ICES WGOH REPORT 2016

SCICOM STEERING GROUP ON ECOSYSTEM PROCESSES AND DYNAMICS

ICES CM 2016/SSGEPD:09

REF. SCICOM

Interim Report of the Working Group on Oceanic Hydrography (WGOH)

5-7 April 2016

Sopot, Poland

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 Working Group on Oceanic Hydrography (WGOH) 2016 meeting was hosted by the Institute of Oceanology, Polish Academy of Sciences (IOPAN), Sopot, Poland, 5–7 April 2016. WGOH meets yearly to review oceanographic conditions in the ICES region and to report on these in the ICES Report on Ocean Climate (IROC). The highlights from this report are presented below.

Highlights of the North Atlantic for 2015

- Lower-than-normal air temperatures were observed throughout the year across the Subpolar Gyre region. Air temperatures over the Northwest Atlantic were particularly cold in the first half of the year.
- By the end of the year, higher-than-normal air temperatures were observed over the European continent, from the Iberian Coast to Svalbard.
- Sea surface temperatures in the North Sea, along the Norwegian coast, and in the Baltic Sea remained higher than normal, except in summer.
- The substantial cold anomaly centred near 50°N in the central North Atlantic persisted through 2015, expanding to influence areas covered by the *in situ* time-series. Lower-than-normal temperatures were observed south of Iceland and in the southern part of the Nordic seas. Temperatures observed in the Iceland Basin were the lowest since 1996.
- Despite colder-than-normal winter air temperatures over the North American continent, ocean temperatures remained above normal on the Northeast US continental shelf.
- Following a period of high salinities observed between 2009 and 2011, freshening has been observed in the upper layers of the Irminger Sea, the Iceland Basin, Hatton–Rockall, and into the Nordic seas. The freshening that was first observed in the upper central waters of the Bay of Biscay region during 2014 continued and strengthened.
- The maximum ice extent in the Baltic Sea was a record low, with an early peak. In the Barents Sea, the peak was reached in February, two months earlier than normal.

Highlights of the North Atlantic atmosphere in winter 2014/2015

- The winter North Atlantic Oscillation (NAO) index was at its most positive (+3.56) since 1995 and the fourth strongest in the last 110 years. The Azores High was strong, but limited in its zonal extension, carrying stronger-than-normal winds between Scotland and the Labrador Sea, but weaker winds west of the Iberian Coast. The wind direction over the Iberian Coast was the reverse of prevailing wind conditions.
- Winter air temperatures were higher than normal over the Nordic seas, Scandinavia, and central and Eastern Europe, but were particularly low across the Northeast American continent, Labrador, West Greenland, and the Subpolar Gyre.

Initial assessment of the North Atlantic atmosphere in winter 2015/2016

An initial assessment of the North Atlantic atmosphere at the end of the IROC year is included. Atmospheric conditions during winter are a determining factor of oceanic conditions for the following year; therefore, this outlook offers some predictive capability for spring–autumn 2016.

The sea level pressure pattern for December 2015–March 2016 indicates that it was a positive, but weaker, NAO index than experienced in the preceding two winters. Average wind speeds from south of Iceland to the Barents Sea were weak, while winds were stronger than normal from the central North Atlantic towards the Bay of Biscay and into the English Channel.

Air temperatures were cold over the Subpolar Gyre, including over the Irminger Sea and Iceland Basin. Warmer-than-average conditions were evident over all the continental land masses as well as the Mid-Atlantic Bight, Baltic Sea, North Sea, Barents Sea, and the Nordic seas.

1 Administrative details

Working Group name

Working Group on Oceanic Hydrography (WGOH)

Year of Appointment within current cycle

2015

Reporting year within current cycle (1, 2 or 3)

2

Chair(s)

Sarah Hughes, Scotland, UK

Karin Margretha Larsen, Faroe, Denmark

Meeting venue

Sopot, Poland

Meeting dates

5–7 April 2016

2 Terms of Reference

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, reanalysis & prediction programmes;

d) Provide expert knowledge and guidance to ICES Data Centre on request;

e) Collaborate with regional integrated ecosystem advice Expert Groups, review products of the ICES Regional Groups (WGIBAR, WGINOR, WGIAB, WGINOSE, WGEAWESS, WGNARS);

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;

g) Prepare contributions for the annual SSGEPD session during the ASC on the topic areas of the Science Plan – as & when requested by SSGEPD;

h) Evaluation and review of WG actions and purpose.

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, work which addresses ToRs a) and b). The remainder of the meeting was spent working through the other ToRs (c–h) and the last couple of hours were spent working on the IROC 2016.

3 Summary of Work plan

Year 1	a) IROC 2015 production & recommendations for modifications to IROC format and content, including discussion on potential for reanalyses, forecast products to be included and addition of ICES Regional Ecosystem area focussed component, also potential move to purely web based product. b) WG Activities progress report including highlights of North Atlantic hydrographic conditions and any significant events synthesized from the national reports and IROC findings. c) Initial identification of climate monitoring, reanalysis and forecasting programmes.
Year 2	a) IROC 2016 production including first implementation of recommended changes. b) WG Activities progress report including highlights of North Atlantic hydrographic conditions and any significant events synthesized from the national reports and IROC findings. c) Map marine climate reanalysis and forecast parameters to ICES interests.
Year 3	a) IROC 2017 production and review of content and requirement to continue IROC process. b) WG Final report

4 List of Outcomes and Achievements of the WG in this delivery period

- Improvement of data delivery on IROC online portal;
- Delivery of Annual IROC (due June 2016);
- New time-series added to IROC and a few new contact persons have agreed to contribute to the IROC.

5 Progress report on ToRs and workplan

ToR a: Update and review results from Standard Sections and Stations

Area Reports were presented to the WGOH and additional scientific work reviewed during a mini-symposium: Some groups support their presentation with a formal report, all of which are included as Annexes 5–13 of this report (see Table1 below). WGOH were grateful to members whom, although unable to attend the meeting, were still able to offer an area report as this is incredibly useful to the group when preparing the IROC.

The written area reports offer valuable comprehensive reviews of the different sea areas within the North Atlantic as covered by members of the WGOH. These reports contained much more detailed information than the ICES Report on Ocean Climate which can only summarise the general conditions.

Table 1. List of Area reports presented to ICES WGOH in 2016.

Area	Region of Report	Presenter	Country	Report/Presentation
1	Greenland	Boris Cisewski	Germany	Presentation, Annex 5
2c	USA	Paula Fratantoni	USA	Presentation, Annex 6
3	Icelandic Waters	Hedinn Valdimarsson	Iceland	Presentation
4	Eastern Bay of Biscay	Victor Valencia	Spain	Presentation, Annex 7
4	Iberian Coast Bay of Biscay	Cesar González-Pola	Spain	Presentation, Annex 7
	Western English Channels	Caroline Cusack, Kieran Lyons	Ireland	Presentation
5	Rockall Trough and Extended Ellet Line	Stefan Gary	UK	Presentation
6	Faroese Waters	Karin Margretha Larsen	Faroe, Denmark	Presentation, Annex 8
7 and 8/9	Scottish Waters	Sarah Hughes	Scotland, UK	Presentation
8 and 9	North Sea	Holger Klein	Germany	Presentation, Annex 9
9	Baltic	Karin Borenäs	Sweden	Presentation, Annex 10
8/9, 10/11	Norwegian Seas and North Sea	Kjell Arne Mork and Jon Albretsen	Norway	Presentation, Annex 11
12	Fram Strait	Waldemar Walkowski	Poland	Presentation
11	Kola Section, Barents Sea	Alexander Trofimov	Russia	Presentation, Annex 12
8,	North Sea, Denmark Strait	Stephen Dye	UK	Presentation
9	Baltic	Tycjan Wodzinowski	Poland	Presentation
	North Atlantic and South Western Channel	N. Kolodziejczyk et. al.	France	Annex 13

ToR 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

At the WGOH 2015 a new editorial team was established for the IROC and although delayed they managed to complete the editing of the report in December 2016. This was a large report covering both 2013 and 2014 data. Unfortunately, the report was not published until March 2016, just prior to the WGOH annual meeting. The editorial team is unchanged and they are Sarah Hughes (Scotland, UK), Agnieszka Beszczynska-Möller (Poland), Karin Margretha Larsen (Denmark, Faroe), Paula Fratantoni (USA), César González-Pola (Spain) with data and technical support from Hjalte Parner (ICES). The aim for this year is to have the IROC 2015 published at the end of June 2016.

The procedure for Data/IROC updates that was agreed in 2015 has improved the number of contributions to the IROC received prior to the meeting, but still many contributions were not submitted at the time of the meeting. This makes the work of preparing the report much greater than should be necessary. All members were reminded to try and submit data 1 week prior to the meetings.

Hjalte Parner at the Data Centre provided information about further developments of IROC web page (initially released in December 2013). He suggested to change the map projection, display of date series, and automatic generation of monthly/annual means. The last suggestion was discussed by the members and not all were happy with this, since an automatic routine may not be suitable for all the data series.

Stephen Dye suggested adding the option to view the time series via the Index on the Summary Table and Sarah Hughes suggest making Figure 1 and 2 interactive. Hjalte Parner agreed. He already had initiated this work and promised to finalise it before next meeting.

It would be useful also for data providers to offer links to supporting documentation and peer reviewed publications relevant to their time-series, these will continue to be developed in 2016.

WGOH agreed that data providers should provide as much additional information as possible, following a template that would be provided by Hjalte. Members were reminded of the need to submit their data in a standard format as this allows the dataset to work efficiently in supporting the development of the summary figures for the IROC. WGOH thanked Hjalte and the ICES datacentre for their commitment to supporting the IROC.

The procedure for Data/IROC updates is as follows:

Data Updates

3 months prior to the meeting, WGOH chairs or ICES Data Centre will send out reminders to all members. Members will download their data files from the IROC website. They will update the time-series and send it back to the ICES Data Centre. Either by email or by uploading to the SharePoint system. The ICES Data Centre will endeavour to quality check all datafiles submitted at least 1 week prior to the WGOH meeting. Summary figures from all submitted data will be prepared in time for the meeting.

Text Updates

3 months prior to the meeting, WGOH chairs will send out reminders to all members. The ICES datacentre will prepare an unformatted text version of the previous year's report. The IROC editors will distribute this to the data contributors for update. Text updates should be finalised by the end of the WGOH meeting and new versions emailed to the WGOH chairs or uploaded to the SharePoint.

The WGOH page on the ICES web-site is available:
http://www.ices.dk/community/groups/Pages/WGOH.aspx.

ToR c: Explore areas of mutual interest with international climate monitoring, reanalysis & prediction programme

WGOH members will continue to raise awareness of WGOH and the IROC when participating in international conferences and meetings.

ToR d: Provide expert knowledge and guidance to ICES Data Centre on request

No specific actions were taken relating to this ToR at the 2016 meeting. Hjalte Parner attended the meeting and the WGOH are working very closely with him in relation to developing the IROC product online.

ToR e: Collaborate with regional integrated ecosystem advice Expert Groups, re-view products of the ICES Regional Groups (WGIBAR, WGINOR, WGIAB, WGINOSE, WGEAWESS, WGNARS)

No specific actions were taken relating to the ToR at the 2016 meeting. The following WGOH members have contributed or have strong links with the regional integrated assessments.

Working Group on the Integrated Assessments of the Norwegian Sea (WGINOR)

WGOH link is Øystein Skagseth and Alexander Trofimov

Working Group on the Integrated Assessments of the Barents Sea (WGIBAR)

WGOH link is Øystein Skagseth and Alexander Trofimov

The Working Group on Northwest Atlantic Regional Sea (WGNARS)

WGOH link is Paula Fratantoni

The Working Group on Integrated Assessments of the Baltic Sea (WGIAB)

No WGOH link

Working Group on Integrated Assessments of the North Sea (WGINOSE)

No WGOH link

Working Group on Ecosystem Assessment of Western European Shelf Seas (WGEAWESS)

No WGOH link

ToR 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

Prior to the meeting, the WGOH had received a recommendation from WGEEL to contribute to a workshop in 2016 on eel migration. Stephen Dye volunteered to contact the WGEEL chair to get more details on the workshop. If needed Stephen could also contact colleagues that work on eel migration or a WGOH member could participate in the workshop (shortly after the WGOH meeting, the WGEEL chair informed WGOH that the workshop was cancelled).

ToR g: Prepare contributions for the annual SSGEPD session during the ASC on the topic areas of the Science Plan – as & when requested by SSGEPD

The SSGEPD requested a Science plan mapping exercise 2016. The exercise (spreadsheet) was handed to the attending members at the meeting where after preliminary answers were added to a joint reply. The chairs will complete the exercise and submitted to SSGEPD.

ToR h: Evaluation and review of WG actions and purpose

WGOH continually review the IROC and the data presented within. The aim is to develop the product to be as useful as possible, whilst remaining a sustainable task for the Working Group. The development of this remains clearly within the existing Terms of Reference.

ASC theme sessions

Active contribution to the ICES Annual Science Conference is an important aspect of ensuring that the WGOH contributes to the ICES Science Plan (ToR g) and also helps to strengthen the role of within ICES (ToR e).

Sarah Hughes planned to attend the ASC2016. The WGOH decided to ask the ICES office to produce an IROC flyer for the ASC 2016 (this was later denied by the office due to lack of funding).

A theme session for 2017 was discussed. It was agreed to suggest a session on new technologies. Heðinn Valdemarsson, Stefan Gary and Stephen Dye were to compile a description.

The WGOH members also discussed the possibilities for nominating persons for the prestigious ICES Outstanding Achievement and Prix d'Excellence awards. Hendrik van Aken was suggested for the Outstanding Achievement. Heðinn Valdemarsson and Sarah Hughes will contact Laura de Steur to hear if she can help with the nomination.

IROC highlights and key issues from the national reports

This report describes the discussion and outcomes relating to the individual terms of references of the WGOH. The bulk of the science discussed by the WGOH is contained in the area reports (included as Annexes 5–13 to the report), which in turn underpin the information presented in the ICES Report on Ocean Climate (IROC).

The IROC represent the scientific highlights of the WGOH meeting, the highlights of this report are presented here.

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- Despite colder-than-normal winter air temperatures over the North American continent, ocean temperatures remained above normal on the Northeast US continental shelf.
- Following a period of high salinities observed between 2009 and 2011, freshening has been observed in the upper layers of the Irminger Sea, the Iceland Basin, Hatton–Rockall, and into the Nordic seas. The freshening that was first observed in the upper central waters of the Bay of Biscay region during 2014 continued and strengthened.
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6 Revisions to the work plan and justification

No revisions needed to workplan. New initiatives for IROC fall within ToR a) and ToR b).

7 Next meetings

Karin Margretha H. Larsen volunteered to host the WGOH 2017 meeting in Torshavn, Faroe Islands. WGOH thanked Agnieszka Beszczynska-Möller and Waldemar Walczowski for hosting an excellent meeting in Sopot.

Karin Borenäs announced that this was her last WGOH meeting and the working group thanked her for her contribution to the group over many years. SMHI will decide on a replacement for Karin.

The 2017 meeting will be hosted in Torshavn, Faroe Islands, 4–6 April.

Annex 1: List of participants

Name	Country	Email
Agnieszka Beszczynska-Möller	Poland	abesz@iopan.gda.pl
Alexander Trofimov	Russia	trofimov@pinro.ru
Boris Cisewski	Germany	boris.cisewski@vti.bund.de
Caroline Cusack	Ireland	caroline.cusack@marine.ie
César González-Pola	Spain	cesar.pola@gi.ieo.es
Heðinn Valdimarsson	Iceland	hv@hafro.is
Hjalte Parner	Denmark	hjalte@ices.dk
Holger Klein	Germany	holger.klein@bsh.de
John Mortensen	Greenland, Denmark	jomo@natur.gl
Jon Albretsen	Norway	jon.albretsen@imr.no
Karin Borenäs	Sweden	karin.borenas@smhi.se
Karin M.H. Larsen	Faroe Islands, Denmark	karinl@hav.fo
Kieran Lyons	Ireland	kieran.lyons@marine.ie
Kjell Arne Mork	Norway	kjell.arne.mork@imr.no
Paula Fratantoni	USA	Paula.Fratantoni@noaa.gov
Sarah Hughes	Scotland, UK	S.Hughes@MARLAB.AC.UK
Stefan Gary	Scotland, UK	Stefan.Gary@sams.ac.uk
Stephen Dye	England, UK	stephen.dye@cefas.co.uk
Tycjan Wodzinowski	Poland	tycjan@mir.gdynia.pl
Víctor Valencia	Spain	vvalencia@pas.azti.es

Annex 2: Recommendations

Recommendation	Adressed to
1. The value of long time-series has been clearly demonstrated by the IROC over the last 10 years. WGOH is concerned that the number of available timeseires is reducing due to cuts in funding and this has implications for the evidence base necessary to undrerpin our understanding of ocean climate variability and its impact on marine ecosystems. Delegates are requested to raise this issue within their member states and ensure that there are no further losses of these vital data.	SCICOM/Delegates
2. The ICES Data centre and WGOH have agreed a future workprogramme to allow development of the IROC product online. The current support from the Data Centre is excellent and continued assistance from the ICES Data Centre is vital to ensure the IROC remains a sustainable product. The WGOH recommends that time continues to be assigned to this task	ICES Data Centre
3. The WGOH has struggled to deliver the IROC over the past few years as a result of an inability of WGOH members to get support for the work needed from their host institutes. The work done to edit the IROC is an essential aspect of the WGOH and this can be time consuiming, over and above the other work of the group. WGOH recommend that the ICES Secretariat should send letters of thanks to the new editorial team and their institutes, emphasising the vital contribution this work makes to the Working Group delivery.	ICES Secretariat
4. WGOH recommends the continuation of the printed version of the IROC report, and in addition a small flyer could be prepared to communicate the report highlights at the ICES ASC – these will be developed for the ASC in 2016.	SCICOM

Annex 3: Agenda WGOH

5-7 April 2016

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

Meeting room: Large conference room

Day 1, Tuesday 5th April

Start at 0900 (Lunch: 12:30)

1. General information, Membership and Introductions

2. IROC

    IROC 2014 review (Sarah Hughes)
    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 2015 Atmospheric conditions (Stephen Dye)

5. Area reports (latest results from standard sections and stations)

1400-1700 Mini-symposium

1400: Emilia Trudnowska et al. Combined traditional and optical methods for studying arctic zooplankton distribution.

1420: Agnieszka Promińska et al. Spatial and temporal variability in distribution of water masses in Hornsund, Spitsbergen.

1440: Agnieszka Beszczynska-Möller. Interannual variability of Atlantic water properties and dynamics in the eastern Nordic Seas and Fram Strait from large-scale summer hydrographic measurements (1996-2015)

1500: Coffe

1520: John Mortensen. Greenland Ice Sheet/Ocean Observing System

1540: Victor Valencia. 1986-2016: Three decades of oceano-meteorological data in the SE Bay of Biscay. Main regime shifts and anomaly patterns observed.

1600: César Gonzalez-Pola: Mid-2000s mode waters shift in the NE Atlantic. Implications for regional circulation and global heat budget.

1620: Stefan Gary. The seasonal cycle of volume, heat, and salt fluxes on in the Rockall Trough

1900: Joint dinner at the "Bulaj" restaurant

Day 2, Wednesday 6th April

Start at 0900 (Lunch 12:30)

5. Continue area reports

Day 3, Thursday 7th April

Start at 0900 (Lunch 12:30)

6. ICES Matters

- Remaining ToR’s
- Recommendation from WGEEL regarding workshop in 2016

7. Relations with international climate monitoring programmes (CLIVAR, Argo, etc.)

8. ASC 2016 (Riga, Latvia), Theme sessions in 2016. ASC 2017?

9. IROC highlights and key issues from the national reports

10. WGOH website

11. Next Meeting

12. AOB

1400 IROC 2015

Work on the IROC 2015

Annex 4: Multi-annual Terms of References (ToRs)

Working Group on Oceanic Hydrography (WGOH)

2014/MA2/SSGEPD04 The **Working Group on Oceanic Hydrography** (WGOH), chaired by Sarah Hughes, UK, and Karin M. Larsen, Faroe Islands, will work on ToRs and generate deliverables as listed in the Table below.

	Meeting dates	Venue	Reporting details	Comments (change in Chair, etc.)
Year 2015	24–26 March	San Sebastian, Spain	Interim report by 1 May to SSGEPD	
Year 2016	5–7 April	Sopot, Poland	Interim report by 30 May to SSGEPD	
Year 2017			Final report by DATE to SSGEPD, SCICOM	

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, reanalysis & prediction programmes;

d) Provide expert knowledge and guidance to ICES Data Centre on request;

e) Collaborate with regional integrated ecosystem advice Expert Groups, review products of the ICES Regional Groups (WGIBAR, WGINOR, WGIAB, WGINOSE, WGEAWESS, WGNARS)

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;

g) Prepare contributions for the annual SSGEPD session during the ASC on the topic areas of the Science Plan – as & when requested by SSGEDP;

h) Evaluation and review of WG actions and purpose.

ToR descriptors

ToR	Description	Background	Science Plan topics addressed	Duration	Expected Deliverables
a	Examine the hydrographic variability of the North Atlantic and its subpolar seas. Identify events, trends and drivers in the region .	The contributors to the WGOH bring together a wide range of observations taken by various national programmes. Here we annually monitor developments in the environmental conditions that they sample.		3 years	Annual interim reports will include details of national programmes and most up to date findings.
b	Standard Sections and Stations summarized into the production of the IROC report and submitted to IROC data portal.	The Working Group recognises the need for disseminating climate information in a timely and appropriate manner. This agenda item will		3years	Annual. IROC report for CRR submission. Text and figures to ICES by June 30th each year. Data to portal by 1st

		allow WGOH members to prepare the document during the meeting. We will review proposed new developments in IROC content.			September each year.
c	Report on developments within international climate monitoring, multi decadal reanalyses & prediction programmes relevant to ICES	Benefit both to ICES and the international monitoring programmes to enhance internal information exchange. Additionally developments in the capacity to make climate forecasts of hydrographic parameters are being made by the international community, that may have the potential to aid future ICES work.		2 years	Identify the products of potential use to ICES. Report as part of 2nd year progress.
d, e, f	Support for ICES processes on hydrographic data and ocean scale marine climate variability. Including Data Centre, other EGs, and advice programmes where and when requested	As required support for ICES Data centre on hydrographic data. Oceanic hydrography remains a fundamental component of assessing the state of marine ecosystems. WGOH documents interannual to multidecadal variability and trends in the oceanic hydrography for most ecoregions and will review the available 'Ecosystem Overviews' as they become available for each regional sea.		ongoing	Response to requests and reviewing input from Datacentre at WG meetings. Submit review to the annual interations of Ecosystem Overviews.
g	Contribute to objectives, activities of parent science steering group SSGEDP	A flexible ToR to allow WGOH to contribute to SSGEDP requirements as they develop over the term of the current science plan.		3 years	As and when defined by our steering group SSGEDP
h	Ongoing self evaluation of the EGs work.	WGOH is a long established EG within ICES and has ToRs that are closer to an annual workplan. The main product is the annual IROC which has been produced for 15 years, and must be continually developed - through ongoing self evaluation and review		3 years	WGOH Final Report under multiannual TORs September 2017.

Summary of the Work Plan

Year 1	a) IROC 2015 production & recommendations for modifications to IROC format and content, including discussion on potential for reanalyses, forecast products to be included and addition of ICES Regional Ecosystem area focussed component, also potential move to purely web based product. b) WG Activities progress report including highlights of North Atlantic hydrographic conditions and any significant events synthesized from the national reports and IROC findings. c) Initial identification of climate monitoring, reanalysis and forecasting programmes.
Year 2	a) IROC 2016 production including first implementation of recommended changes. b) WG Activities progress report including highlights of North Atlantic hydrographic conditions and any significant events synthesized from the national reports and IROC findings. c) Map marine climate reanalysis and forecast parameters to ICES interests.
Year 3	a) IROC 2017 production and review of content and requirement to continue IROC process. b) WG Final report

Supporting information

Priority	Oceanic hydrography remains a fundamental component of assessing the state of marine ecosystems. WGOH documents interannual to multidecadal variability and trends in the oceanic hydrography setting the vital context for prevailing conditions & ecosystem change. The IROC has been cited more than 70 times (Google Scholar) since 2009 demonstrating that it an important resource for the marine science community within and beyond ICES.
Resource requirements	The research programmes which provide the main input to this group are already underway, and resources are already committed. The additional resource required to undertake additional activities in the framework of this group is negligible.
Participants	The Group is normally attended by about 15–20 members and guests. SSGEDP, ICES Data Centre participant.
Secretariat facilities	None.
Financial	No financial implications.
Linkages to ACOM and groups under ACOM	There are no obvious direct linkages.
Linkages to other committees or groups	There is a very close working relationship with all the groups of SSGEDP. The most direct link is to WGOOFE where the activities of the 2 groups are complementary. WGOH focusses on the larger Atlantic space and long term climate scales. Link to PUBCOM for the annual production of the IROC.
Linkages to other organization	IOC, JCOMM, CLIVAR

Annex 5:

Regional report on West Greenland 2015
(Area 1)

Regional report on West Greenland 2015 (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 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. The monitoring is carried out by the Thünen-Institute of Sea Fisheries (TI-SF) from board of R/V '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 2014/2015, the NAO index was positive (3.56) representing the highest value since 1995 (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. Both, the Icelandic Low and the Azores High were strengthening resulting in an increased pressure difference over the North Atlantic sector than normal during winter 2014/2015 (Figure 5b). The resulting negative anomalies in the north and the positive in the south reveal a positive NAO character (Figure 5c). Air temperature at Nuuk was used to characterize the atmospheric conditions in 2015. Annual and monthly mean values were obtained from the Danish Meteorological Institute (Cappelen, 2013).

In 2015, the monthly mean air temperatures were lower than the long-term mean except for the summer months June, July and August (Figure 6). The resulting annual mean temperature at Nuuk was -2.9°C in 2015, which was -1.5°C below the long-term mean (1981-2010) (Figure 7).

Hydrographic Conditions

Here a short overview of the hydrographical condition west off Greenland during autumn 2015 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 I 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 2015 indicate positive anomalies in the Northwestern Atlantic with highest values occurring northeast of Iceland (Figure 8), whereas negative anomalies were observed in the central area of the North Atlantic.

CTD profiles were conducted with a Sea-Bird 911plus sonde attached to a 12-bottle water sampler. The hydrographic database consisted of 55 hydrographic stations sampled between October 8 and November 17, 2015, 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 an OPTIMARE Precision Salinometer (OPS) 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 2–6 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} = 1.13°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 32.0 was observed at station 987 (Figure 9b). The most offshore station of the section done in 2015 (Station 984) corresponds to the standard Cape Desolation Station 3, which was reported in ICES WGOH since 2001 (Stein, 2010). In 2015, the water temperature of the upper 700 meters was lower than its long-term mean, whereas the salinity reveals slightly positive anomalies between 0 and 700 m water depth (Figures 10a, b). In 2015, the water temperature and the salinity in the 75-200 m layer at Cape Desolation Station 3 was 5.4°C (Figure 11a) and 34.93 (Figure 11b), which was 0.31°C below and 0.01 above the long-term mean, respectively. The properties of the North Atlantic Deep Water (NADW) in the deep boundary current west of Greenland are monitored at 2000 m depth at Cape 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, the temperature of the NADW revealed a positive trend until 2014, whereas its salinity rather stagnated between 2007 and 2014. In 2015, the temperature decreased and salinity increased, and were 0.03°C and 0.02 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 2015, 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 304 and 468 m water depth at station 1035, which corresponds to standard Fyllas Bank Station 4 (e.g. ICES, 2002; ICES, 2004). This station reveals negative potential temperature anomalies within the upper 700 m except from a thin layer at about 300 m water depth, where negative anomalies occur. While strong positive salinity anomalies are restricted to the upper 50 m, negative anomalies are found between 50-275 m. The depth range between 275 and 700 m however reveal positive salinity anomalies (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 2015, the temperature of this water mass was 2.31°C, which was 0.33°C below its long-term mean (1983-2010). The salinity decreased in 2015 and was 0.17 above its long-term mean (Figure 15a and b).

Tables

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

Name	Lat (°N)	Lon (°W)	Type	Source
Nuuk (4250)[1]	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)	$\theta \geq 4.5$	$S \geq 34.95$

[1] 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).

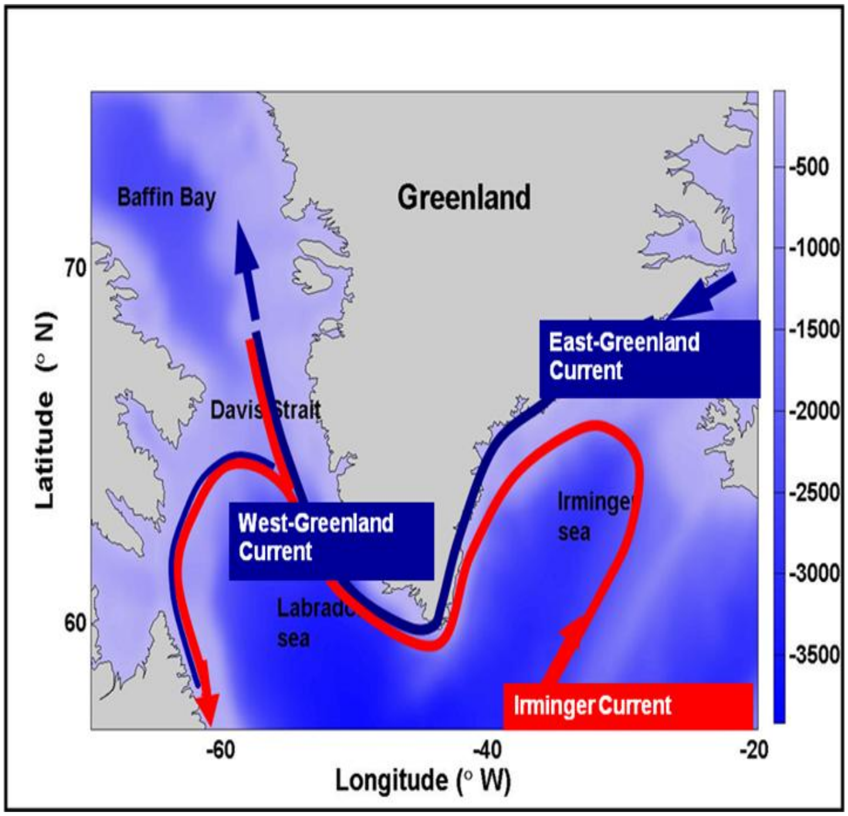


Figure 1. Scheme of the upper ocean circulation in the study area. Red and blue curves show the trajectories of warm Irminger Sea Water and cold Surface Polar Water, respectively.

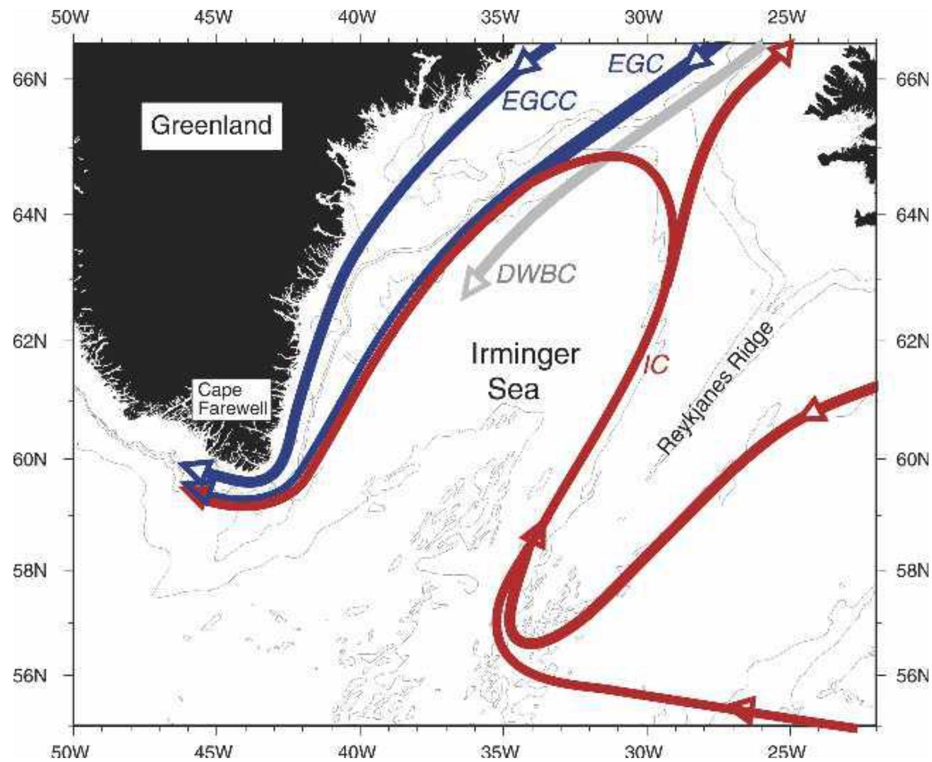


Figure 2. Schematic of the boundary currents of the Irminger Sea (depicted from Pickart et al., 2005)

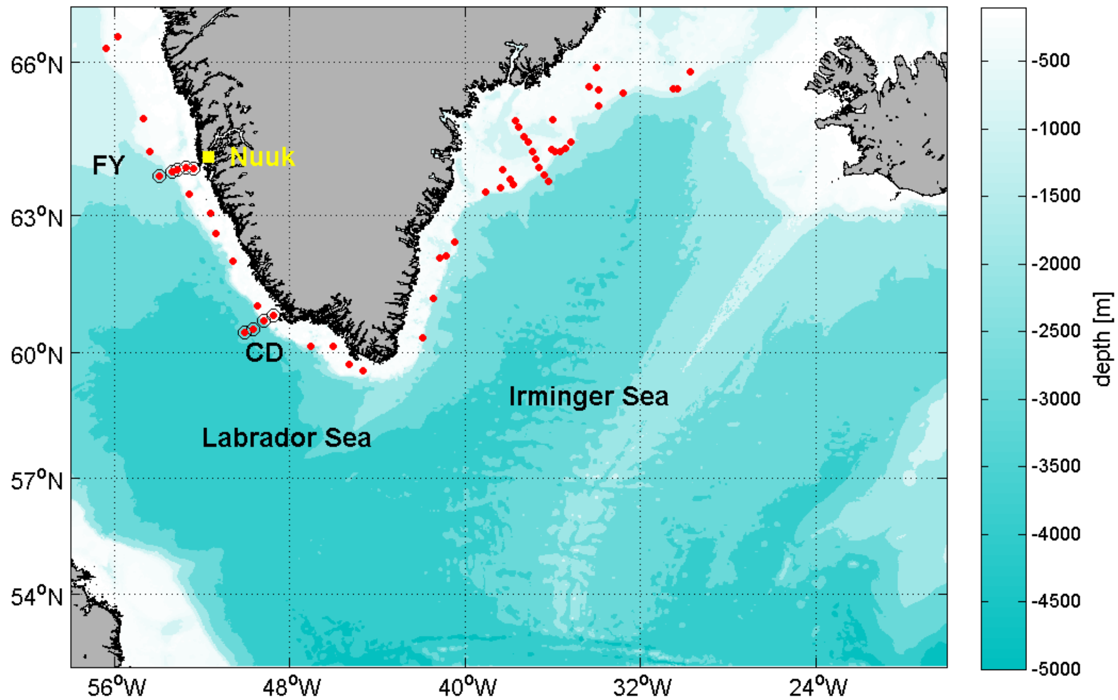


Figure 3. Map and bathymetry of the study region. Meteorological station location is shown in yellow. Red dots show the location of the hydrographic stations, conducted during the survey in 2015. Gray edged dots show the two ICES/NAFO standard sections (CD – Cape Desolation section, FY – Fyllas Bank Section; geographic coordinates are given in table 1).

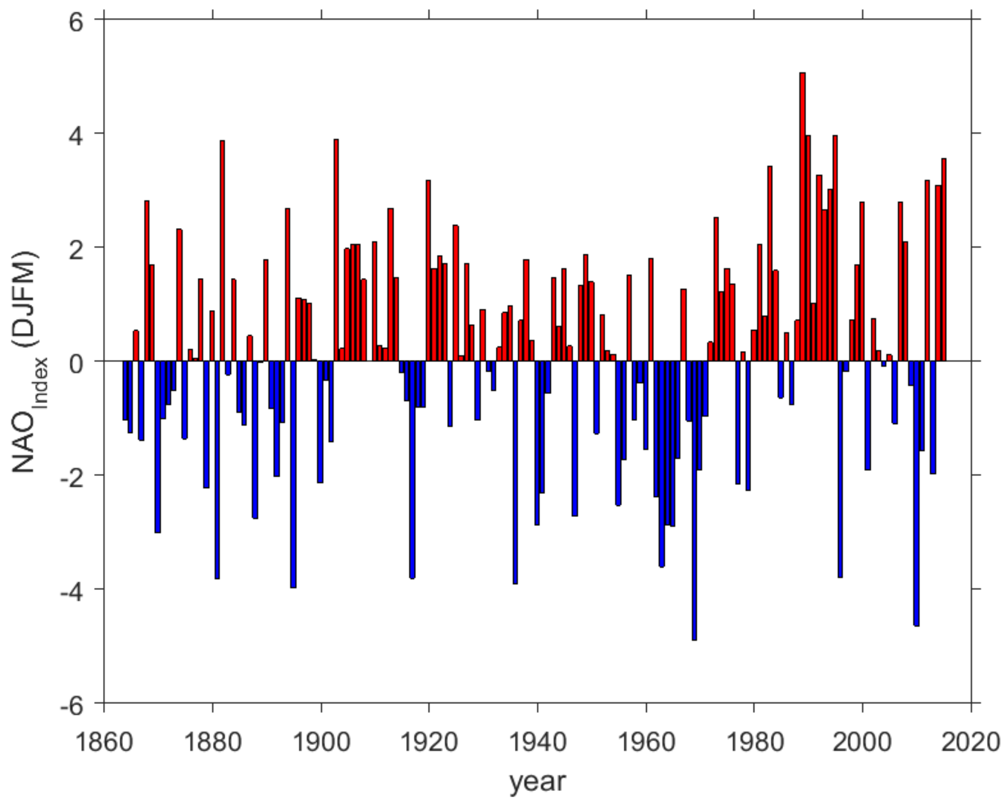


Figure 4. The Hurrell winter (DJFM) NAO index.

Data source: http://www.cgd.ucar.edu/cas/jhurrell/nao.stat.winter.html.

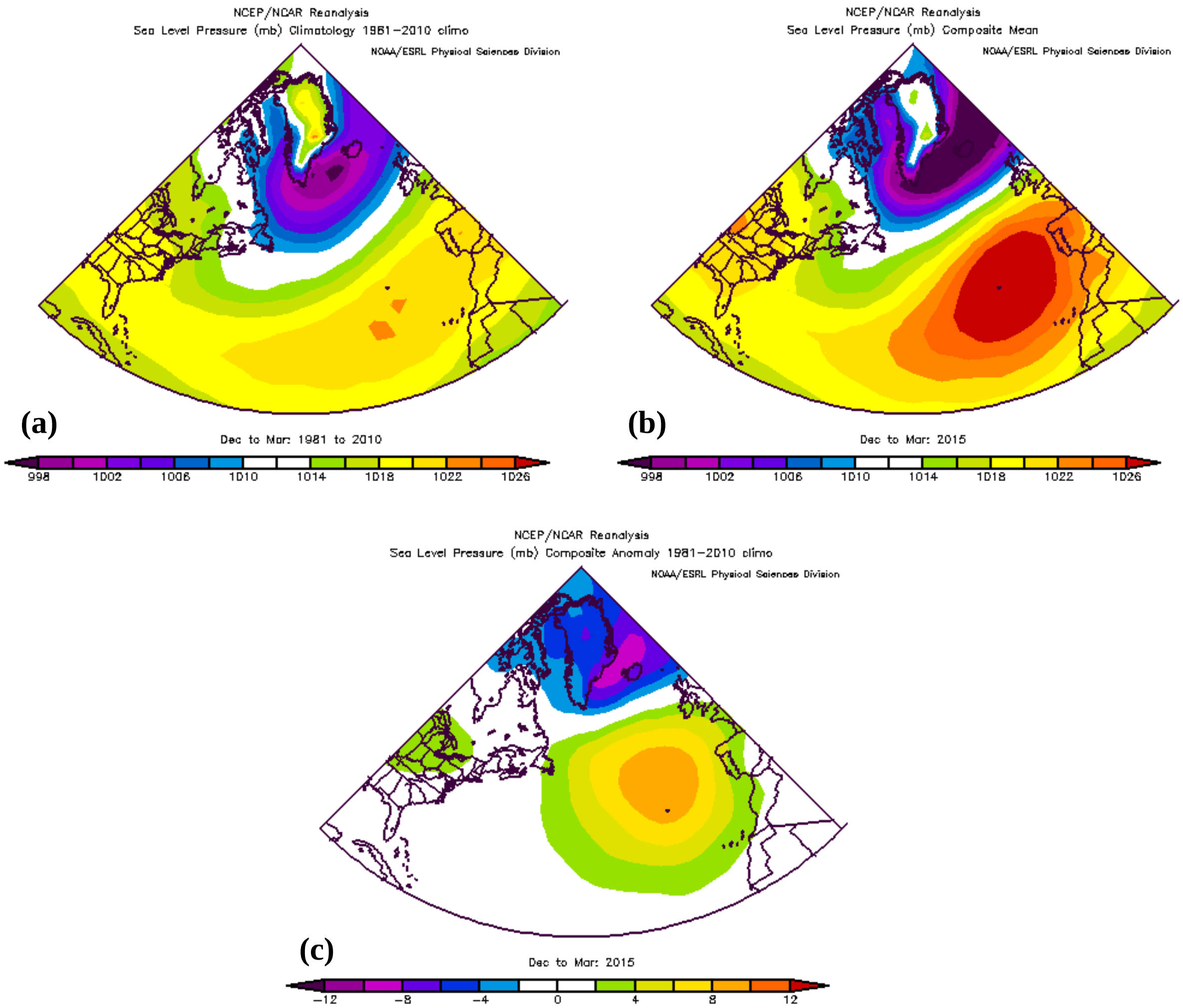


Figure 5. Maps of winter 1981-2010 (DJFM) mean sea level pressure (SLP) **(a)**, winter 2015 SLP **(b)**, and resulting SLP anomaly **(c)** over the North Atlantic. *Images are provided by the NOAA/ESRL Physical Science Division, Boulder, Colorado*

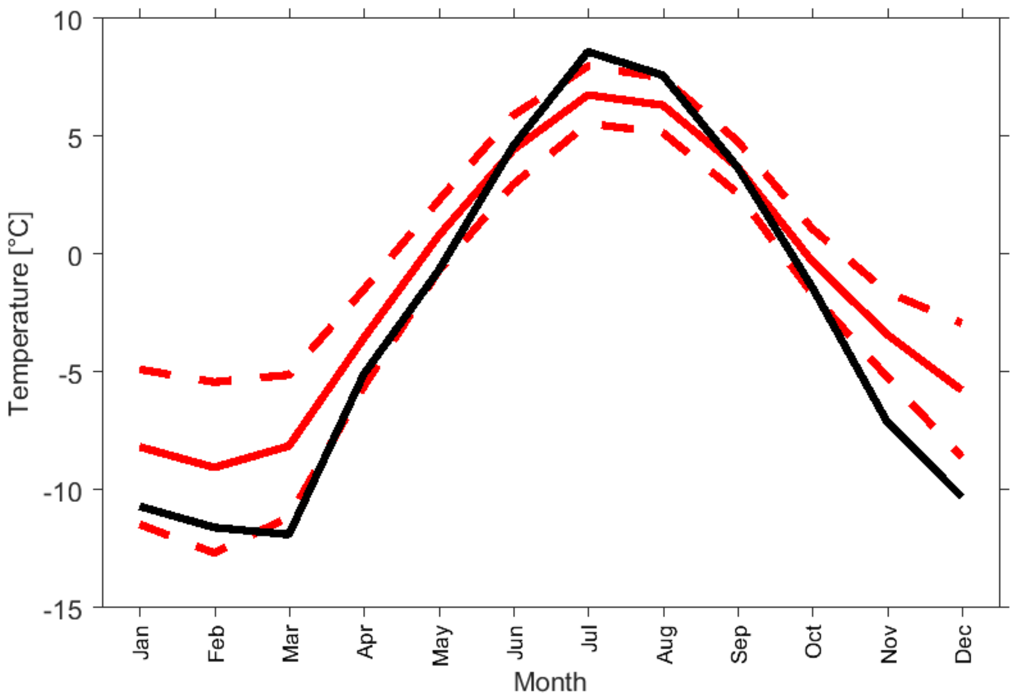


Figure 6. Monthly mean air temperature at Nuuk station in 2015 (black line), long-term monthly mean temperature (red solid line) and one standard deviation (red dashed lines) are shown. Reference period is 1981 to 2010. Data source: Danish Meteorological Institute (DMI)

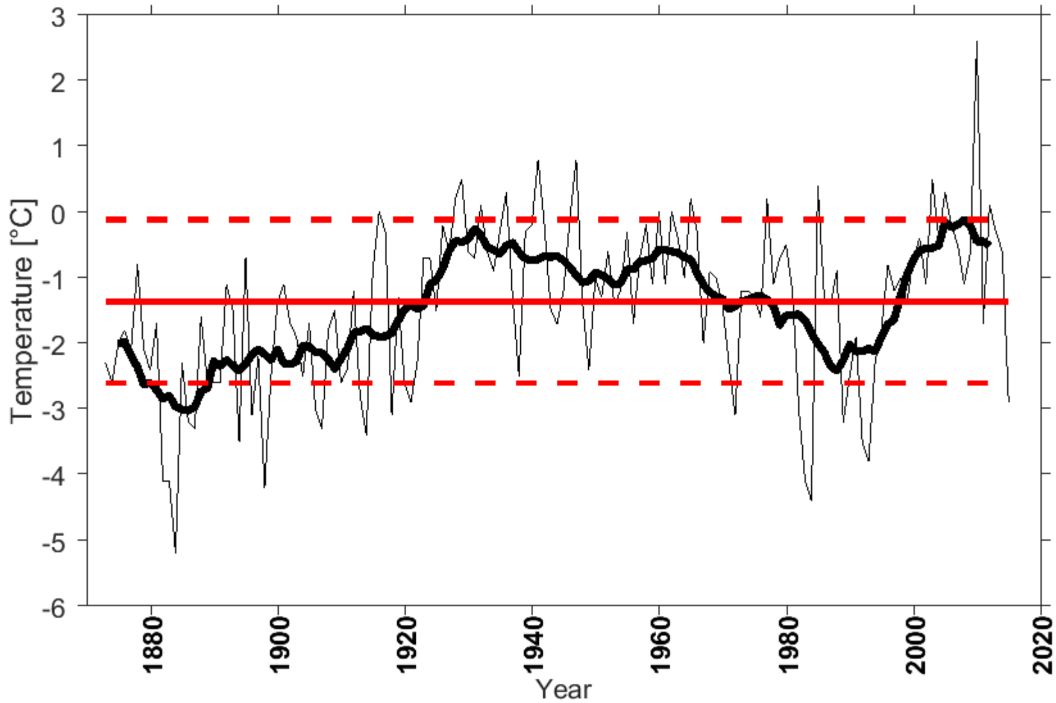


Figure 7. Annual mean air temperature at Nuuk station. Thick black line shows the 5-year smoothed data. Red solid line indicates the long-term mean temperature, referenced to 1981-2010. Dashed red lines mark corresponding standard deviations. Data source: Cappelen, J. (ed.), 2013: Greenland - DMI Historical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

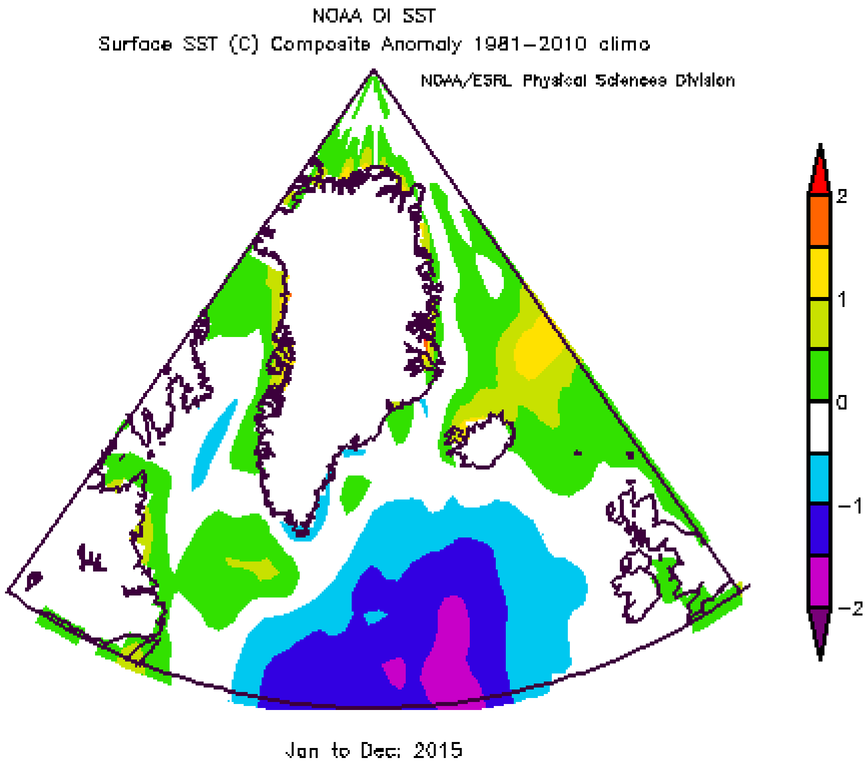
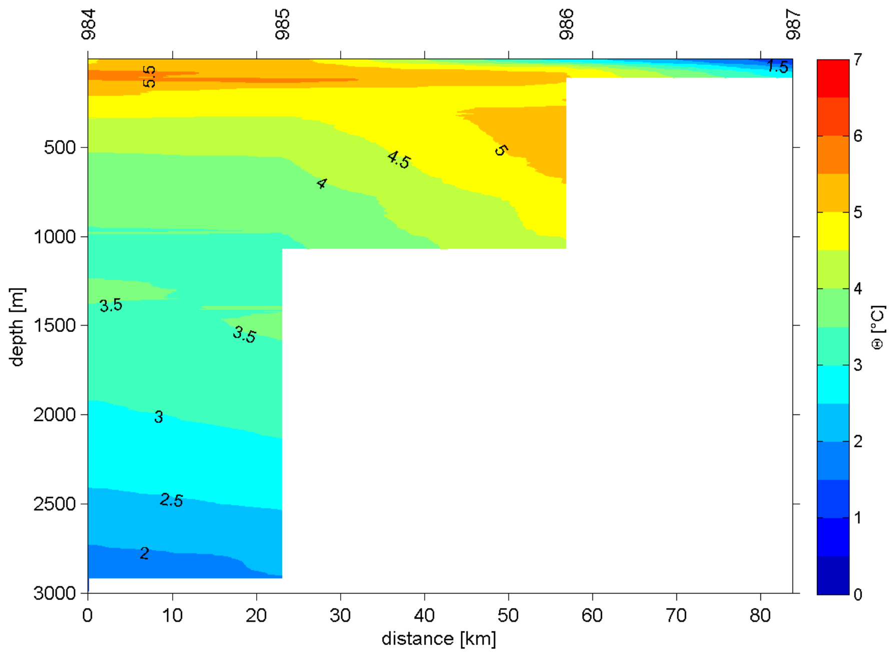
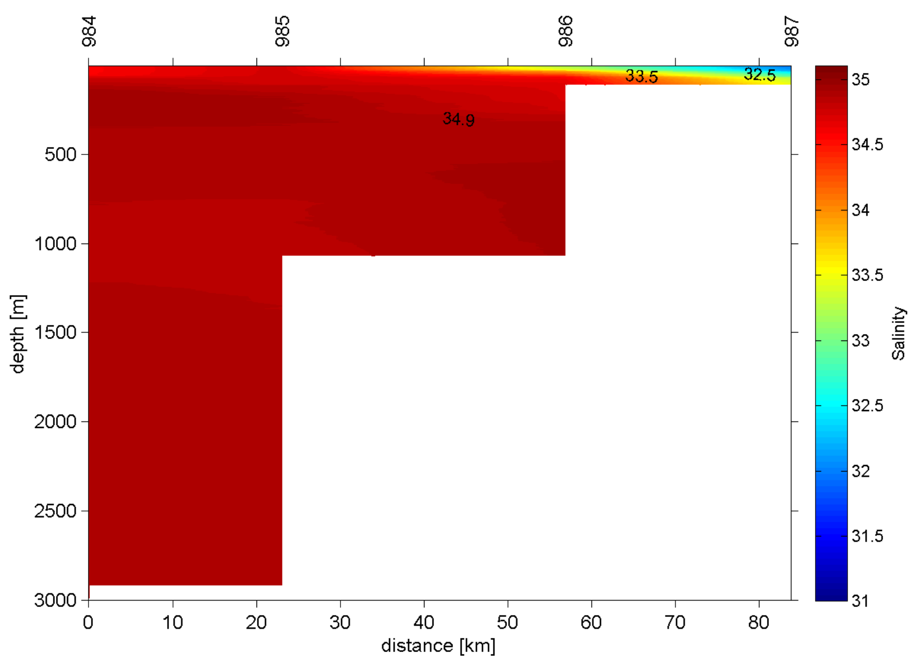


Figure 8. Map of 2015 annual sea surface temperature (NOAA OI SST) anomalies in the study region. The long-term mean corresponds to 1981-2010. *Image is provided by the NOAA/ESRL Physical Science Division, Boulder, Colorado*



(a)



(b)

Figure 9. Vertical distribution of potential temperature **(a)** and salinity **(b)** along the Cape Desolation section in 2015.

