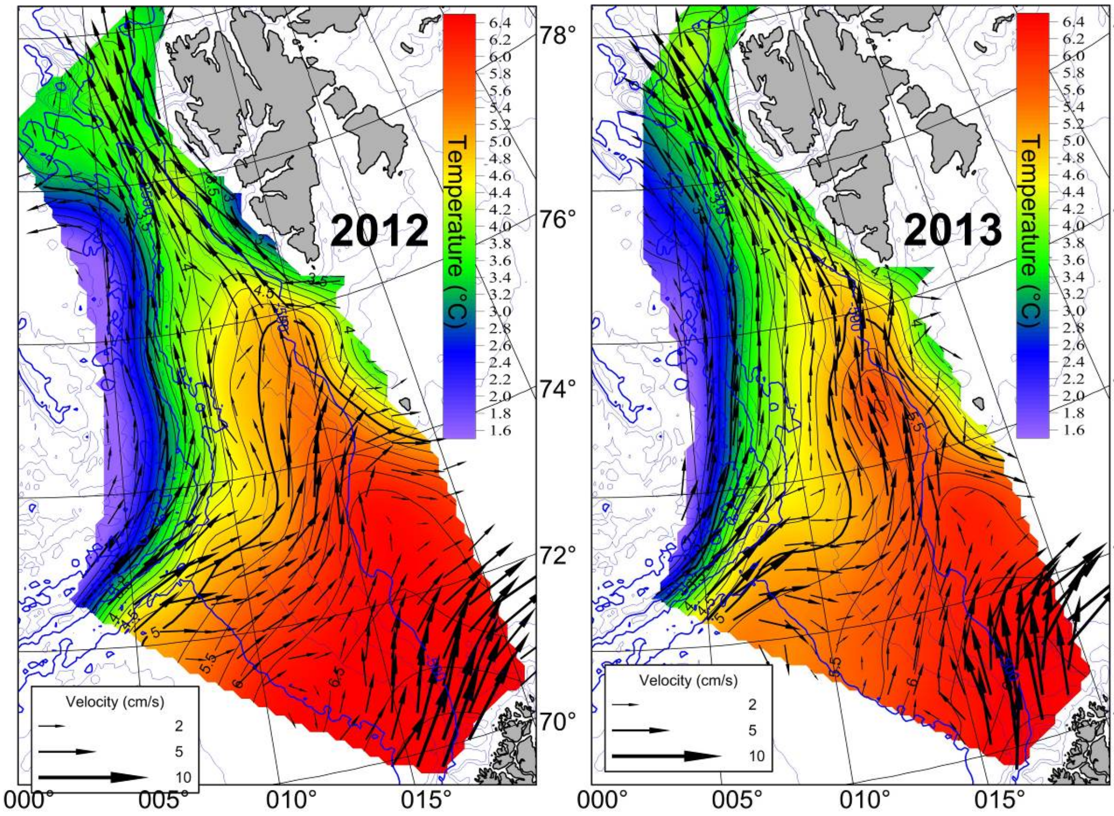

Figure 7: Temperature and baroclinic currents at 100 dbar as observed in summer 2012 and summer 2013.

Annex 14: Regional report – Russian sections in the Barents Sea 2013 (Area 11)

Karsakov and A. Trofimov

Knipovich Polar Research Institute of Marine Fisheries and Oceanography (PINRO), Russia

The analysis of hydrographic conditions in the Barents Sea is based on the available observations along standard sections and the data from fish stock assessment surveys. The total number of hydrographic stations made by PINRO in 2013 was 1 421 including 224 stations at the standard sections.

Fig. 1 shows the main Russian standard sections in the Barents Sea the data from which are discussed further.

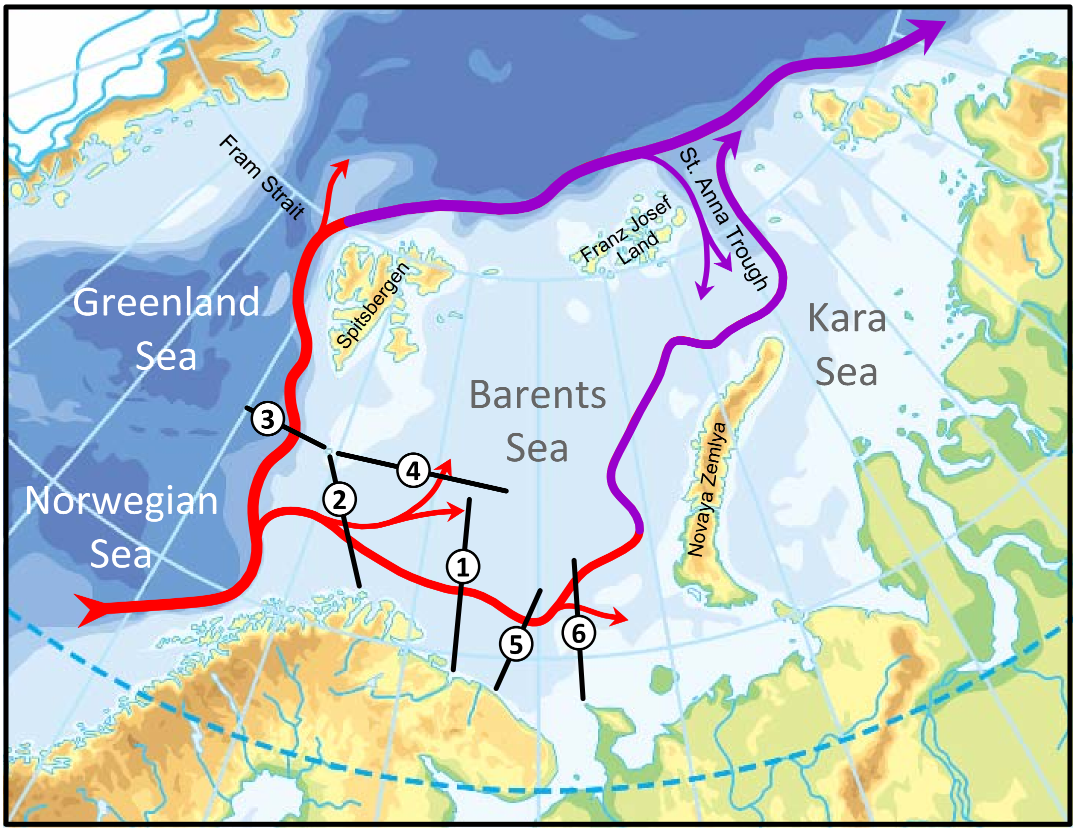

Figure 1. Main Russian standard sections in the Barents Sea: Kola (1), North Cape – Bear Island (2), Bear Island – West (3), Bear Island – East (4), Kharlov (5), Kanin (6).

The observations along these hydrographic sections have been made since the first half of the last century (the Kola Section – since 1900, the North Cape – Bear Island Section – since 1929, the Bear Island – West Section – since 1935, the Bear Island – East Section and the Kanin Section – since 1936). The Kola Section has been occupied more than 1 100 times by now.

Published time series from the main standard sections (Bochkov, 1982; Tereshchenko, 1997, 1999; Karsakov, 2009) were also used in the analysis. Anomalies were calculated using the long-term means for the periods 1951–2010 (Kola Section), 1954–1990 (Kanin Section), 1951–1990 (other standard sections).

Air temperature data were taken at http://nomad2.ncep.noaa.gov and averaged over the western (70–76°N, 15–35°E) and eastern (69–77°N, 35–55°E) Barents Sea. During 2013, positive air temperature anomalies prevailed in the Barents Sea with the largest values (up to 5°C) in the eastern sea in January, February and April.