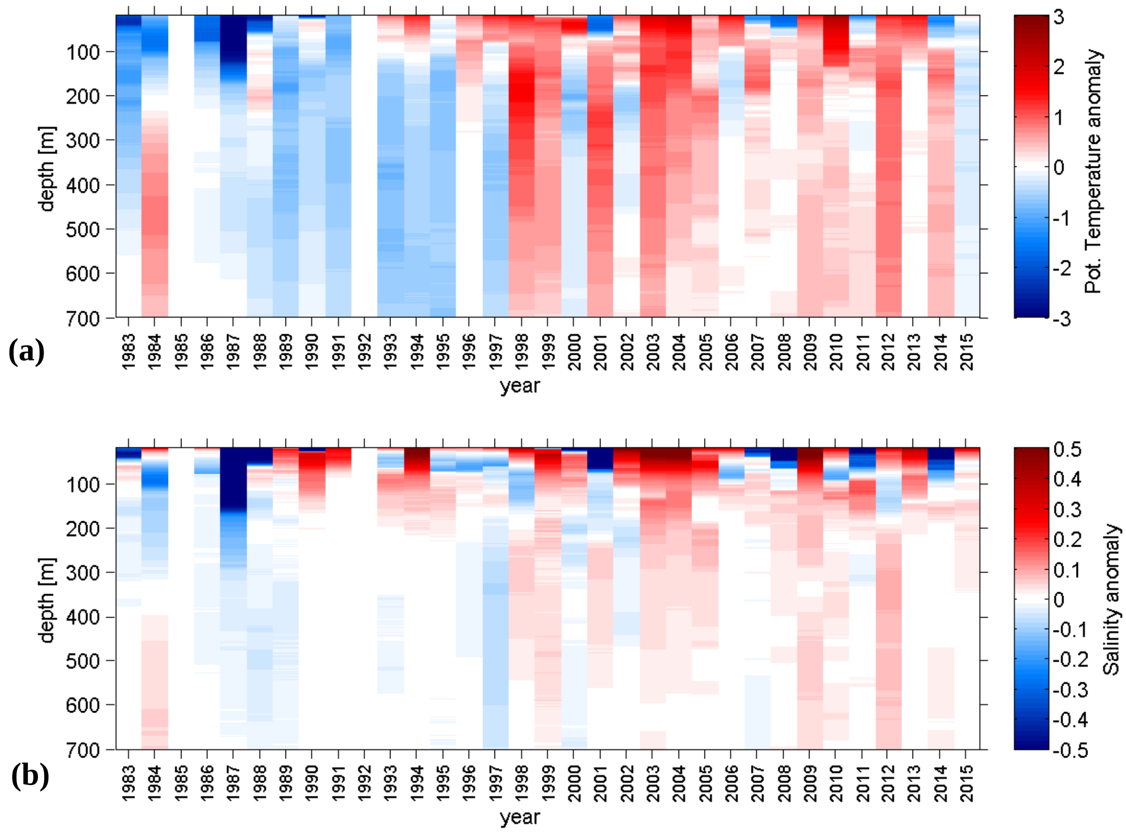


Figure 10. Hovmoeller diagram of the potential temperature anomalies **(a)** and salinity anomalies **(b)** in the upper 700 m at Cape Desolation Station 3. Reference period is 1983-2010.

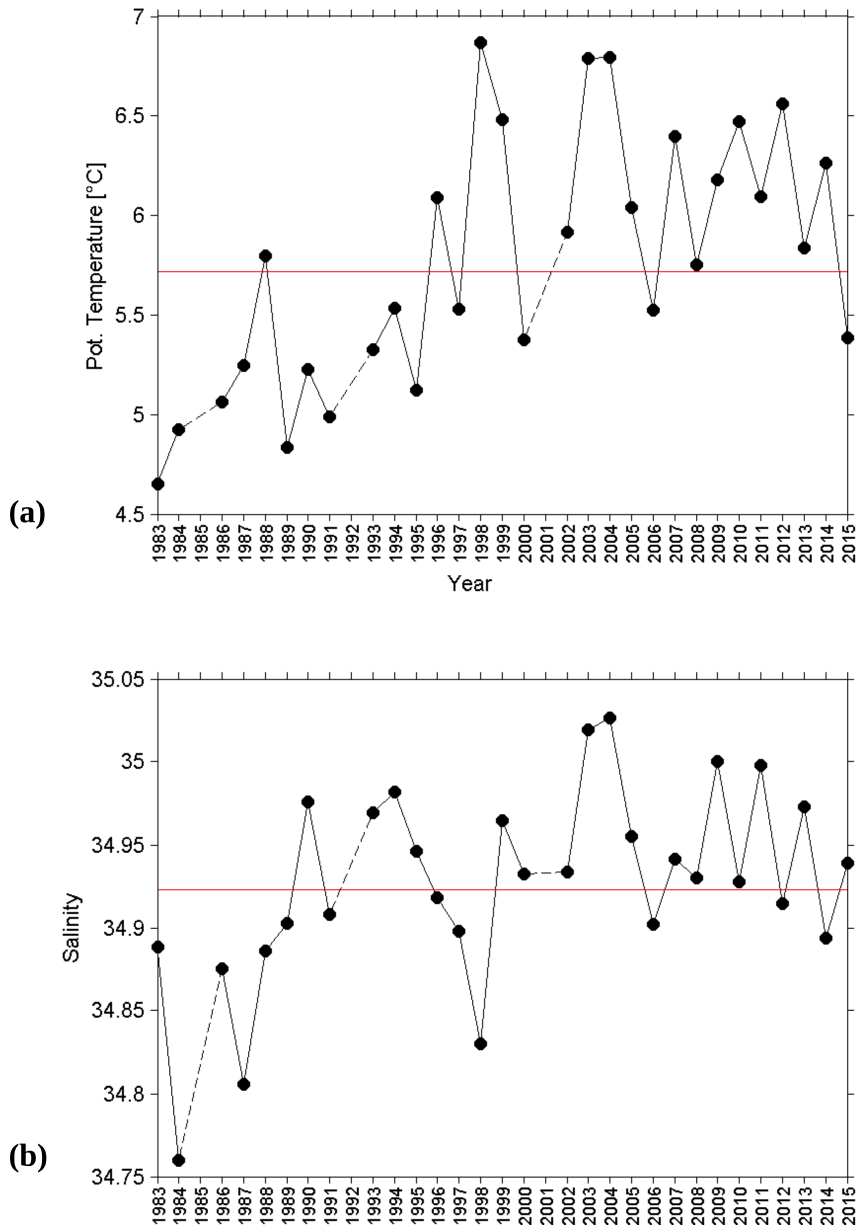
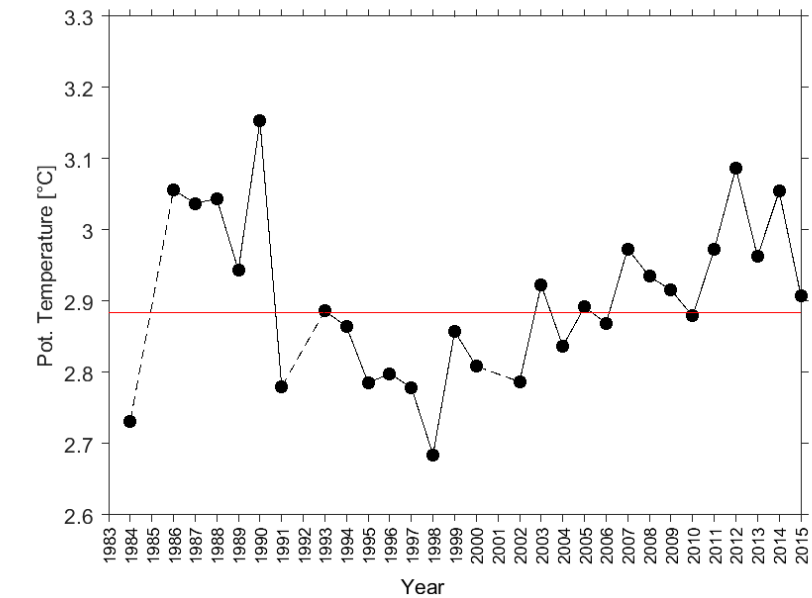
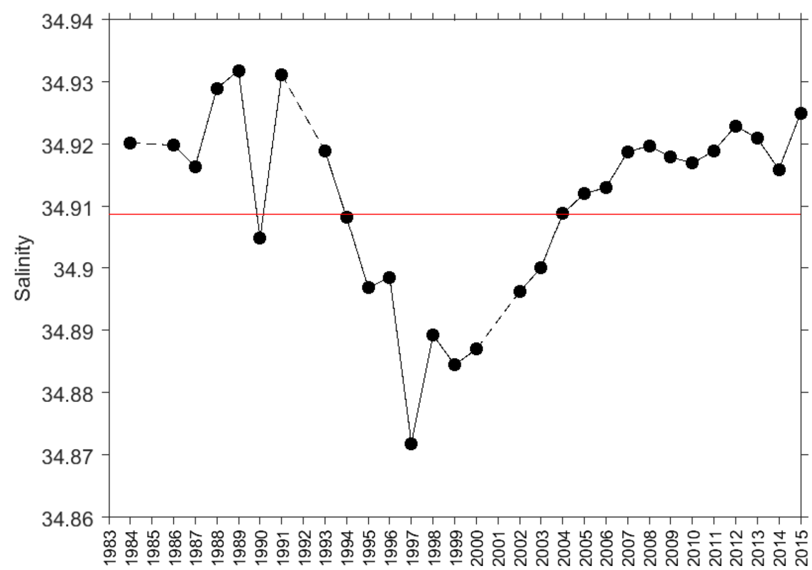


Figure 11. Potential temperature **(a)** and salinity **(b)** in 75-200 m water layer at Cape Desolation Station 3 (60.47°N, 50°W). Red lines indicate the long-term mean potential temperature and salinity, referenced to 1983-2010.



(a)



(b)

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.

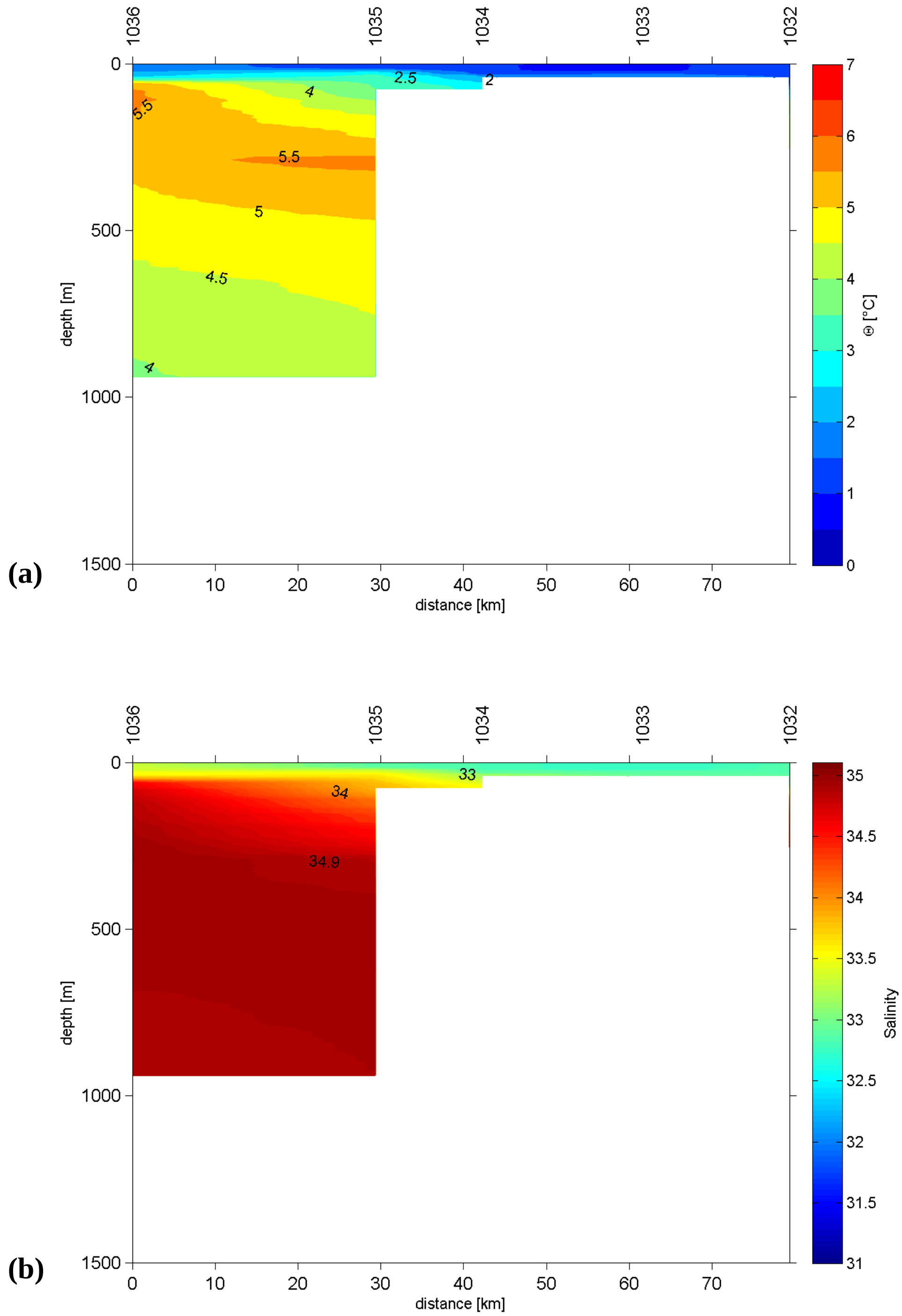
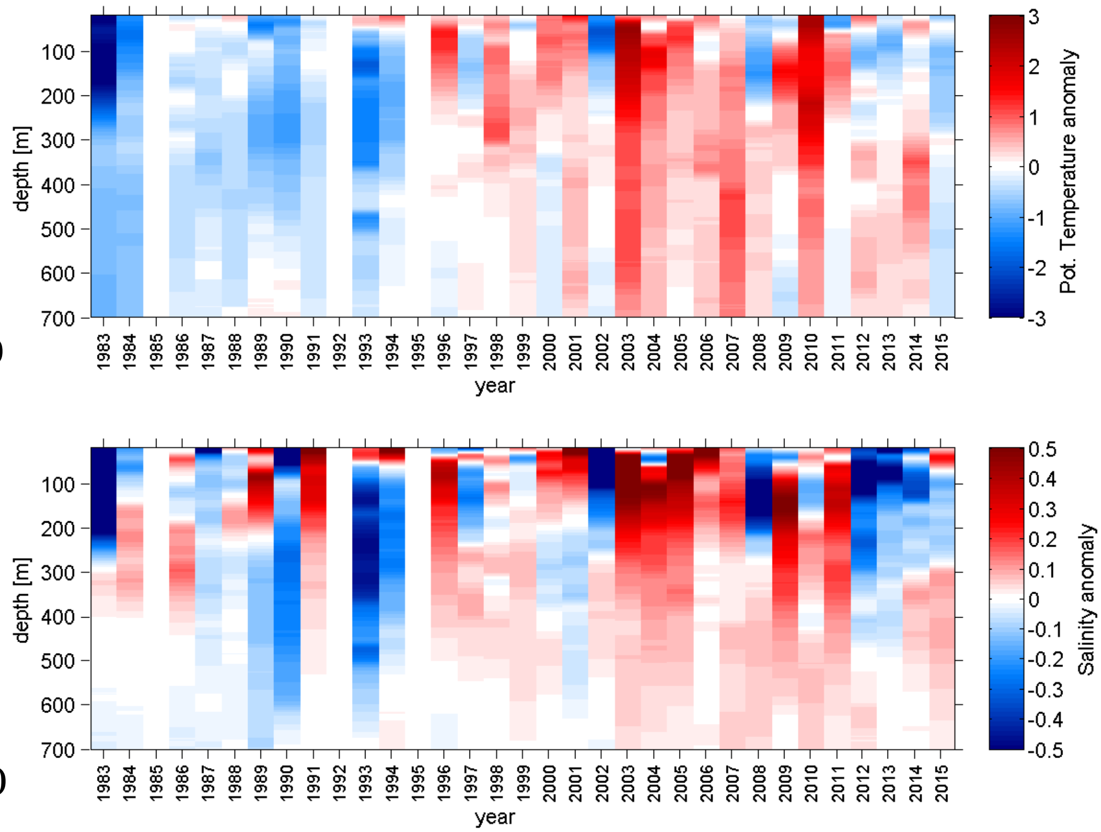


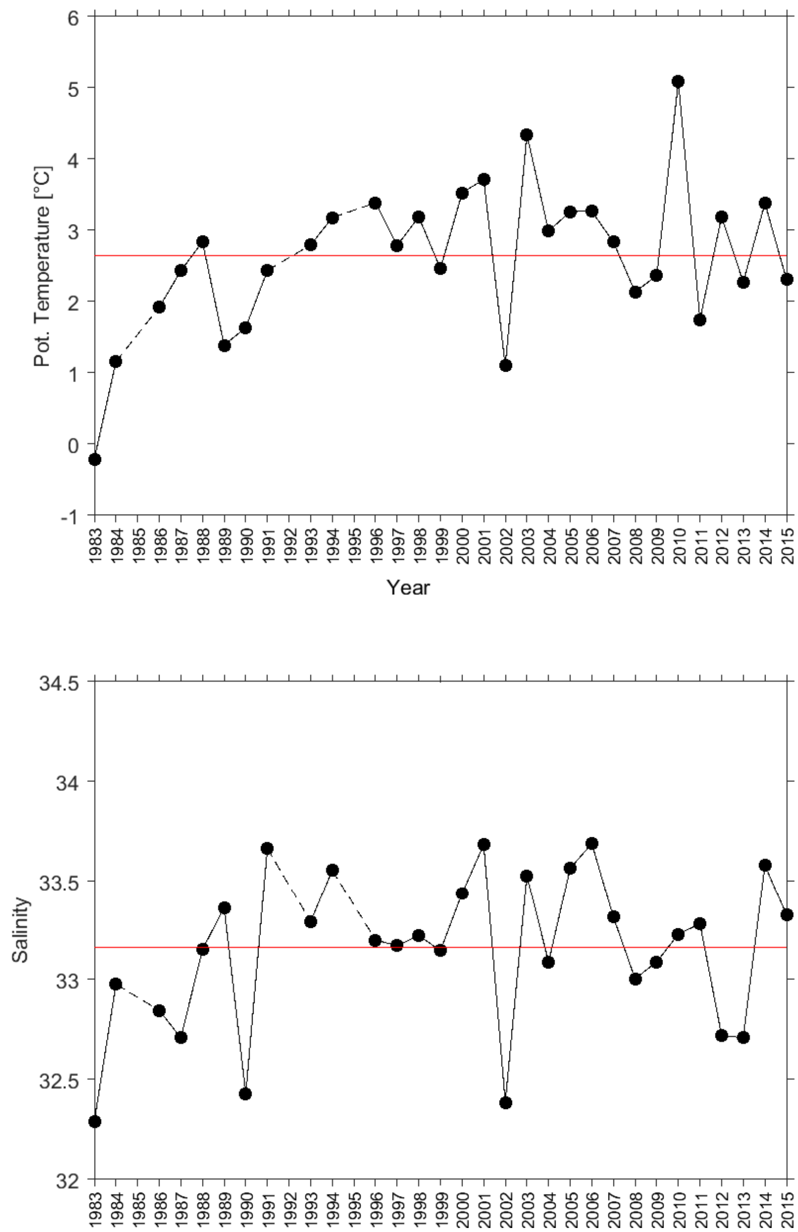
Figure 13. Vertical distribution of potential temperature **(a)** and salinity **(b)** along Fyllas Bank section (Figure 8) in 2015.



(a)

(b)

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.



(a)

(b)

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 – Hydrographic Conditions on the Northeast United States Continental Shelf in 2015 (Area 2c)

Area 2c: Hydrographic Conditions on the Northeast United States Continental Shelf in 2015

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Background

The Northeast United States (NEUS) Continental Shelf extends from the southern tip of Nova Scotia, Canada, southwestward through the Gulf of Maine and the Middle Atlantic Bight, to Cape Hatteras, North Carolina (Fig. 1). Contrasting water masses from the subtropical and subpolar gyres influence the hydrography in this region. Located at the downstream end of an extensive interconnected coastal boundary current system, the NEUS shelf is the direct recipient of cold/fresh arctic-origin water, accumulated coastal discharge and ice melt that has been advected thousands of kilometers around the boundary of the subpolar North Atlantic. Likewise, subtropical water masses, advected by the Gulf Stream, slope currents and associated eddies, also influence the composition of water masses within the NEUS shelf region. The western boundary currents of the subpolar and subtropical gyres respond to variations in basin-scale forcing through changes in position, volume transport and/or water mass composition and it is partly through these changes that basin-scale climate variability is communicated to the local NEUS shelf.

To first order, hydrographic conditions along the NEUS shelf are determined by the relative proportion of two main sources of water entering the region: cold/fresh arctic-origin water advected by the coastal boundary current from the north and warmer, more saline slope waters residing offshore of the shelf break. The source waters first enter the NEUS shelf region through the Gulf of Maine, a semi-enclosed shelf sea that is partially isolated from the open Northwest Atlantic by two shallow banks, Browns and Georges Banks. Below 100 meters, exchange between the Gulf of Maine and the deeper North Atlantic is restricted to a single deep channel, the Northeast Channel, which bisects the shelf between the two banks. This deep channel interrupts the continued flow of cold, fresh arctic-origin water along the coast, redirecting the majority of this flow into the Gulf of Maine. In the meantime, denser slope waters enter the basin through the same channel at depth, gradually spreading into a network of deep basins within the Gulf of Maine (Fig. 1b). In the upper layers of the Gulf of Maine, the shelf waters circulate counter-clockwise around the basin before continuing southwestward through the Middle-Atlantic Bight (Fig. 1b). The shelf water is progressively modified by atmospheric fluxes of heat and salt and through mixing with both deeper slope waters and the discharge of several local rivers. In this way, the Gulf of Maine represents the gateway to the NEUS shelf region, responsible for setting the initial hydrographic conditions for water masses entering the Middle Atlantic Bight further downstream.

The pronounced seasonal cycle of heating and cooling over the region drives seasonal variations in water mass composition that are typically larger than interannual variations. During fall and winter, intense cooling at the surface removes buoyancy, resulting in overturning and vertical homogenization of a significant portion of the water column. During spring and summer, surface heating re-stratifies the surface layer, isolating a remnant of the previous winter's cold/fresh mixed water at depth. Variations in these seasonal processes (e.g. less intense cooling in the winter or shifts in the timing of springtime warming) can result in interannual variations in the composition and distribution of water masses. In addition, fluctuations in the composition and volume of source waters entering the Gulf of Maine may also drive interannual variations in water properties relative to this seasonal mean picture.

The slope water that enters the Gulf of Maine is a mixture of two water masses: warm, saline, relatively nutrient-rich Warm Slope Water (WSLW) originating in the subtropics and cold, fresh, relatively nutrient-poor Labrador Slope Water (LSLW) originating in the subpolar region. Seaward of the Gulf of Maine, the relative proportion of these two water masses varies over time. However, in general, the volume of each decreases with increasing along-slope distance from their respective sources; LSLW (WSLW) volume decreases from north to south (south to north). Decadal shifts in the position of the Gulf Stream appear to be closely tied to changes in slope water temperature offshore of the NEUS shelf and to the composition of slope water entering the Gulf of Maine (Pers. Comm. T. Joyce and Y-O. Kwon.) Cooling in the slope water offshore is accompanied by a southward shift in the Gulf Stream and a predominance of northern source water (LSLW) in the deep layers of the Northeast Channel.

Basin-Scale Conditions in 2015

Surface air temperatures were colder than average (1981-2010) over the North American continent, Labrador Sea and central North Atlantic during winter and warmer than average during summer and fall suggesting a larger seasonal range in 2015 (Fig. 2). Sea surface temperature mirrored these patterns, with cooler than average SST in the central basin and near shore along the NEUS Shelf during winter/spring and enhanced warming over the NEUS shelf in summer and fall (Fig. 3). Annually, the magnitude of the warming was comparable to that observed in the 1950s but, unlike the 1950's, 2015 was characterized by an increased seasonal range with enhanced warming in summer and fall (Fig 4).

Hydrographic Conditions in 2015

The U.S. National Oceanic and Atmospheric Administration's Northeast Fisheries Science Center (NEFSC) conducts multiple shelf-wide surveys every year in support of its mission to monitor the NEUS ecosystem. Monitoring efforts have been ongoing since 1977. Typically, the NEFSC completes six full-shelf hydrographic surveys per year, in addition to several more regionally focused surveys – the minimum required to resolve the dominant seasonal cycle in this region. However, budget cuts led to the elimination of two of these six surveys in 2015 and ship maintenance issues led to truncation of the remaining surveys so that overall roughly half as many stations were occupied in 2015 over just two seasons, leading to a critical loss of seasonal resolution.

Relative to historical values, regional ocean temperatures across the NEUS shelf were warm during 2015 (Fig. 5). Annually, waters in the upper 30 meters were between 0.3-1.4°C warmer than normal everywhere, with the largest anomalous occurring in the Middle Atlantic Bight. Of the seasons sampled, warming was most pronounced during late-summer/early-fall, particularly in the Middle Atlantic Bight where regional temperature anomalies exceeded 2°C all the way to the bottom (Fig. 6). During winter/spring, regional upper ocean temperatures were near normal to slightly colder than normal across the NEUS Shelf. By contrast, bottom waters were warm year round in the eastern Gulf of Maine, and anomalously cold in the western Gulf of Maine, particularly during spring. The details of the seasonal differences are revealed in synoptic maps, which show colder temperatures primarily near the coast during spring and enhanced warming along the shelf edge during fall (Fig 7).

Annually, surface waters in the upper 30 meters were saltier than normal in 2015, particularly in the Middle Atlantic Bight (Fig. 8). Large anomalies were observed during fall and spring when in the Middle Atlantic Bight, where anomalies exceeded 1 psu (Fig. 9a). By comparison, bottom waters were slightly saltier than normal everywhere except the western Gulf of Maine, where conditions were near normal (Fig. 8). Synoptically, the large regional salinity anomalies observed at the surface in the Middle Atlantic Bight are reflective of enhanced positive anomalies aligned with regions of warming (Fig. 9) extending shoreward from the shelf edge in the northern (southern) Middle Atlantic Bight in fall (spring) (Fig 10).

The extreme temperature and salinity anomalies observed during summer/fall were presumably caused by a procession of Gulf Stream warm core rings, whose interaction with the topography at the shelf break drove an incursion of Gulf Stream water onto the inner shelf between spring and fall of this year. The conditions are indicative of a significant intrusion with the largest temperature anomalies occurring in the upper 20 m and throughout the water colunn over the shelfbreak and upper slope. Gradients in the seasonal thermocline are enhanced by the inundation and appear to support the shoreward protrusion of high salinity water (Fig 11). The flooding of Gulf Stream water also eroded the cold pool – a seasonal bottom-trapped feature formed when winter-cooled shelf water is isolated from the surface by summer heating (Fig 11). This feature serves as critical habitat for a number of fisheries on the NEUS shelf.

Deep inflow through the Northeast Channel continues to be dominated by Warm Slope Water (Fig. 12). Springtime temperature-salinity profiles indicate the presence of a pronounced Cold Intermediate layer in the western Gulf of Maine during 2014, a mid-depth water mass formed seasonally as a product of convective mixing driven by winter cooling (Fig. 13). In fact, the remnant winter water resident in the Cold Intermediate Layer extends to the bottom of Wilkinson Basin in spring 2015, confirming that robust convective mixing took place in the preceding winter (Fig. 14). This is not surprising considering the fact that air temperatures over the Northeastern U.S were more than 2°C colder than normal in 2015 (Fig 2). Cold/dry winds blowing off the continental land mass lead to more efficient evaporative cooling in the western Gulf of Maine and deeper convective mixing. In general, deeper vertical mixing has greater potential to tap into nutrient rich slope water at depth and should result in a thicker intermediate layer during spring, both potentially having an impact on the timing or intensity of spring phytoplankton blooms.

Fisheries Implications

Episodic events such as the extreme Gulf Stream water intrusion that was observed in fall 2015 have the potential to cause significant changes in the ecosystem. For instance, this event could lead to significant changes in nutrient loading on the shelf, the seasonal elimination of critical habitats such as the cold pool and shelf-slope front, disruption of seasonal migration cues, and an increase in the concentration of offshore larval fish on the shelf.

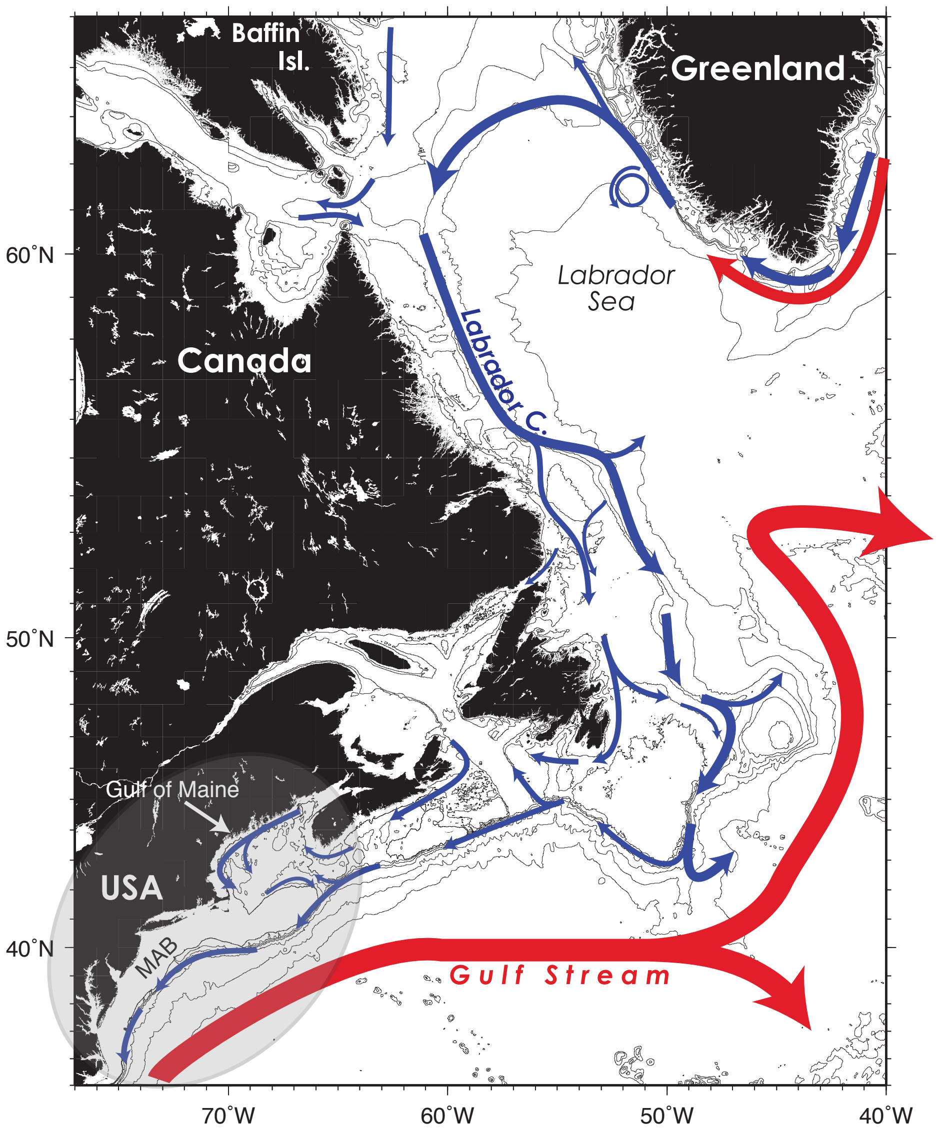


Figure 1a: Circulation schematic of the western North Atlantic. The Northeast U.S. Shelf region is identified by the shaded oval. The 100, 200, 500, 1000, 2000, 3000 and 4000 meter isobaths are shown.

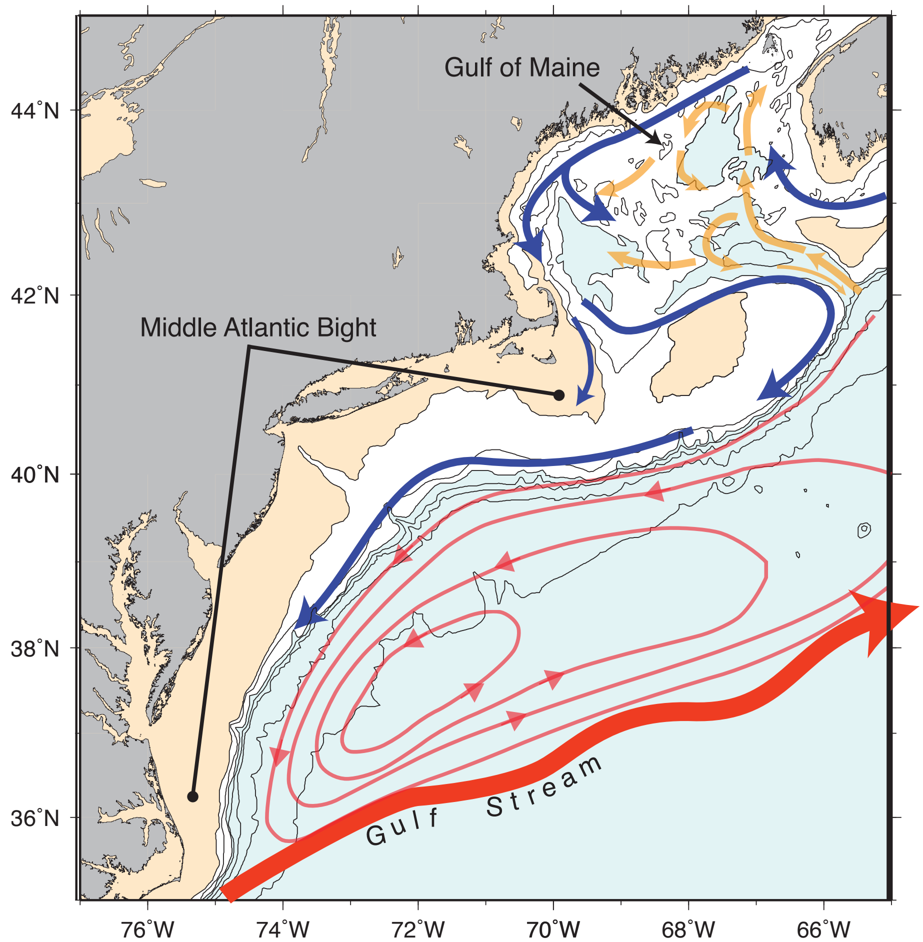


Figure 1b: Circulation schematic for the Northeast U.S. Shelf region, where blue arrows represent shelf water circulation and orange arrows represent deeper slope water circulation pathways. Water depths deeper than 200 meters are shaded blue. Water depths shallower than 50 meters are shaded tan.

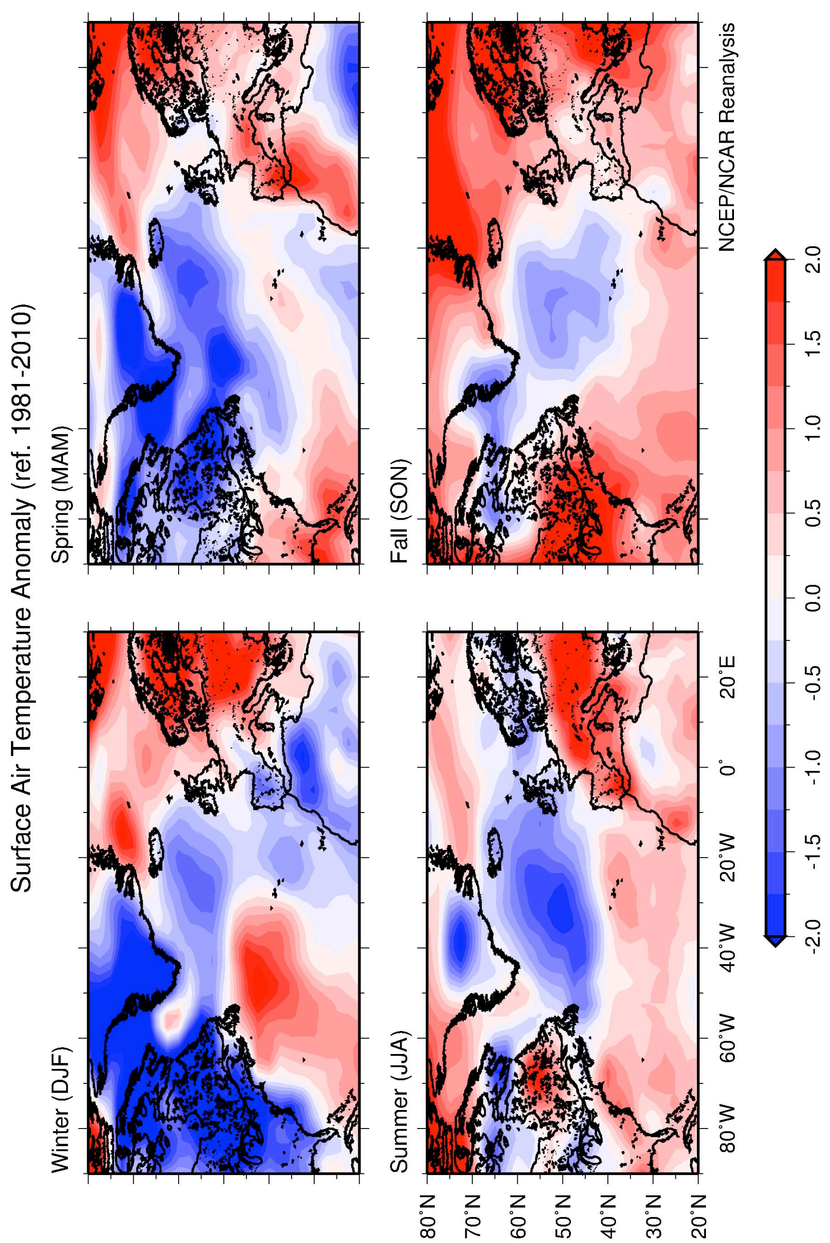


Figure 2: Surface air temperature anomaly derived from the NCEP/NCAR Reanalysis product (http://www.esrl.noaa.gov/psd/data/composites/day/). Seasons are made up of 3-month periods where winter spans December-February. Positive anomalies correspond to warming in 2015 relative to the reference period (1981-2010).

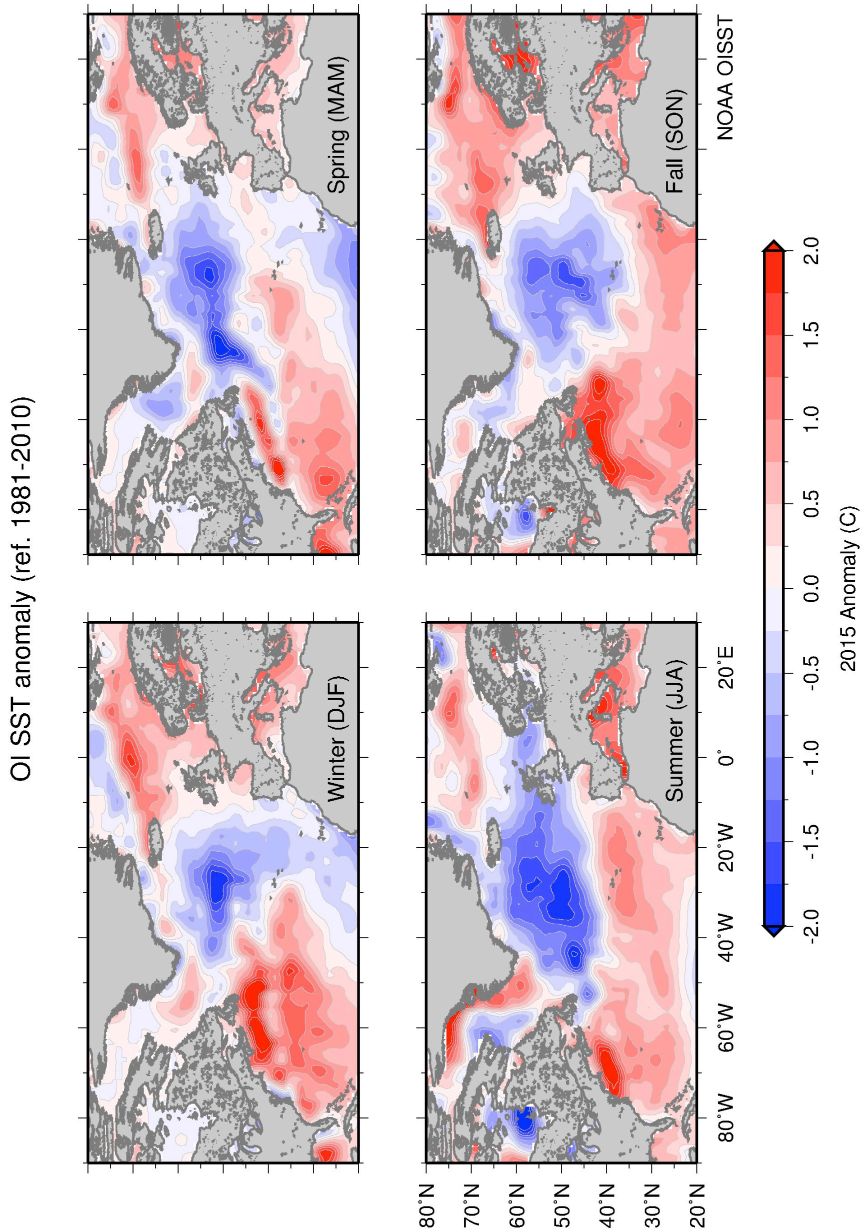
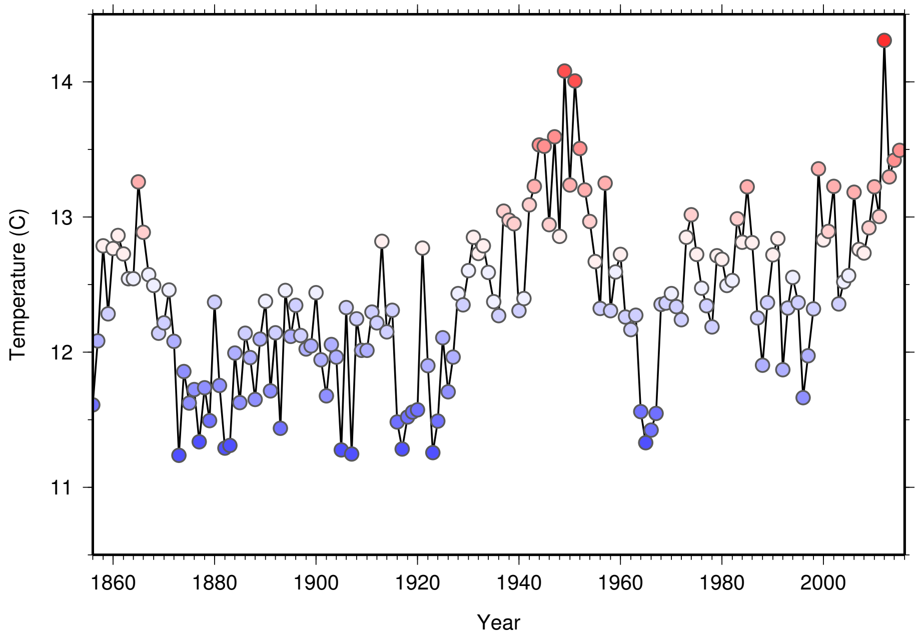


Figure 3: Sea surface temperature anomaly derived from the NOAA's Optimum Interpolation (OI) SST product (http://www.esrl.noaa.gov/psd/data/gridded/data.noaa.oisst.v2.html). Seasons are made up of 3-month periods where winter spans December-February. Positive anomalies correspond to warming in 2015 relative to the reference period (1981-2010).



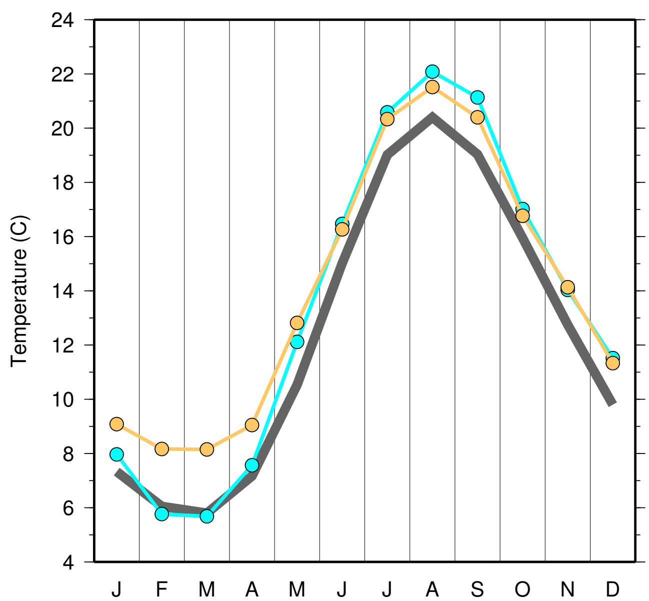


Figure 4: Top: Regional average annual sea surface temperature for the NEUS shelf region calculated from NOAA's extended reconstructed sea surface temperature product (http://www.esrl.noaa.gov/psd/data/gridded/data.noaa.ersst.html). Colors correspond with the anomaly scale in Figure 3. Bottom: Regional average monthly mean SST for the NEUS shelf for 2015 (cyan), 1950 (orange) and 1981-2010 (gray).

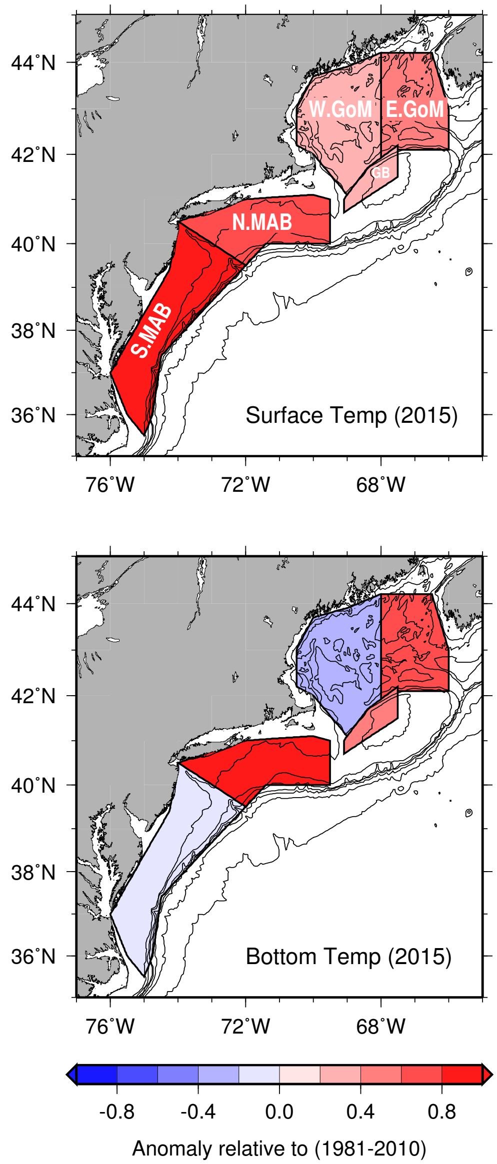


Figure 5: Surface (upper panel) and bottom (lower panel) regional annual temperature anomaly (°C). Positive anomalies correspond to warming in 2015 relative to the reference period (1981-2010). The region labels correspond to the panels in Figure 6.

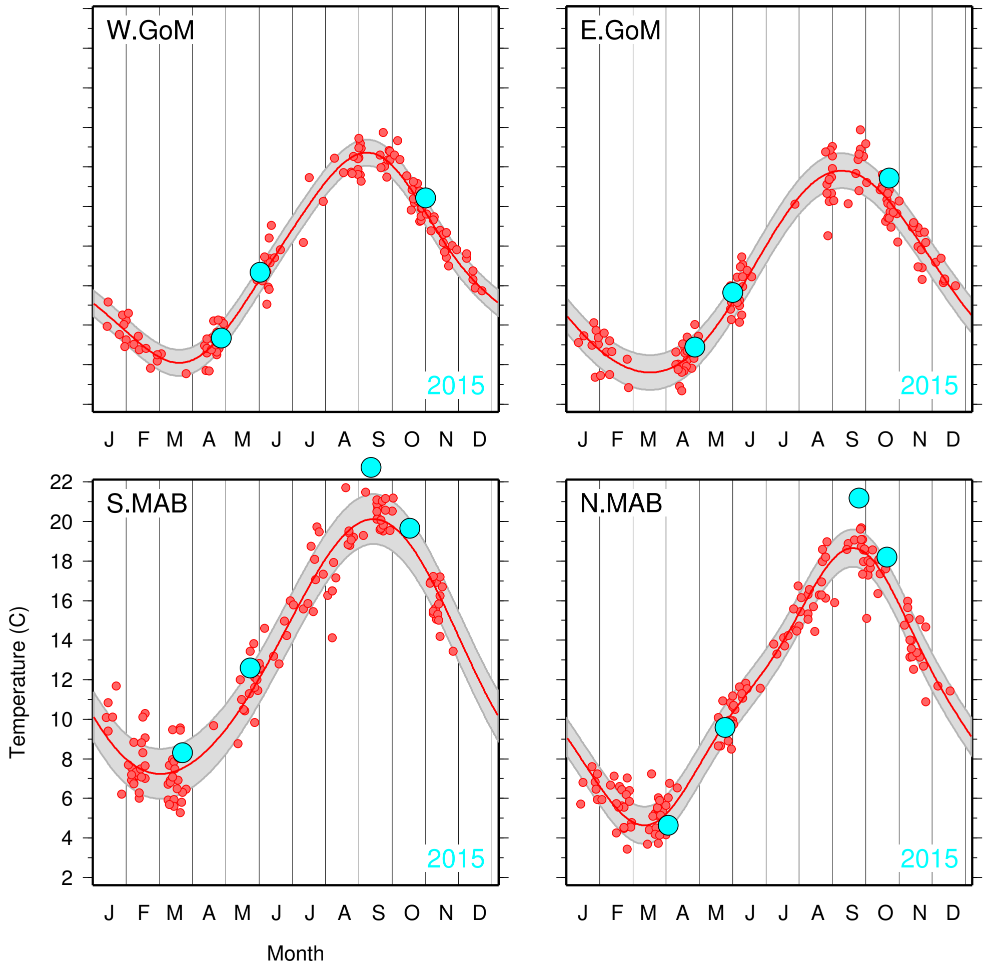


Figure 6a: Regional average 0-30 meter temperature (°C) as a function of calendar day. Each dot represents a volume-weighted average of all observations from a single survey falling within the regions delineated in Fig. 5. An annual harmonic fit to the regional average temperatures from 1981-2010 is shown by the red curve with the points contributing to the fit also shown in red. The gray shading depicts one standard deviation around this fit. The regional average temperatures from 2015 surveys are shown in cyan.