Sea surface temperature (SST) data were taken at http://iridl.ldeo.columbia.edu and averaged over the southwestern (71–74°N, 20–40°E) and southeastern (69–73°N, 42–55°E) Barents Sea. During 2013, positive SST anomalies prevailed in the Barents Sea. At the beginning of the year, they did not exceed 1.0°C and were decreasing towards March. In April–May, small negative SST anomalies (–0.2 to –0.3°C) were observed in the western Barents Sea. From May to August, a significant increase in SST anomalies took place in the Barents Sea. The largest anomalies (up to 4.0°C) were found in the eastern sea, where the highest SST since 1981 occurred in July, August and September 2013. Then the SST anomalies were decreasing by the end of the year (down to 0.5°C) due to stronger-than-usual north and northeast winds.

At the end of 2012 and beginning of 2013, meteorological conditions over the Barents Sea resulted in increasing the sea ice coverage. In 2013, the ice coverage (expressed as a percentage of the sea area) was still lower than normal but higher compared to 2012 (Fig. 2). In January, it was only 2% higher than in the previous year. In February–June, the ice coverage was 7–17% higher than in 2012 and 5–19% lower than the long-term averages. In July, ice was only observed near the Franz Josef Land Archipelago. In August and September, there was no ice in the Barents Sea. Ice formation started in the northern Barents Sea in October, when ice appeared around the Spitsbergen and Franz Josef Land Archipelagos. In October, the ice coverage was 3% that was 12% less than usual and 2% more than in 2012.

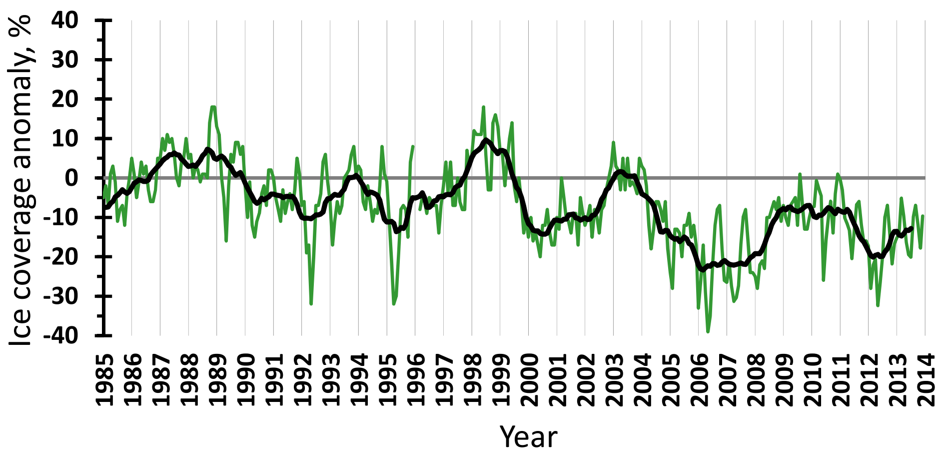

Figure 2. Ice coverage anomalies in the Barents Sea in 1985–2013. The green line shows monthly values, the black one – 11-month running means (Anon., 2014).

According to the observations along the Kola Section sampled 9 times in 2013, the Atlantic water temperature in the section (the Murman Current and the central branch of the North Cape Current) was 0.5–1.0°C higher than normal but 0.1–1.2°C lower than in 2012 throughout the year (Fig. 3).

In the coastal waters, positive temperature anomalies were 0.6–1.2°C in 2013 with the largest values (>1.0°C) in August, November and December (Fig. 3). In August and November, the temperature was the highest since 1951. Compared to 2012, the positive temperature anomalies in the coastal waters were on average 0.3°C lower in the first half of 2013 and 0.4°C higher in the second half of 2013 due to stronger-than-usual southwest winds.

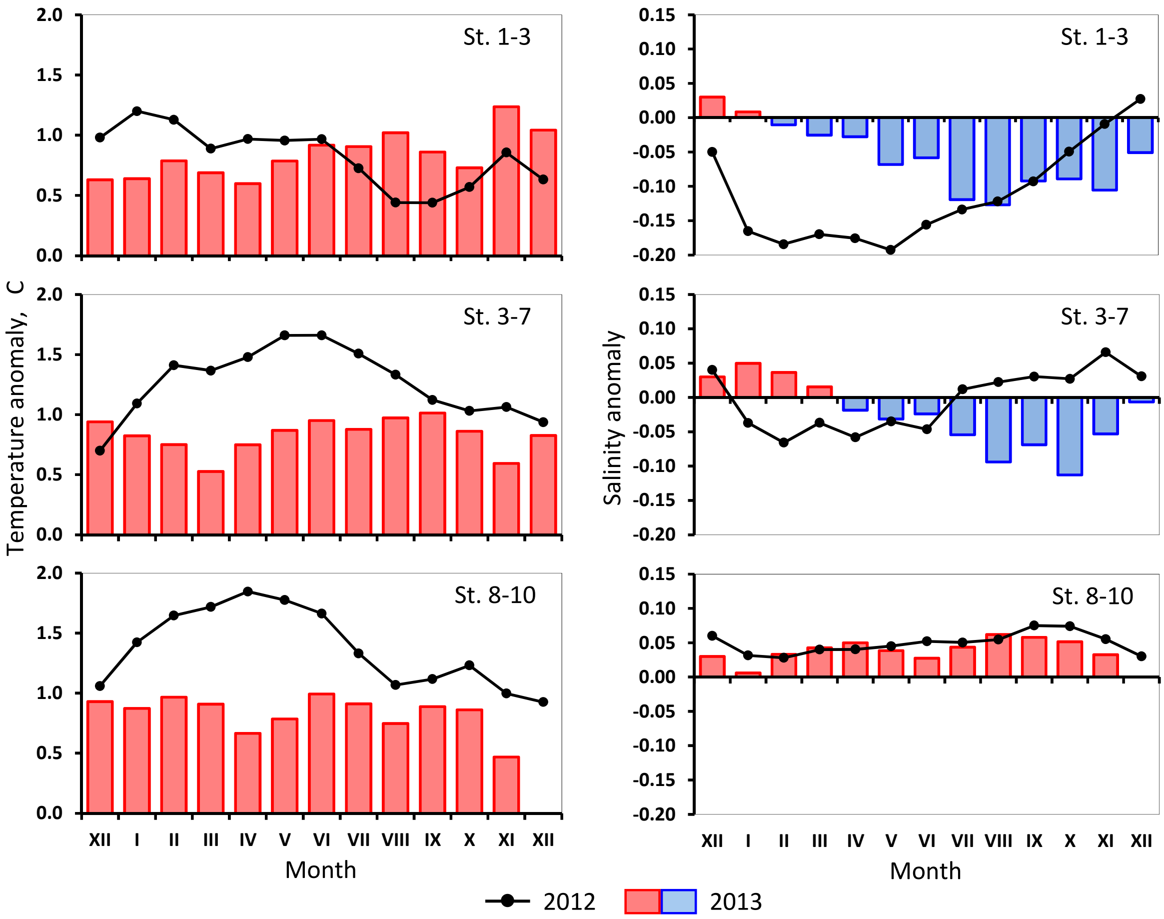

Figure 3. Monthly mean temperature (left) and salinity (right) anomalies in the 0–200 m layer in the Kola Section in 2012 and 2013. St. 1–3 – Coastal waters, St. 3–7 – Murman Current, St. 8–10 – Central branch of the North Cape Current (Anon., 2014).

It should be mentioned that seasonal warming was enhanced during summer 2013: the surface water temperature in the Kola Section was typical of anomalously warm years. From July to October, the temperature in the upper 50 m layer in the section was the highest since 1951.

In 2013, salinity in the coastal waters and the Murman Current in the Kola Section was mainly lower than normal with the largest negative anomalies in July–November (–0.09 to –0.13 in the coastal waters and –0.05 to –0.11 in the Murman Current) (Fig. 3). In the central branch of the North Cape Current, salinity was on average 0.04 higher than normal throughout 2013 and close to that in 2012.