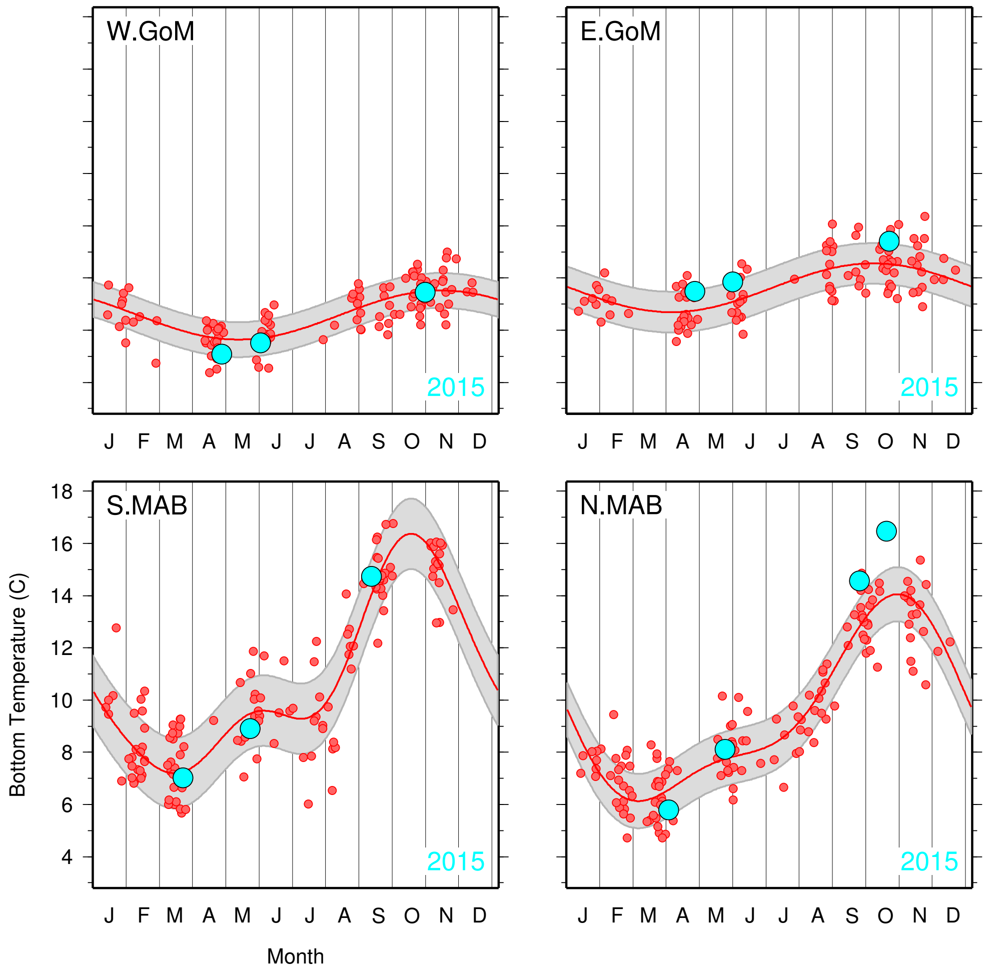


Figure 6b: As in Fig. 6a, but for bottom temperatures.

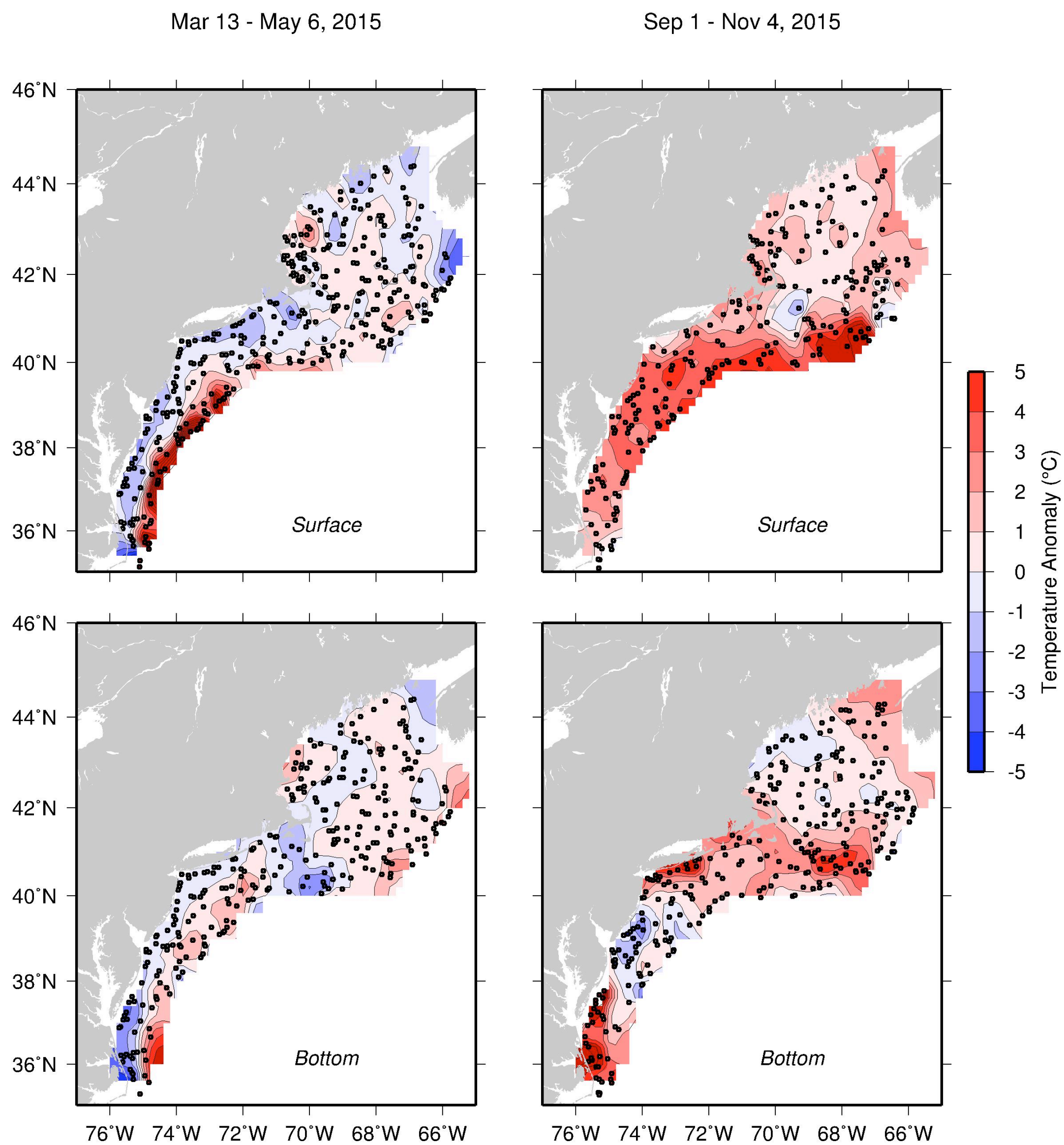


Figure 7: Surface (upper panels) and bottom (lower panels) temperature anomaly from the spring 2015 (left) and fall 2015 (right) ground fish surveys. Positive anomalies correspond to warming in 2015 relative to the reference period (1977-1987).

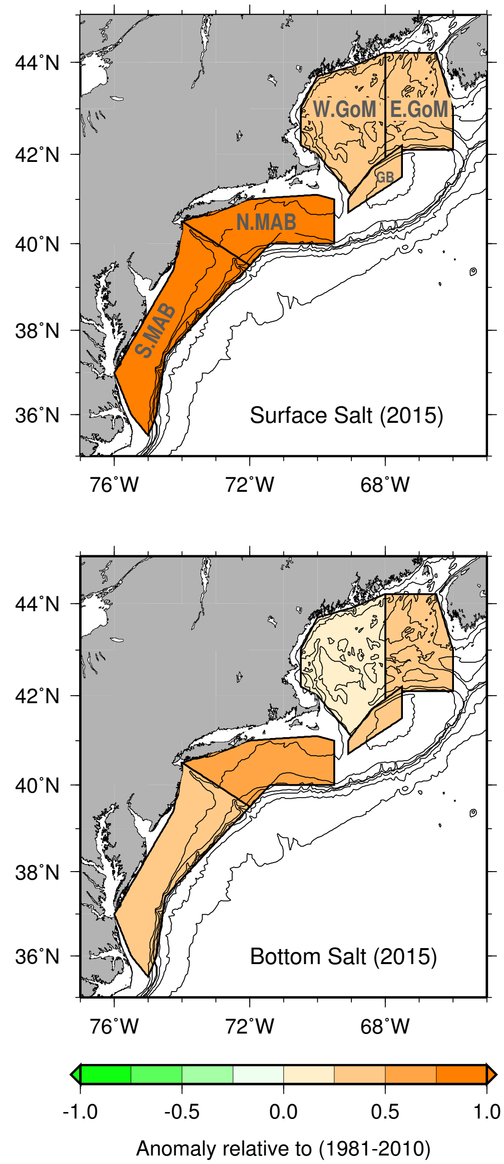


Figure 8: Surface (upper panel) and bottom (lower panel) regional annual salinity anomaly. Positive anomalies correspond to more saline conditions in 2015 relative to the reference period (1981-2010). The region labels correspond to the panels in Figure 6.

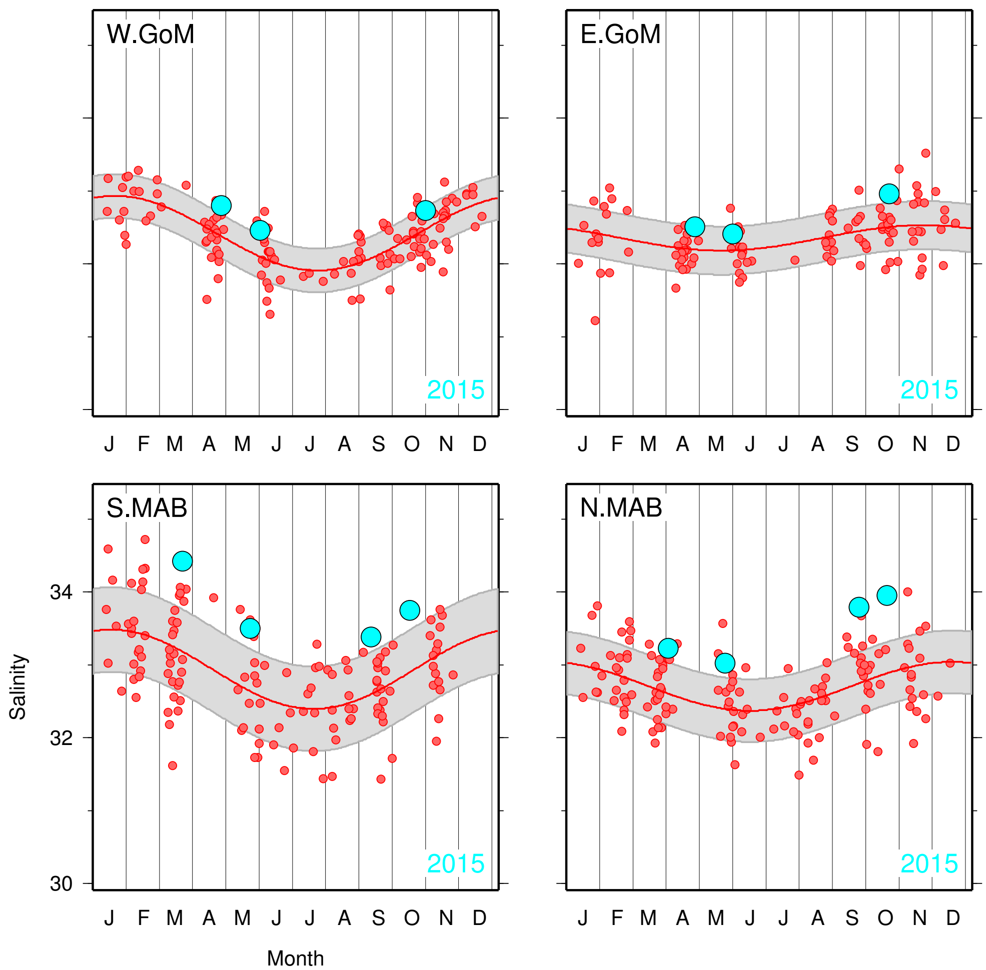


Figure 9a: Regional average 0-30 meter salinity as a function of calendar day. Each dot represents a volume-weighted average of all observations from a single survey falling within the regions delineated in Fig. 5. An annual harmonic fit to the regional average salinities from 1981-2010 is shown by the red curve with the points contributing to the fit also shown in red. The gray shading depicts one standard deviation around this fit. The regional average salinities from 2015 surveys are shown in cyan.

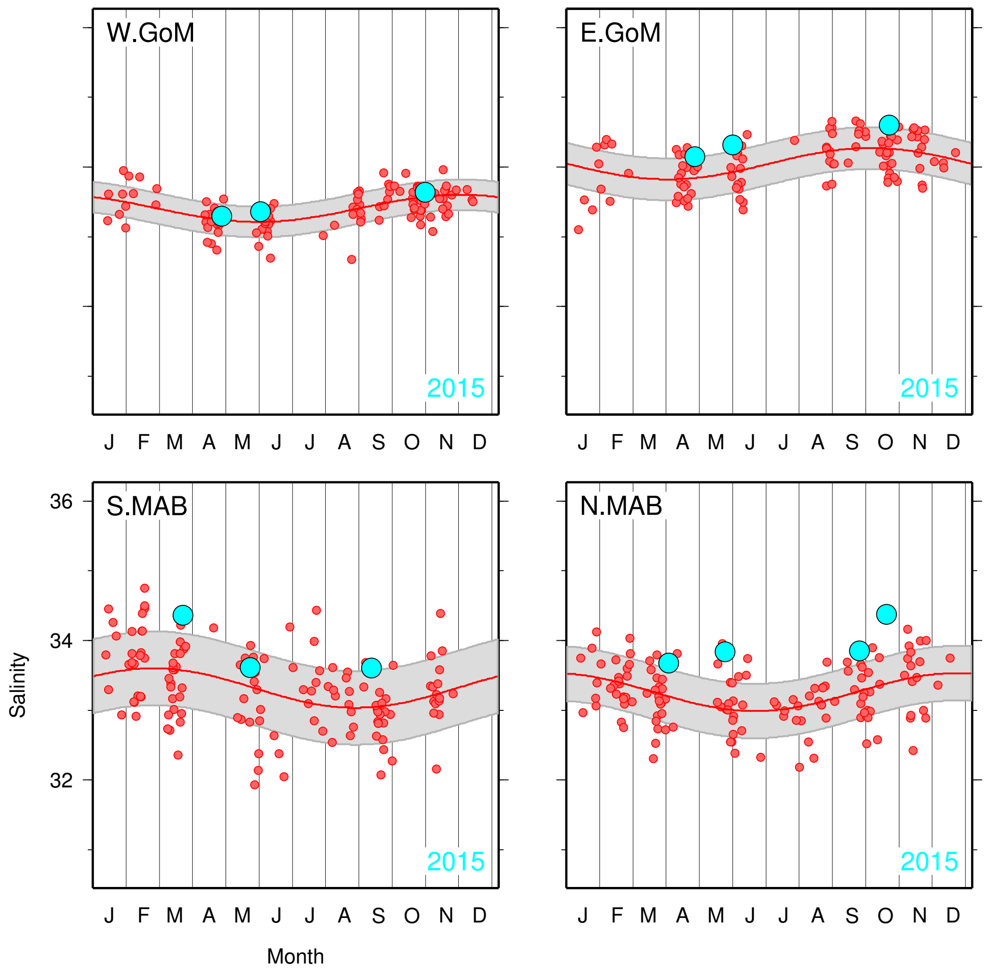


Figure 9b: As in Fig. 9a, but for bottom salinity.

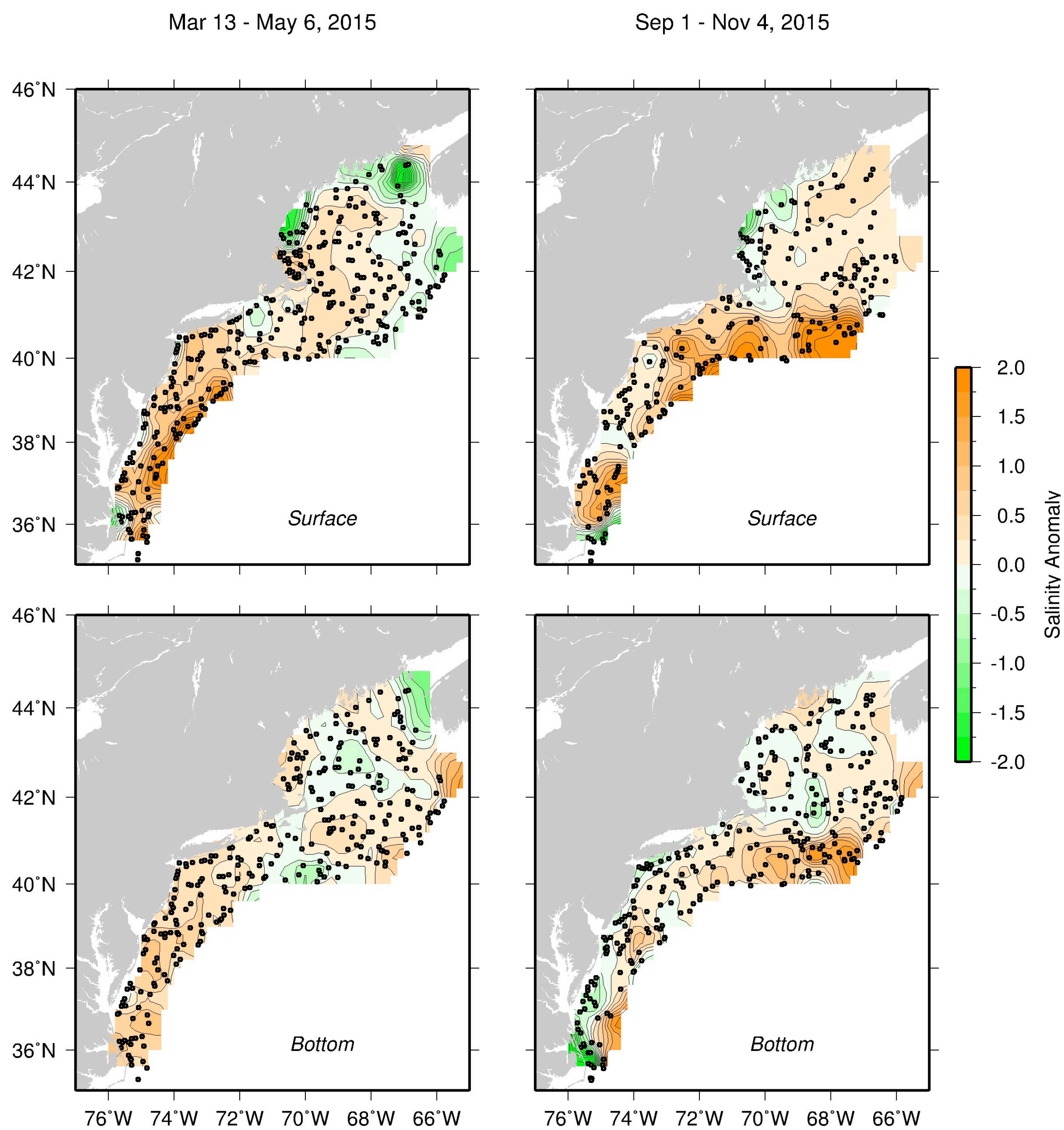


Figure 10: Surface (upper panels) and bottom (lower panels) salinity anomaly from the spring 2015 (left) and fall 2015 (right) ground fish surveys. Positive anomalies correspond to more saline conditions in 2015 relative to the reference period (1977-1987).

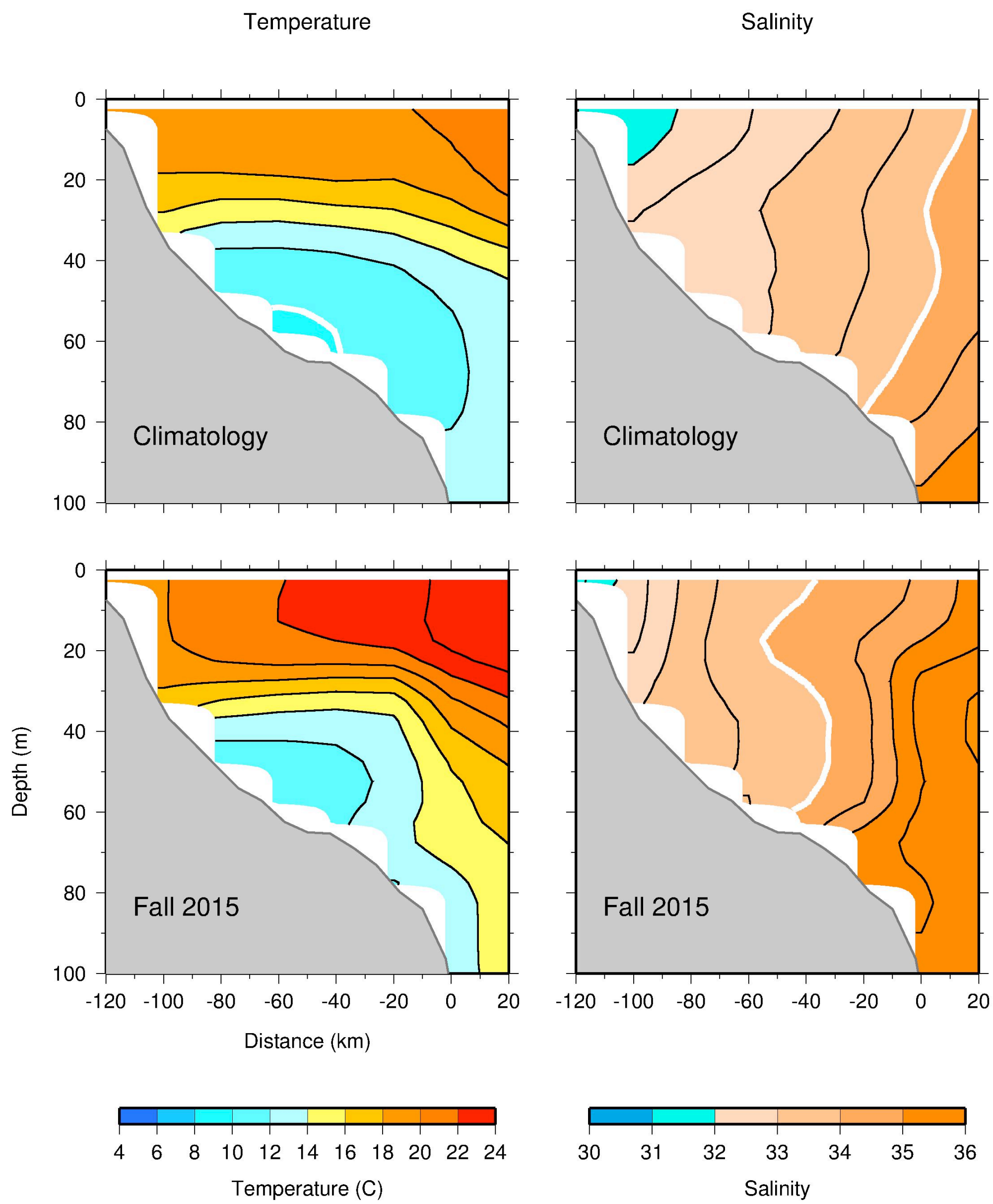


Figure 11: Vertical sections of temperature (left) and salinity (right) crossing the continental shelf in the Middle Atlantic Bight. The top panels show the climatological average for September spanning the years 1981-2010. The bottom panels show the synoptic mean section for September 2015. The heavy white contour highlights the 10°C isotherm as an indicator of the boundary of the cold pool and the 34 isohaline typically aligned with the shelf-slope front.

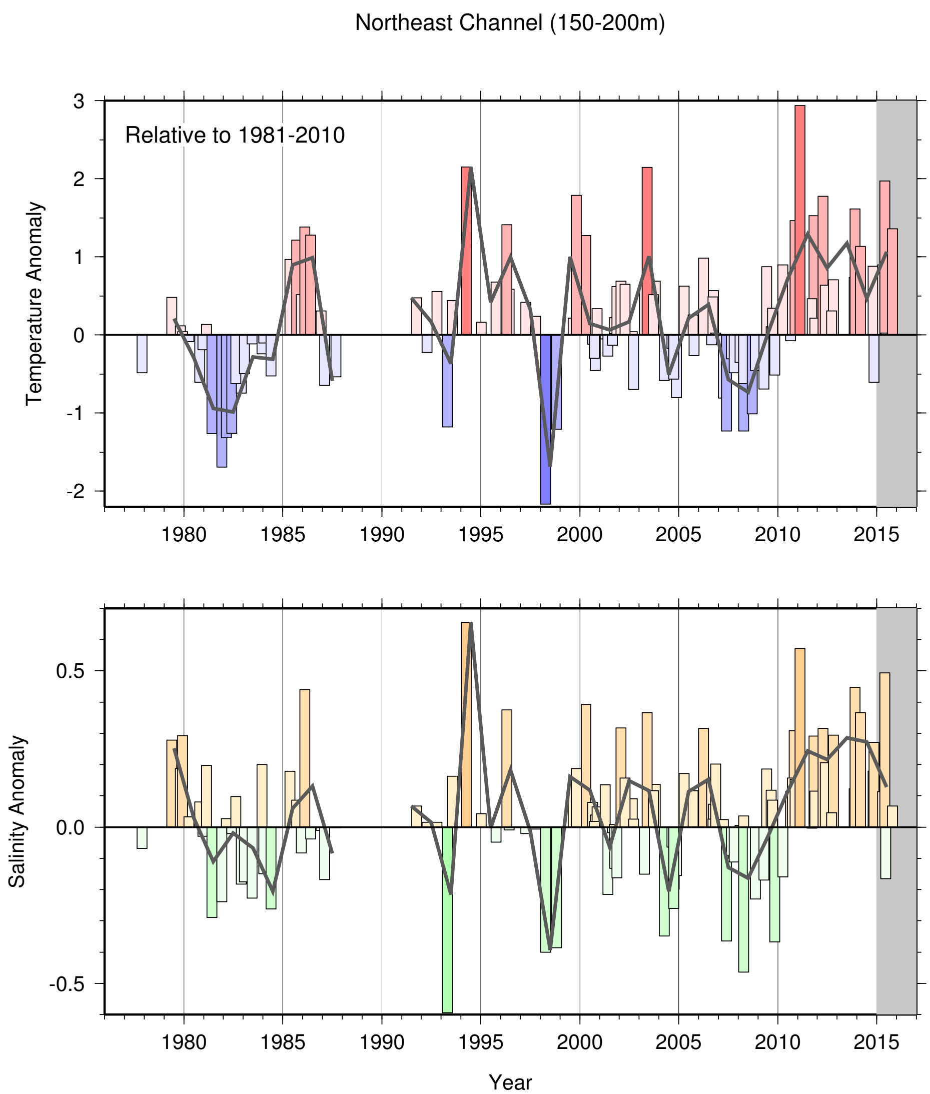


Figure 12: Time series of temperature and salinity anomaly in the deep Northeast Channel. Each bar represents a volume-weighted average of all observations from a single survey collected between 150-200 meters in the Northeast Channel. The grey curve shows the annual average anomaly time series. Positive values are warmer and saltier than the long-term mean calculated for 1981-2010. The gray shading highlights observations made in 2015.

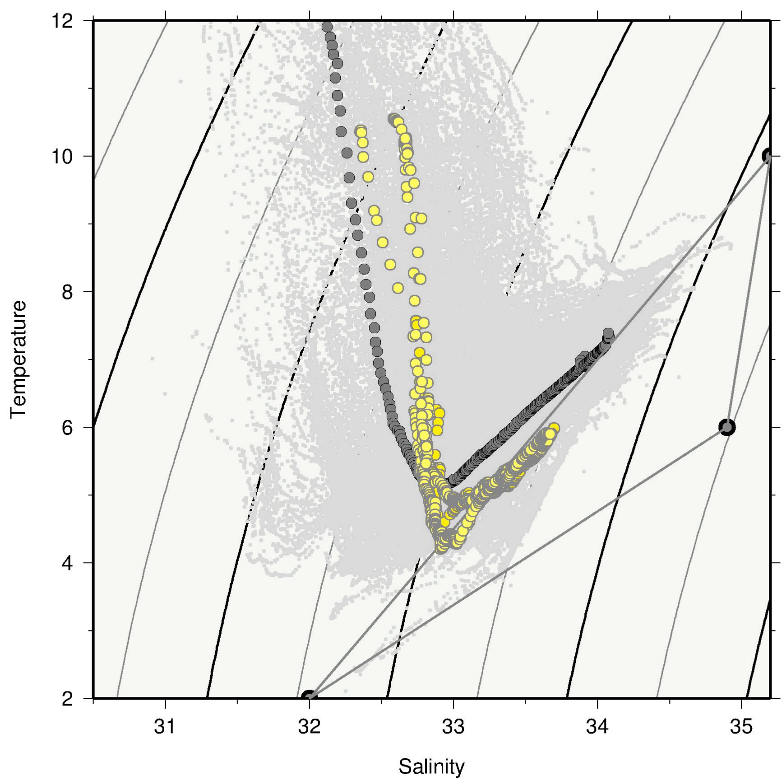


Figure 13: Temperature-salinity diagram showing water properties in Wilkinson Basin in the western Gulf of Maine. All observations from spring 2015 (yellow) are shown along with the spring climatological average profile (1981-2010, dark gray). The lightest gray dots show the historical range encompassed by observations from the reference period, 1981-2010. Temperature and salinity properties representative of source waters entering the Gulf of Maine are shown by the mixing triangle.

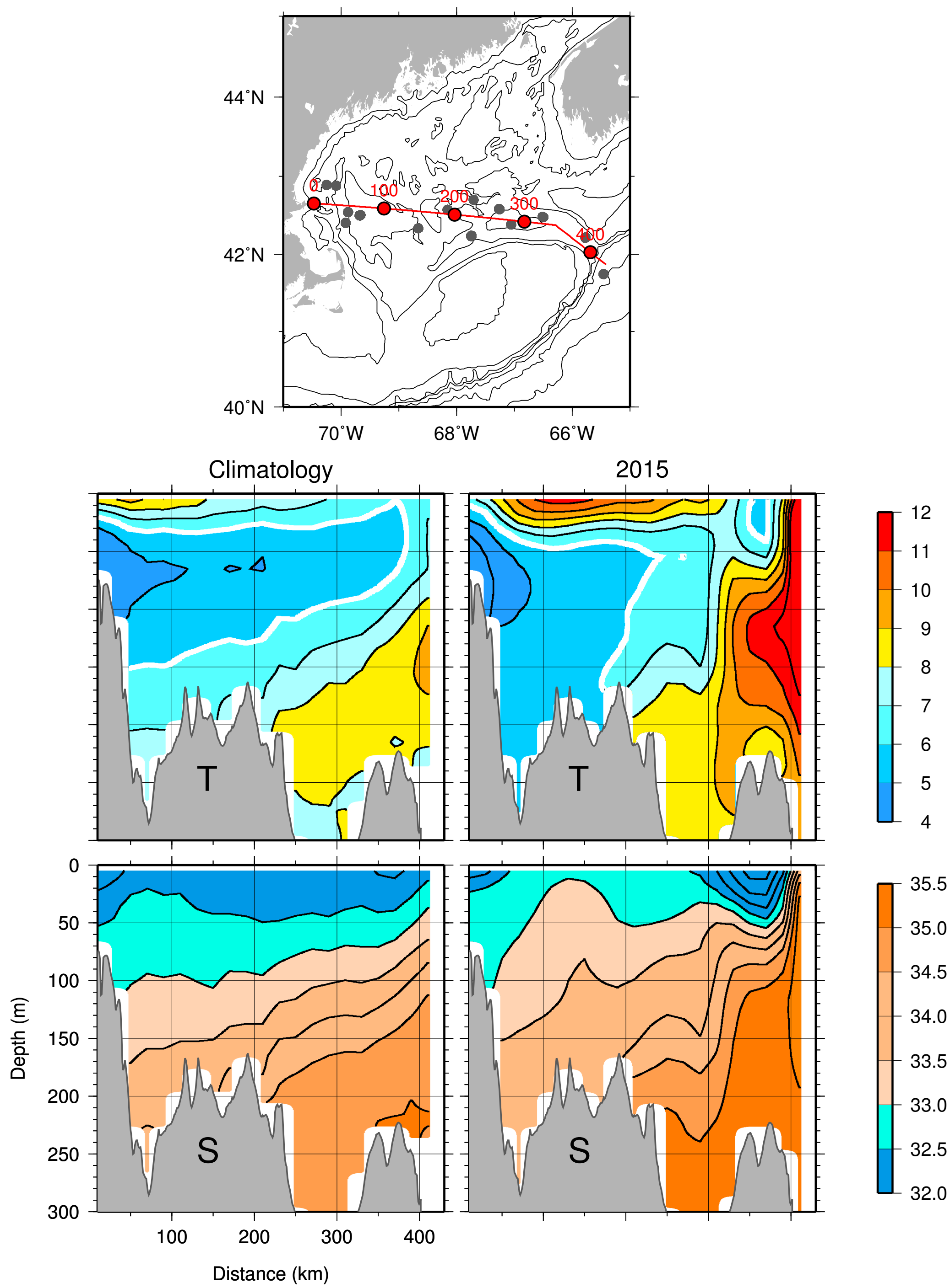


Figure 14: Vertical sections of temperature (top) and salinity (bottom) crossing the Gulf of Maine along a zonal transect shown in the map. The left panels show the climatological average for May spanning the years 1981-2010. The bottom panels show the synoptic mean section for May 2015. The heavy white contour highlights the 6°C isotherm as an indicator of the boundary of the cold intermediate layer. Along-transect distances and the May 2015 station distribution are shown on the map for reference.

Annex 7:

Hydrographic Status Report 2015:
Spanish Standard Sections
(Area 4)

Hydrographic Status Report 2015: Spanish Standard Sections.

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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). Besides the assessment of the Biscay region as in previous national reports, this year we will introduce hydrographical series at the deep western Iberian margin, Canary Basin and the Gulf of Cádiz.

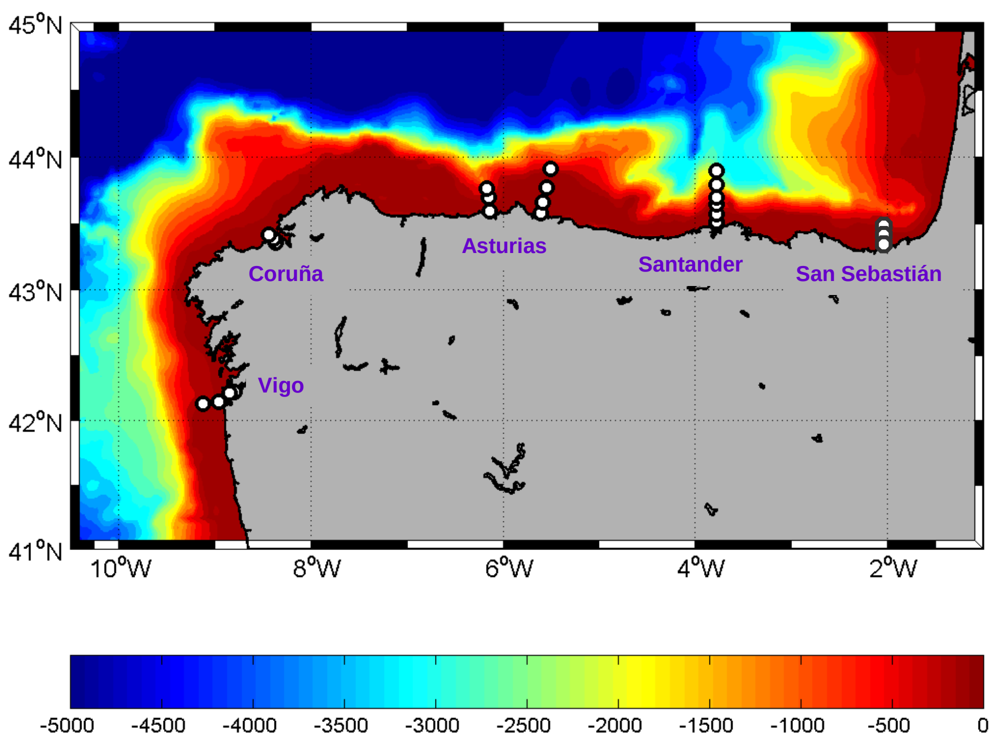


Figure 1. *Spanish Standard Sections from the 'Instituto Español de Oceanografía' in North-NW Iberia (Vigo, Coruña, Asturias, Santander) and from AZTI (San Sebastián).*

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 2015 indicate that it was a very warm year, slightly below current records of 2011 and 2014. Annual mean air temperature was 15.3ºC in Santander (43º30'N, 3º47'W), 0.8°C above 1981-2010 series. Towards the easternmost part of the Bay of Biscay, the annual air temperature average in 2015 at the Igeldo Meteorological Observatory (San Sebastian, 43°18.5°N, 02°2.37°W) was 14.11°C, 0.60°C above the 1981-2010 reference period average and 0.45°C above the 1986-2015 average.

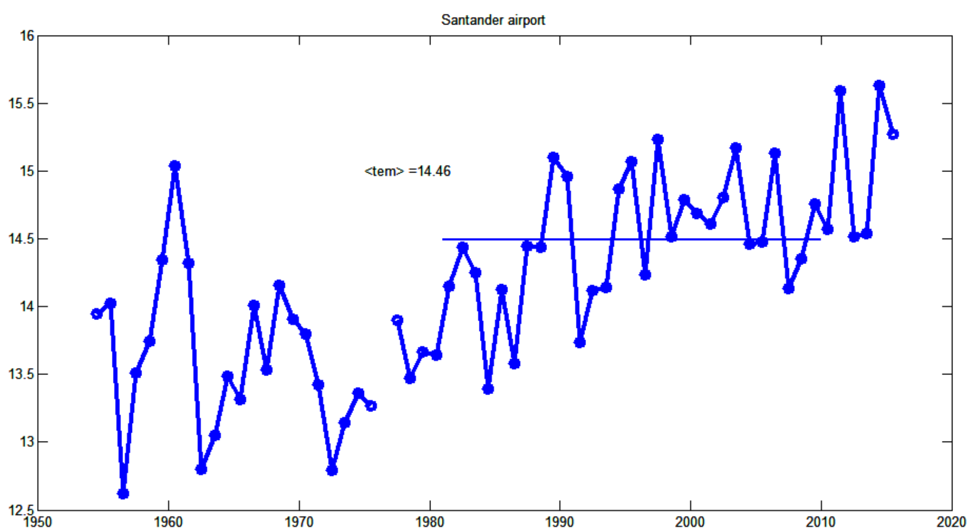


***Figure 2**. Air temperature in Santander meteorological station.*

In general, the seasonal cycle was characterized for being very irregular, starting with a very cold winter season followed by a sharp increase of the temperature in April and overall spring and summer warmer than usual, especially in July. Late summer and early autumn show low or medium values of temperature. Again, late autumn was very warm, especially December, with a positive anomaly of 4.3° C for the monthly average (Figure 3).

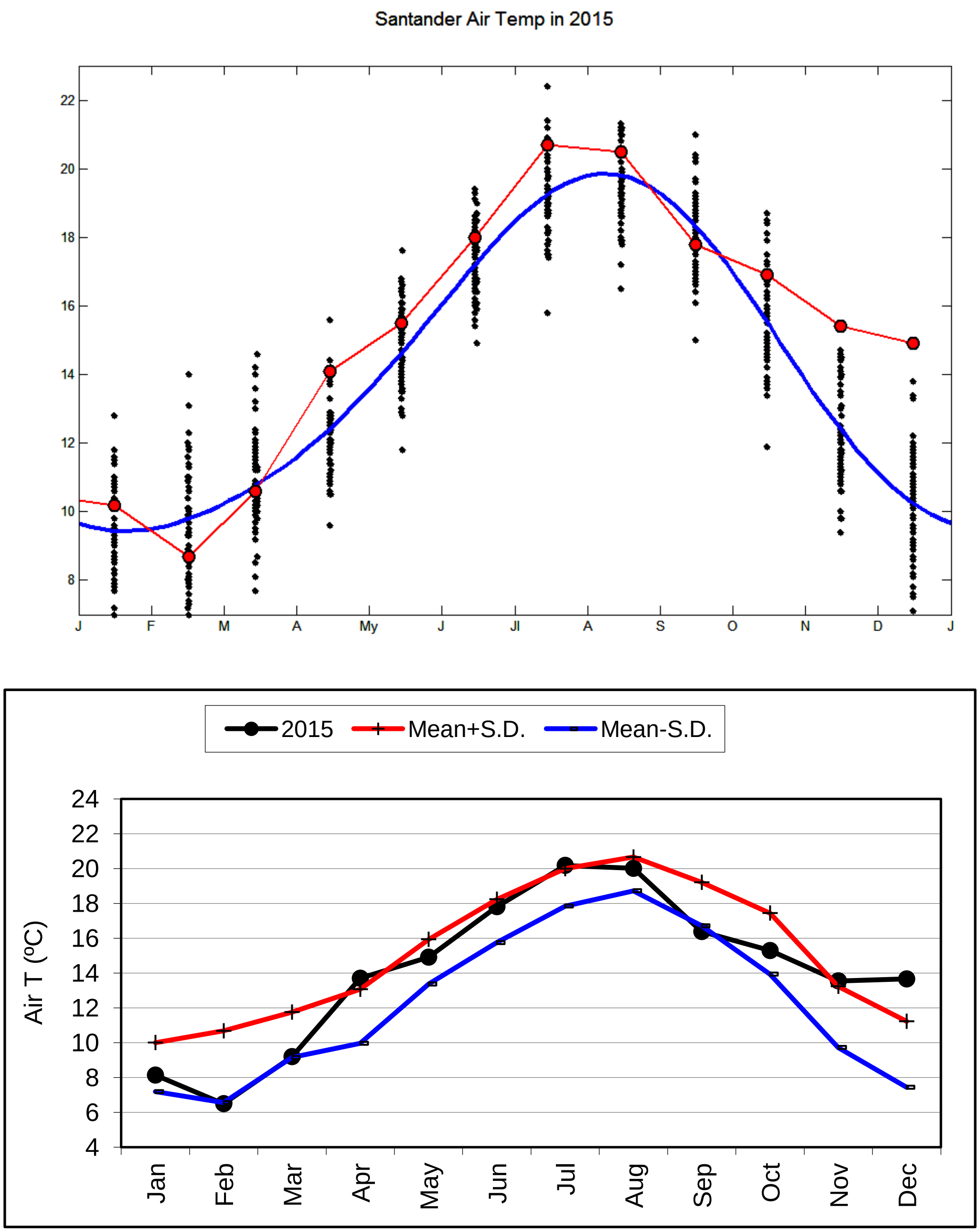


Figure 3. *Monthly mean air temperature (°C) in in Santander (43º30'N, 03º47'W,upper) and San Sebastián (43°18.5'N, 02°2.37'W, lower) in 2015compared with the mean ± standard deviation for the period 1986-2015. Courtesy of the 'Agencia Estatal de Meteorología.*

Precipitation and evaporation

2015 can be defined as a slightly dry year concerning the precipitation regime. Nevertheless, winter was very wet especially February. Conversely, spring, summer and autumn were very dry, with the exception of August and the second half of November (Figure 4). The annual mean precipitation was 120 mm, only 7 mm below above the 1986-2015 average (127 mm).

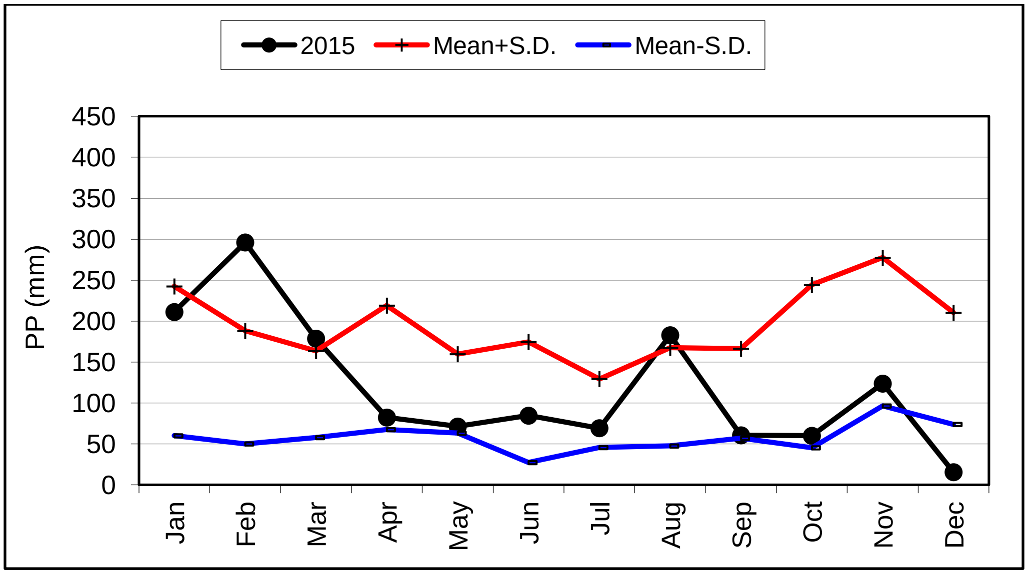
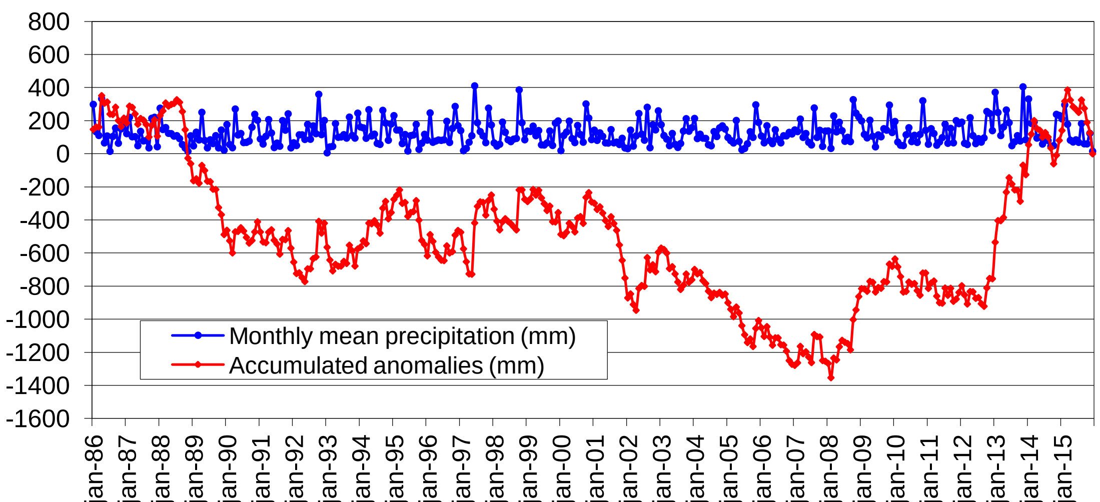


Figure 4. *Monthly precipitation (mm) in San Sebastián (43°18.5′N 02°2.37′W) in 2015 compared with the mean ± standard deviation for the period 1986-2015. Data Courtesy of the 'Agencia Estatal de Meteorología'.*

With regard to water balance, the year 2015, within the context of the previous years, both precipitation and precipitation minus evaporation show a slight moderation of the increasing trends in terms of accumulated anomalies of the previous years (Figures 5a, b).



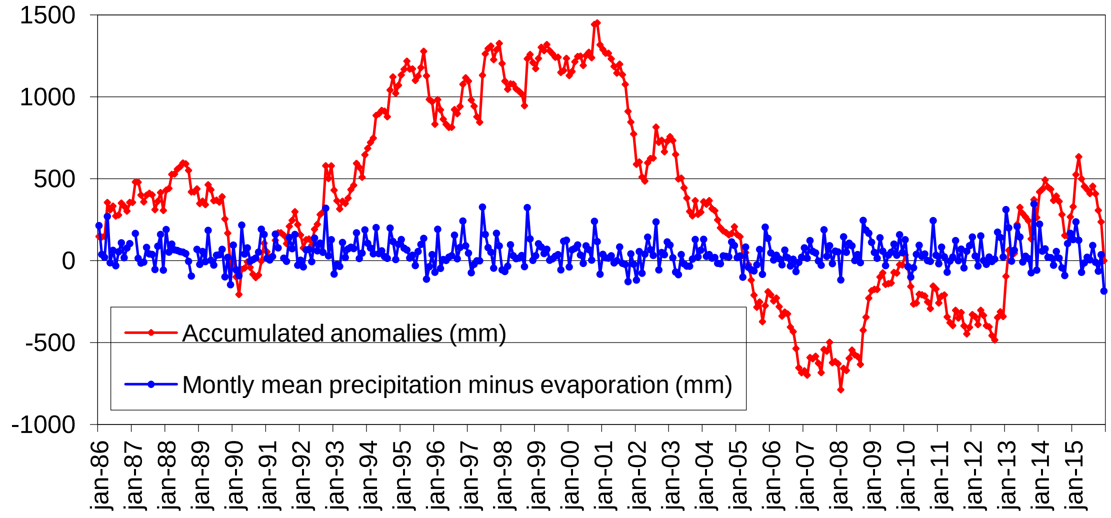


Figure 5. *a) Monthly precipitation (mm) in San Sebastián (43°18.5'N 02°2.37'W) in 1986-2015 and accumulated anomalies. b) Same as (a) for precipitation minus evaporation (mm). Data Courtesy of the 'Agencia Estatal de Meteorología'.*

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 1986-2015. 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	0.61***			
PP SPRING		NS		
PP-EV SPRING		NS		
PP SUMMER			0.40*	
PP-EV SUMMER			0.47*	
PP AUTUMN				0.49*
PP-EV AUTUMN				0.55**

The Gironde River flow in 2015, 666 $m^3 \cdot s^{-1}$, was 158 $m^3 \cdot s^{-1}$ below the 1986-2015 average. On a monthly basis, the flow was around or below the average for the period 1986-2015, with the exception of February and March. In this context, except for January and August-September period the Gironde River flow positive and negative anomalies are in agreement with the positive and negative precipitation anomalies in San Sebastián (Fig. 5).