On the whole, the 2013 annual mean temperature in the 0–200 m layer in the Kola Section was typical of anomalously warm years but 0.5°C lower than in 2012 (Fig. 4). The 2013 annual mean salinity in the 0–200 m layer in the section was close to normal and that in 2012 (Fig. 4).

Besides the Kola Section, some other sections were occupied in the Barents Sea in 2013.

The North Cape – Bear Island Section was sampled in April and November. Positive temperature anomalies in the 0–200 m layer in the North Cape Current were 0.6°C.

The Bear Island – West Section (along 74°30'N) was only occupied in November. Temperature in the 0–200 m layer in the eastern branch of the Norwegian Atlantic Current (74°30'N, 13°30'–15°55'E) was close to the long-term mean with a small positive anomaly of 0.1°C.

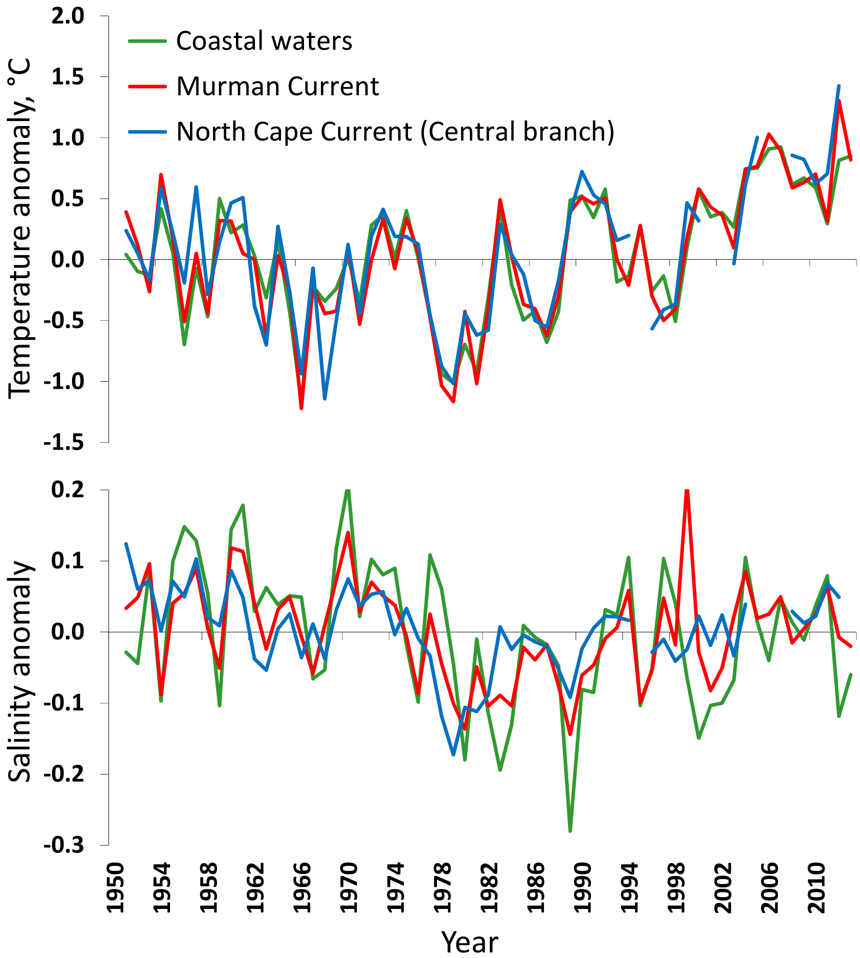

Figure 4. Annual mean temperature (top) and salinity (bottom) anomalies in the 0–200 m layer in the Kola Section in 1951–2013. Coastal waters – St. 1–3, Murman Current – St. 3–7, Central branch of the North Cape Current – St. 8–10 (Anon., 2014).