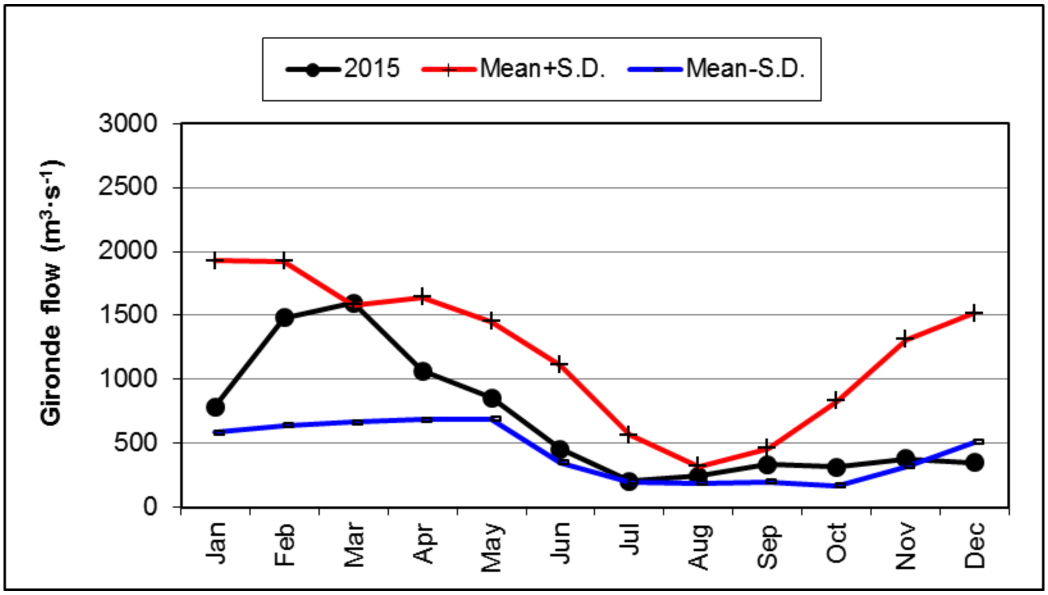


***Figure 6**. Monthly mean flow ($m^3\ s^{-1}$) of the Gironde River in 2015 compared with the mean ± standard deviation for the period 1986-2015. Data Courtesy of the 'Bordeaux Harbour Authority'.*

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 processes have a strong seasonal character with regional differences:

- Seasonal warming/cooling cycle is enhanced towards the southeastern 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 northern Spanish mountains. Therefore the salinity surface minimum is delayed as we move towards the east (Fig.7).

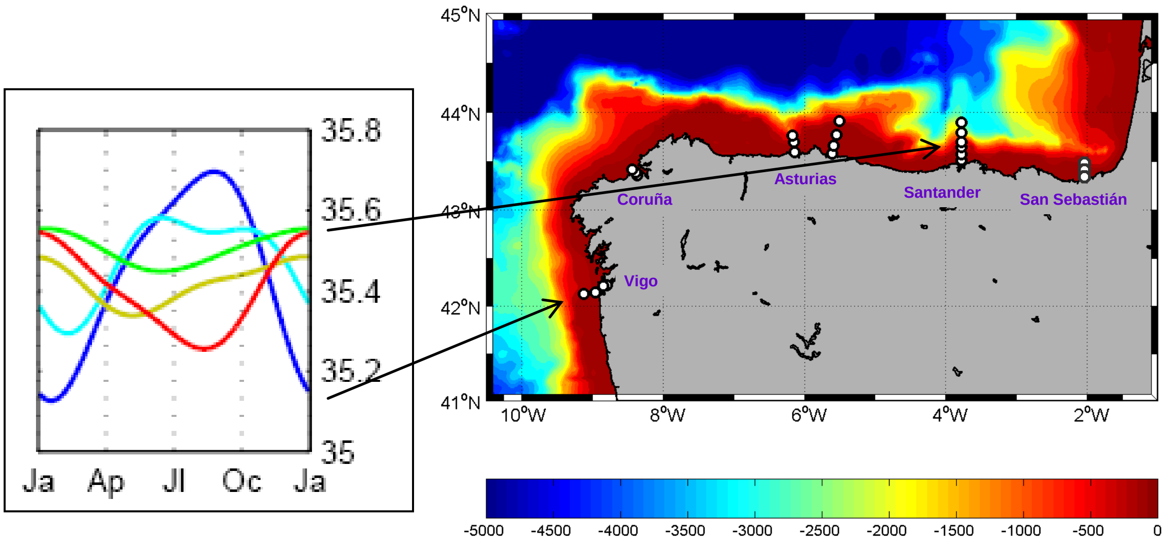


Figure 7. *Surface salinity seasonal cycle at the shelf along the western Iberian margin and the Cantabrian Sea.*

Contours of temperature and salinity (over the shelf, 100 m depth) in the Santander section are shown in Figure 8. The main characteristic of 2015 is that the subsurface structure was fresher that in previous years, salinity anomalies are now negative after a record high period. Temperature at the shelf remained moderate besides the atmospheric warm conditions. This behaviour is a consistent with northern advective influence and upwelling, 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 low values of temperature and fresh conditions. The end of the high salinity anomaly that developed in 2011 and 2012 is 2015 turning into low salinity conditions.

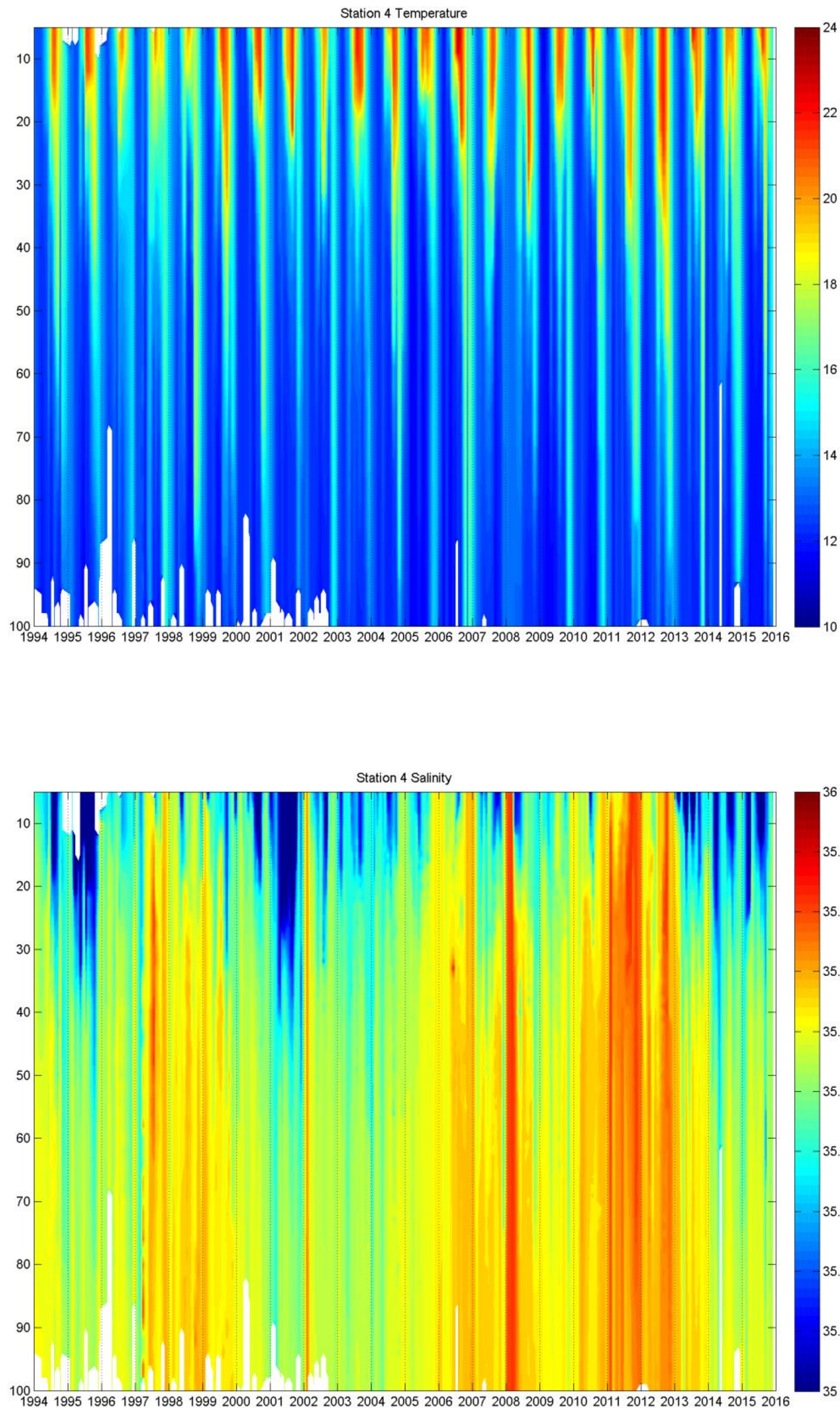


Figure 8.*Timeseries of temperature (upper) and salinity (lower) at the shelf at Santander (43º35'N,3º47'W).*

Figure 9 shows the evolution of the monthly averaged sea surface temperature (SST) in 2015 in a station close to the coast (on the basis of a time-series obtained from the Aquarium of the Sociedad Oceanográfica de Gipuzkoa). Starting from a relatively high value in January, the sea surface temperature follows a pattern similar to the air temperature seasonal pattern. The main exception is the low monthly average SST in August (-0.6°C vs +0.3°C for the atmospheric temperature in the same month).

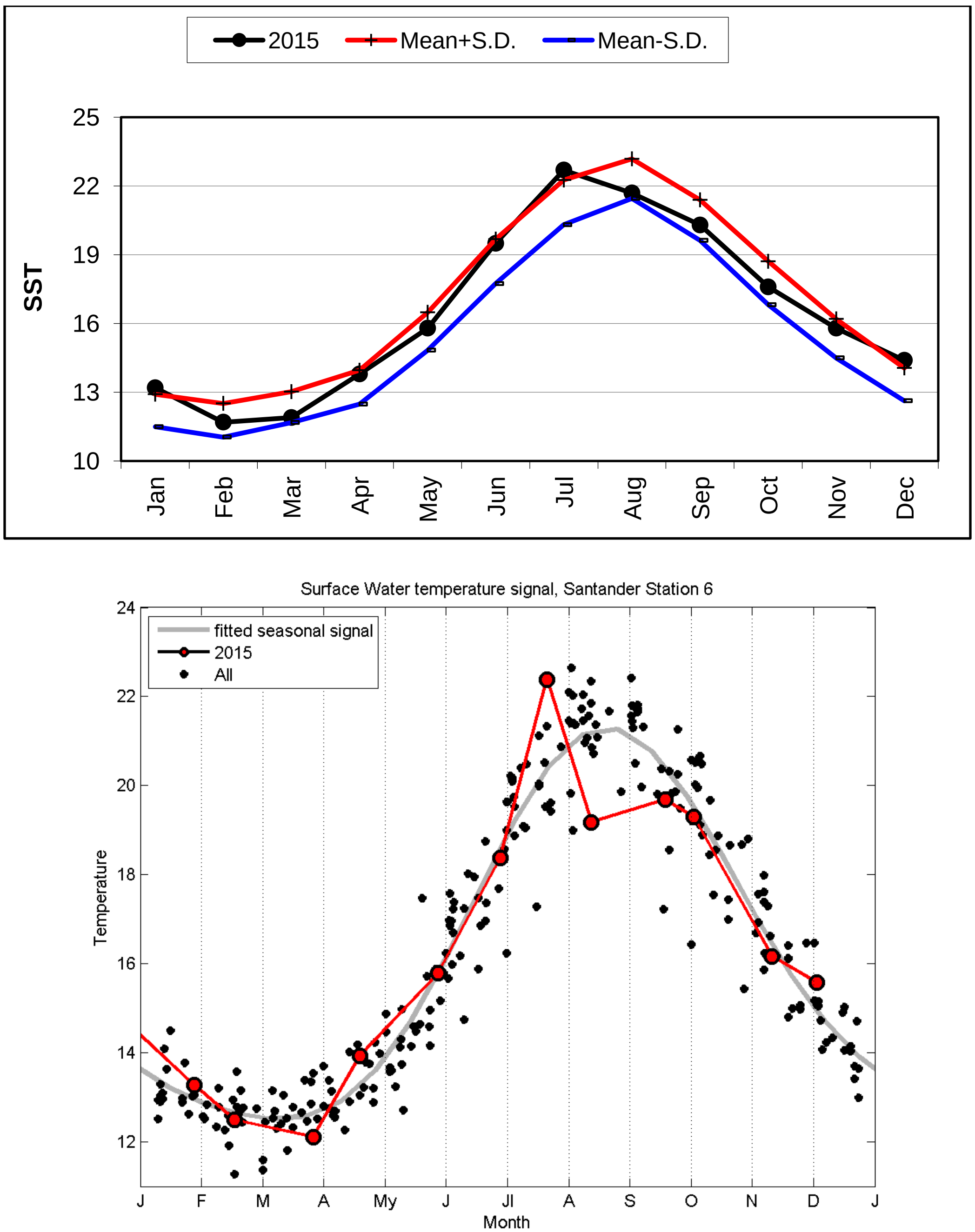


Figure 9. *Monthly averaged sea surface temperature (°C) in San Sebastián (43°20'N 02°00'W) in 2014 in comparison with the mean ± standard deviation for the period 1986-2014 period. Data Courtesy of the 'Sociedad Oceanográfica de Gipuzkoa'. Lower panel is SST at station 6 in Santander (43° 42.6'N, 3° 47' W).*

The signal of cold or relatively cold waters in August seems to be related with some mixing events between the surface waters and relatively cold subsurface waters pushed up to shallow depth levels by the rise of the thermocline. In San Sebastián, the signal of relatively cold land runoff can be observed also. Strong attenuation of the autumn cooling during November and December is also noticeable, as result of the mild atmospheric conditions along the late autumn. Annual mean SST in 2015 was 16.53° C, 0.32° C above the 1986-2015 average.

A detailed view of hydrographic conditions in 2015 at the southeasternmost Bay of Biscay can be summarised from TS diagram representing waters over the continental shelf (43°30′N, 02°00′W) as shown in Figure 10. A summary of monthly hydro-meteorological data for 2015 in the shelf waters of the Basque Coast can be observed in Table 2.

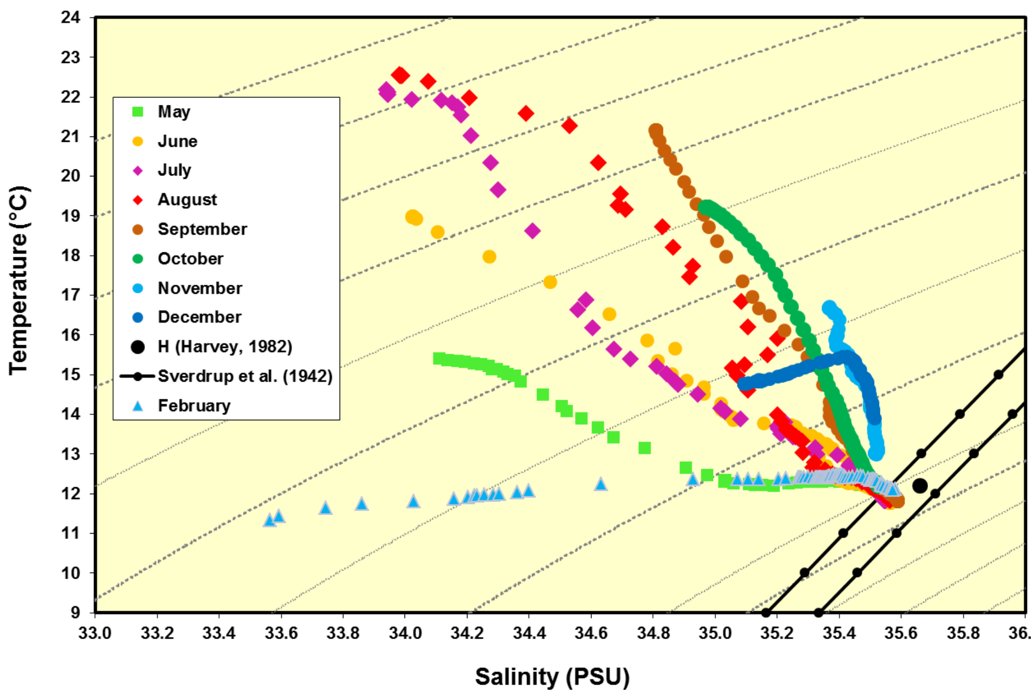


Figure 10. *TS diagram of the waters over the continental shelf of the SE Bay of Biscay (43°30′N 02°00′W) in 2015.*

As a result of the high precipitation (Figure 4), the TS line is characterised by haline stratification in February, including a moderate thermal inversion in the surface waters. Despite the warm atmospheric conditions in April, thermal stratification in May remain moderate. The prevalence of thermal stratification is observed in the period between June and October, especially between July and September, in relation to the progression of the summertime warming.

The progressive reduction of the presence of low salinity waters in the surface layers can be related with the strong decrease of the precipitation along late summer and autumn. On the other hand, relatively cold and moderately low salinity Eastern North Atlantic Central Waters (indicating a lack of recent inputs of southern Central Waters driven by the Iberian Poleward Current) occupied the near bottom layers until October. Both patterns change in November and December. First, convection and vertical mixing reduce the thermohaline stratification and the TS signature of the ENACW is lost in the bottom layer. Second, almost all the precipitation recorded in November (120 mm) falls concentrated in the 8 coldest days (20th to 27th) of the month. As consequence of the river plumes advected, the TS line for early December can be split in two parts (Figure 10): a segment representative of the thermal inversion for low salinity waters and a second one as a fraction of the TS line recorded in November. In fact, the progression of the vertical mixing produces the highest bottom temperature of the year.

Table 2. *Hydro-meteorological data in the shelf waters of San Sebastián (43°30'N 02°00'W) in 2014. Mean temperature and salinity calculated for the upper 100 m.*

2015	**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	8.14	211	782	13.20						
February	6.50	296	1481	11.70	33.565	12.25	35.230	12.10	35.571	
March	9.20	179	1596	11.90						
April	13.70	82	1065	13.80						
May	14.91	71	856	15.80	34.109	12.97	35.275	12.02	35.556	16
June	17.81	85	453	19.50	34.022	13.49	35.214	11.93	35.543	24
July	20.18	69	203	22.70	33.940	13.84	35.217	11.83	35.546	26
August	20.01	183	244	21.70	33.982	14.17	35.245	11.83	35.565	28
September	16.38	61	334	20.30	34.808	14.65	35.338	11.82	35.589	37
October	15.29	60	313	17.60	34.968	15.86	35.252	12.21	35.526	58
November	13.55	124	380	15.80	35.370	14.46	35.471	13.01	35.516	49
December	13.66	16	348	14.40	35.094	15.03	35.361	14.51	35.497	> 100

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. Modal waters are freshening progressively. Figure 12 shows average TS values for the upper-ocean influenced by the mixed layer development (0-300 dbar) highlighting the below normal current conditions.

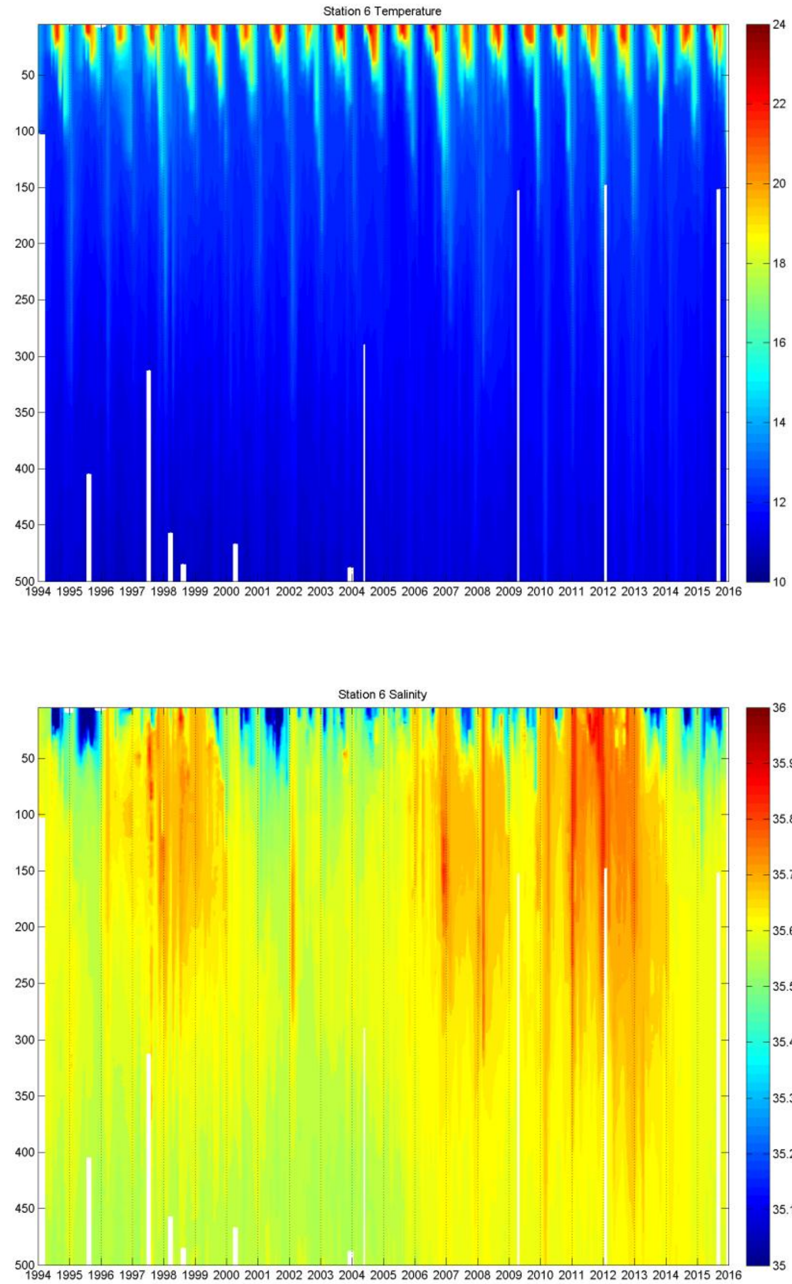
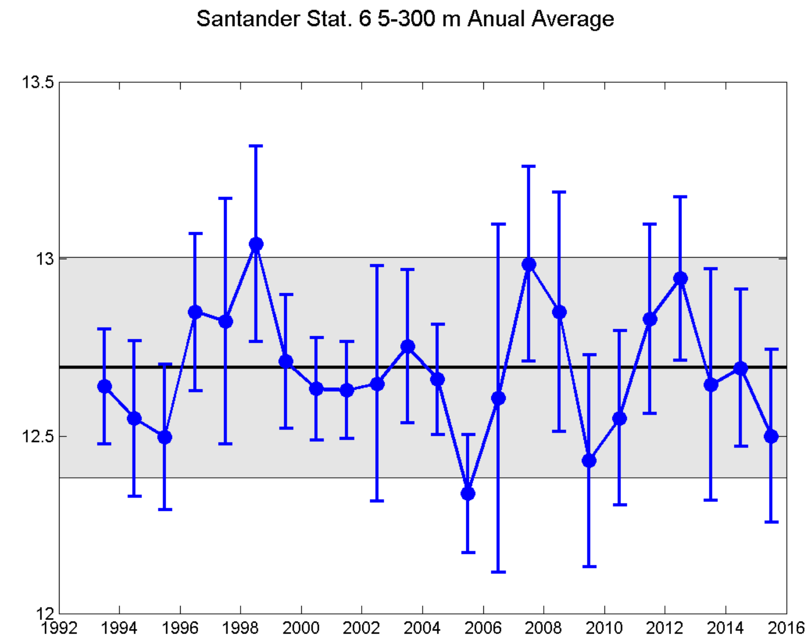


Figure 11.Timeseries of temperature (up.) and salinity (low) at the slope at Santander (43º42'N,3º47'W).



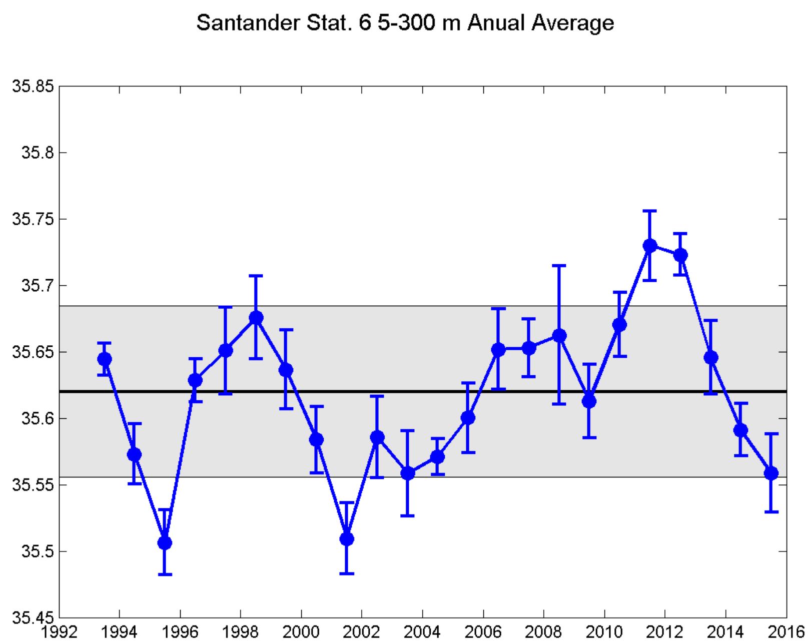


Figure 12.*Temperature (up.) and salinity (low) averagesfor the upper 300 m. at the slope at Santander* (43º42'N,3º47'W).

Intermediate 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 2014, upper central waters showed freshening for the first time in about a decade. In 2015 salinity values fell continuously along the year being by the end of 2015 about 0.05 units lower than in mid 2014. Deeper at the level of the MW the water masses continues pretty stable since mid-00`s, fresher at its core in 2015 after peaking around 2007-2009 and slightly colder..

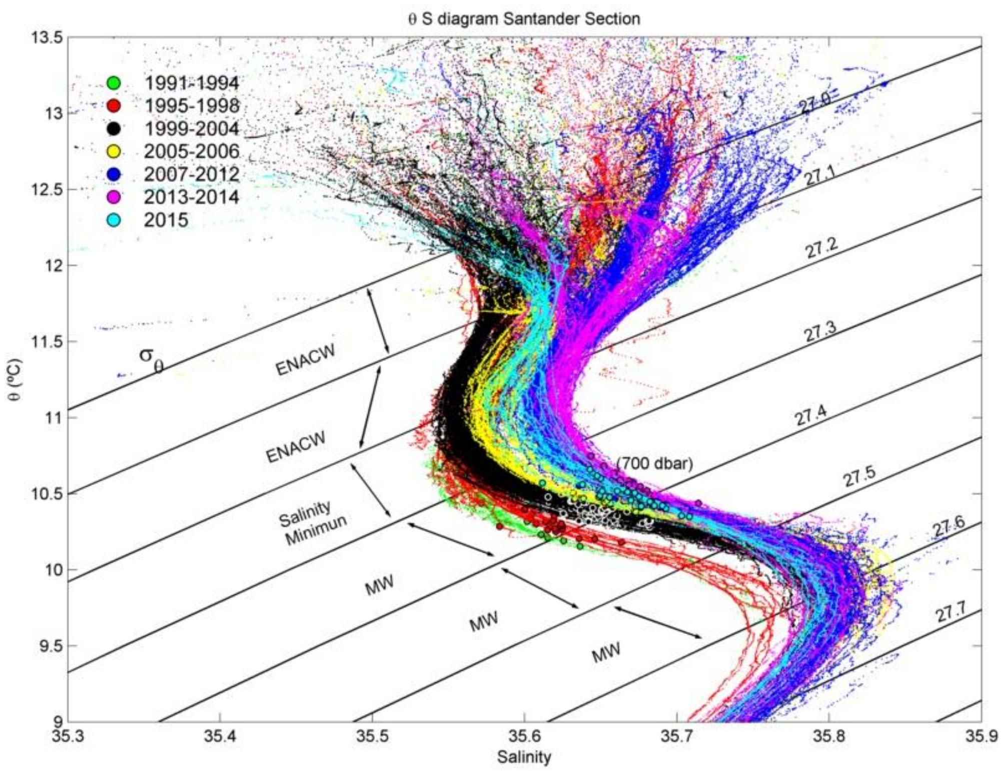


Figure 13. *TS diagram of water mass properties at Santander station 7(43º 48'N, 3º 47'W) (outer slope).*

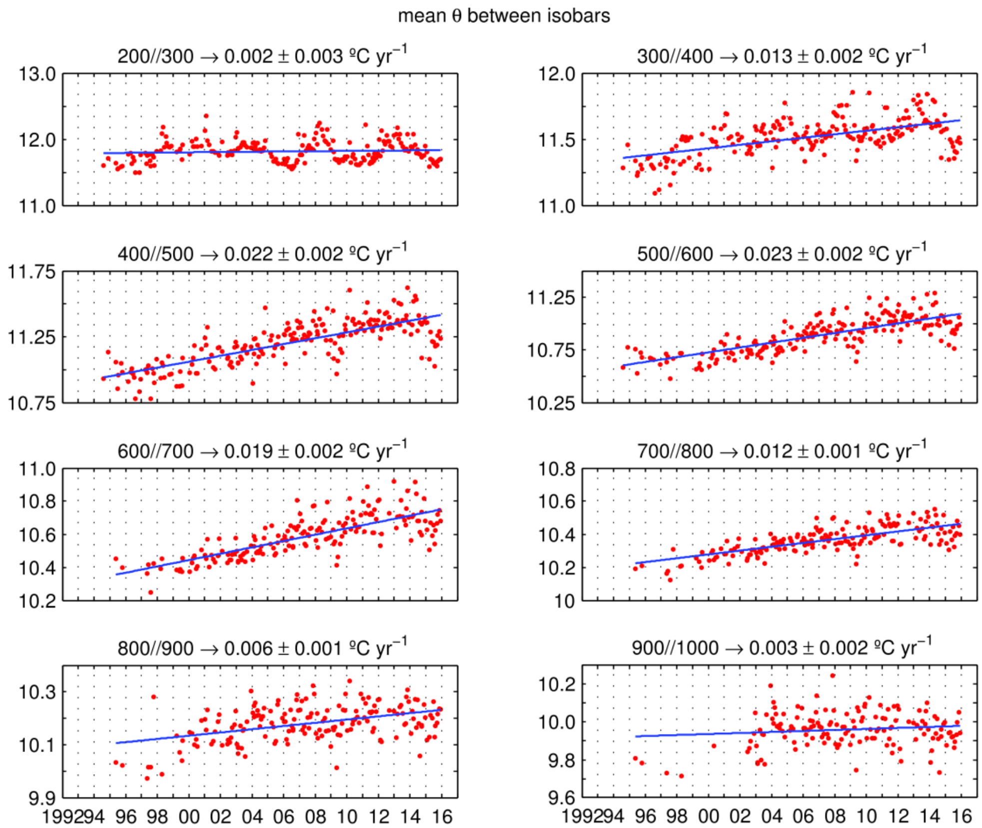


Figure 14. *ENACW and MW potential temperature at Santander station 7(43º 48'N, 3º 47'W) (outer slope).*

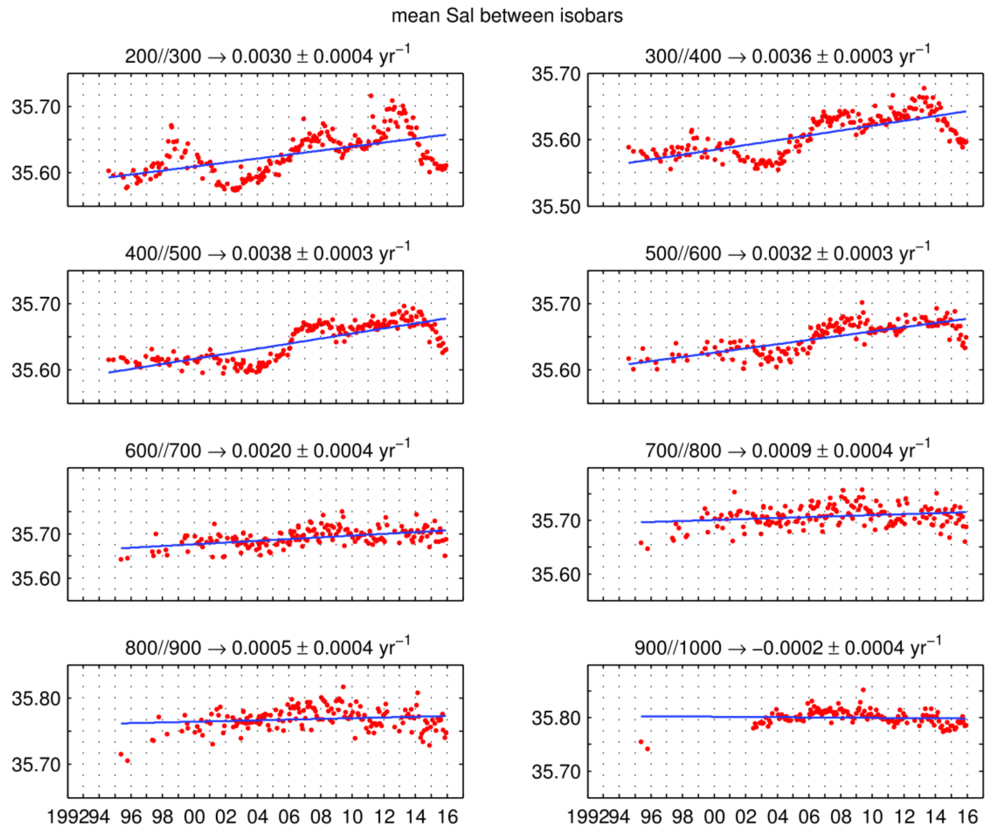


Figure 15. *ENACW and MW salinity at Santander station 7(43º 48'N, 3º 47'W) (outer slope).*

Western Iberian Basin. Finisterre Section.

A Deep Sections program is being run by Spanish Institute of Oceanography since 2003, providing full-depth (>5500 m) hydrography and biogeochemistry at Western Iberia and Biscay. Cruises have been carried out semiannually for the period 2003-2010 and annually after that. The Finisterre section, about ~400 km, reaches the center of the Iberian Abyssal Plain. The section has been occupied 19 times so far.

Figure 16 shows the section, Fig.17 show the hydrographic anomaly averaged across the section and Fig.18 show the overall trends observed. Roughly, Central Waters (200-800) have behaved as in Biscay. Lower thermocline waters (MW and LSW) subjected to strong variability linked to large-scale atmospheric patterns and the main highligh is the passage of a cold+fresh anomaly in late 00`s. No relevant changes have been observed in deep waters (2000-5500 m). 2015 continues the upwards swing of temperature and salinity observed in these intermediate waters in 2014 concurrent with the decrease at Eastern North Atlantic Central Waters level..

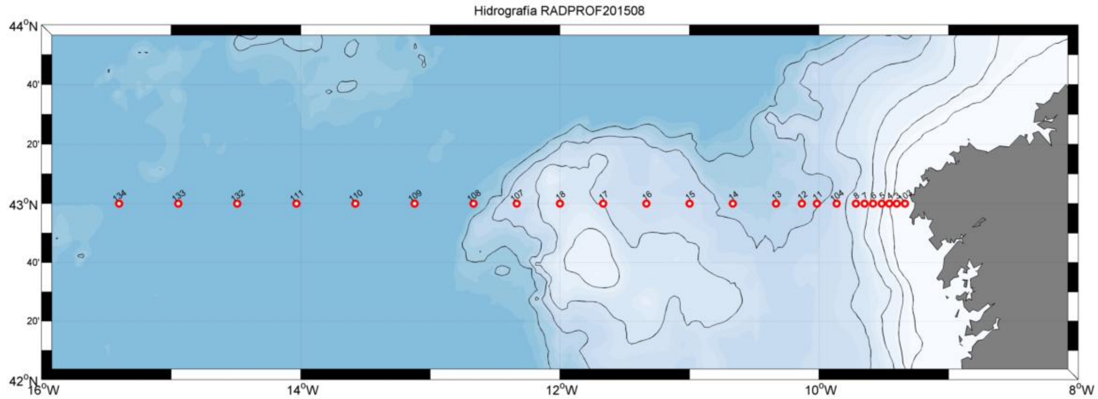


Figure 16. Finisterre Section from the 'Instituto Español de Oceanografía' in NW Iberia.

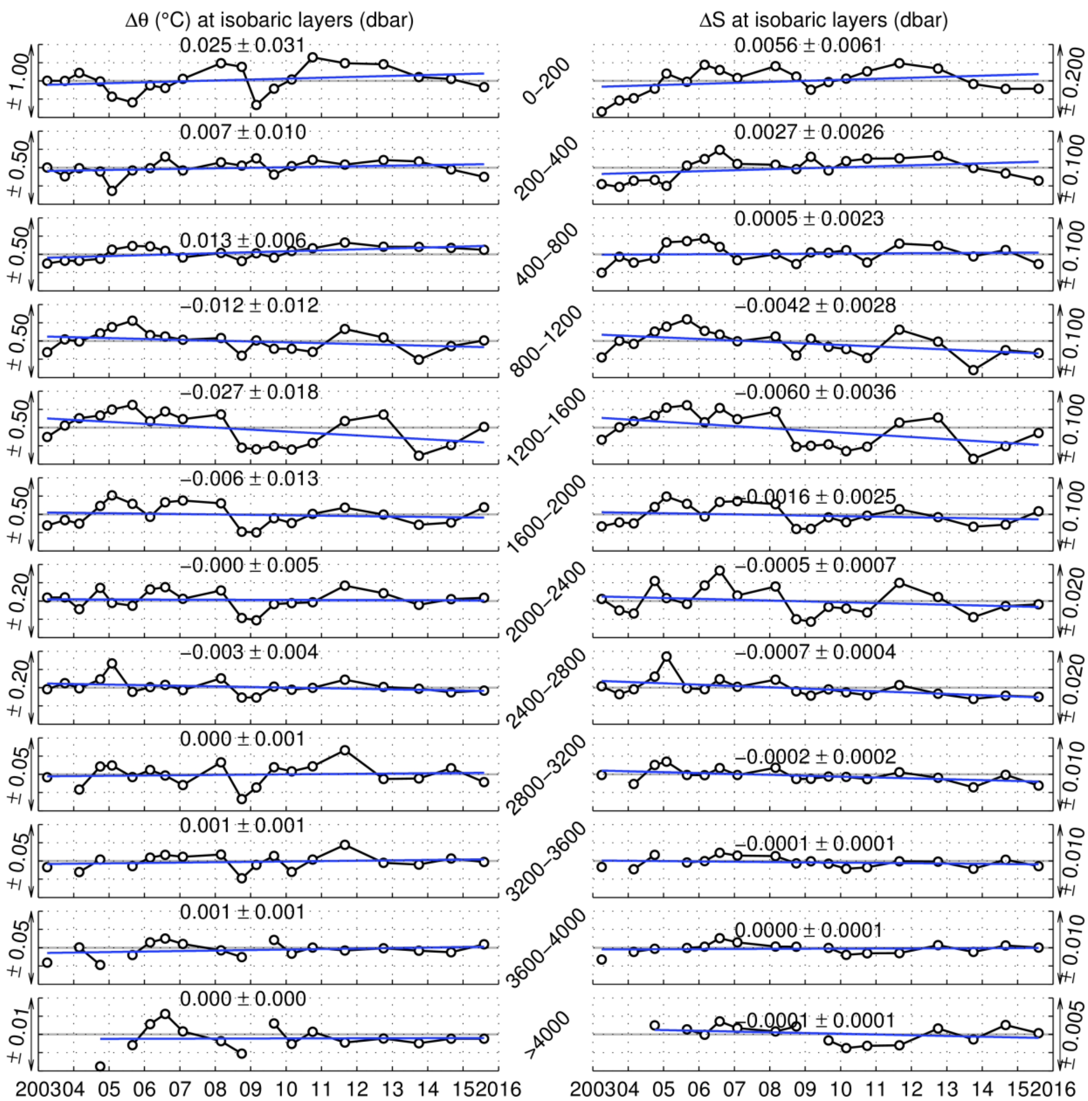


Figure 17. Timeseries of anomalies in hydrographic properties in the Finisterre section. Seasonal cycle at deep waters is removed.

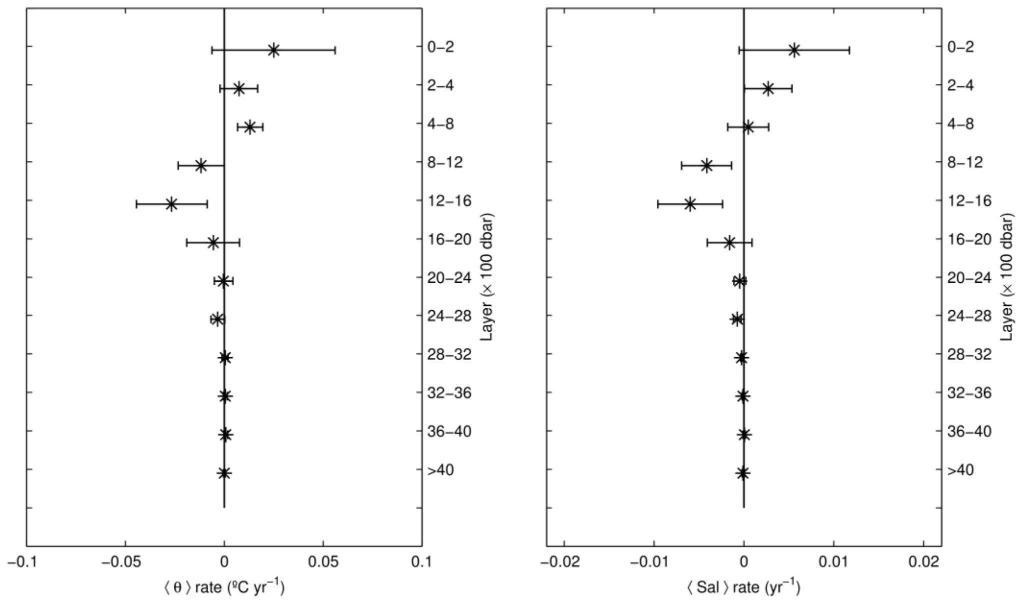


Figure 18. Overall linear trends derived from timeseries shown in Fig.17.

Gulf of Cádiz routinely sampling.

The Gulf of Cadiz is the key area where Mediterranean Water is formed after the intense mixing of Mediterranean Outflow Waters and local Atlantic modal waters. The Spanish Institute of Oceanography has covered the area since late 90`s by several per year multidisciplinary grid-based cruises (Fig.19). Due to strong mixing and circulation, timeseries of hydrographic properties (Fig.20) are noisy and it is difficult to draw a clear picture, recent changes if any may be masked by background noise. 2015 is characterized by warmer and saltier upper waters.

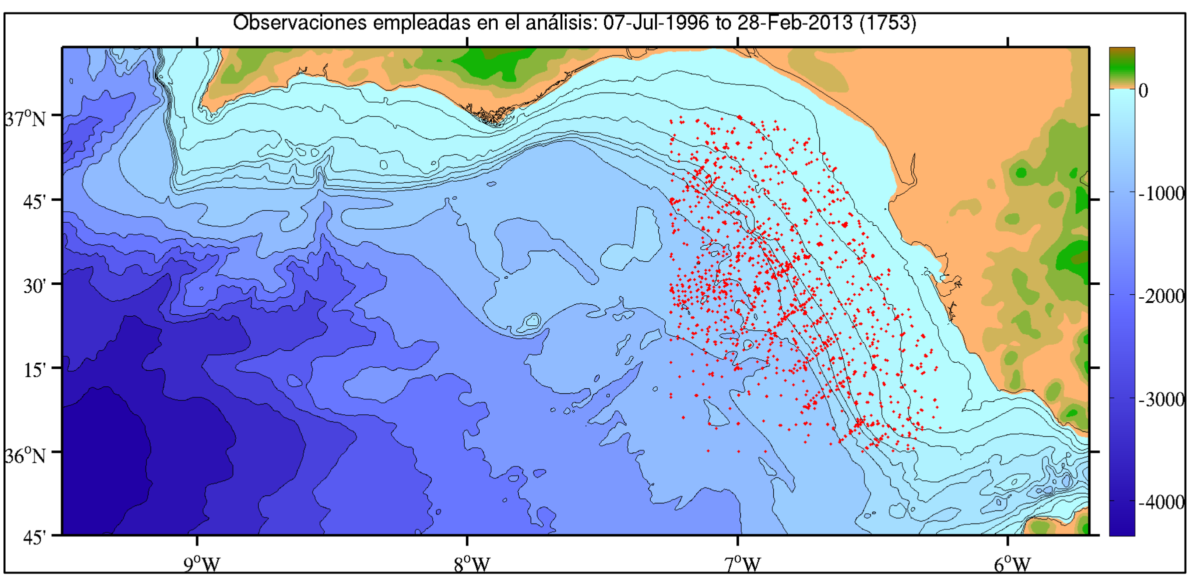


Figure 19. Gulf of Cadiz (SW Iberia.) hydrographical record from the ‘Instituto Español de Oceanografía’

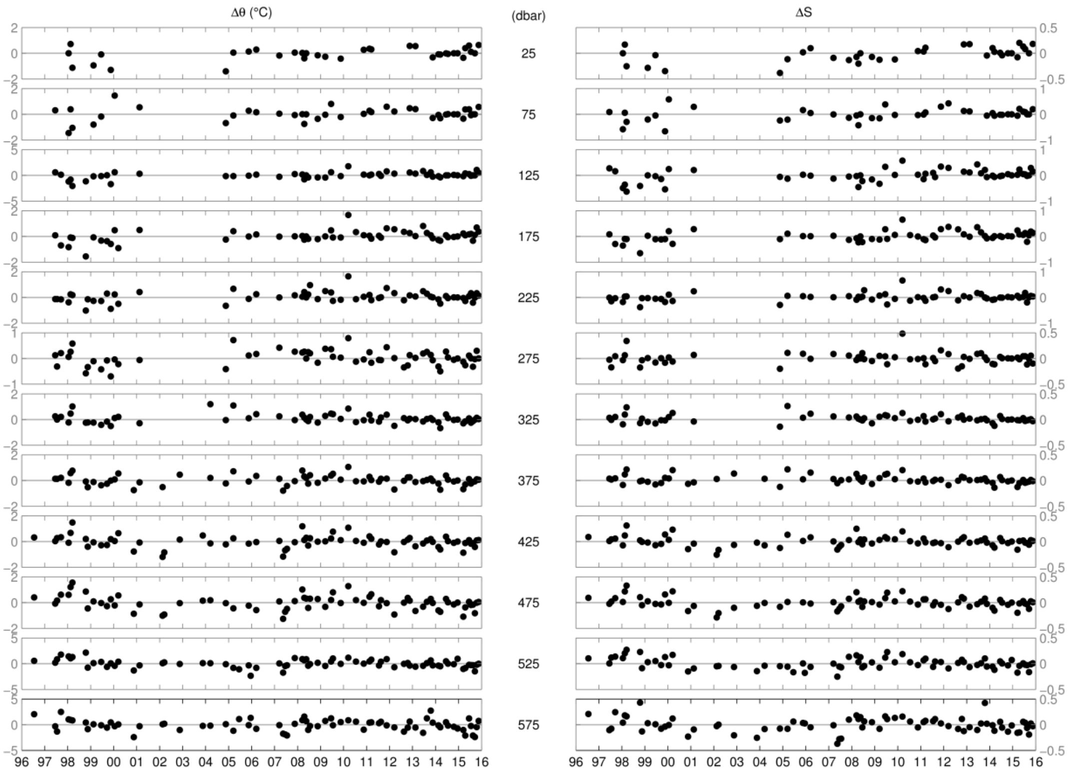


Figure 20. Timeseries of anomalies in hydrographic properties in the Gulf od Cádiz region.

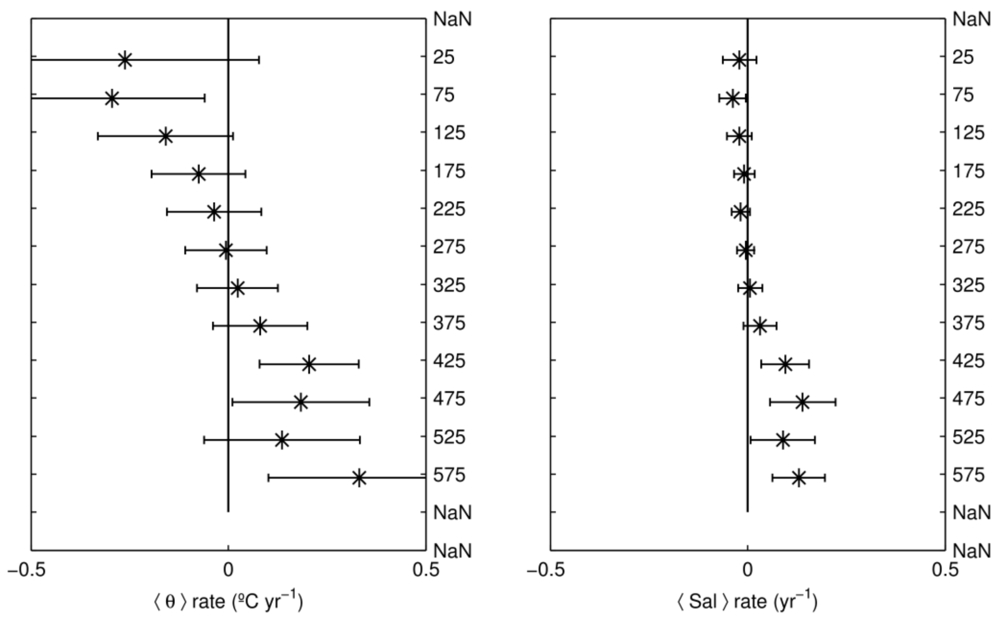


Figure 21. Overall linear trends derived from timeseries shown in Fig.20.

Canary Basin.