The Bear Island – East Section (along 74°30'N) was sampled in April, July and November. Positive temperature anomalies in the 0–200 m layer in the northern branch of the North Cape Current (74°30'N, 26°50'–31°20'E) were 0.4–0.9°C with the largest value in July.

The Kharlov Section was not occupied in 2013.

The Kanin Section (along 43°15'E) located in the eastern Barents Sea was sampled in February, August and December. In the 0–200 m layer in the Novaya Zemlya Current (71°00'–71°40'N, 43°15'E), positive temperature anomalies decreased from 1.5–1.6°C in February and August to 1.2°C in December.

In August–October 2013, the joint Norwegian-Russian ecosystem survey was carried out in the Barents Sea. Compared to earlier observations the surface temperatures were 2.0–3.3°C higher than the long-term means all over the sea (Fig. 5). The highest positive anomalies (more than 3.0°C) were found in the southeastern Barents Sea as well as south and southeast of the Spitsbergen Archipelago. Compared to the previous year, the surface temperatures in 2013 were 1.3–2.7°C higher in most of the sea, especially in its central and southern parts.

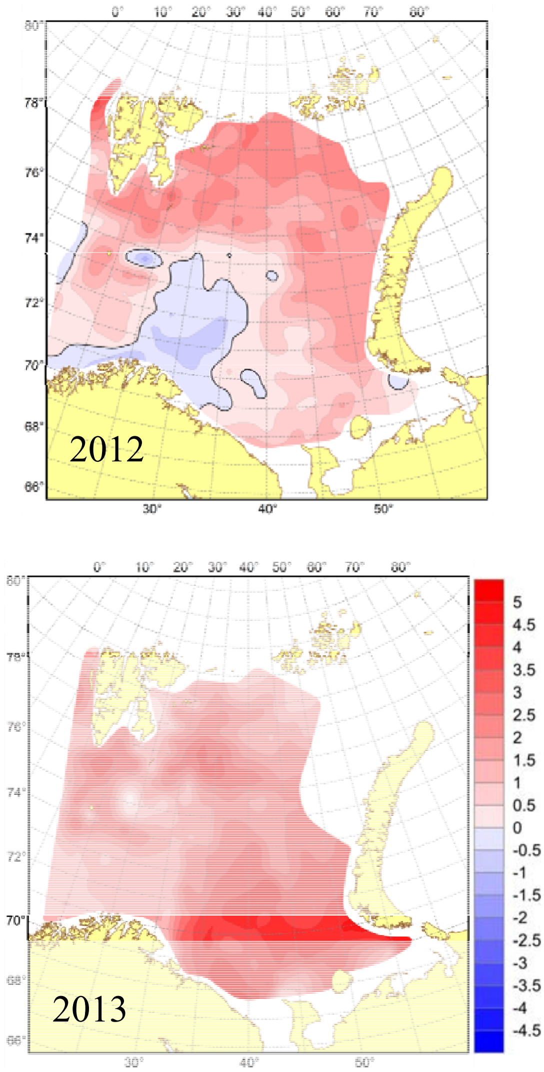

Figure 5. Surface temperature anomalies in August–September 2012 (left) and 2013 (right).

In August–September 2013, the surface temperatures were the highest since 1951 in about 50% of the surveyed area (Fig. 6).