Two areas has been monitored since the early 2000's in Canary Islands archipelago region by the Spanish Institute of Oceanography, the oceanic waters west of Lanzarote (stations 6-19, figure 22) and the Coastal Transition Zone (CTZ) of the upwelling region of the Canary Current Large Marine Ecosystem (stations 1-5, figure 22)

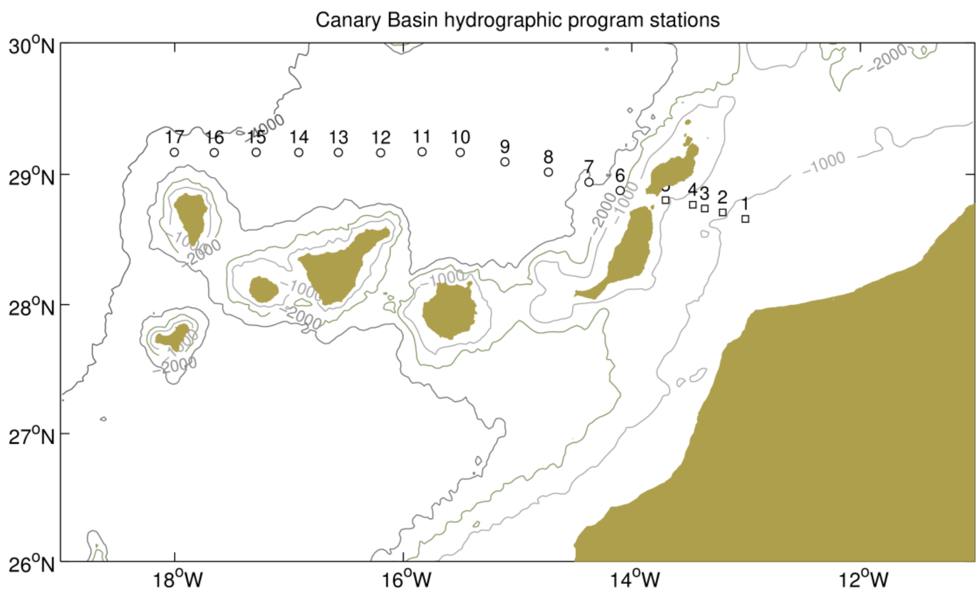


Figure 22. Distribution of the hydrographic stations sampled Canary Islands archipelago region.

The area is characterized by four waters masses, the North Atlantic Central Waters (NACW), roughly between 200 dbar and 600 dbar and lighter than the 27.25 kg m-3 isopycnal; the intermediate waters, mainly Mediterranean (MW) and Antarctic Intermediate Waters (AAIW), between 600 dbar and 1600 dbar, and lighter than the 27.85 kg m-3 isopycnal; and the North Atlantic Deep Waters (NADW), deeper than 2600 dbar and heavier than the 27.85 kg m-3 isopycnal.

The surface waters in the CTZ shows a non-statistical significant cooling of -0.34±0.57°C decade-1, and a non-statistical significant decrease in salinity of -0.043±0.115 decade-1, both coherent with an increase in the upwelling in the Canary Current Large Marine Ecosystem. During 2015 there was a decrease in the cooling and decrease in salinity, if compared to the 2014, which was the coolest and fresher year in the record for the upwelling influenced surface waters.

In the depth stratum that characterize the NACW waters (200-600 dbar), both the oceanic area and the CTZ area shows a statistically significant warming trend, 0.25±0.12°C decade-1 for the oceanic area and 0.05±0.28°C decade-1 for the CTZ. The variability in the CTZ is higher due to the proximity of the upwelling region, and the frequent intrusions of upwelling filaments, and therefore the uncertain is higher in the trend estimations. In this stratum there is an increase in salinity of 0.04±0.020 decade-1 for the oceanic area and of 0.006±0.045 decade-1 for the CTZ. The increase in temperature and salinity almost compensate in density, corroborating that the observed trends are due to deepening of the isoneutral surfaces rather than changes along the isoneutrals. During 2015 there was a decrease in the warming and increase in salinity, if compared to the 2014, which was the saltier and warmest year in the record for the NACW waters.

In the intermediate waters, the trends for temperature and salinity were not statistically significant, neither in the oceanic region nor in the CTZ. Both time series show high variability due to the two very different intermediate water masses converge in the region.

In the layer corresponding to the upper NADW (1700-2600 dbar), there was a weak warming and increase in salinity, statistically non different from zero. However, in stratums corresponding to the NADW (2600-3600 dbar), a marginally statistical significant cooling (-0.01±0.01°C decade-1) and freshening (-0.002±0.002°C decade-1) was observed.

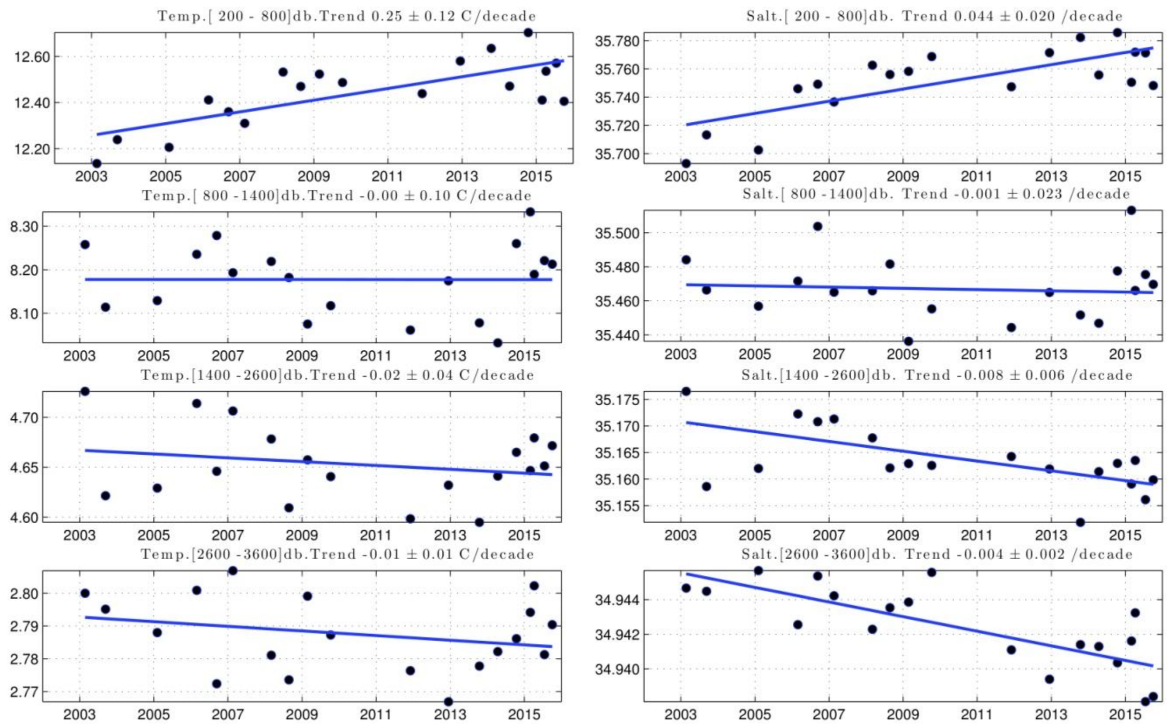


Figure 23. Timeseries of hydrographical properties in the Oceanic waters of the Canary basin

Annex 8:

Regional report – Faroese Waters 2015
(Area 6)

Area 6 - Faroese Waters 2015

By Karin Margretha H. Larsen and Bogi Hansen

Hydrographic conditions in Faroe waters are monitored by regular CTD cruises along four standard sections three times a year. In addition, 8 ADCPs are moored on three of these sections (Figure 1). These activities are designed to monitor the properties (T and S) and volume transport of the Faroe Bank Channel (FBC) overflow and two Atlantic inflow branches: the Faroe Current north of the Faroes, and inflow through the Faroe-Shetland Channel (FSC) (together with the Marine Laboratory in Aberdeen that also has 4 ADCP moorings in the Faroe-Shetland Channel).

Time series plots of the temperature (Figure 2) and the salinity (Figure 3) of the Atlantic water on the section across the FBC and northwards from the Faroes show the increased temperatures and salinities from the mid-1990s that were high through the 2003-2011period. In 2012 both temperatures and salinities declined, but whereas annual average salinities have stayed at a lower level temperatures have been more variable. In 2015 both temperatures and salinities were close to the long term mean (1988-2010).

On the Faroe Shelf the annual average temperature has been relatively high since the early 2000s, but in 2015 the annual averaged temperature was the lowest observed since 2000 (Figure 4). The main reason for this was the unusually cold spring and summer air temperatures. The conditions though still remain warm in a century-long perspective as indicated by the Faroe coastal temperature time-series from Mykines (Figure 4, left panel), although, like all coastal and shelf time-series, it is affected by atmospheric and terrestrial effects. The long term trend in salinity on the Faroe Shelf (Figure 5) follows the trend observed in off-shelf waters, but with some lag. Thus salinities increased from the start of the observations in 1995 to record high values in 2010. Since 2010 salinities have been decreasing and are now close to the values observed in the beginning of the series.

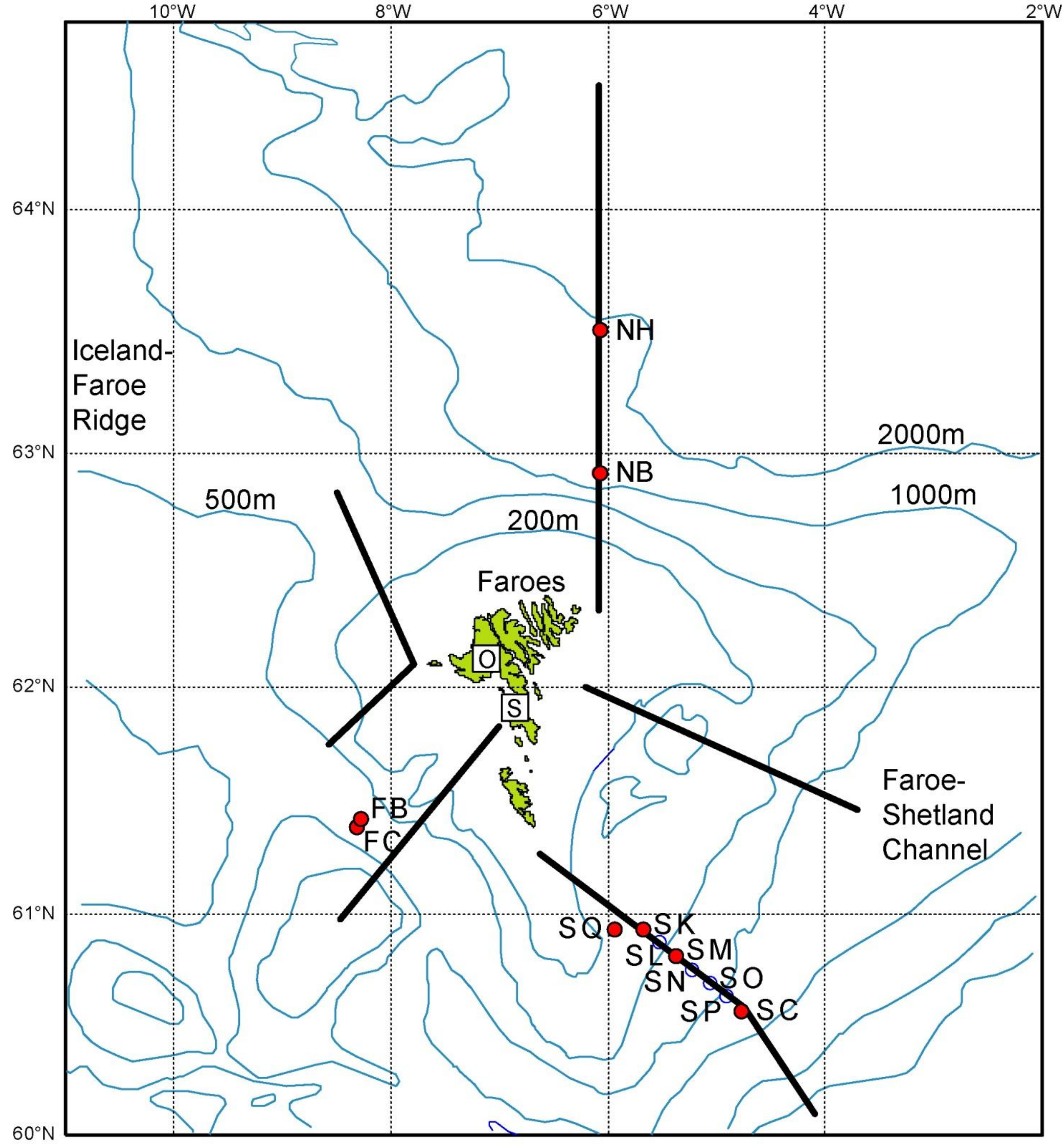


Figure 1. Standard sections 2015 (black tick lines) and moored ADCPs at the top of traditional moorings (NB, NH, FB, FC, SM and SC) or in trawl-protected frames (SQ and SK) deployed in 2014. Blue circles are moorings deployed by Marine Science Scotland. Black squares with the letters O and S indicate the coastal stations Oyrargjógv and Skopun, respectively.

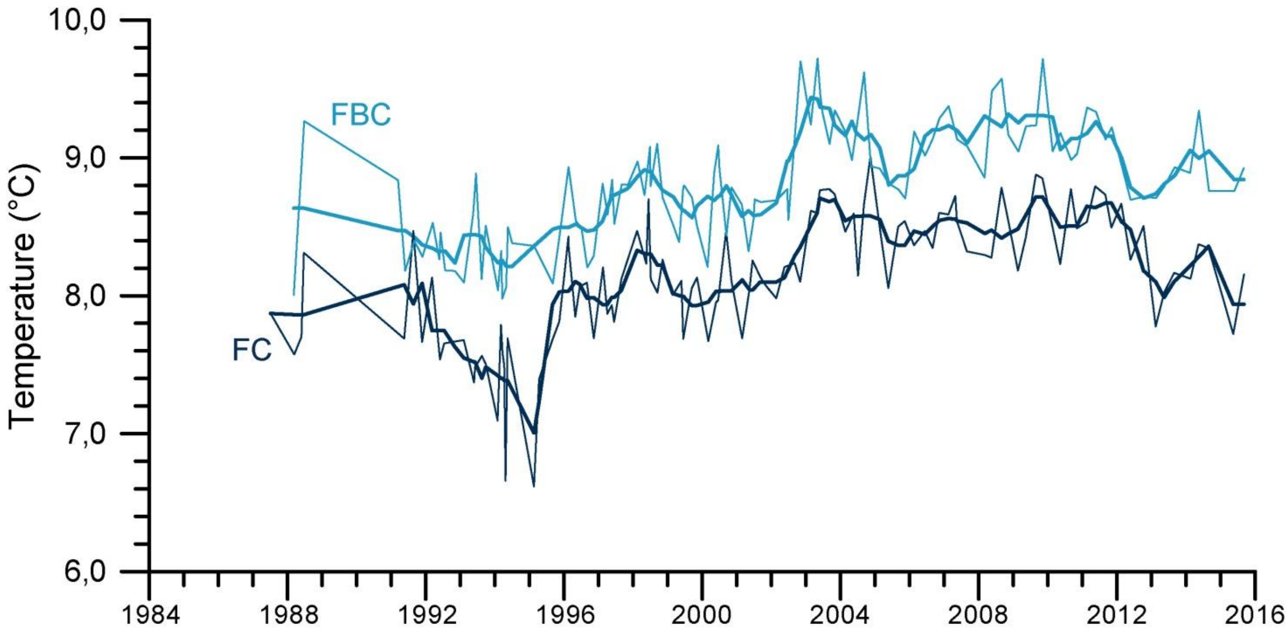


Figure 2. De-seasoned temperature from individual cruises (thin lines) in the FBC (light blue) and the core of the Faroe Current (dark blue). Thick lines are annual means. The figure represents the average temperature in that 50 m layer on the section that has the highest salinity (the core).

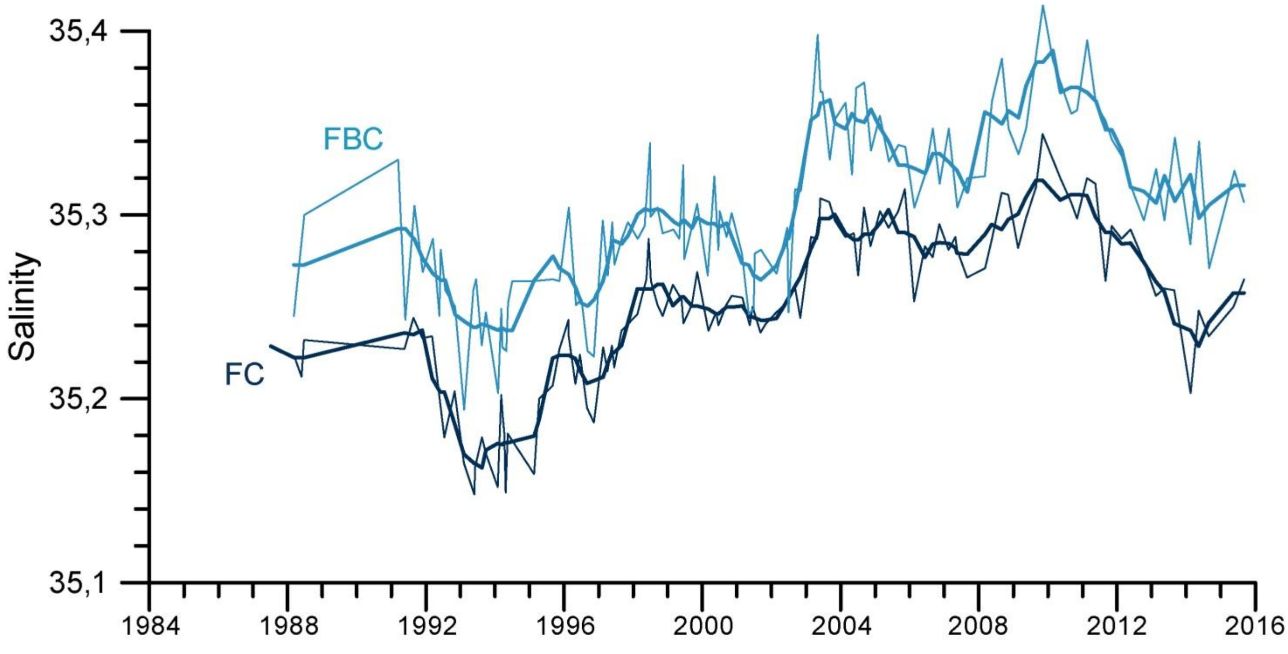


Figure 3. De-seasoned salinity from individual cruises (thin lines) in the FBC (light blue) and the core of the Faroe Current (dark blue). Thick lines are annual means. The figure represents the average salinity in that 50 m layer on the section that has the highest salinity (the core).

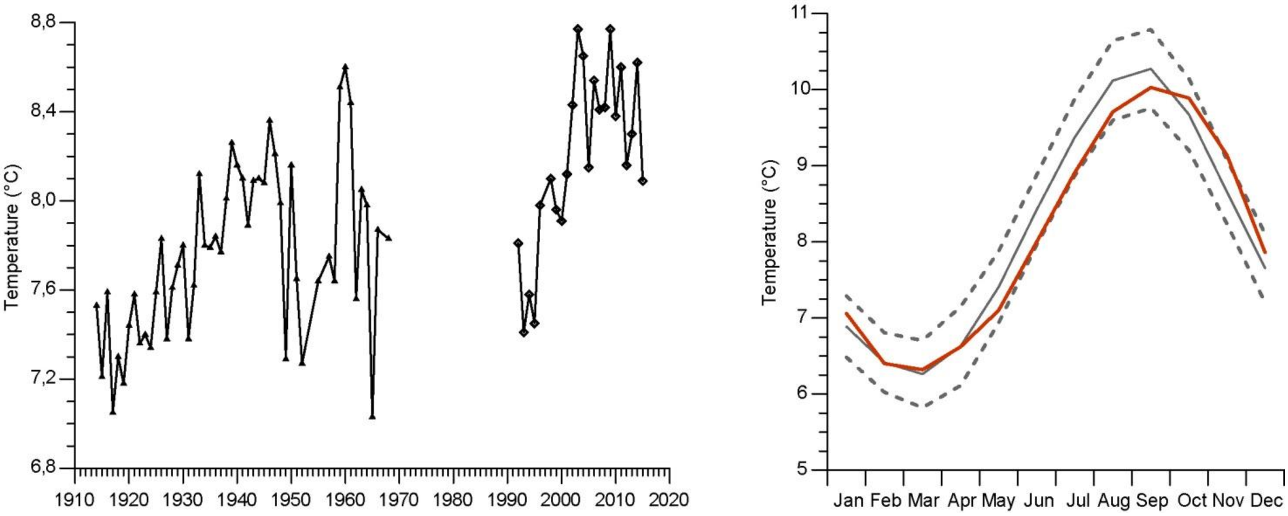


Figure 4. Annually averaged Faroe coastal temperature (left panel) monitored daily in Mykines 1914-1969 and several times daily at the neighbouring site Oyrargjógv from 1992. In the Mykines timeserie, years with less than 8 months of observations are omitted. The right panel shows the monthly averaged Faroe coastal temperature monitored at Oyrargjógv in 2015 (red line) and the monthly mean climatology from Oyrargjogv (1991-2010) (grey line) $\pm$ one standard deviation (dotted lines). Inter-comparison experiments support that the two sites represent the same water mass (Faroe Shelf Water).

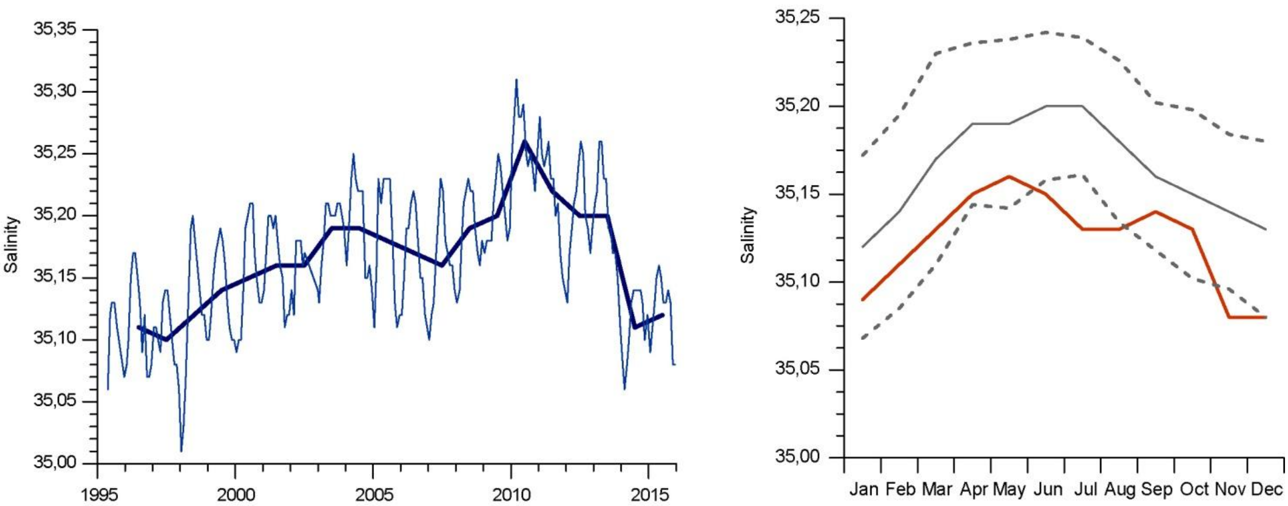


Figure 5. Monthly and annually averaged Faroe coastal salinity (left panel) monitored weekly at coastal station Skopun from May 1995. The right panel shows the monthly averaged Faroe coastal salinity in 2015 (red line) and the monthly mean climatology (1995-2010) (grey line) $\pm$ one standard deviation (dotted lines).

Annex 9:

Regional report – North Sea 2015
(Areas 8 & 9)

Oceanographic Status Report
North Sea 2015

Working Group on Oceanic Hydrography

IOPAN, Sopot, Poland

April 5th – 7th, 2016

BUNDESAMT FÜR
SEESCHIFFFAHRT
UND
HYDROGRAPHIE

Holger Klein, Alexander Frohse, Peter Loewe, Achim Schulz

Bundesamt für Seeschifffahrt und Hydrographie (BSH) Hamburg
(Federal Maritime and Hydrographic Agency)

(OSR-NS-2015.docx, 24.02.2016)

CONTENTS:

1 North Sea 2015: Annual Survey

1.1 Global Radiation

In 2015 the monthly means of global radiation at the East Frisian island of Norderney (Fig. 1.1) exceeded the means of the reference period 1981–2010 from February to April and during June. The April mean was highest since 1971. The annual averages of daily global radiation totals at Norderney indicate a positive trend for the last three decades.

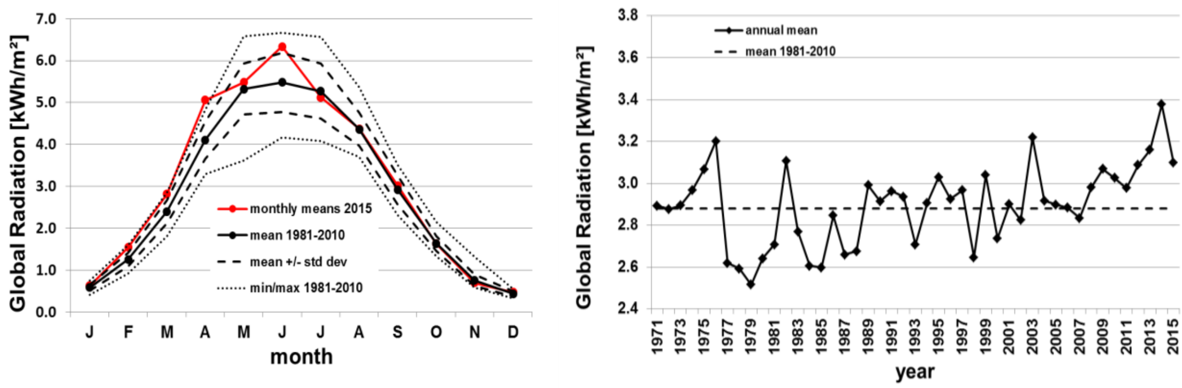


***Fig. 1.1**: Left: Red: Seasonal cycle of monthly averaged daily global radiation totals 2015 in kWh/m² at Norderney. Black: Monthly means of the 1981-2010 base period ± standard deviations (broken lines) and extreme values (dotted lines). Right: Annually averages of daily global radiation totals at Norderney 1971-2015 in kWh/m². Broken line: mean of the base period 1981-2010. Data provider: German Meteorological Service (DWD).*

1.2 Elbe River Run-Off

With the exception of January all monthly run-off volumes were below the reference period 1981–2000 (Fig. 1.2). However, the annual run-off volume (15 km³/a) was still within the 95%-band.

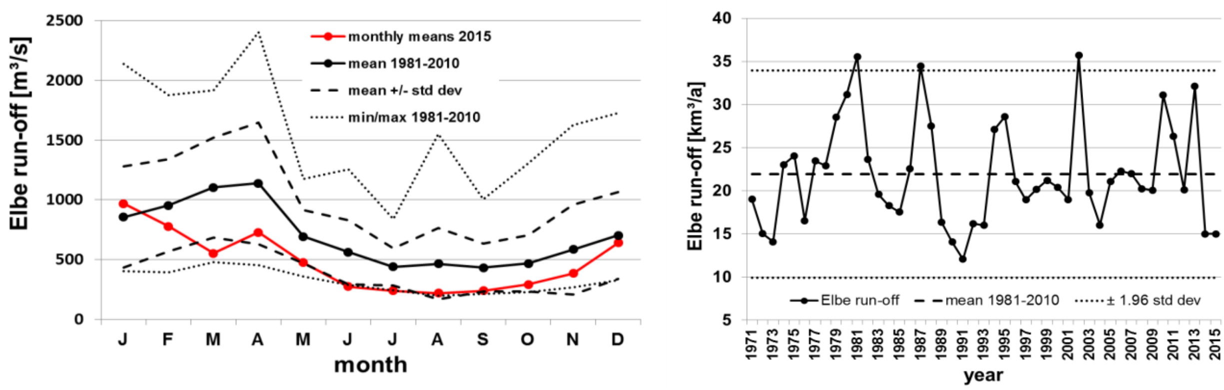


***Fig. 1.2:** Left: Monthly means of Elbe discharge at weir Neu Darchau in m³/s and 1981-2010 mean ± standard deviations in 2015. Right: Total annual run-off in in km³/year 1971-2015 and 1981-2010 mean ±1.96 standard deviations. Data provider: BfG / WSA Lauenburg.*

1.3 North Sea SST

Between January and October the monthly means of area averaged North Sea SST were close to those of the reference period 1981-2010. During the last months of 2015 the SST increased with a monthly anomaly of +1.3 K in December. With 9.5 °C this is – together with 2006 – the warmest December since 1971 (Fig. 1.3, left).

After a maximum of 11.4 °C in 2014 the annual SST mean dropped back to 10.6 °C in 2015 which is still 0.4 K above the annual mean of the reference period (Fig. 1.3, right).

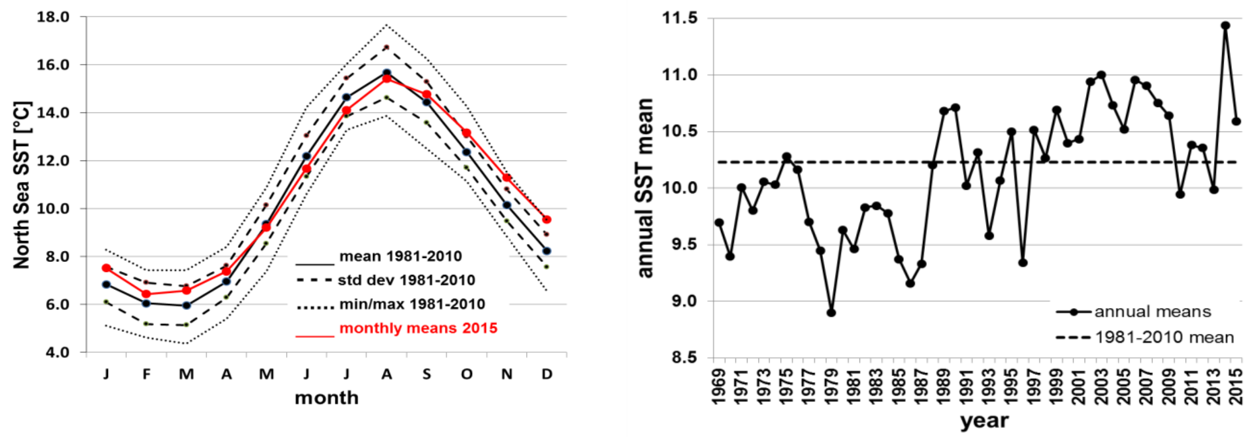


***Fig. 1.3**: Left. Monthly means of area averaged North Sea SST in °C for 2015 (red line). Black solid line: mean of reference period 1981-2010 ± standard deviation (broken lines), dotted lines: min/max of reference period. Right: Annual North Sea SST means 1969-2015 in °C. Broken line: 1981-2010 mean.*

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 are shown in Fig. 1.4 for the period 2000-2015. The pronounced warming and increasing length of the summer season continues in the volume temperature but is ceasing in the SST.

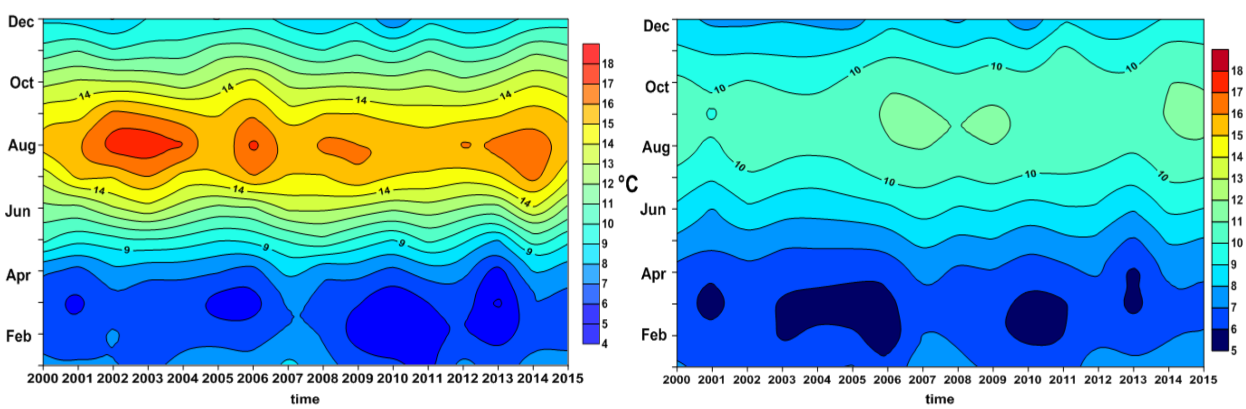


***Fig. 1.4:** Observed monthly and area averaged North Sea SSTs (left) and monthly mean temperature of the total North Sea volume in °C based on BSHcmod model data (right) for the period 2000–2015.*

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; 007° 27' E, water depth 38 m) at depths between 3 and 30 m for the period 2013 to 2015 (Fig. 1.5). Gaps in the time series are caused by technical problems, bio-fouling or dockyard lay time for maintenance. The thin horizontal grey lines gives the climatological seasonal extreme values in the surface layer according to Janssen et al., 1999[1] with a range of about 13.5 K. The winter minimum 2014/2015 was again about 2 K above the climatological cycle. Stratification started in the midst of April (Fig. 1.5). From July to December the light vessel was moved into the ships yard for refurbishment, therefore, there are no summer and fall data available. However, at all surrounding stations the water column was vertically mixed again about one week before the end of August.

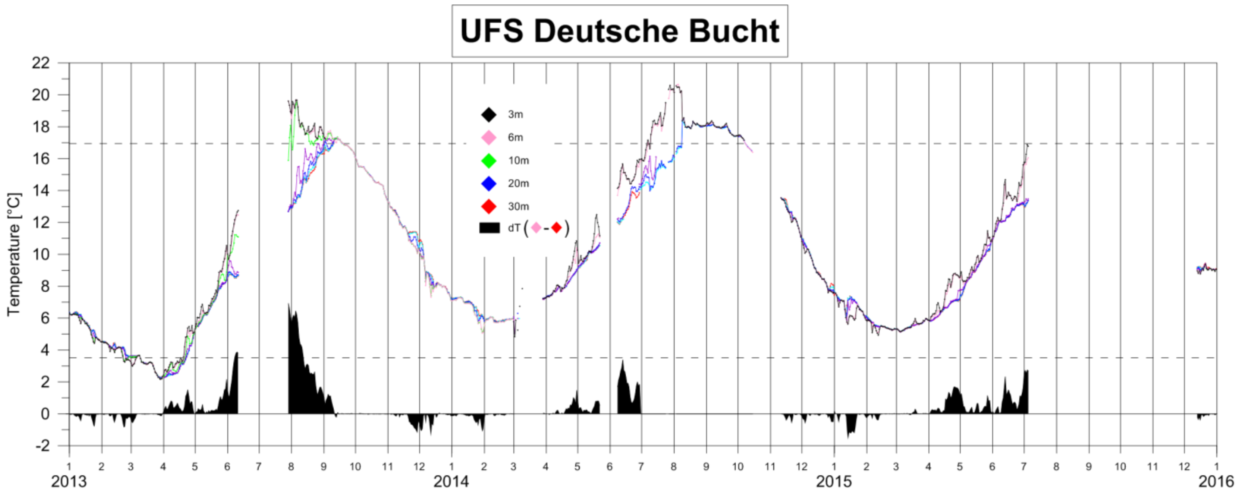


Fig. 1.5: *Temperatures [°C] at light vessel "German Bight" 2013–2015. Broken lines: climatological seasonal maximum and minimum of the surface layer according to Janssen et al., 1999.*

2 North Sea Summer Status 2015

2.1 The BSH North Sea Summer Surveys

The North Sea summer state is primarily assessed by the data of the annual *BSH North Sea Summer Surveys* (NSSS) which started in 1998. They cover the entire North Sea with seven zonal coast to coast 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 (temperature, salinity, fluorescence for chlorophyll-a and turbidity, and oxygen saturation. Additionally, ship-mounted temperature-, salinity-, and optical sensors provided data at about 4 m depth.

For the assessment of the North Sea status a 10 years reference period (RP) from 2000 to 2010 was defined which skips the year 2002 because the 2002 survey was much too early with regard to the seasonal cycle.

[1] 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.

2.2 North Sea Summer Temperature and Salinity Distribution

Temperature

In 2015 the large scale horizontal temperature distribution of the surface layer differs significantly from the RP. The southern part was slightly warmer than the RP, while the area north of 55° N was clearly colder with negative anomalies up to -2 K west off Utsira. In the bottom layer the pattern was different with positive anomalies over large areas of the North Sea and a local maximum of +3.5 K over the Dogger Bank. Small negative anomalies up to -1 K had been observed west off Dogger Bank, in the Skagerrak and along the eastern coast, and around the Shetlands (Fig.2.2a).

Table 1 lists the extreme values of the vertical temperature gradients >0.5 K/m and of the thermocline depth along the zonal sections. The maximum gradient was 1.5 K/m, the 54° N section was mostly vertically mixed with vertical gradients <0.5 K/m. The depth of thermocline varied between 16 and 55 m. Figure 2.2b shows the difference between surface and bottom temperature which exceeded 8 K in a small patch in the central North Sea north of the Dogger Bank. The vertical temperature sections basing on vertical CTD profiles (in Fig. 2.2c, d) show a weakening of the thermocline strength from south to north.

Compared to 2014 the total heat content decreased to 1.663×10^{21} J and exceeded the reference mean of 1.631×10^{21} J by 0.4 standard deviations only (see Table 2 and Fig. 2.2g).

Salinity

The southern boundary of Atlantic Water (AW) >35 psu intruding from the north was located at about 58° N at the surface and at about 57° N in the bottom layer. The general pattern shows a positive anomaly in the eastern North Sea and a negative anomaly in the western North Sea (Fig. 2.2e). At the surface a local positive anomaly of >2 psu was observed west of Utsira.

The area covered by Atlantic Water >35 psu is larger than in 2014 at the surface and comparable to 2014 in the bottom layer (Fig.2.2f). Nevertheless, the total salt content decreased to 1.039×10^{12} t which is the lowest value since 2001 (Fig. 2.2g and Table 2). This is caused by the fact, that the water the central North Sea with salinities between 34 and 35 psu has been much fresher than in previous years. Further on, the vertical extension of the bottom layer with higher salinities intruding from the north was reduced in its vertical extension in 2015 (Fig. 2.2c, d).

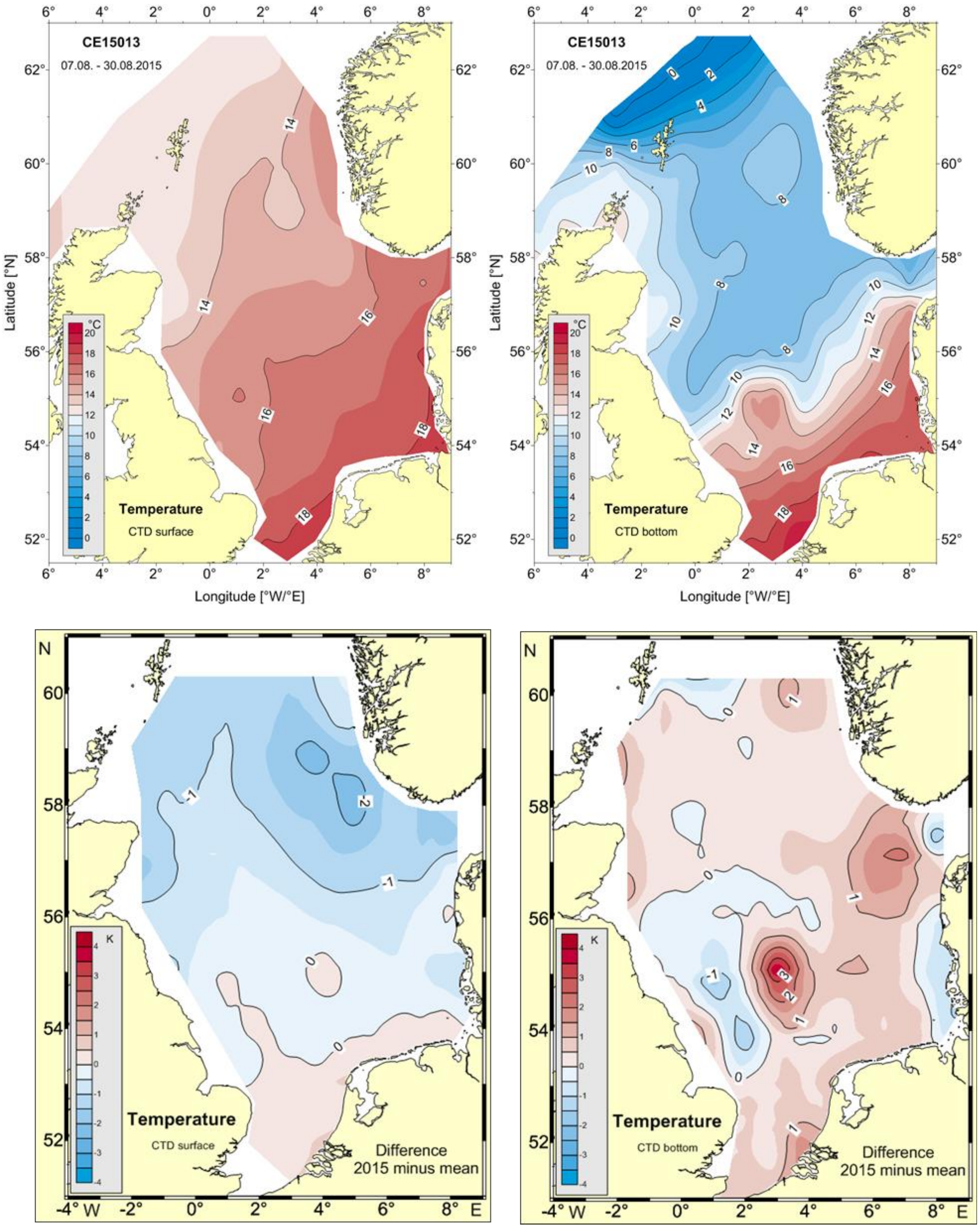


Fig. 2.2a*: Top: Horizontal surface (left) and bottom (right) temperature distribution in °C. Bottom: Horizontal surface (left) and bottom (right) temperature anomalies (2015 – reference period 2000-2010) in K.*

section	vertical gradient (≥0.5 K/m)		depth of thermocline [m]	
	min	max	min	max
60° N	0.7	1.0	**16**	33
59° N	0.7	1.0	33	**55**
58° N	**0.5**	1.0	22	39
57° N	0.6	1.2	29	38
56° N	0.7	**1.5**	24	34
55° N	0.6	**1.5**	25	31
54° N	-	-	-	-
mean±std	0.6±0.1	1.2±0.2	24.8±5.8	38.3±8.7

Table 1: *Extreme values of vertical temperature gradients and thermocline depths (depths of maximum gradients) for the zonal sections. Last line: Mean and standard deviation over all sections.*

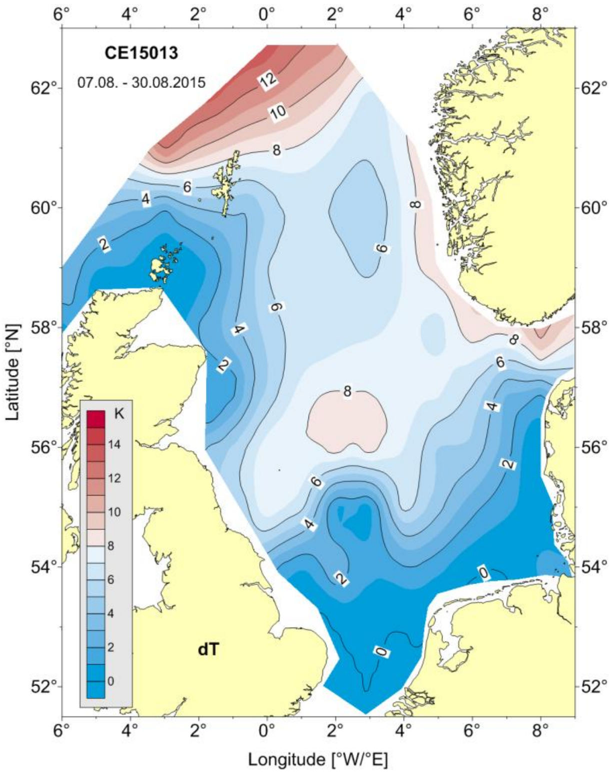


***Fig. 2.2b**: Difference surface temperature minus bottom temperature in K.*

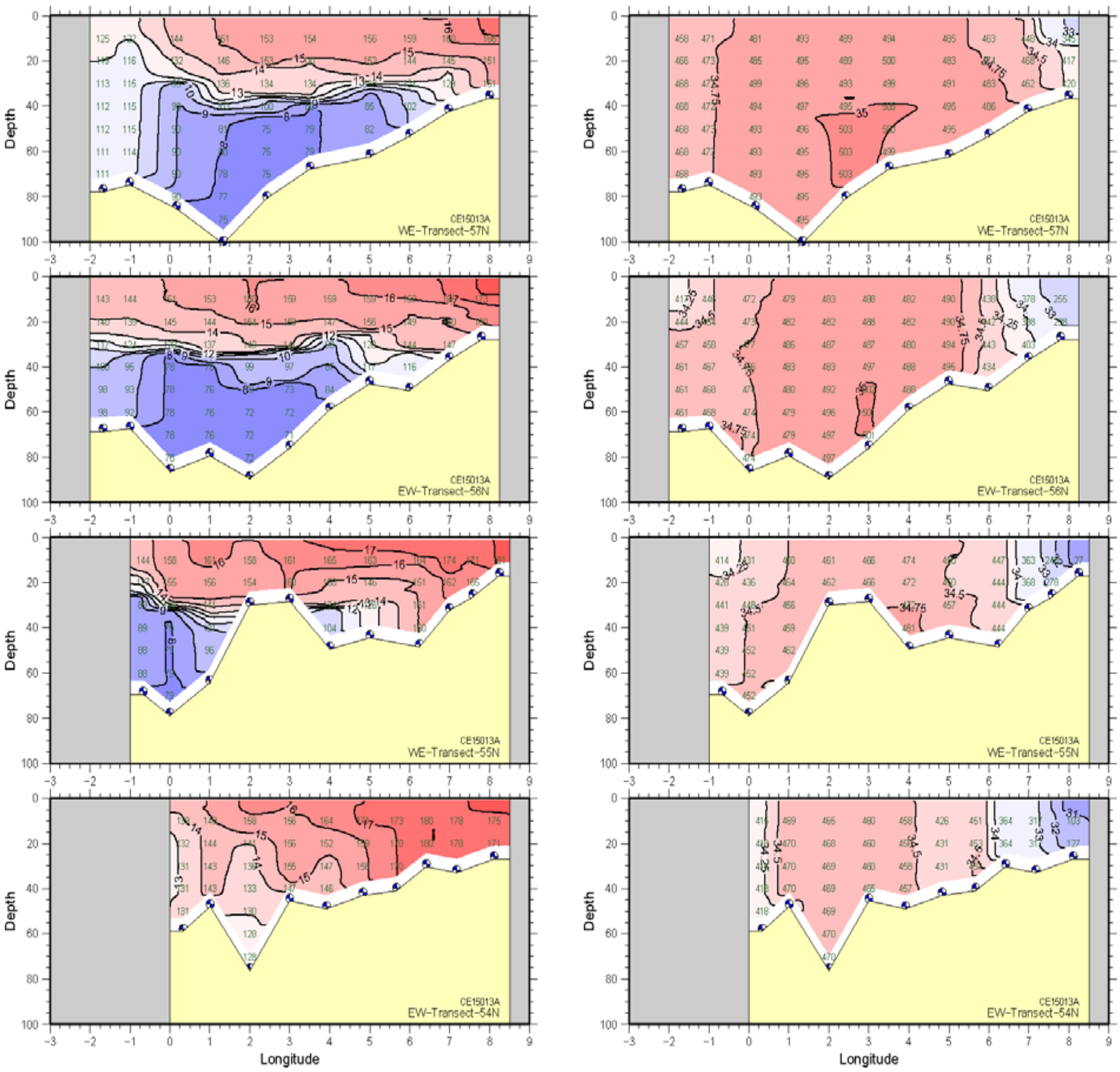


Fig. 2.2c: Vertical temperature (left) and salinity (right) sections along 54°, 55°, 56°, and 57° N basing on CTD data. The numbers in the temperature sections give the temperatures×10 in °C for selected data points. The numbers in the sanity section give the (salinities×100) - 3000 for selected data points in psu.

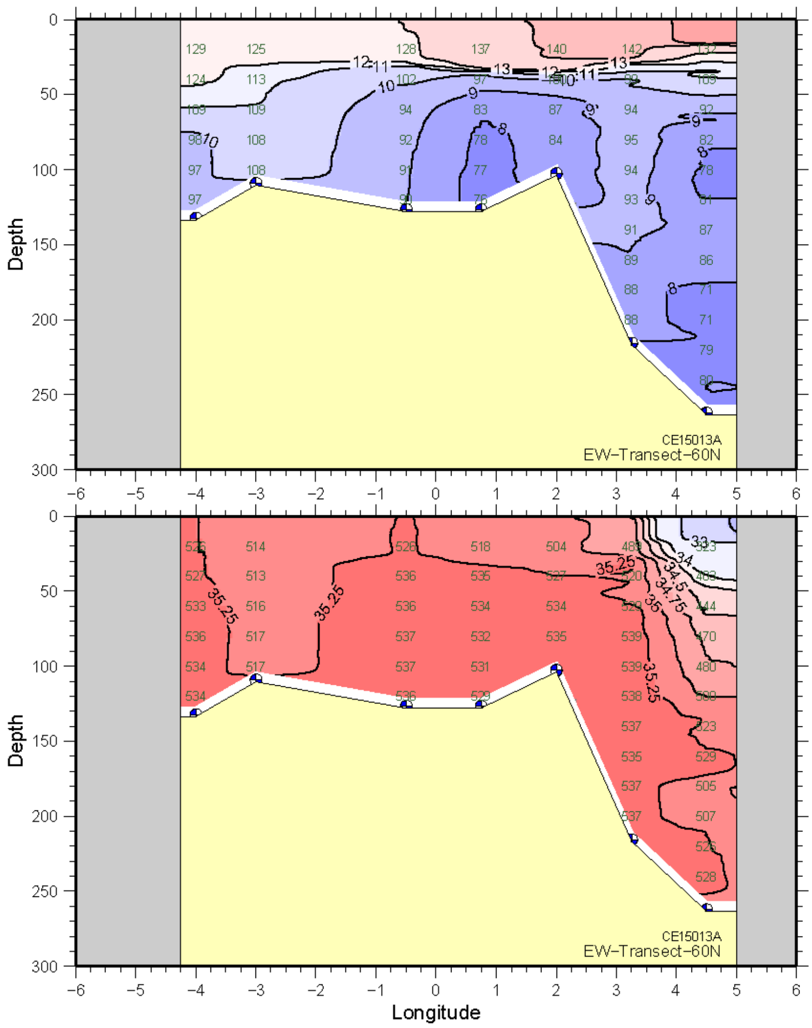


Fig. 2.2d: Vertical temperature (top) and salinity (bottom) sections in °C along the 60° N basing on CTD data. The numbers in the temperature sections give temperatures×10 in °C for selected data points. The numbers in the sanity section give the (salinities×100) - 3000 for selected data points in psu.