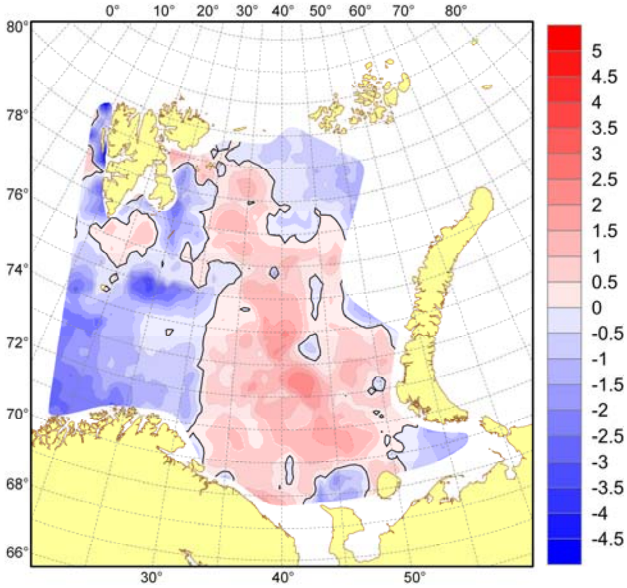

Figure 6. Differences between the surface temperatures in August–September 2013 and their highest values for the whole period of observations, °C.

In August–September 2013, the bottom temperatures were in general higher than normal (by 0.5–1.1°C) with the largest positive anomalies over Spitsbergen Bank (Fig. 7). Compared to the previous year, the bottom temperatures in 2013 were on average 0.5–1.3°C lower in most of the sea. The area occupied by bottom waters with temperatures below zero was larger in 2013 than in 2012.

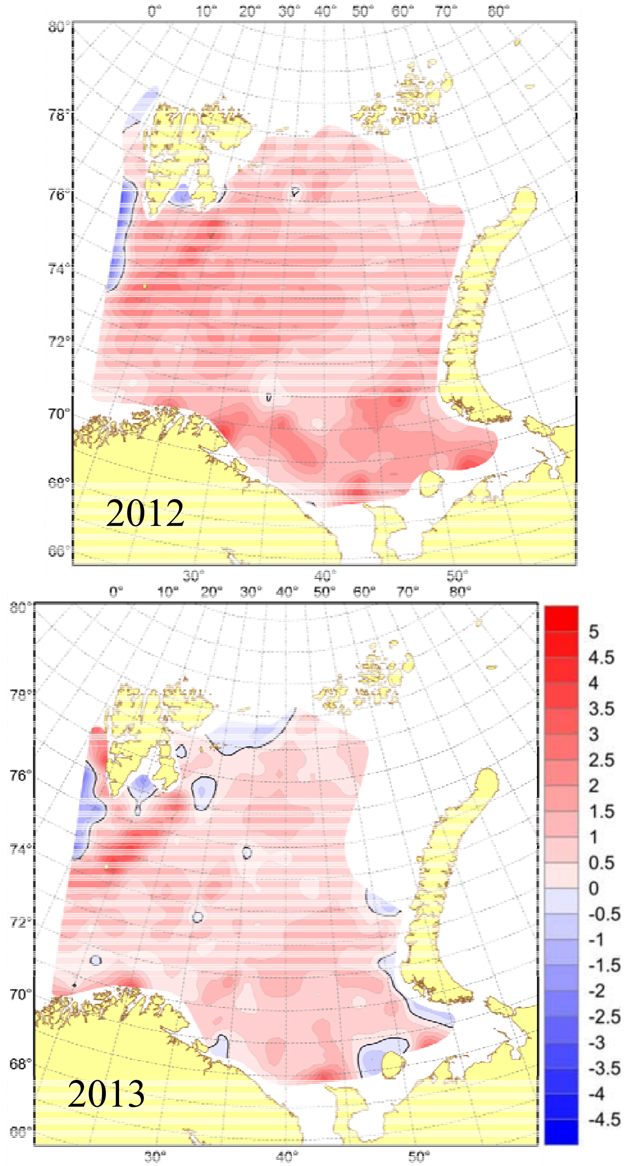

Figure 7. Bottom temperature anomalies in August–September 2012 (left) and 2013 (right).

In summary, the temperature in the Barents Sea in 2013 was still higher than normal. According to the observations along the standard sections, the temperature anomalies in the main warm currents of the Barents Sea in 2013 were typical of warm and anomalously warm years. The surface water temperatures were typical of anomalously warm years: from July to October, the temperature in the upper 50 m layer in the Kola Section was the highest since 1951. Throughout 2013, the ice coverage of the Barents Sea was still less than usual but more than in 2012.

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