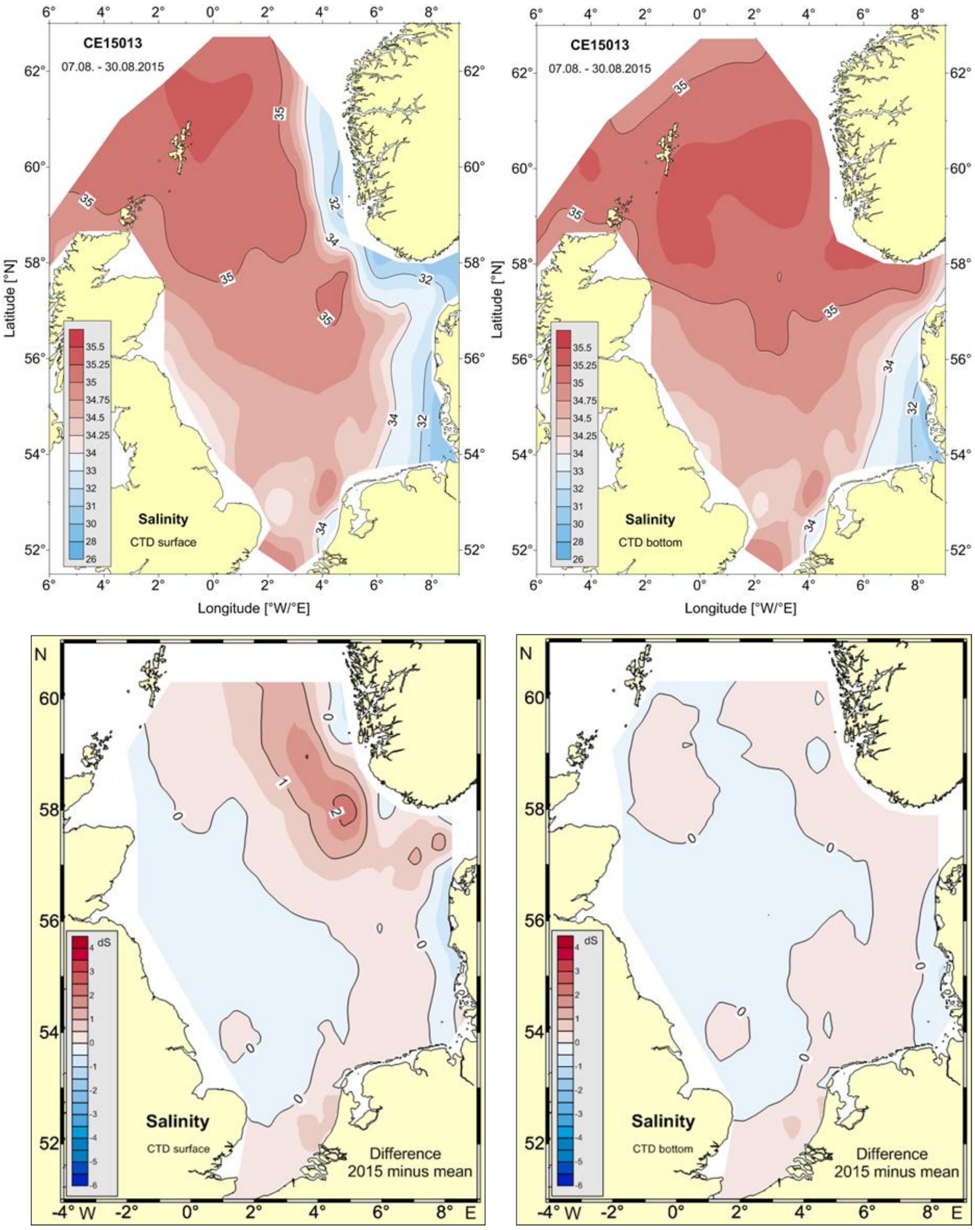


Fig. 2.2e: *Top: Horizontal surface (left) and bottom salinity distribution (right). Bottom: Salinity anomalies (2015 – reference period 2000-2010), in the surface (left) and bottom layer (right).*

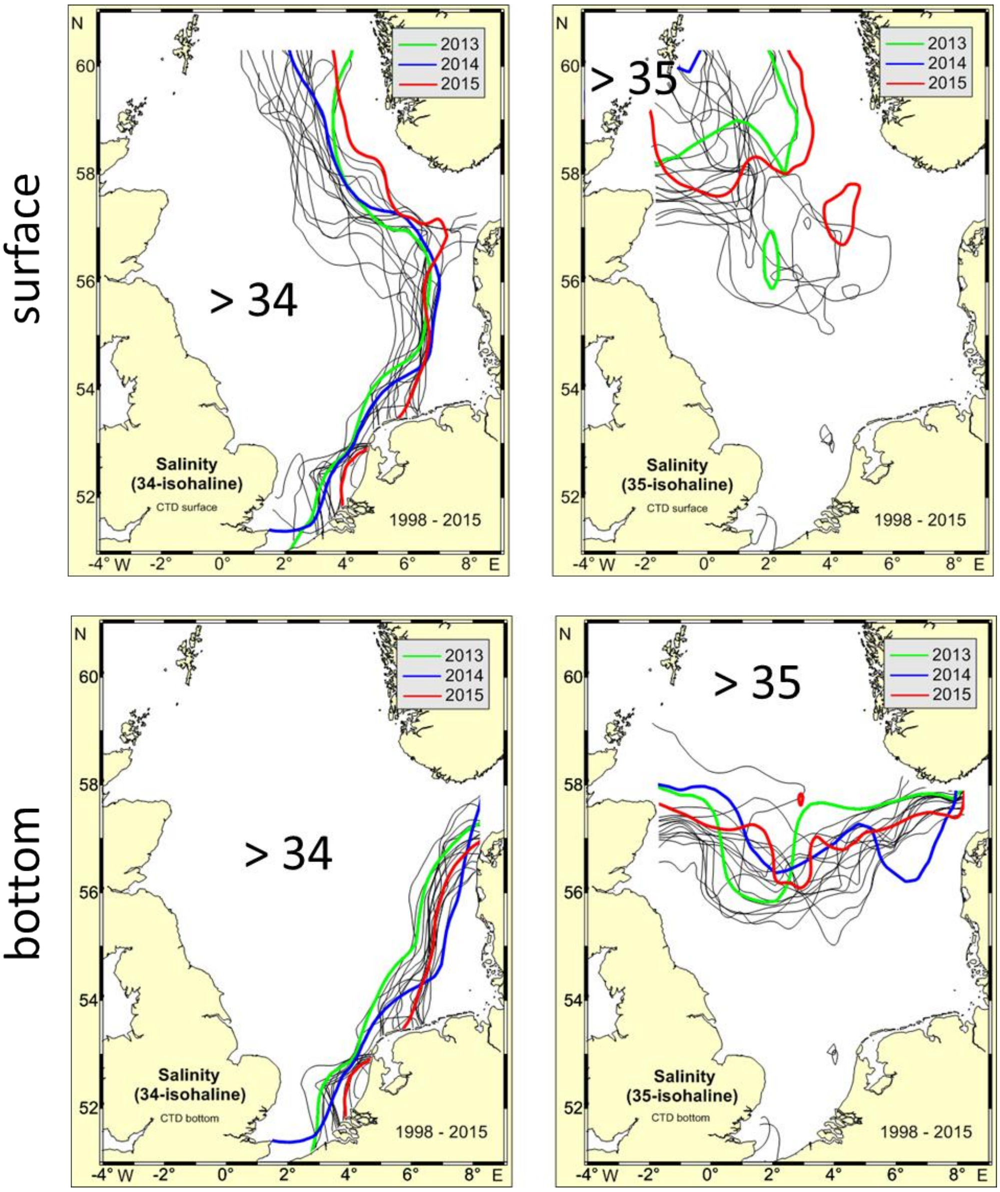


Fig. 2.2f: *Position of the 34 (left) and 35 (right) isohalines 1998 – 2015. Top panel: surface layer, bottom panel: bottom layer. Red: 2015, blue: 2014, green: 2013, and grey: 1998-2012.*

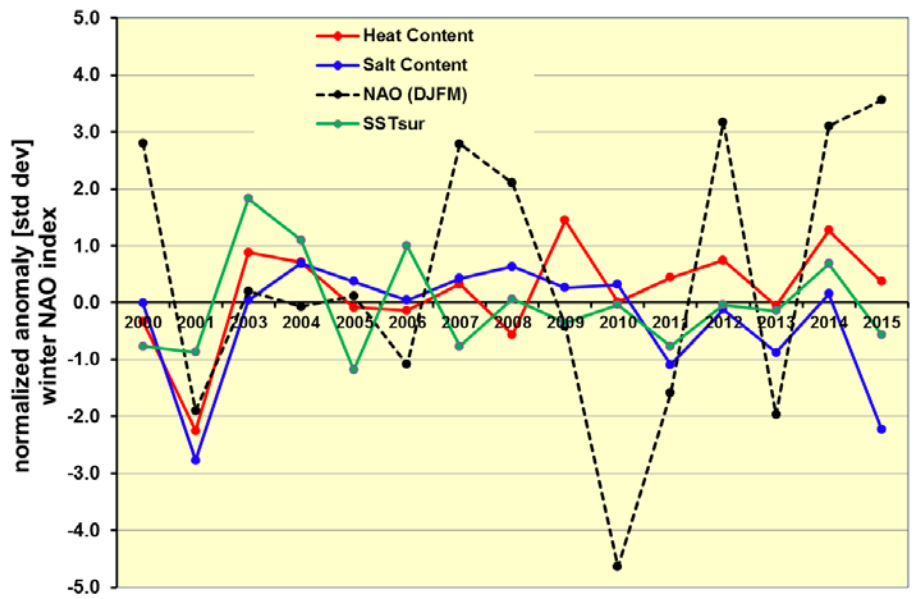


Fig. 2.2g: *Normalised anomaly of total heat and salt content and mean SST of survey period in standard deviations. Broken line: Hurrell winter NAO station index (DJFM)[2], reference period 2000-2010 but without 2002.*

3 Summary Table

		Annual Means				North Sea Summer Survey Data					
year	NAO Winter Index[1)]	SST_{annual} [°C]	ΔSST [std dev]	Elbe Run-off [km³/a]	ΔERO [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	10.7	0.84	21.22	-0.12	15.2	-0.87	1.427	-2.38	1.122	-0.66
2000	2.80	10.4	0.31	20.41	-0.25	15.3	-0.77	1.603	-0.33	1.134	-0.01
2001	-1.90	10.4	0.37	18.99	-0.48	15.2	-0.87	1.438	-2.25	1.083	-2.77
2002	0.76	10.9	1.29	35.69	2.24	15.4	-0.66	1.587	-0.52	1.131	-0.17
2003	0.20	11.0	1.40	19.79	-0.35	17.8	1.83	1.707	0.88	1.135	0.04
2004	-0.07	10.7	0.91	16.03	-0.97	17.1	1.10	1.692	0.71	1.147	0.69
2005	0.12	10.5	0.53	21.08	-0.14	14.9	-1.18	1.624	-0.08	1.141	0.37
2006	-1.09	11.0	1.32	22.29	0.05	17.0	1.00	1.619	-0.14	1.135	0.04
2007	2.79	10.9	1.23	21.98	0.00	15.3	-0.77	1.659	0.32	1.142	0.42
2008	2.10	10.7	0.95	20.25	-0.28	16.1	0.06	1.583	-0.56	1.146	0.64
2009	-0.41	10.6	0.74	20.06	-0.31	15.7	-0.35	1.755	1.44	1.139	0.26
2010	-4.64	9.9	-0.52	31.08	1.49	16.0	-0.04	1.632	0.01	1.140	0.31
2011	-1.59	10.4	0.28	26.30	0.71	15.3	-0.77	1.669	0.44	1.114	-1.09
2012	3.17	10.4	0.23	20.12	-0.30	16.0	-0.04	1.695	0.74	1.132	-0.12
2013	-1.97	10.0	-0.44	32.11	1.66	15.9	-0.15	1.627	-0.05	1.118	-0.88
2014	3.10	11.4	2.55	15.00	-1.13	16.7	0.68	1.740	1.32	1.137	0.15
2015	3.56	10.6	0.65	15.00	-1.13	15.5	-0.56	1.663	0.37	1.093	-2.23
reference period	-	1981-2010		1981-2010		2000-2010		2000-2010		2000-2010	

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

Δ is the normalized anomaly in standard deviation relative to the reference period

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

Table 2: *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 total salt content (TSC), and normalised anomalies in standard deviations (Δ) 1999-2015.*

[2] https://climatedataguide.ucar.edu/sites/default/files/climate_index_files/nao_station_djfm.txt

Annex 10:

Regional report – Skagerrak, Kattegat and the Baltic (Area 9b)

National report

Area 9b- Skagerrak, Kattegat and the Baltic

Karin Borenäs, SMHI

Owing to its central location relative to the Skagerrak, Kattegat, and Baltic, the weather in Sweden can be taken as representative for the area. Since 1860 only two years, 1935 and 2014, have had a mean temperature higher than the one obtained for 2015. The anomaly from the yearly mean was 2.1° C. All months, except for May, June and July, were warmer than normal. The mean precipitation was somewhat higher than normal in most parts of the country. October was, however, a very dry month. The number of sun hours was close to normal in the north, otherwise above normal.

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. For five of these stations the annual cycles of surface temperature and salinity are presented in Figure 2.

The sea surface temperatures were above normal at the beginning and end of the year in most areas. Only in the Skagerrak did the year start with temperatures close to normal. In summer the water temperatures were below normal since it took some time to warm up the surface layer after the cold weather in early summer. The surface salinities were mostly normal in the Skagerrak and the Kattegat except for August and October, and in some parts also September, when the values were below normal. These low values of the salinity were probably due to an increase in the discharge from the Baltic Sea. There were inflows of more saline water into the Baltic at the beginning and the end of the year. As a consequence higher than normal values of the surface salinity were found in the southern parts of the Kattegat and the Baltic Proper. The rest of the Baltic proper showed close to normal values

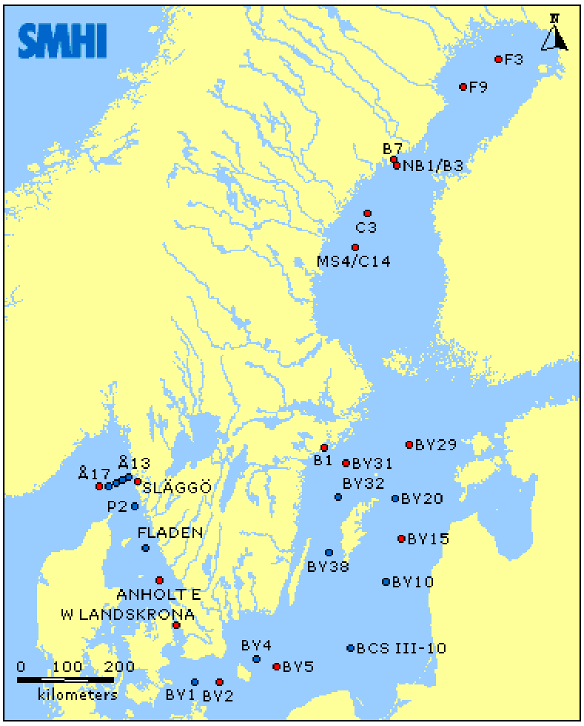


Figure 1. Position of stations visited on a regular basis. Stations marked with red pertain to the Swedish National Monitoring Programme while stations in blue are additional stations sampled by SMHI.

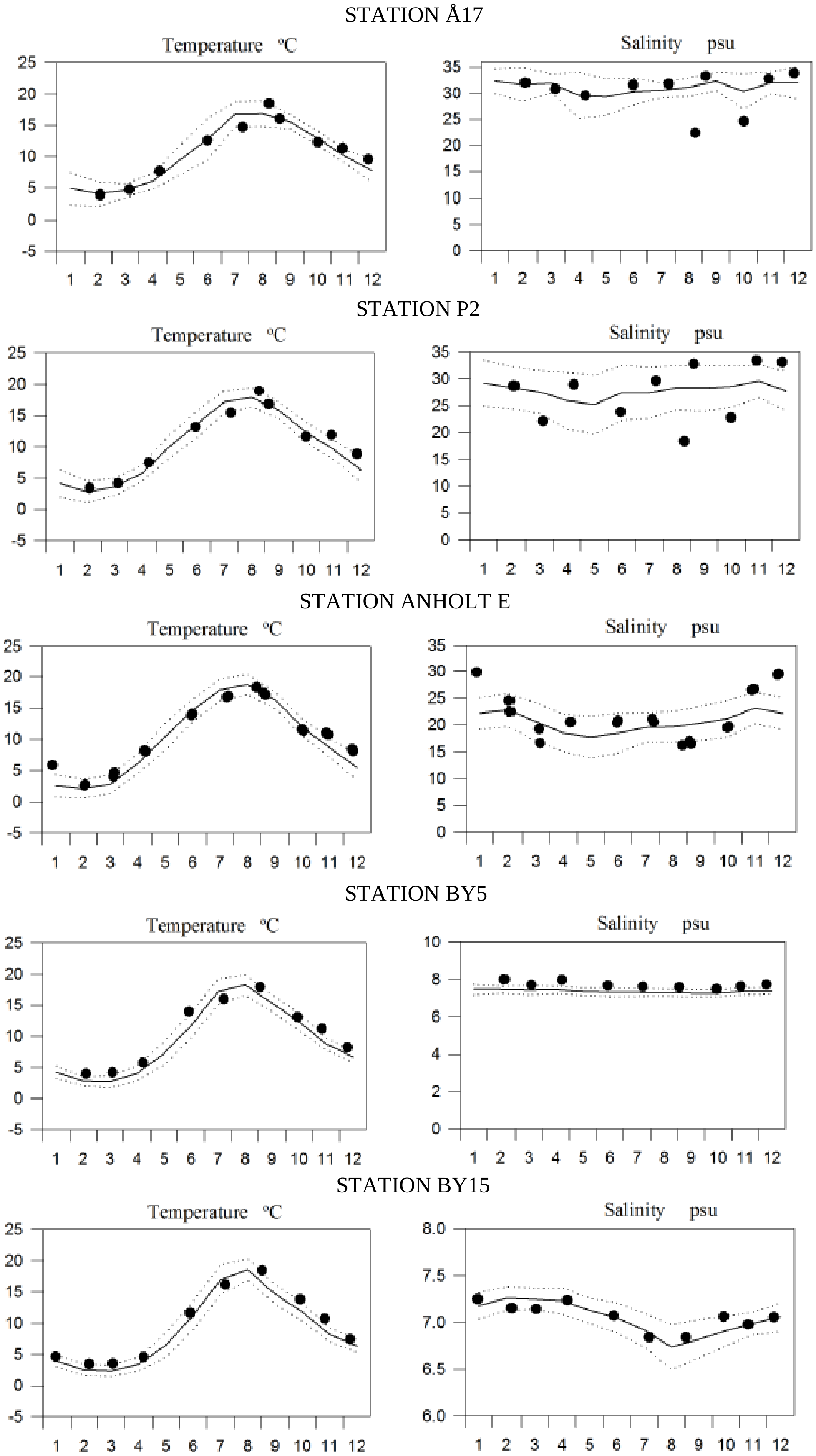


Figure 2. Annual cycles of sea surface temperature (left column) and salinity (right column), see Figure 1 for station positions. Solid line shows the mean for the period 1996-2010 and filled circles the 2015 observations. Dotted lines indicate ± 1 standard deviation. (SMHI)

Long term observations at BY15

At station BY15, east of Gotland, the yearly mean surface temperature continued to increase (see Figure 3 upper panel).
The normalized anomaly above the long-term (1990-2010) yearly mean was just over 0.7 °C. The yearly mean surface salinity at BY15 increased for 2015 after two years with low values. The anomaly was still below the long-term (1981-2010) yearly mean (Figure 3 lower panel).

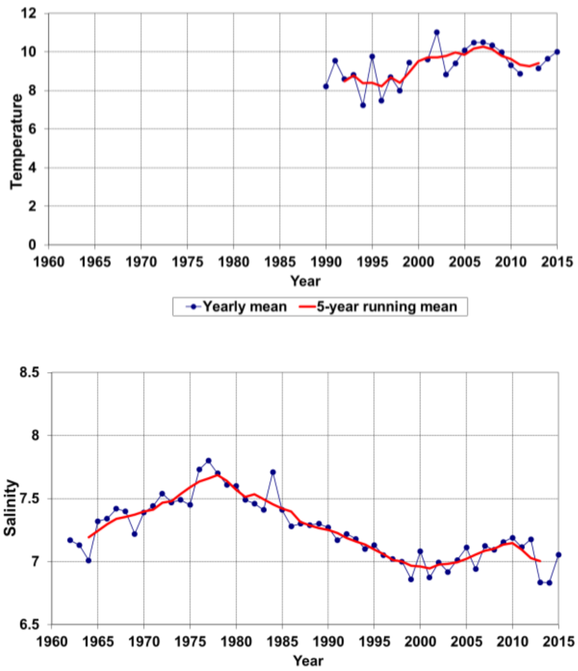


Figure 3. Sea surface temperature (upper panel) and salinity (lower panel) at BY15 (see Figure 1) in the Baltic Proper. Yearly mean (blue curve) and 5-year running mean (red curve). SMHI

Water exchange

The inflow that took place in December 2014, followed by a minor inflow in January 2015 (see Figure 4), could be tracked on its way into the deeper parts of the Baltic Sea by the monthly monitoring. The effect of the inflow was not long lasting and the oxygen rates have started to decrease again. The inflow never reached the northern and western parts of the Gotland Basin. The reason for this situation is probably that the salinity of the inflowing water was too low. Furthermore, the oxygen levels of the inflowing water were lowered due to the warm fall keeping the water temperatures above normal.
At the end of the year a series of minor inflows took place (see Figure 4).

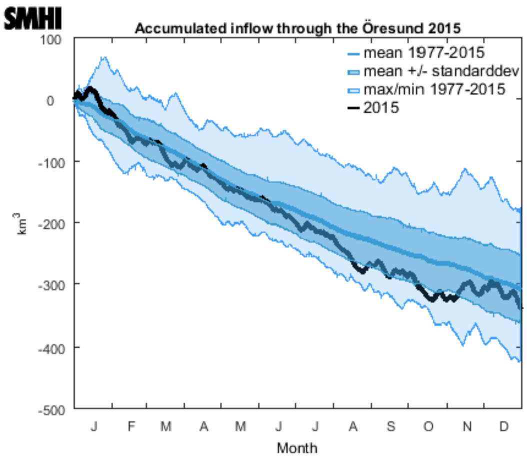


Figure 4. Accumulated inflow (km^3) through the Öresund into the Baltic in 2015 (black line) compared to 1977-2015 (blue line). The darker blue area delimits ±1standard deviation and the lighter blue area maximum and minimum values.

Ice conditions

The ice season 2014/2015 had a late start due to higher than normal sea water temperatures at the end of 2014. Cold periods were then mixed with windy periods which made it hard to establish an ice cover. The ice season was very mild and short with a maximum ice extent of 45 000 km^2 reached already on January 24 (Figure 5). Around May 7 the Bothnian Bay was ice-free which is about three weeks earlier than normal.

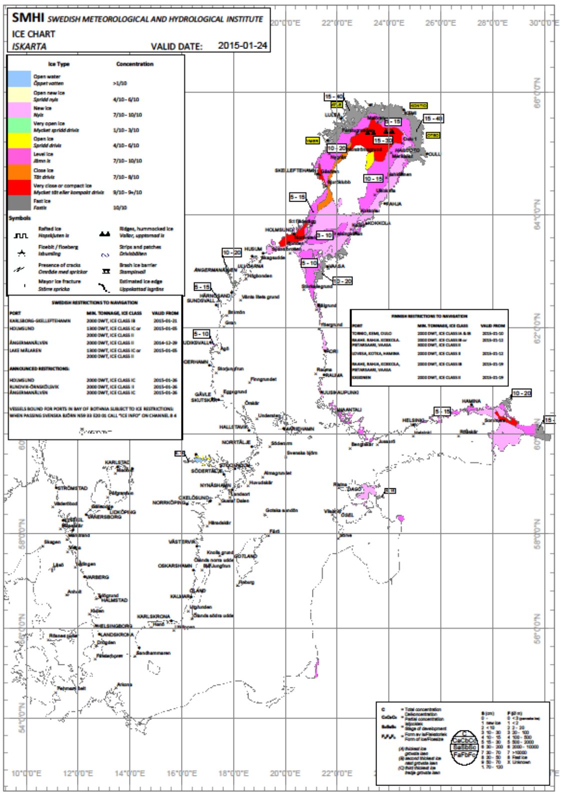


Figure 5.The maximum ice extent in the Baltic Sea during the winter 2014/2015. The map was constructed by the Ice Service at SMHI.

In Figure 6 the maximum ice extent in the Baltic is plotted for the period 1957-2015. The value for 2014/2015 was the lowest one obtained, at least since 1957.

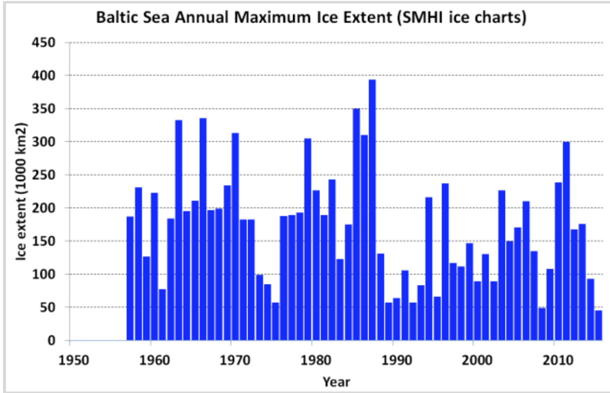


Figure 6. The maximum ice extent in the Baltic starting from 1957. (Graph constructed by Lars Axell, SMHI).

Oxygen conditions

Extensive surveys of the oxygen conditions in the Baltic Proper, including the Gulf of Finland and the Gulf of Riga, are regularly carried out in the fall. The preliminary results for 2015 show that, despite the major inflow to the Baltic Sea in December 2014, approximately 16% of the bottom area was affected by anoxia and 29% by hypoxia.

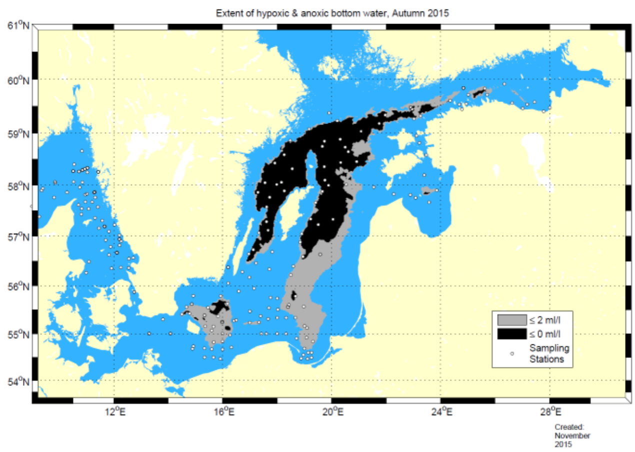


Figure 7. The preliminary oxygen situation in the Baltic Proper,including the Gulf of Finland and the Gulf of Riga, in autumn 2015. The map is based on measurements carried out by SMHI, together with data from Poland, Finland, Estonia, Latvia and Lithuania.. Visited stations (grey dots), hypoxia (grey) and anoxia (black).

Annex 11:

Regional report – Norwegian Waters
(Areas 8-11)

Working Document **ICES 2016**
Working Group on Oceanographic Hydrography
3 May 2016

Norwegian Waters (Areas 8-11)

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Main summary

The temperatures of the inflowing Atlantic water were in 2015 slightly above the long-term means (1981-2010) for the Norwegian Sea and Skagerrak while in the Barents Seas it was considerable above the long-term mean. The heat content in the North Sea remained stable in 2015 as the summer heating compensated the winter cooling. In the Norwegian Sea the heat content has since 2000 been above the long-term mean. In the Barents Sea the ice cover during 2015 was below the long-term mean both winter and summer.

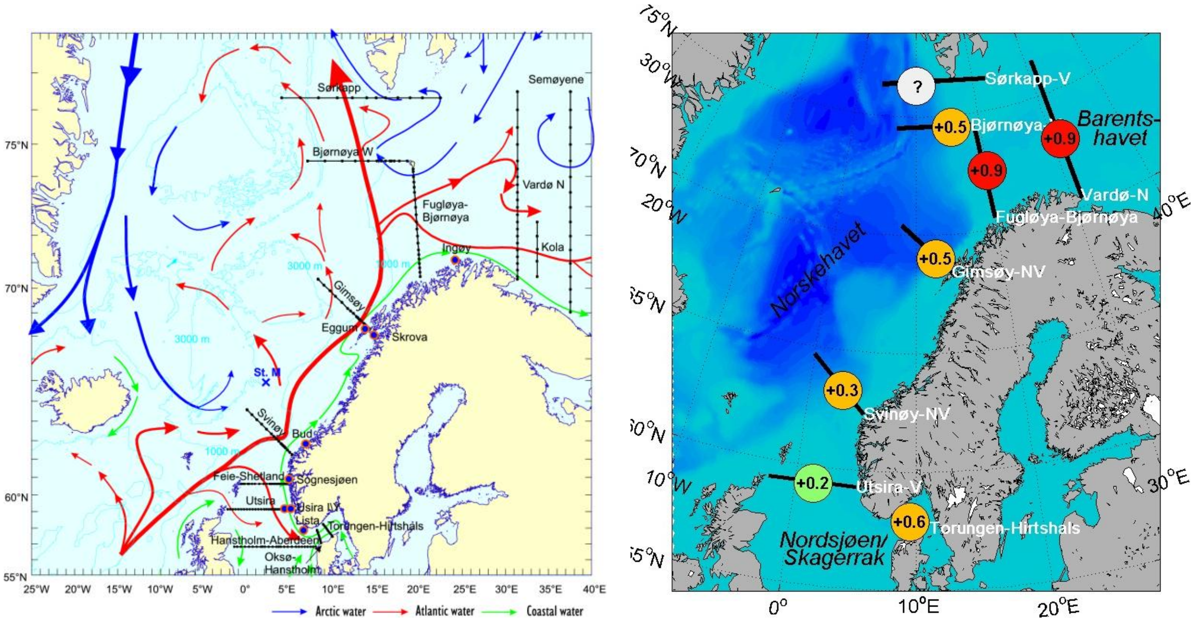

Figure 1. *Standard sections and fixed oceanographic station worked by Institute of Marine Research, Bergen. The main surface currents are also shown. Right: Annual temperature anomalies (50-200 m) relative to 1981-2010 at the standard sections for 2015.*

The Norwegian Sea

Kjell Arne Mork

Summary

- Temperature of the inflowing AW has the last three years been close to or slightly above the long-term mean.
- The salinity has since 2010-2011 decreased and was in 2015 close to normal, except further north (WSC) where it was still higher than the long-term-mean
- Cooling in the southern Norwegian Sea in spring 2015 (- 1-2 °C)
- High heat content in the Norwegian Sea (covering the AW) since 2000

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 2015. At the Svinøy section, the temperature in 2015 was near the normal and close to 2014 except in May-August. On average the temperature at the Svinøy section was for 2015 0.3°C above the normal. Further north at the Gimsøy, the temperatures during the whole year were considerable higher than normal and also compared to 2014. In average the temperature at the Gimsøy section was for 2015 0.5 °C above the normal. Further north, at the Bear Island-West section, the temperature was close to normal except in November when it was considerable higher. The salinity was close to normal in 2015 for the southernmost section while it was for the Gimsøy section considerable higher than normal most of the year.

There has been an linear 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 except at the Bear Island-West section. 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 has decreased and in the south it is close to the long-term mean. 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.

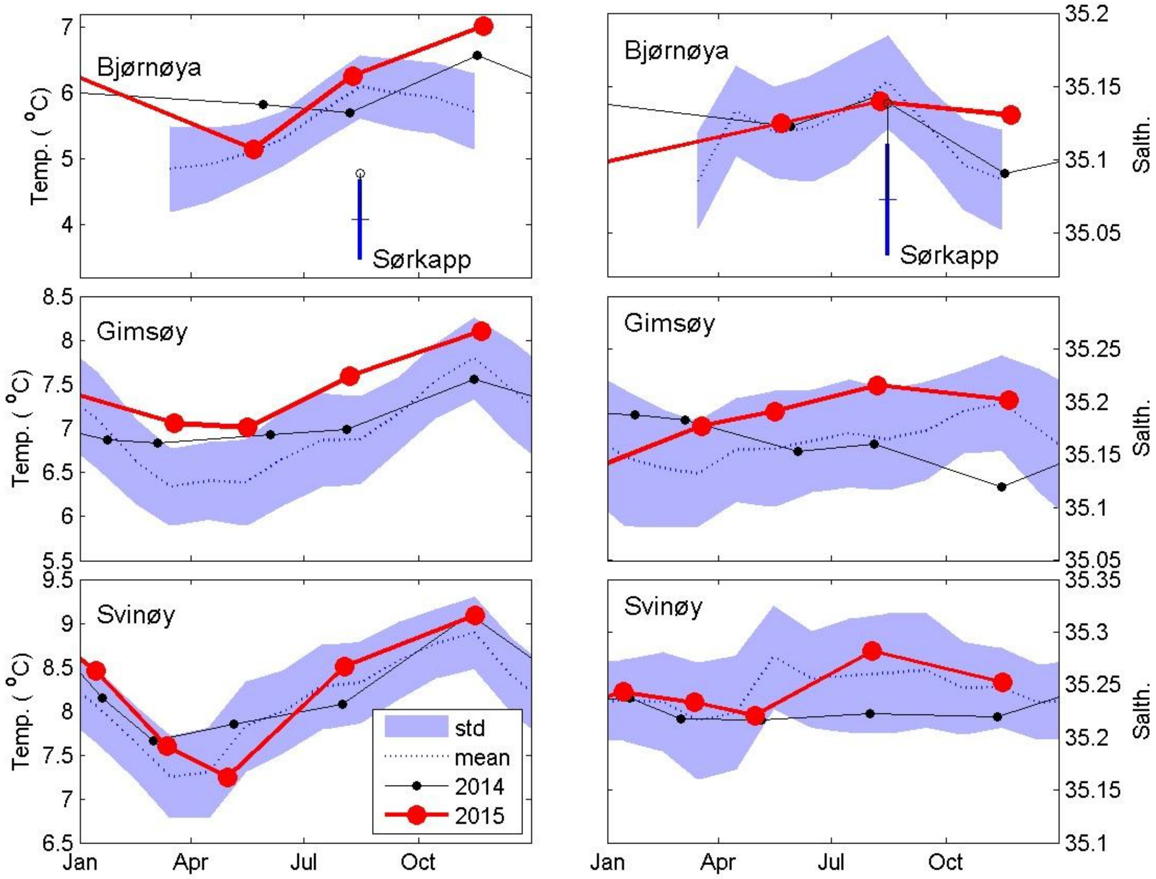

Figure 2. *Temperature (left) and salinity (right) in the core of Atlantic water), averaged between 50 and 200 m depth, for the sections Bjørnøya-W (upper figures), Gimsøy-NW (middle figures), Svinøy section (lower figures) and Sørkapp-W section (in the upper figure, only for August) for the years 2015 and 2014.*

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. After 2011 the inflow has declined and was in 2014 and 2015 (updated to Oct 2015) about 0.5 Sv below the long-term mean.

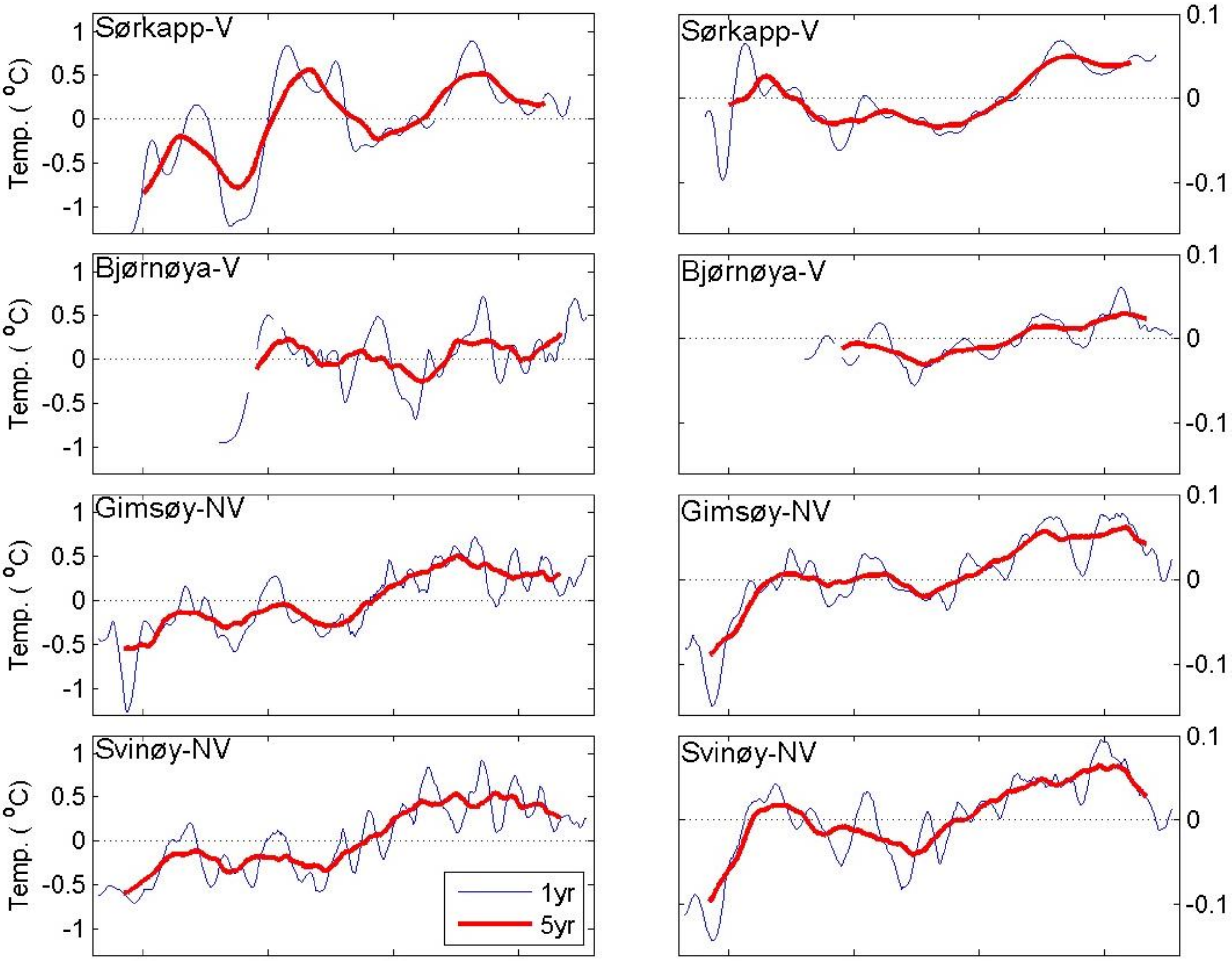

Figure 3. *Temperature (left) and salinity (right) anomalies in the core of Atlantic water, averaged between 50 and 200 m depth, for the sections Svinøy-NW, Gimsøy-NW, Bjørnøya-W and Sørkapp-W. Both yearly and five years averages are shown. The anomalies are calculated relative to the 1981-2010 averages.*

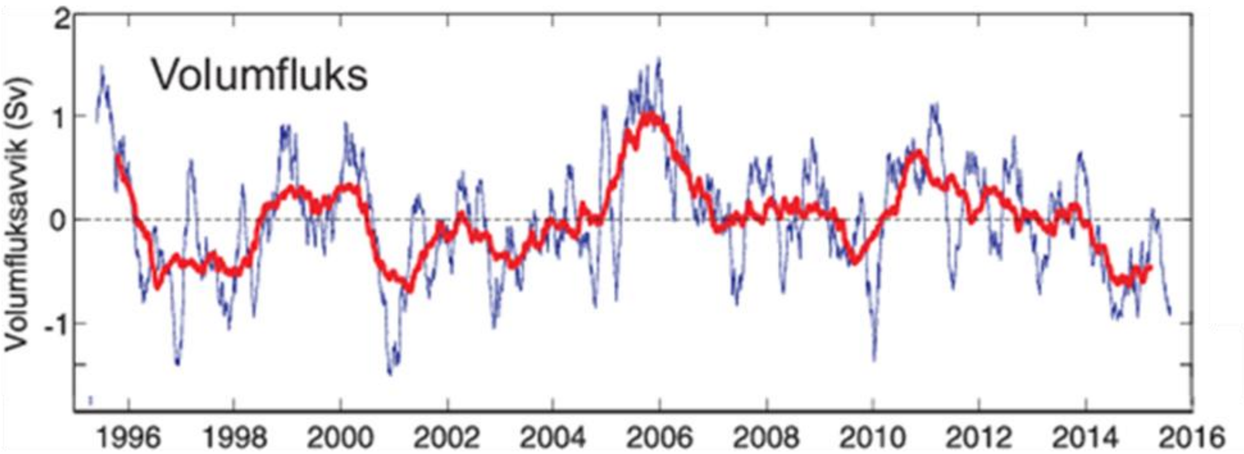

Figure 4. *Volume transport anomaly in the Svinøy section. Updated from Orvik et al. (2001). The blue line is 3 months anomaly averages while the red line is one year anomaly averages.*

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 0-50 m, 50-200 m and 200-500 m depth in 2015, 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. The temperature was above considerable lower in the southern Norwegian Sea. At all depths the temperatures were there 1-2 ^{o}C lower than the long-term-mean. In central and northern parts the temperatures were in general about 0.5 ^{o}C above the long-term average.

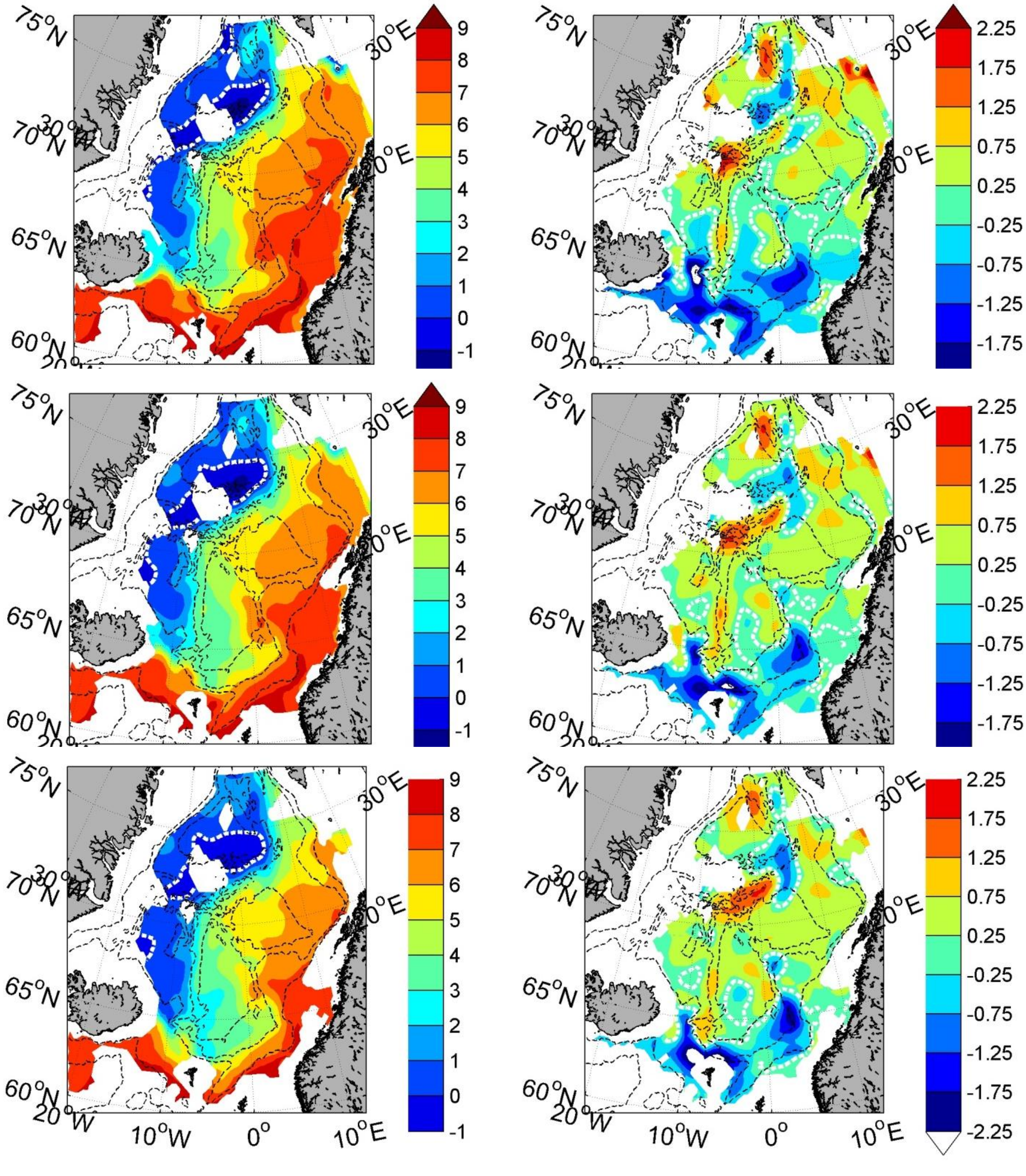

Figure 5. *Left: Temperature, averaged over 50-200 m depth, in May 2015. Right: temperature anomalies, averaged over 0-50m (upper), 50-200 m depth (middle), and 200-500 m (lower) relative to a 1995-2015 mean.*

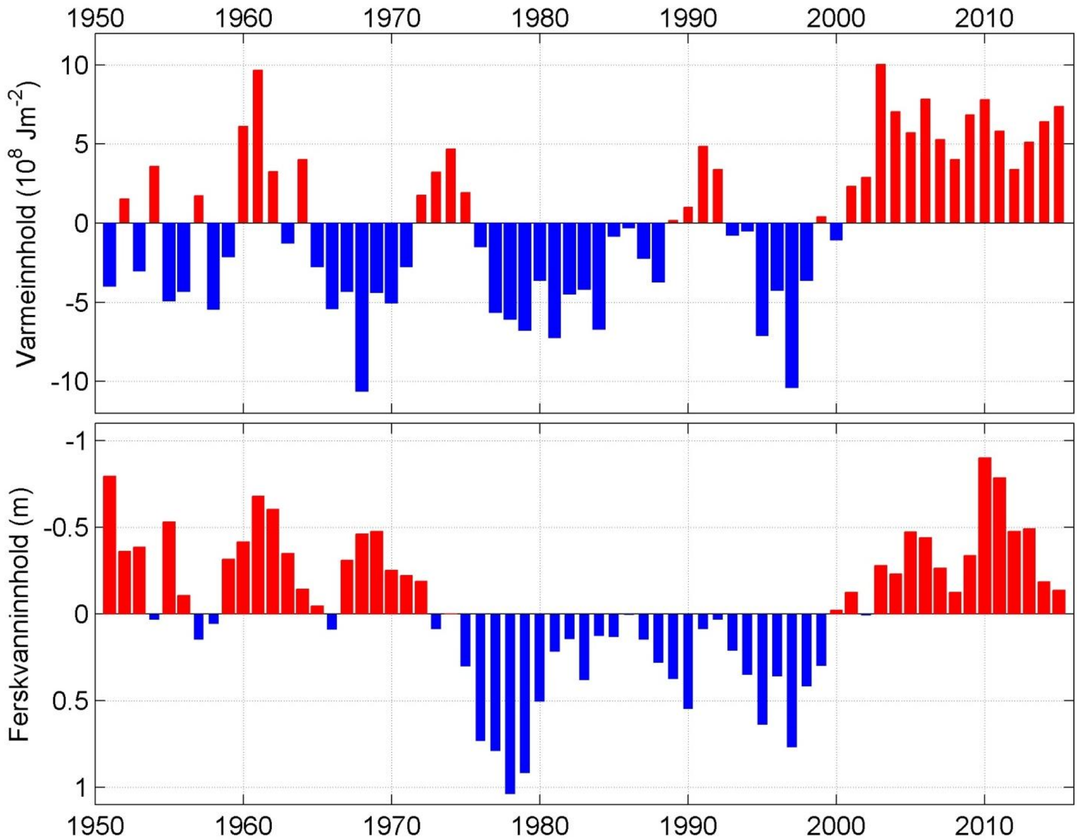

Figure 6. *Heat (upper) and freshwater (lower) content anomaly during spring (1951-2015) in Atlantic Water, averaged over the Norwegian Sea. Note that the y-axis is reversed for the freshwater content.*

The heat content of AW in the Norwegian Sea has since 2000 been above the long-term-mean, and was in 2015 considerable above the mean (Fig. 6). The freshwater content was at minimum in 2010 (i.e., the water mass was saltier than normal) and has declined afterwards to near the long-term-mean in 2015.

The area of total occupied Atlantic Water in the Svinøy section is shown in Figure 7. After a relatively low extension of AW in the first half of the 1990s the area of AW has increased. In 2015 the area was lower than the long-term mean for both the spring and summer. The averaged temperature in the occupied AW has increased linearly since 1978 and has, during the whole period, become 0.8°C warmer for both spring and summer. In 2015 the temperatures decreased from 2014, and were 0.1°C and 0.2°C higher than the long term means for spring and summer, respectively.

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 8 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 2015, the amount of Arctic water in the Svinøy section was at the bottom level while over the larger area in the Norwegian Sea it was close to the bottom level.

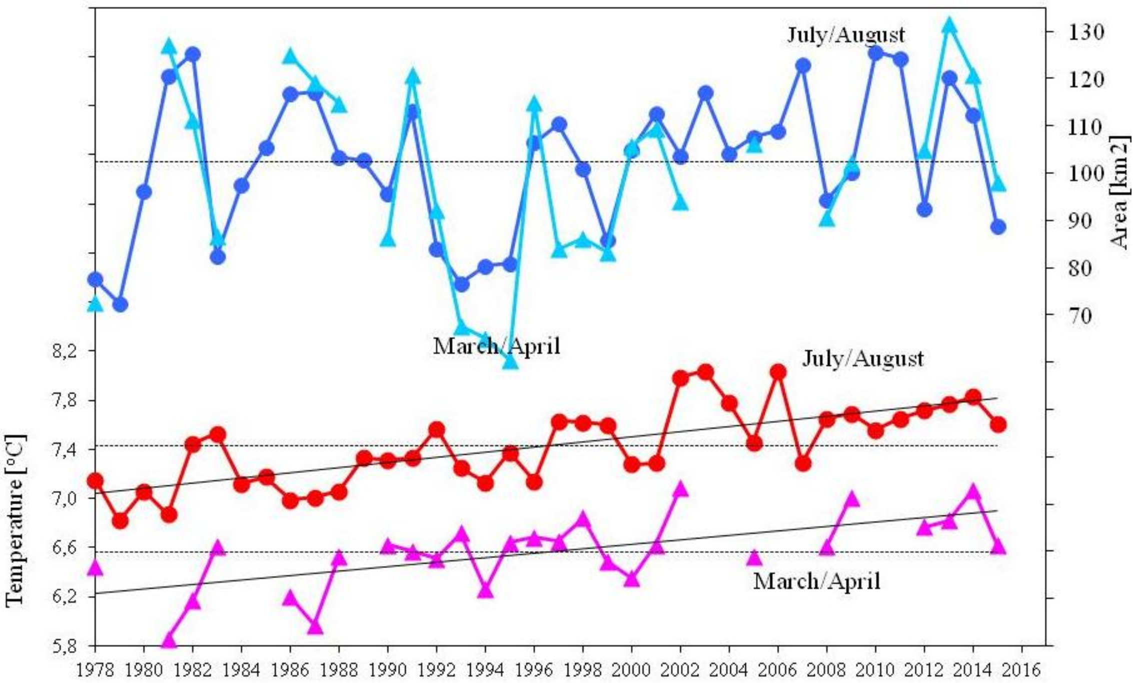

Figure 7. Area of Atlantic water and averaged temperature of AW in the Svinøy section for spring (March/April) and summer (July/August).

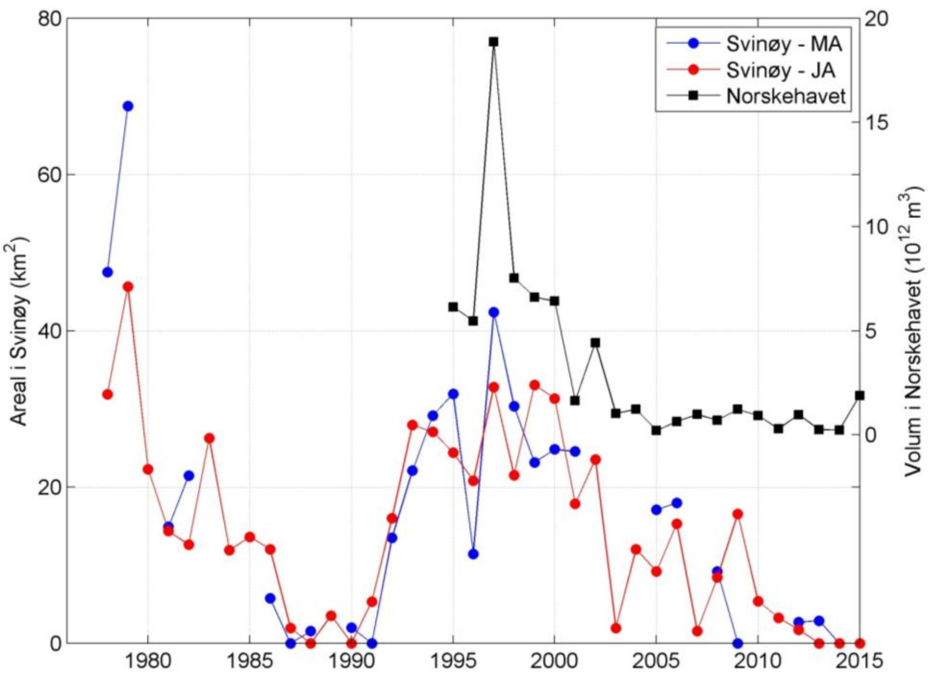

Figure 8. *Amount of Arctic water (salinity<34.9) at the four westernmost stations in the Svinøy-NW section at 50-500 m depth in spring (March-April, MA) and summer (July-August, JA), and in the southern Norwegian Sea (62-68 N, 150-300 m depth).*

The Barents Sea

Randi Ingvaldsen

Summary

- The temperature in the Barents Sea is higher than in 2014. Highest anomalies were observed in the eastern Barents Sea.
- There were small amounts of ice both winter and summer compared to the long-term mean.
- The inflow to the Barents Sea has since 2007 been close to the long term mean. The inflow was low during fall 2014 but increased substantially during winter 2014-2015 and was about 1.5 Sv above the long-term mean in spring 2015.

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 0.7-0.9 °C above the long-term mean during 2015 (Figure 9). This is somewhat higher compared to the year before.

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 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.

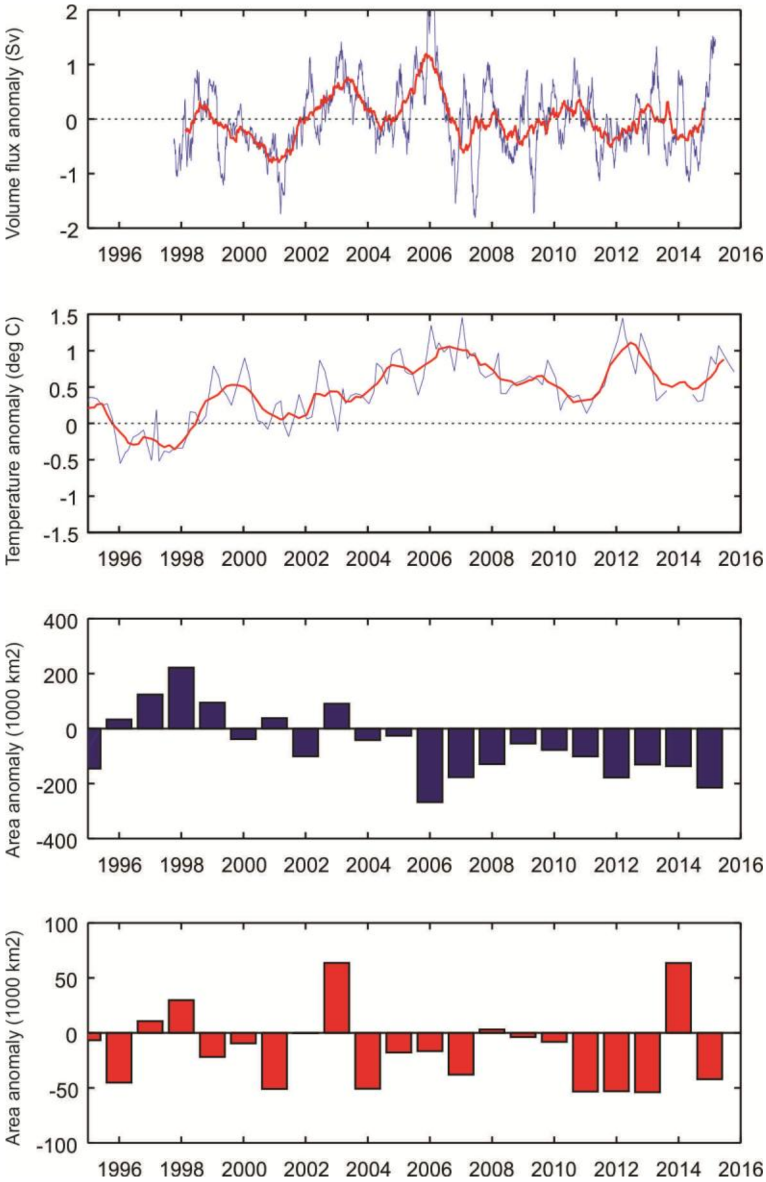

Figure 9. Upper panel: Volume flux anomalies (in Sv) in the Atlantic Water in the south-western entrance to the Barents Sea. The lines show 3 months (blue) and 1 year (red) moving average. Second panel: Temperature anomalies in the Atlantic Water in the 50-200 m layer. The lines show measured values (blue) and 1 year (red) moving average. Lower panels: Ice area in the Barents Sea (10–60^{o}E, 72-82^{o}N) at maximum (April) and minimum (September) ice coverage.

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 9). 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 2014 the inflow was about low, but it increased significantly during winter 2014-2015. In spring 2015 the inflow was about 1.5 Sv above the long-term mean. The data series presently stops in spring 2015, thus no information about the fall and early winter 2015 is yet available.

Hydrographic observations during late summer 2015 show that the temperatures were above 0.5oC in the 50-200 m depth layer in most of the Barents Sea (Figure 10). This is somewhat higher than was observed in last year. The highest temperatures were observed in the eastern parts.

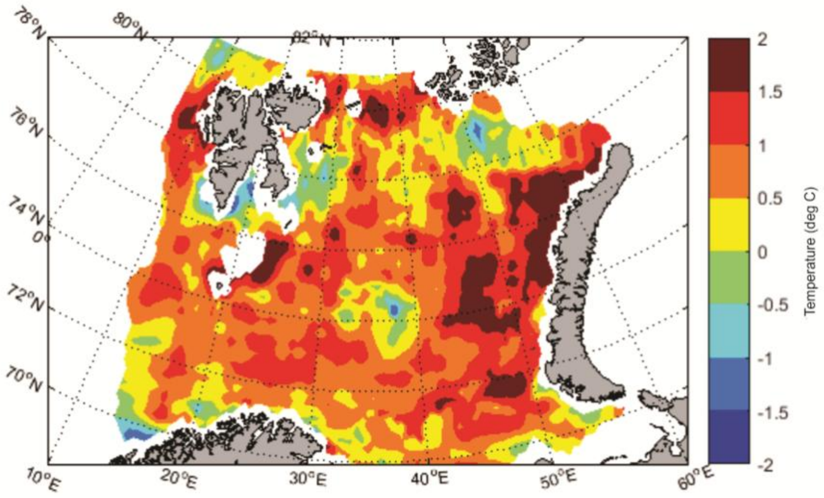

Figure 10. Temperature anomalies at 100 m depth in August-September 2015 relative to the long-term mean (1977-2006).

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. During winter 2015 there was less ice than the year before as well as the long-term mean (Figure 11).

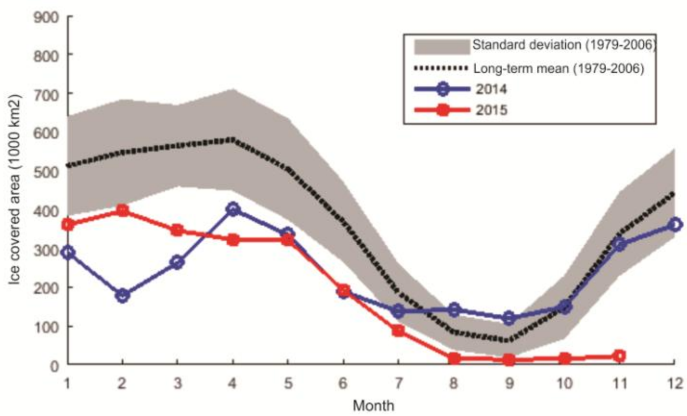

Figure 11. Seasonal variations in ice cover in the Barents Sea (10–60°E, 72-82°N). Long-term mean and standard deviation are calculated based on the period 1979-2006.

The North Sea

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

Summary

- In 2015, normal temperatures and normal inflow of Atlantic water into the North Sea except for warmer water and increased inflow in November and December.
- The heat content in the North Sea remained stable in 2015 as the summer heating compensated the winter cooling.

Temperature and water masses

The sea surface temperature in the Skagerrak and North Sea has been warmer than the long-term average (reference period is 1971-93) throughout 2015 except for colder conditions in June and July. November and December 2015 were particularly warm with temperatures up to 3°C above the long-term average, and the largest warm-anomalies during 2015 were registered in the eastern North Sea and in the Skagerrak (source: BSH, Bundesamt für Seeschifffahrt und Hydrographie).

The Skagerrak deep-water (~100-200m) is mainly characterized by Atlantic Water (AW), and a fixed station approximately 10km off the Torungen lighthouse near Arendal, Norway, is used to indicate the hydrographical variability. The AW temperatures were close to normal (reference period is here 1981-2010) during 2015 except for remarkably high temperatures in November and December. Only four times earlier have a higher temperature at 150m depth off Norway in the central Skagerrak been registered in November, based on the monthly time series starting in 1952. The AW salinity at the same location was normal during 2015 except for relatively low values in January-March and November-December (Figure 12).

The Norwegian Trench is an elongated depression in the sea floor off the southern coast of Norway reaching from the Norwegian west coast to the Oslofjord in the Skagerrak. Off the Norwegian southwest coast, it is about 270 m deep, and its deepest point is off Arendal where it reaches more than 700m (close to the central Skagerrak). The Skagerrak basin can then be considered similarly to a fjord basin where stagnating water masses below sill depth are exchanged more or less regularly. Exchange of Skagerrak bottom waters takes place every 1-5 years and usually during March/April. After 1990, 14 exchanges are registered, the last one in March/April 2013 (Figure 13). The Skagerrak bottom water is either replaced by heavier deep AW subducting after flowing southward above the sill in the Norwegian Trench, or by cooled North Sea surface water as a result of heavy winter cooling. The latter exchange mechanism has been rare during the last 30 years, and a Skagerrak bottom water cooling (along with an increase in oxygen level) has only been registered in 1996 and 2010 during the last three decades. The bottom water has not been exchanged in 2015, but a renewal is expected during spring 2016.

Transports and heat content

The ocean circulation model NORWECOM is conducted to calculate transports of inflowing AW through a transect between Utsira, Norway, and the Orkneys. The main AW inflow pathway into the North Sea is from the north following the western slope of the Norwegian Trench. The main proportion of this AW deep water enters the Skagerrak and then circulates anti-clockwise following the direction of the Norwegian Coastal Current. The model indicates that the volume flux of the AW inflow was similar to the long-term average (1985-2010) during the first two quarters in 2015, then relatively low during the third quarter and relatively high during the last quarter (Figure 14). There is also a net inflow of AW through the English Channel, but the volume fluxes during 2015 were normal except for higher values in the last quarter.

Both seasonal variability and long-term oscillations of the heat content in the North Sea are computed for 1985-2015 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. In 2015, both the winter cooling and the summer heating were normal, and the summer heating approximately compensated the winter cooling. This implies that the heat content in the North Sea remained constant and the accumulated excess heat, which already is positive referring to the initialization of the time series in 1985, was not changed (Figure 15).

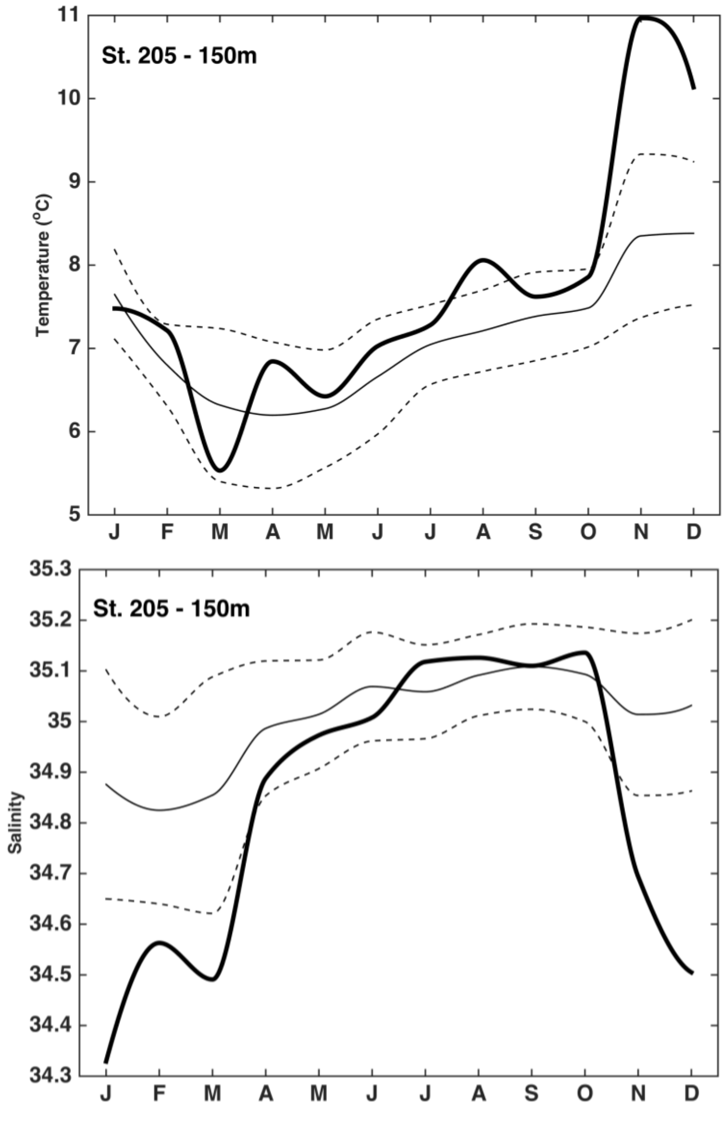

Fig. 12. Temperature (upper panel) and salinity (lower panel) at 150m depth based on monthly observations in 2015 sampled approx. 10km off Torungen lighthouse near Arendal, representing AW in the Skagerrak. The long-term mean (thin solid line) and the standard deviation (dotted lines) are based on measurements sampled between 1981 and 2010.

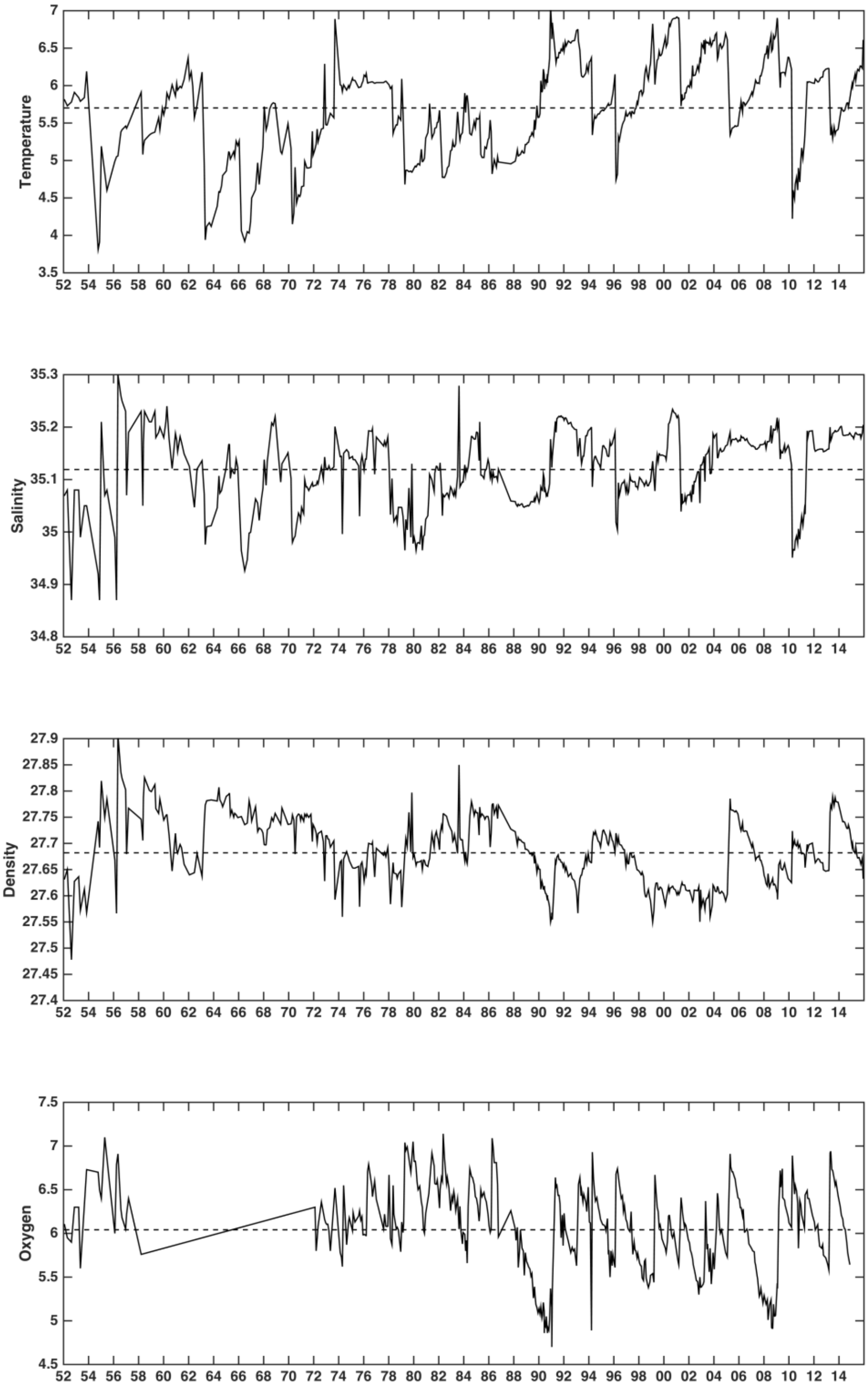

Fig. 13. Temperature (^{o}C), salinity, density (σ_t in kg/m^3) and oxygen (ml/l) at 600m depth in the Skagerrak Basin from 1952 to 2015. This location depicts the physical environment in the Skagerrak bottom water.

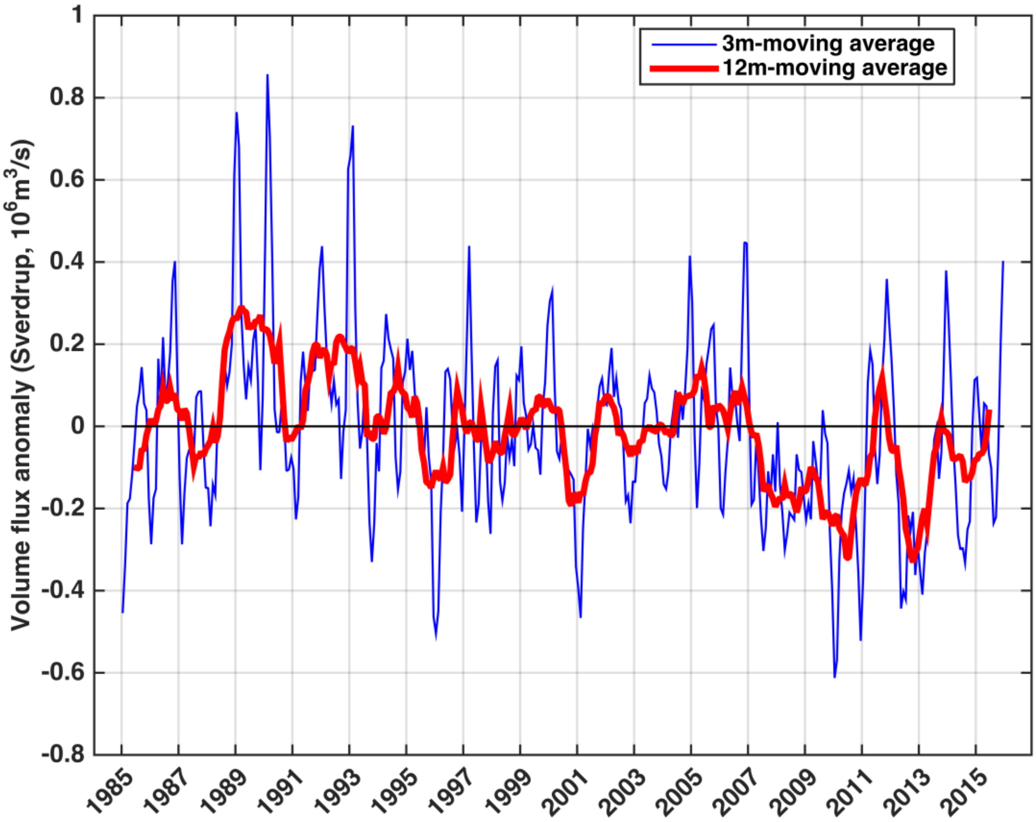

Fig. 14. Time series (1985-2015) of modelled monthly mean volume transport anomalies of AW into the northern and central North Sea southward between the Orkney Islands and Utsira, Norway. The vertical axis denotes transport anomaly in Sv ($10^6 m^3 s^{-1}$). The anomalies are calculated from the reference period 1985-2010. The blue and red line displays the 3 and 12 months running average, respectively.

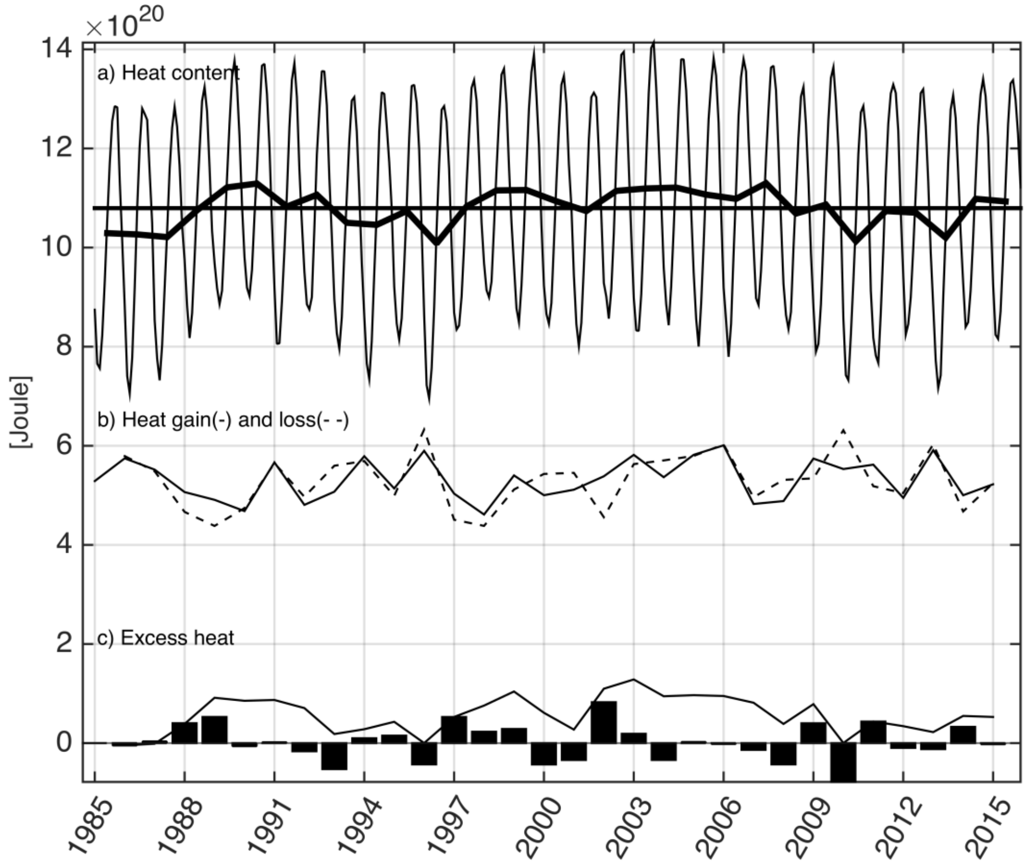

Fig. 15. a) Modelled North Sea heat content for the period 1985-2015. Monthly (thin line) and annual (thick line) values are shown. b) Heat gain (solid) and loss (dashed line). Heat gain is defined as difference between heat content maximum (in August or September) and minimum (in February or March) 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 winter heat loss is less than the summer heating.

Annex 12:

Regional report –
Russian standard sections in the Barents Sea, 2015
(Area 11)

Russian standard sections in the Barents Sea, 2015

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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 2015 was 1 182 including 220 stations at the standard sections.

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

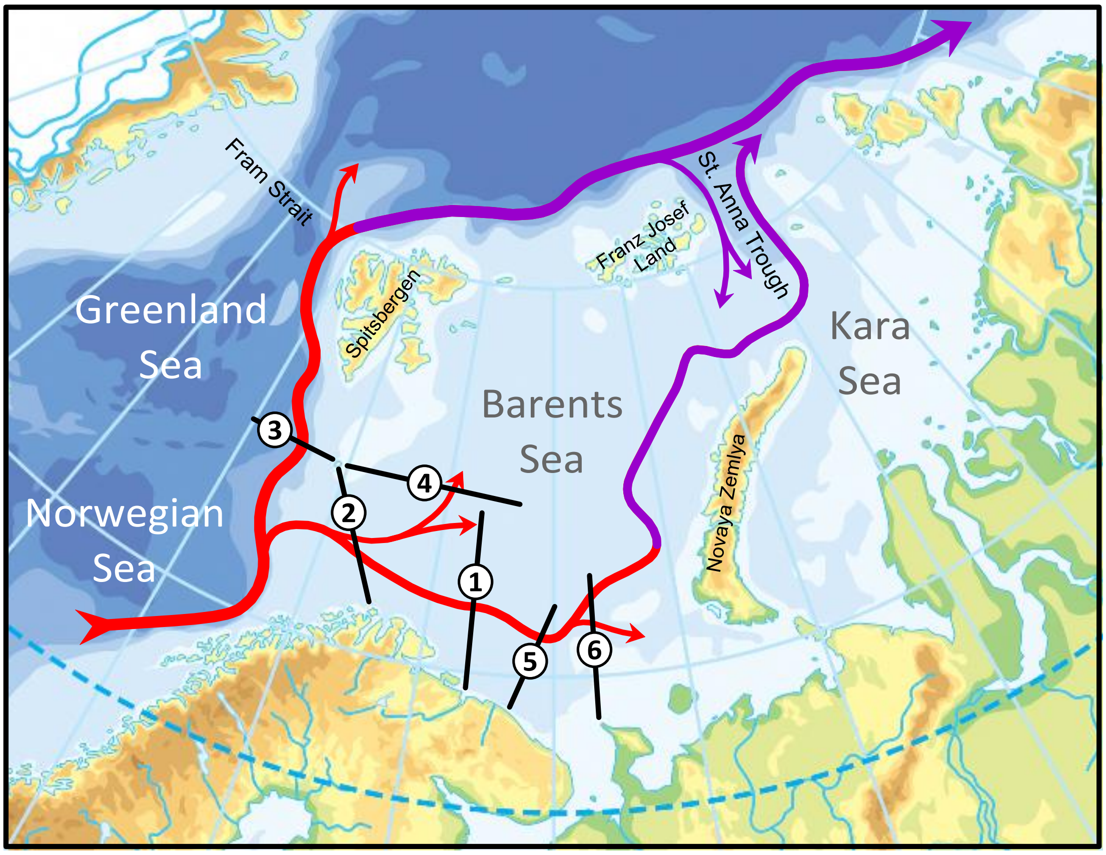

Figure 1. Main Russian standard sections in the Barents Sea: Kola (1), North Cape – Bear Island (2), Bear Island – West (3), Bear Island – East (4), Kharlov (5), Kanin (6).

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 1 150 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 2015, positive air temperature anomalies prevailed in the Barents Sea. The largest positive anomalies (3.0°C in the west, 5.6°C in the east) were found in March. Small negative anomalies were only observed in the western part of the sea in July and in the eastern part in January and July.

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 2015, positive SST anomalies prevailed in the Barents Sea. In the western part of the sea, the positive anomalies were not high (0.1–0.7°C), whereas in the eastern Barents Sea, they were higher (0.8–2.2°C) with the largest values (2.0–2.2°C) in summer. Only in January and February, the SST in the east was close to the average.

At the end of 2014 and beginning of 2015, meteorological conditions over the Barents Sea resulted in increasing the sea ice coverage. In 2015, the seasonal maximum of ice coverage took place in February (two months earlier than usual). Melting started in March. In April, the ice coverage of the Barents Sea (expressed as a percentage of the sea area) was 25% lower than normal and 14% lower than in 2014 (Fig. 2). From August to October, there was no ice in the Barents Sea. In autumn, freezing started in the northern Barents Sea at the end of October, when ice appeared around the Franz Josef Land Archipelago. In October, the ice coverage was 1% that was 14% less than usual and 12% less than in 2014. In November and December, the ice coverage was less than both the average and that in 2014 by more than 20%.

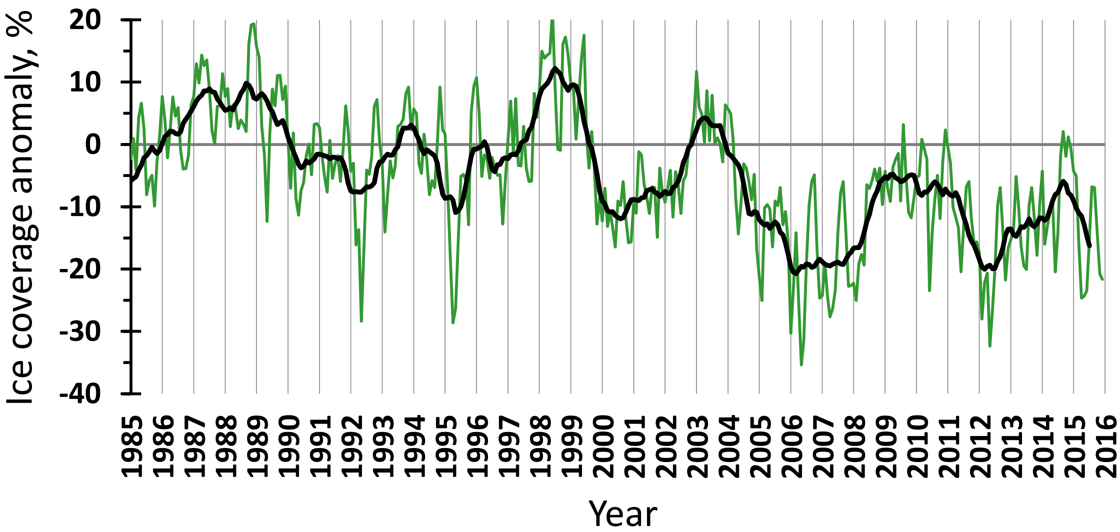

Figure 2. Ice coverage anomalies in the Barents Sea in 1985–2015. The green line shows monthly values, the black one – 11-month running means (Anon., 2016).

According to observations along the Kola Section sampled 8 times in 2015, Atlantic and coastal waters in the 0–200 m layer had positive temperature anomalies increasing during the first half of the year from 0.4–0.8°C in January–February to 1.1–1.3°C in May–June (Fig. 3). During the second half of the year, the anomalies remained high and were close to or more than 1°C. Some increase in temperature anomalies took place in autumn due to westerly winds in September–October. Compared to 2014, the Atlantic and coastal waters were warmer from April–May until the end of 2015. It should be mentioned that, in some months, the coastal (June–September and November) and Atlantic (September–December) waters had the highest positive anomalies since 1951.

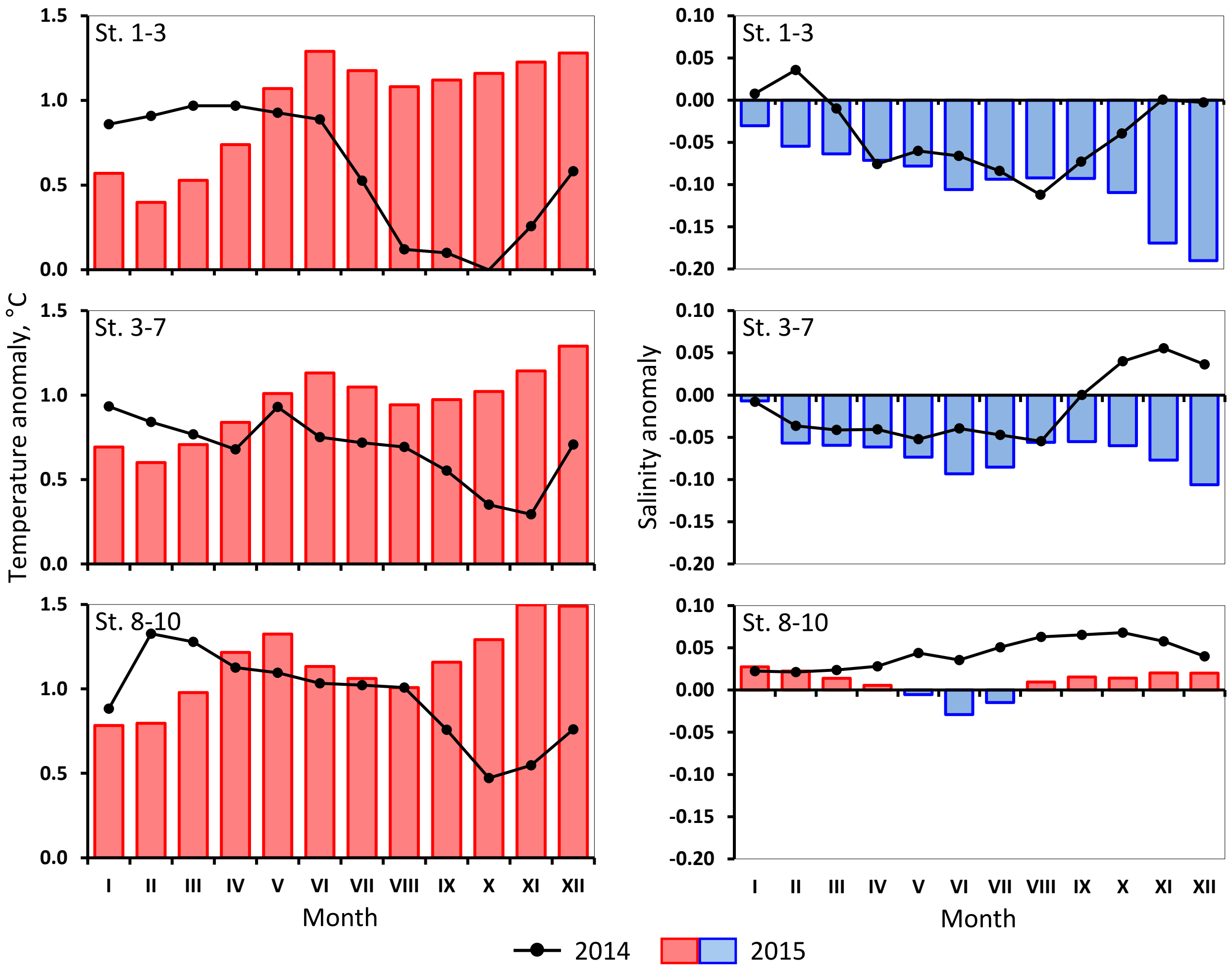

Figure 3. Monthly mean temperature (left) and salinity (right) anomalies in the 0–200 m layer in the Kola Section in 2014 and 2015. St. 1–3 – Coastal waters, St. 3–7 – Murman Current, St. 8–10 – Central branch of the North Cape Current (Anon., 2016).

In 2015, the salinity of the coastal and Atlantic waters in the Kola Section was lower than in 2014 (see Fig. 3). The coastal waters were much fresher than normal with negative salinity anomalies increasing over the year up to –0.2 in December. Throughout 2015, the Atlantic water salinity was lower than the average in the central part of the section but close to normal in the outer part of it.

On the whole, the 2015 annual mean temperature of Atlantic waters in the 0–200 m layer in the Kola Section was typical of anomalously warm years and 0.2–0.3°C higher than in 2014 (Fig. 4). The 2015 annual mean salinity of Atlantic waters in the 0–200 m layer in the Kola Section was 0.03–0.05 lower compared to 2014; it was 0.07 lower than normal in the Murman Current and close to the average in the outer part of the section (see Fig. 4).

Besides the Kola Section, some other sections were occupied in the Barents Sea in 2015.

The North Cape – Bear Island Section was sampled in April, June and October. Positive temperature anomalies in the 0–200 m layer in the North Cape Current amounted 1.0°C in April, 1.3°C in June and 1.1°C in October.

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 0.6°C above normal.

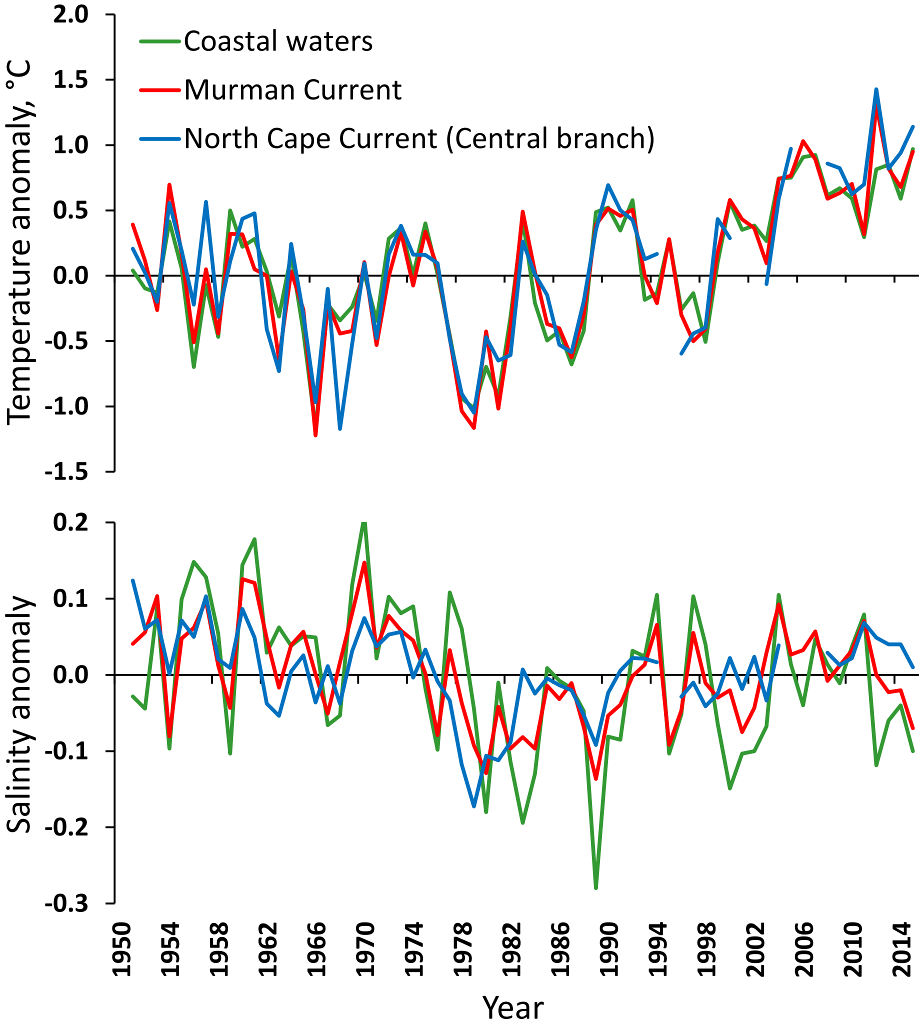

Figure 4. Annual mean temperature (top) and salinity (bottom) anomalies in the 0–200 m layer in the Kola Section in 1951–2015. Coastal waters – St. 1–3, Murman Current – St. 3–7, Central branch of the North Cape Current – St. 8–10 (Anon., 2016).

The Bear Island – East Section (along 74°30'N) was sampled in May and October. 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 1.4°C in May and 1.3°C in October.

The Kharlov Section was occupied in June and December. Positive temperature anomalies in the 0–200 m layer in the Murman Current were 1.5°C in June and 1.4°C in December.

The Kanin Section (along 43°15'E) located in the eastern Barents Sea was sampled in September and December. Positive temperature anomalies in the 0–200 m layer in the Novaya Zemlya Current (71°00'–71°40'N, 43°15'E) increased from 1.3°C in September to 1.6°C in December.

In August–September 2015, the joint Norwegian-Russian ecosystem survey was carried out in the Barents Sea. The surface temperature was on average 1.2°C higher than the long-term mean for the period 1931–2010 almost all over the Barents Sea (Fig. 5). Overall, positive temperature anomalies were increasing from west to east. Negative anomalies (–0.4°C on average) occupied under 10% of the surveyed area and were mostly found south and south-east of the Spitsbergen Archipelago. Compared to 2014, the surface temperature was much higher (by 1.3°C on average) in most of the Barents Sea (about three quarters of the surveyed area), especially in the north-eastern part of the sea. The surface waters were on average 1.0°C colder than in 2014 only in some places in the south-eastern and western Barents Sea, especially south of the Spitsbergen Archipelago.

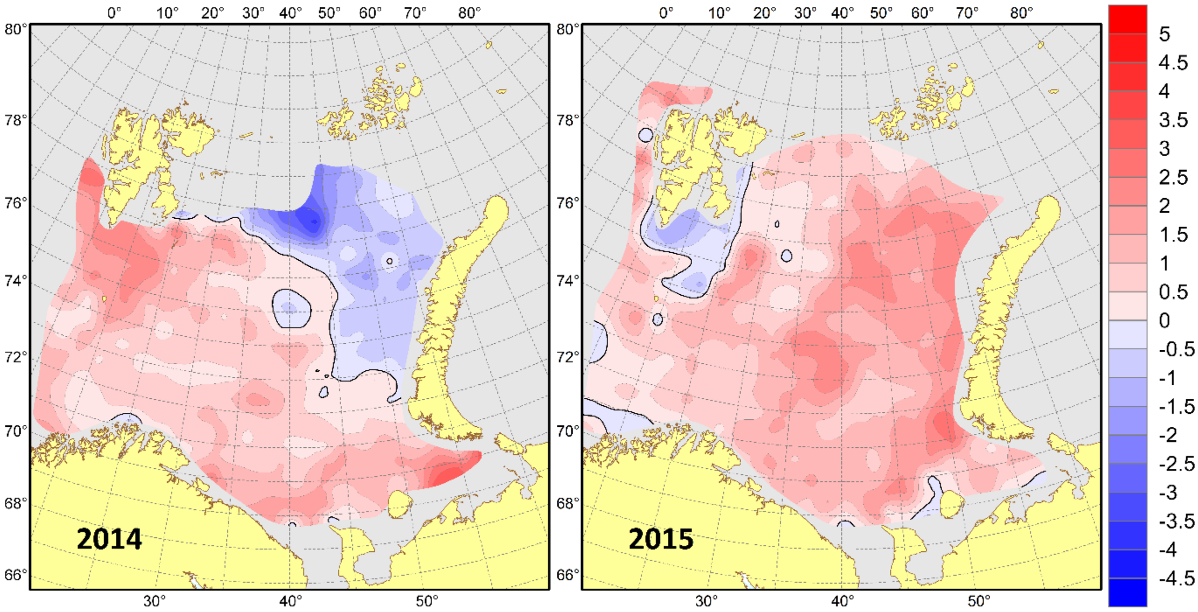

Figure 5. Surface temperature anomalies (°C) in August–September 2014 and 2015.

Arctic waters were, as usual, most dominant in the 50–100 m layer north of 77°N. The temperatures at depths of 50 and 100 m were mainly higher than the long-term mean (on average, by 1.2 and 1.0°C respectively) nearly all over the Barents Sea (Fig. 6). Small negative anomalies (–0.3°C on average) were found in some small areas in the northern part of the sea, especially right south and east of the Spitsbergen Archipelago. Compared to 2014, the 50 and 100 m temperatures were higher (on average, by 0.8 and 0.6°C respectively) in most of the Barents Sea (three quarters of the surveyed area). Negative differences in temperature between 2015 and 2014, changing with depth, on average, from –0.6°C at 50 m to –0.3°C at 100 m, took place in some areas in the central, south-eastern and north-western Barents Sea, especially south and south-east of the Spitsbergen Archipelago.

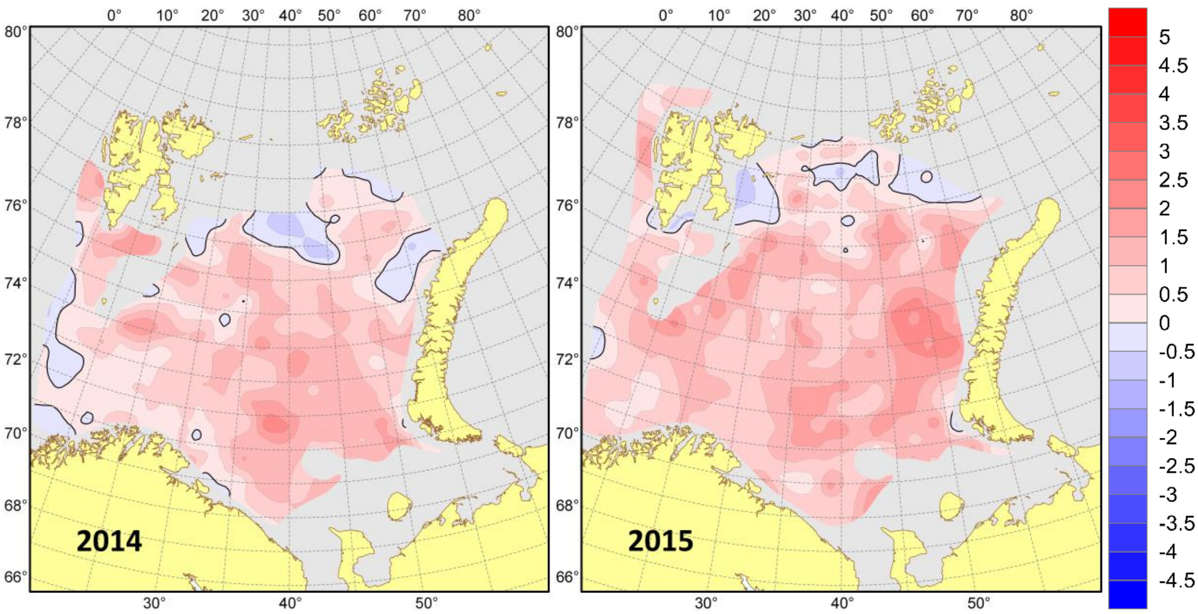

Figure 6. Temperature anomalies (°C) at 100 m in August–September 2014 and 2015.

The bottom temperature was in general 0.9°C above the average throughout the Barents Sea (Fig. 7). Negative anomalies (–0.6°C on average) occupied under 10% of the surveyed area and were mainly found in the north-western part of the sea, especially south and east of the Spitsbergen Archipelago. Compared to 2014, the bottom temperature was in general 0.5°C higher in most of the Barents Sea (two thirds of the surveyed area). Negative differences in temperature between 2015 and 2014 were on average –0.4°C and took place in some small areas of the sea, especially south and south-east of the Spitsbergen Archipelago.

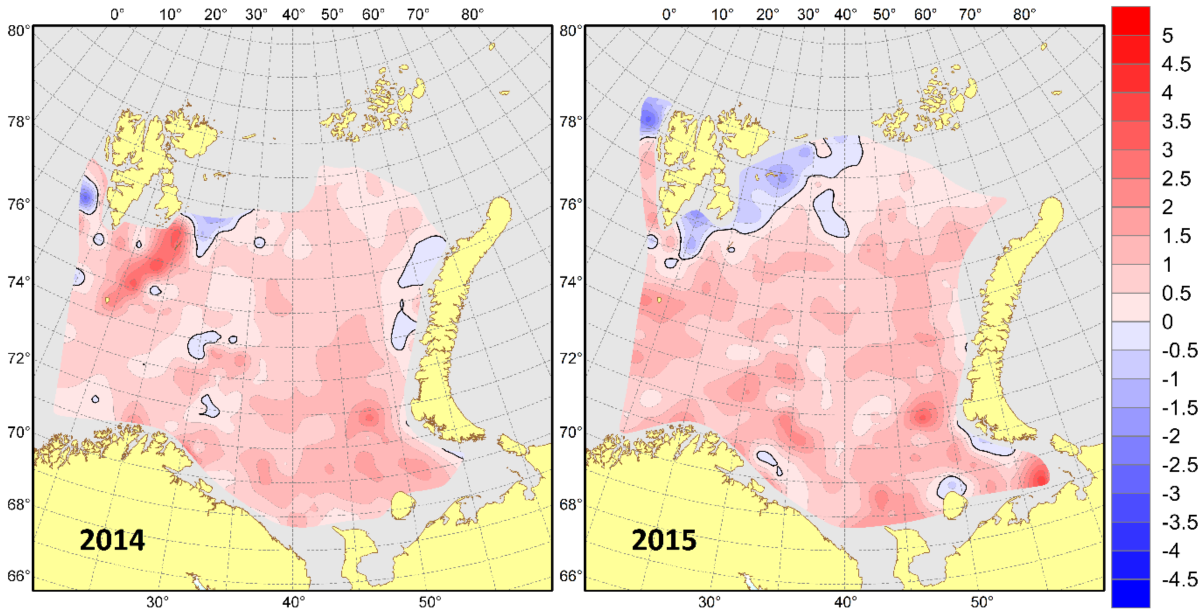

Figure 7. Bottom temperature anomalies (°C) in August–September 2014 and 2015.

In 2015, at 50 and 100 m as well as near the bottom, the area occupied by water with temperatures below zero was less than in the previous two years, whereas the area of warm water was larger (Fig. 8–10).

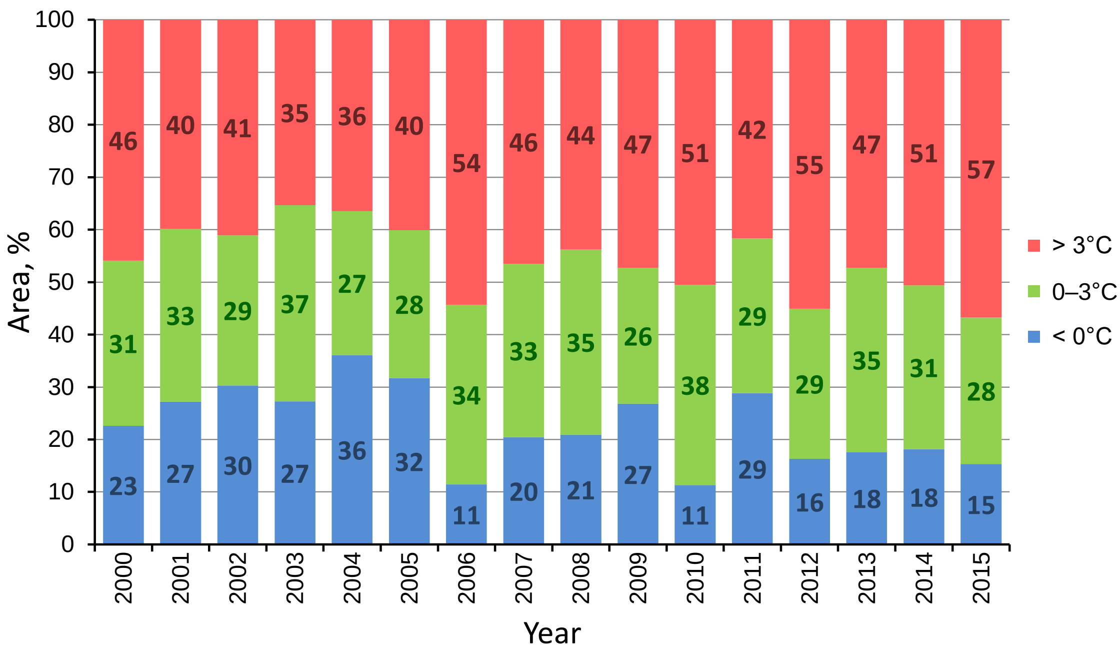

Figure 8. Areas covered by water with different temperatures at 50 m in August–September 2000–2015 (69–80°N, 20–60°E).

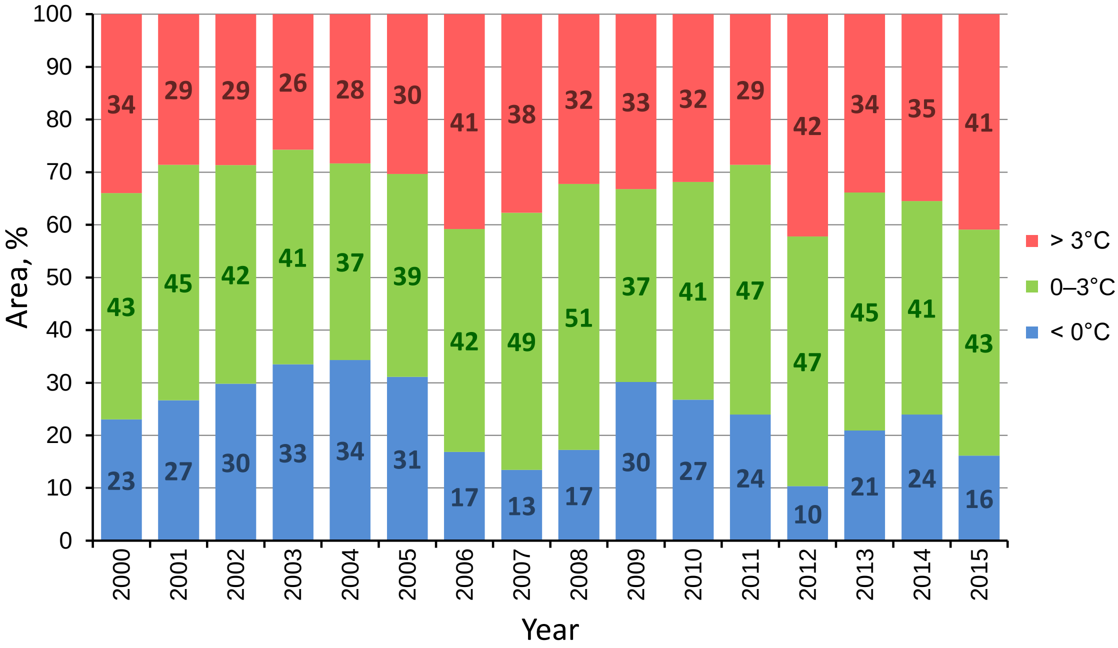

Figure 9. Areas covered by water with different temperatures at 100 m in August–September 2000–2015 (69–80°N, 20–60°E).

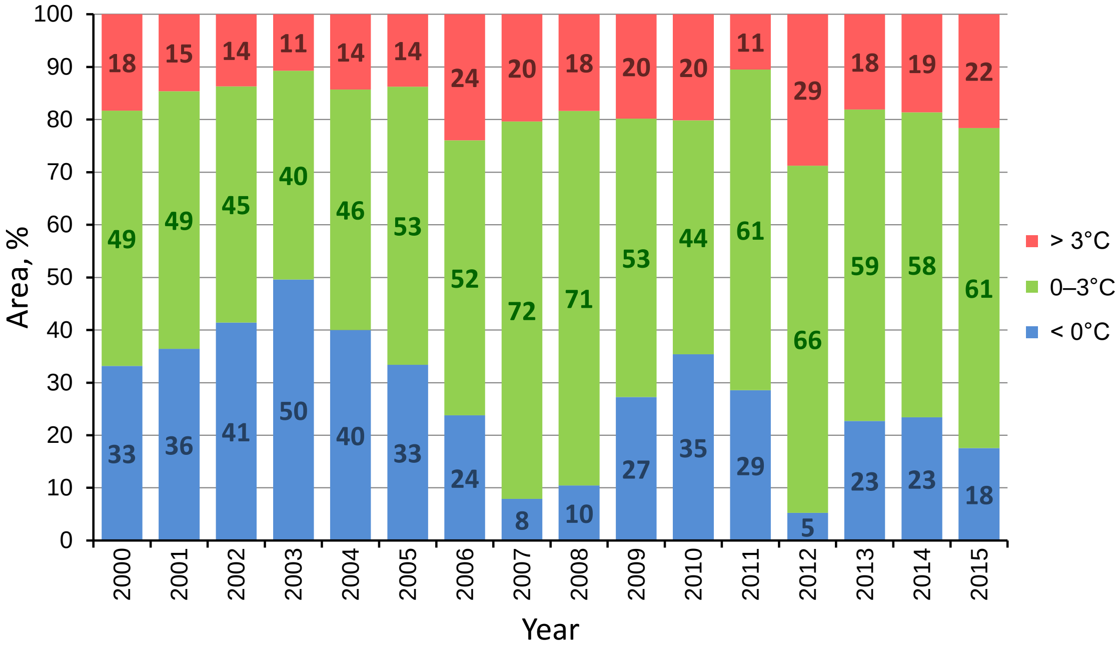

Figure 10. Areas covered by water with different temperatures near the bottom in August–September 2000–2015 (69–80°N, 20–60°E).

The surface salinity in August–September 2015 was on average 0.4 higher than both the long-term mean (1931–2010) and that in the previous year in most of the Barents Sea with the largest positive anomalies (>0.5) mainly north of 76°N (Fig. 11). The largest positive differences (>1.5) in salinity between 2015 and 2014 took place north of 77°N and resulted from different ice conditions in these two years: in summer 2014, drift ice was located much further south and resulted in much fresher surface waters in this area. Negative anomalies were found in the south-western and south-eastern parts of the sea as well as south and south-west of the Spitsbergen Archipelago. In August–September 2015, the surface waters were fresher compared to 2014 west and south-west of the Novaya Zemlya Archipelago as well as in the western Barents Sea, especially south and south-west of the Spitsbergen Archipelago.

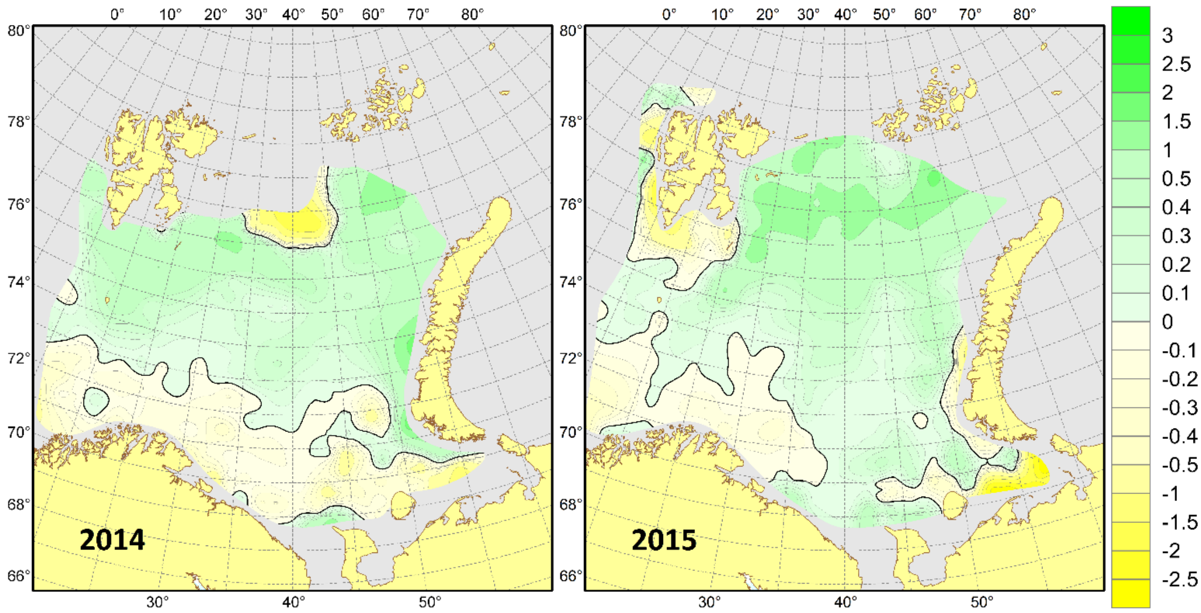

Figure 11. Surface salinity anomalies in August–September 2014 and 2015.

The salinity at depths of 50 and 100 m was higher than the long-term mean (on average, by 0.1) in more than 80% of the surveyed area (Fig. 12). Small negative anomalies were only observed in some areas in the southern and south-western Barents Sea. Positive and negative differences in salinity between 2015 and 2014 covered almost equal areas at these depths. The largest differences were at 50 m, and they decreased with depth down to negligible values at 200 m.

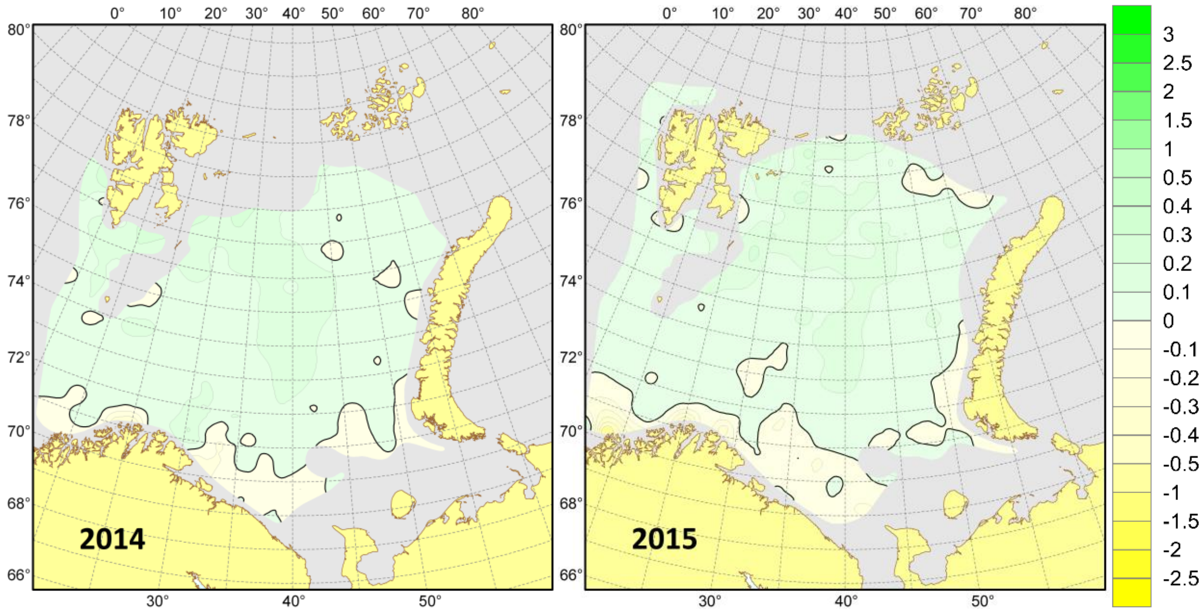

Figure 12. Salinity anomalies at 100 m in August–September 2014 and 2015.

The bottom salinity was close to that in 2014 and slightly higher than the long-term mean (by up to 0.1) in more than three quarters of the surveyed area (Fig. 13). Negative anomalies were mainly found in some areas in the south-western and south-eastern Barents Sea as well as in shallow waters in the north-western part of the sea. Relatively large differences (more than 0.1) in salinity between 2015 and 2014 were only found in shallow waters between Bear and Hopen Islands (negative values) and in the south-eastern Barents Sea (positive values).

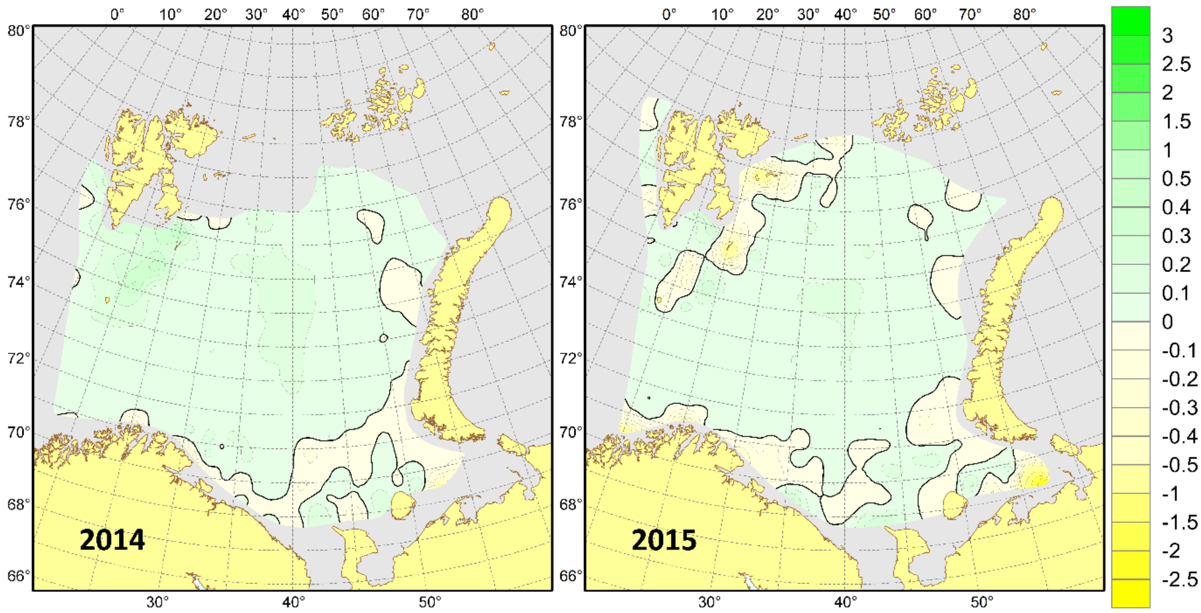

Figure 13. Bottom salinity anomalies in August–September 2014 and 2015.

In summary, the air and water temperature in the Barents Sea in 2015 was higher than average and compared to 2014. The mean annual temperature of Atlantic and coastal waters in the Kola Section was typical of anomalously warm years and 0.2–0.4°C higher than in 2014; Atlantic water temperature in September–December was the highest since 1951. The mean annual salinity in the Kola Section was lower than in 2014, and its anomaly changed from –0.10 in the coastal waters to 0.01 in Atlantic waters in the outer part of the section. In autumn 2015, the area covered by cold water was smaller than in the previous two years. In 2015, the ice coverage of the Barents Sea was lower than average and compared to 2014; there was no ice in the sea in summer 2015. The seasonal maximum of ice coverage took place in February (two months earlier than usual).

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Annex 13:

Regional report –
France: Argo data (North Atlantic)
and South Western Channel, 2015
(Area 4b)

Laboratoire d'Océanographie Physique et Spatiale
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Contribution to the ICES Working Group on Oceanic Hydrography

National report: France, Juin 2016

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Rapport : LOPS-WGOH-2016-01

Summary

1 Argo gridded temperature and salinity field

The ARGO network of profiling floats has been set up to monitor the large-scale global ocean variability (http://www.argo.ucsd.edu/). Argo data are transmitted in real time and hastily made available by the two Global Data Assembly Centres (Argo-GDAC). Delayed mode data undergo expert calibration processes and are delivered later. In the North Atlantic, the temperature and salinity conditions of the upper 2000 m are adequately described since 2002. This dataset is thus suitable for an overview of the oceanographic conditions in this basin, giving the general context for the repeat stations and sections collected mostly at the periphery of the basin by the partners of the ICES Working Group on Ocean Hydrography (WGOH).

1.1 ISAS: gridded temperature and salinity fields

Temperature and salinity fields are estimated on a regular half degrees (Mercator scale) grid using the In Situ Analysis System (ISAS), (*Gaillard et al.*, 2016). The dataset is downloaded from the Coriolis Argo GDAC (http://www.coriolis.eu.org/). It should be noted that Coriolis assembles many types of data transmitted in real time, merging the ARGO data set with data collected by the GTS such as mooring data, marine animals, gliders, CTDs. However, the ARGO dataset remains the main contributor in the open ocean. The last years of the analyzed series uses the Near Real Time dataset prepared by Coriolis at the end of each month from real time data. Delayed mode data are progressively taken into account for the previous years, replacing the NRT data.

Data are pre-processed before entering the analysis. First we perform a climatological test to detect outliers then we vertically interpolate the profiles on 152 standard levels between the surface and 2000m. The analysis to produce gridded fields is performed at each standard level independently. The method is based on optimal estimation principles and includes a horizontal smoothing through specified covariance scales. The results presented here were produced with version 6 of ISAS (*Gaillard*, 2012). The reference state was computed as the mean of a 2004-2010 analysis (D2CA1S2) and the a priori variances were computed from the same dataset. The period 2002-2012 was fully reprocessed to take into account new delayed mode data and flags. Near-Real Time (NRT) temperature and salinity fields provided by Coriolis Center (Ifremer) are used to complete the time series from 2013 to 2015. Over this period, data are interpolated using ISAS v6 including only Real Time mode data (i.e. only from automatic QC processing).

1.2 Surface layers

During winter 2015, the near surface waters were anomalously cold and fresh in the middle of subpolare gyre. The cold temperatures in the Labrador Sea were associated with a strengthening of North-easterly winds (Fig. 1). Further South, waters were extremely warm and salty in the western basin south of 40°N, indicating a northward shift of the Gulf Stream. A warmer than normal subtropcial gyre is also observed.

This subpolar cold anomaly persistes and increases troughout the year 2015 (Fig. 1). Summer 2015 has been anomalously cold over most of the subpolar basin, north of 40°N. South of 40°N, a strong warm anomaly is persistent over the whole subtropical gyre.

During summer fresh salinity anomalies north of 40°N is also more intense than during the winter period and correlated with temperature anomalies. Waters were very salty in the Greenland Sea/Norvegian Sea and along the East Greenland coast. They were fresh along the western boundary: starting from the West Greenland coast, following the North American coast and from there, extending toward the west.

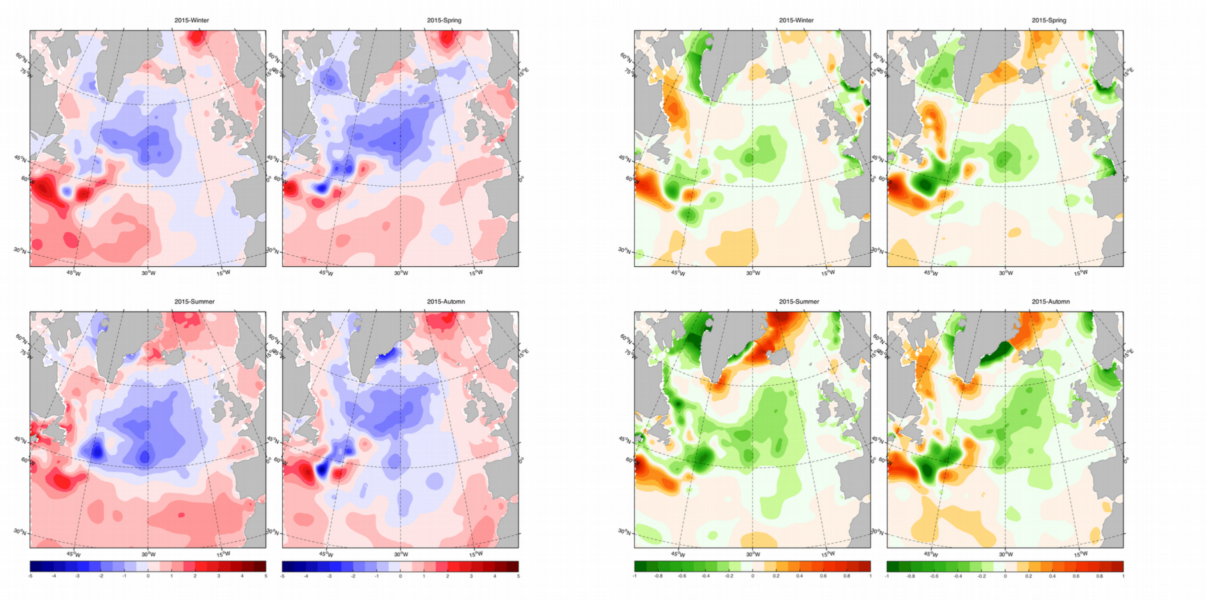
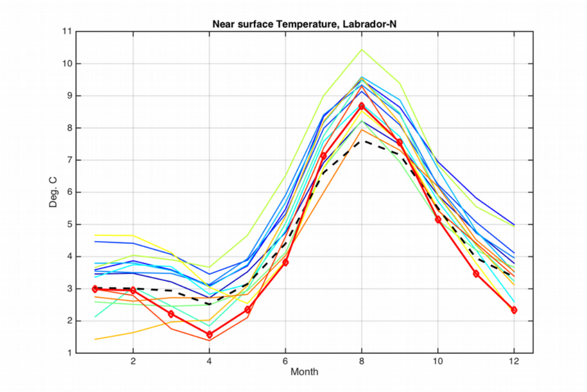
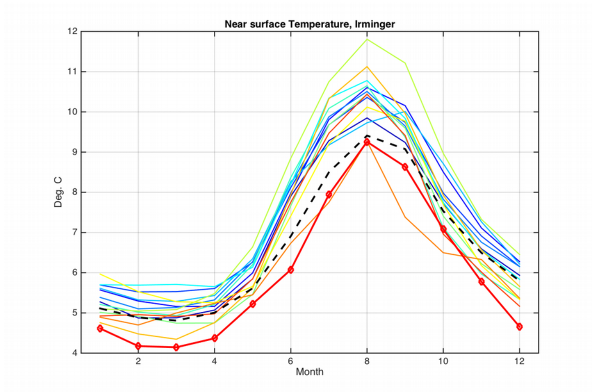


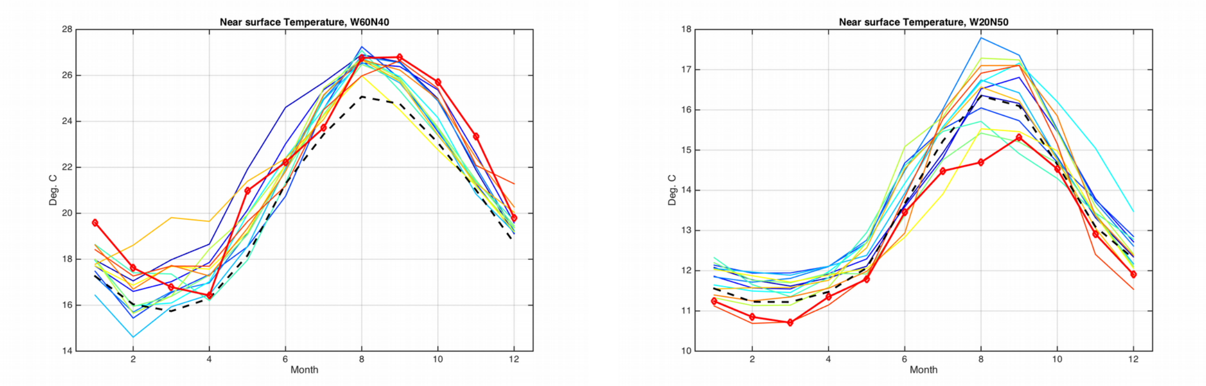
Figure 1: Near surface (10 meter) temperature (left) and salinity (right) averaged over Winter (JFM), Spring (AMJ), Summer (JAS) and Autumn (OND) 2015. The anomalies are shown relative to the World Ocean Atlas (WOA-05).



a)

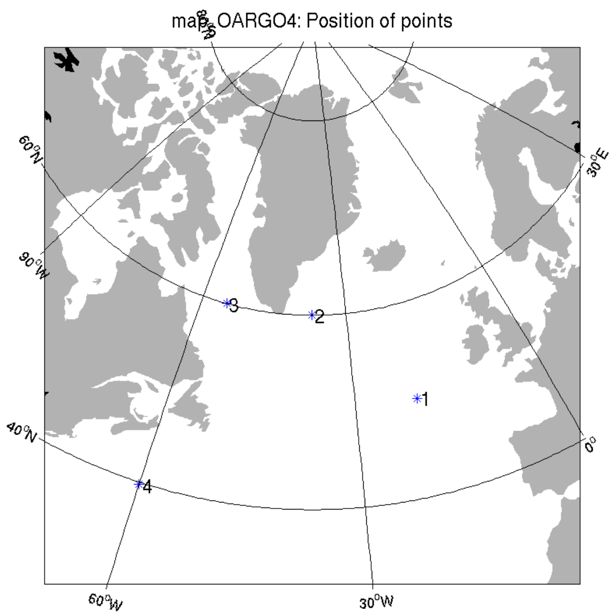


b)



c) d)

Figure 2: Seasonal cycle for temperature at 4 points in the North Atlantic basin (see the map below). In heavy red the year 2015, in dashed black the WOA05 climatology, other curves show the years 2002-2014.



The year 2015 appears as an extremum in the 2002-2015 decade for the cold winter observed in the Labrador Sea and the Irminger Sea, (Fig. 2ab) where temperatures went well below the climatological mean (nearly 2° lower in the Irminger Sea) and the warm temperature in early winter in the south-west part of the basin (Fig. 2c). North of 40°N, the cold temperatures persists during the summer especially in the Irminger Sea and in the Eastern basin off European coasts (Fig. 2bd). In contrast, the warm summer that extends south of 40°N shows extrem values in the Eastern basin (Fig. 2c).

Winter surface conditions determine the mixed layer properties. In order to compare all areas over the decade, we adopt a simple definition for the mixed layer depth, using the level at which temperature changes by more than 0.5°C with respect to the 10 meter depth. The month of February is selected as the common period for maximum mixed layer depth. This is not perfectly true since the time of the deepest mixed layer may vary from year to year at a single location and does not occur at the same time over the whole basin.

During the year 2015 the area covered by a deep mixed layer (deeper than 900 m) is more extended than usual in the North of the basin (even more than during the 5 previous winters since 2010), extending from the Labrador Sea to the Irminger Sea (Fig. 3). This deeper than usual mixed layer may reflect strong winter convection in both Labrador and Irminger basin. Unusual deep mixed layer is also observed in the eastern side of the basin off Scotland and Ireland coasts. In the South-East of the basin, the deep mixed layer extension stops around 48/50°N such that only moderate mixed layer depths are observed along the shelf in the Bay of Biscay contrary to the 2009, 2010 and 2011 winters. Note that the deep mixed layer anomaly centered at 45°N-20°W in 2014 is likely an artifact due to Near Real Time data in use of this period. Additional quality control and analysis is needed for this period.

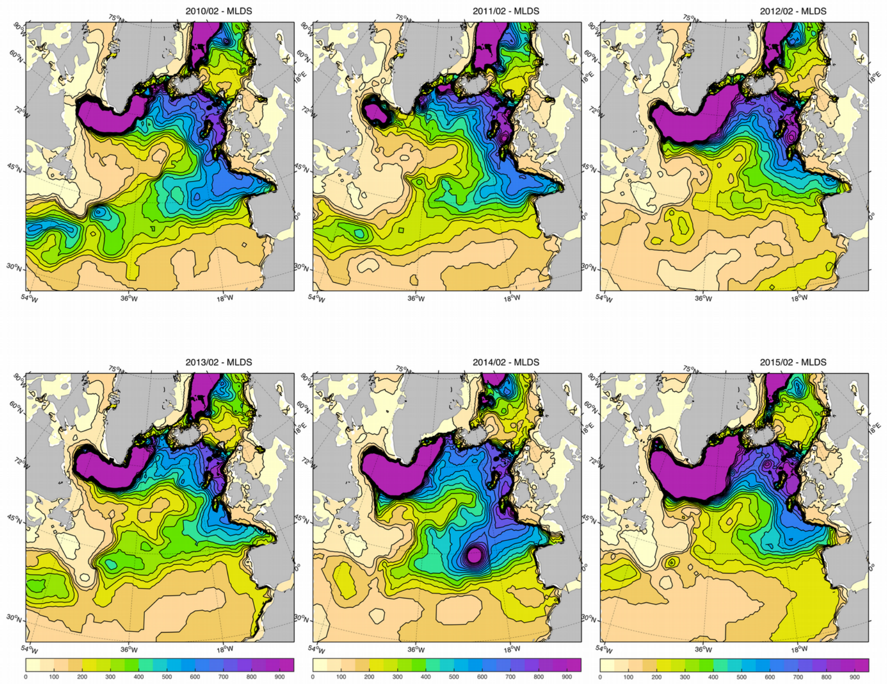
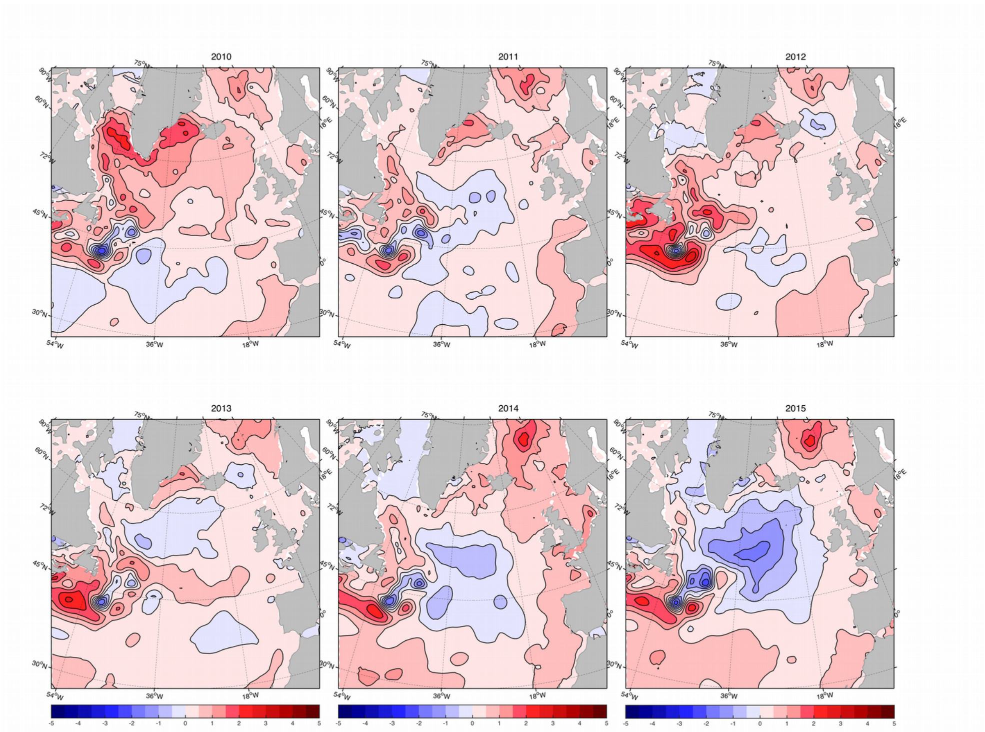


Figure 3: North Atlantic mixed layer depth in February from 2010 to 2015. The mixed layer is defined as the depth at which the temperature has decreased by more than 0.5° from the temperature at 10 m. This criterion is not suitable for areas of salinity compensation or very week stratification.

The most salient feature of the 2015 annual mean temperature is an intense cold anomaly (persistant and increasing since 2013) over the subpolar basin from the tip of Greenland to 40°N and the persistence of a moderately warm anomaly over the Greenland Sea and along the East Greenland coast (Fig. 4a).

Since 2013, the structure of the salinity anomaly appears correlated with the temperature anomalies with cold/fresh anomaly in the subpolare gyreand the Labrador Sea (Fig. 4b); and warm/salty anomaly over the Greenland Sea. In 2015, the most remarkable feature is the large cold/fresh anomaly, 2°C/0.2 pss below the ‘normal’ WOA05 conditions, is observed in the subpolar gyre and Labrador Sea.



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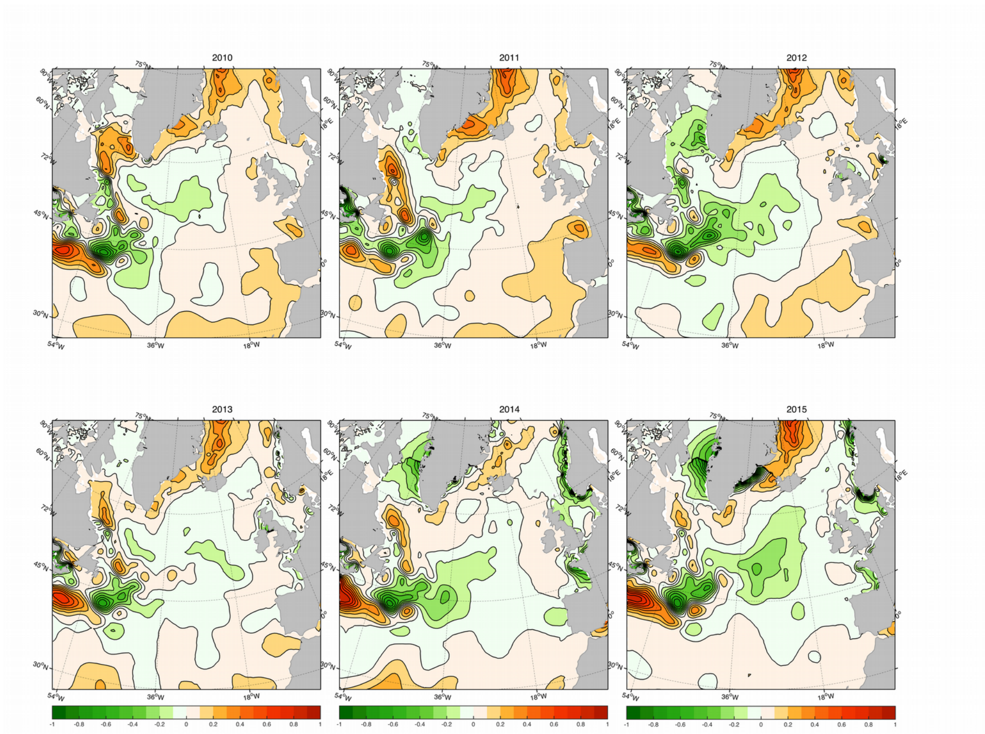
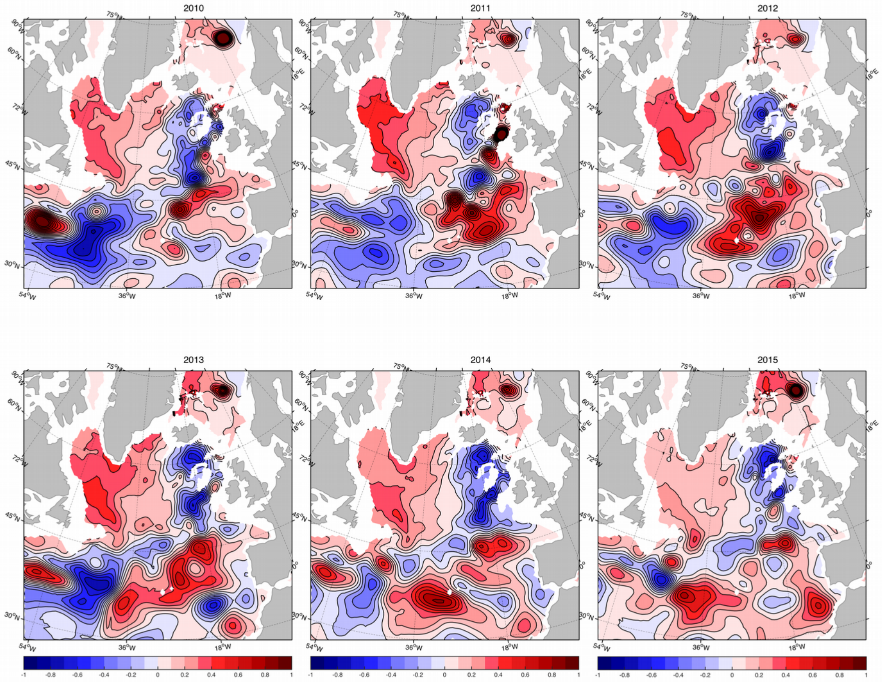


b)

Figure 4: Annual average temperature (a) and salinity (b) anomalies at 10 m during 2010-2015



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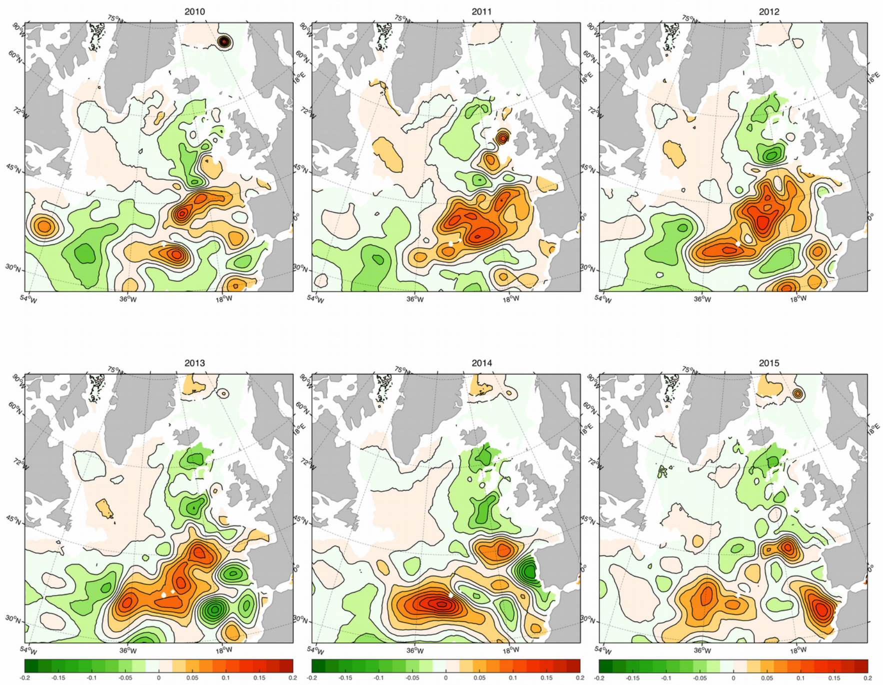


b)

Figure 5: Annual average temperature (a) and salinity (b) anomalies at 1000 m during 2010-2015.

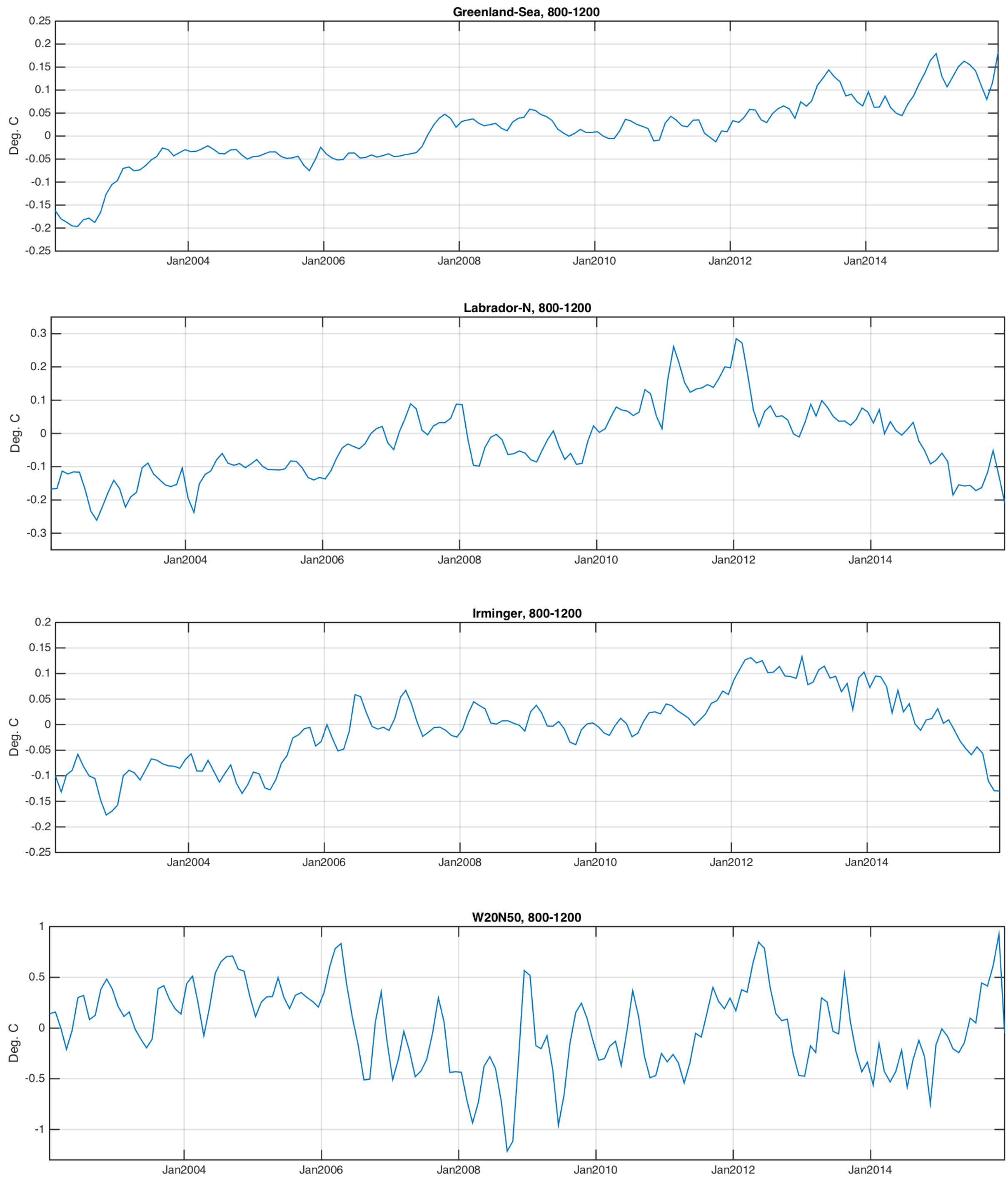


Figure 6: Time series of temperature anomalies averaged over the 800-1200m layer over 2002-2015 period.

1.3 Deep layers

At 1000 m (Fig. 5) :

- The Labrador Sea and the Irminger Sea are warmer than normal, but the warming tendency observed since 2002 is interrupted since 2012 as seen in the time series (Fig. 6). However, deep Greenland Sea keeps on warming (Fig. 6).

- The Mediterranean Outflow water seems warmer and saltier south of 40°N and off Gibraltar straight. The salt increase seems to extend over the basin.
- A cold and fresh anomaly stands from the South of Iceland down to Rockall Trough
- A warm and salty anomaly is observed south of the Gulf-Stream and Azores current (subtropical gyre).

1.4 References

Gaillard, F., 2012. ISAS-Tool Version 6: Method and configuration. Rapport LPO-12-02, http://archimer.ifremer.fr/doc/00115/22583/

Gaillard, F., T. Reynaud, V. Thierry, N. Kolodziejczyk and K. von Schukmann , 2016 : In Situ–Based Reanalysis of the Global Ocean Temperature and Salinity with ISAS: Variability of the Heat Content and Steric Height, *J. Clim.,* 29, 1305-1323.

2 Surface sampling along AX1 and AX2 (North Atlantic subpolar gyre)

The two shipping routes along which surface sampling was continued were (Fig. 7) lines AX2 (since mid-1993; in 2015, MV Skogafoss) between southern Newfoundland and Reykjavik; and AX1 (since mid-1997; in 2015, MV Nuka Arctica) between Denmark and west Greenland. Both ships were equipped with thermosalinograph and XBT launchers, and are part of a concerted multi-disciplinary effort, including the measurement of the current with a ship-ADCP on Nuka Arctica (Univ. Bergen) and pCO2 measurements on Skogafoss (NOAA/AOML) and Nuka Arctica (Univ. Bergen). Because of large sea ice extent in late winter and early spring, as well as numerous winter storms in the winter and early spring 2015, the nominal AX1 route was not often followed during these seasons. Both ships also experienced frequent failures of their water circuit resulting in loss of data from the thermosalinograph.

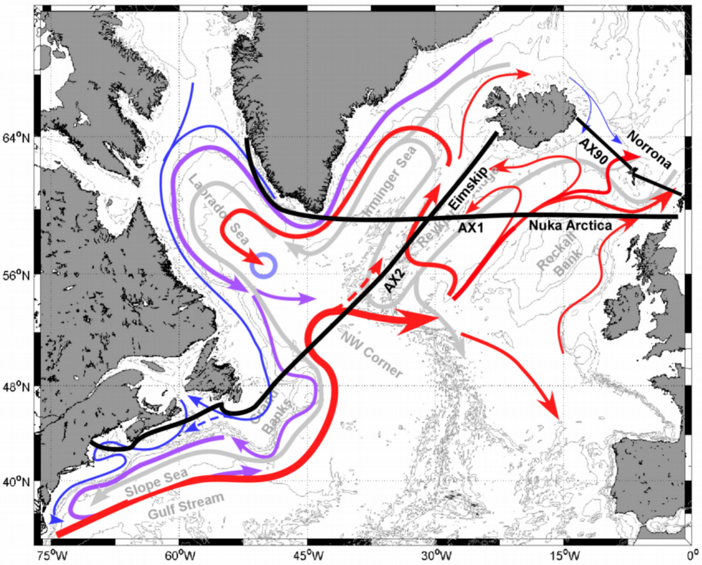


Figure 7 : AX1 and AX2 ship of opportunity lines equipped with Thermosalinograph and XBT launcher. Surface (red arrows) and deep (bleu and purple arrrow) main currents are indicated.

We present Hövmuller diagrams of SSS as a function of latitude (AX2) (Fig. 8) and longitude (AX1) (Fig. 9). For AX2, only the part of the section between the shelf break off Cape Farewell and the approaches of Scotland is presented. To complement the TSG measurements, we also use nearby ARGO 5m depth data.

We will fist comment the AX2 section (Fig. 8). In early 2015, SSS is anomalously low both on the shelf and on the region north of it until 54°N. This anomaly already seen in this region intermittently since 2011, persists until the end of 2015. Further north, the weak positive anomalies at the end of 2014 diminish or become slightly negative north of 60°N. These differences between the two regions are commonly witnessed in this time series, except in 1994-early 1996, when both experienced mostly large negative anomalies. This indicates that in 2015 there were larger meridional contrasts around 54°N, in the region separating mostly eastward flow of the southern limb of the subpolar gyre and the anticyclonic circulation around the Reykjanes Ridge (much more salty).

We will now comment the AX1 zonal section (along 59°N, the most sampled latitude band) (Fig. 9). On this section, there are rather different anomalies east of the Reykjanes Ridge in the Iceland Basin (15-30°W) and west of it (interestingly, AX2 cuts this section very close to the 0-anomaly). Since 2011, there is a negative anomaly east of Reykjanes Ridge, which became very large throughout 2015. Interestingly at 10°W or further east, anomalies were on the other hand small or slightly positive. Such patterns suggest reinforced fronts near 15°W, close to a branch of the NAC, something also noticed on the XBT sections collected by Nuka Arctica, and by Argo floats.

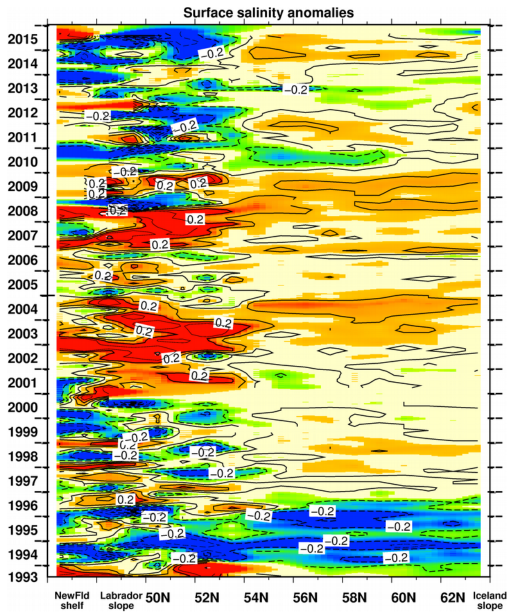


Figure 8: Monthly salinity anomalies from the Eimskip along AX2 between Reykjavik and Southern Newfoundland between 1993 and 2016.

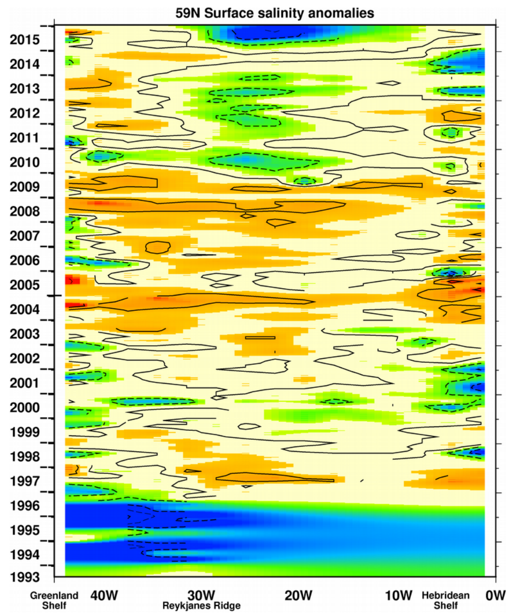


Figure 9: Monthly salinity anomalies from the Nuka Arctica along 59°N from the shelf break south-east of Cape Farewell to the north-west of Scotland between 1993 and 2016.

3 South western Channel: Astan and Estacade time series

3.1 The year 2015 vs Climatology

Here, we present measurements collected twice a month at two stations located on the north coast of Brittany in France. The Estacade site is located at the end of a pier (3°58'58°W and 48°43'56°N) (Fig. 10) in the city of Roscoff (France) where the bottom depth varies from 3 to 12 m depending on the tides. Measurements began in 1985 and are collected at 1 m depth. The Astan site (3°56'15°W; 48°46'40°N) is located 3.5 kilometers offshore from the Estacade site (Fig. 10) and measurements began in 2000. Seawater biogeochemical properties at this site are typical of the Western Channel waters. Bottom depth is about 60 m depth and the water column is well mixed for most of the year. More details can be found at http://somlit.epoc.u-bordeaux1.fr/fr/ and http://www.sb-roscoff.fr/en/coastal-observatory/marine-system-hydrological-parameters-offshore-roscoff. The Western Channel is connected to the eastern boundary current and linked to the North Atlantic drift. The climatic conditions are impacted by the westerlies blowing over the Atlantic basin which transport heat and moisture towards the Western Europe. These conditions explain the typical weather conditions observed in the Roscoff area: Winter precipitations generate intensive weathering of the soils loaded with important nutrients amounts from intensive agriculture. River discharges contribute to influence the salinity cycles and to feed the stocks of nutrients in coastal waters. Salinity of this coastal waters remained close to 35.5, a typical value of the waters adjacent to the North Atlantic Ocean. This system can be considered as a coastal system.

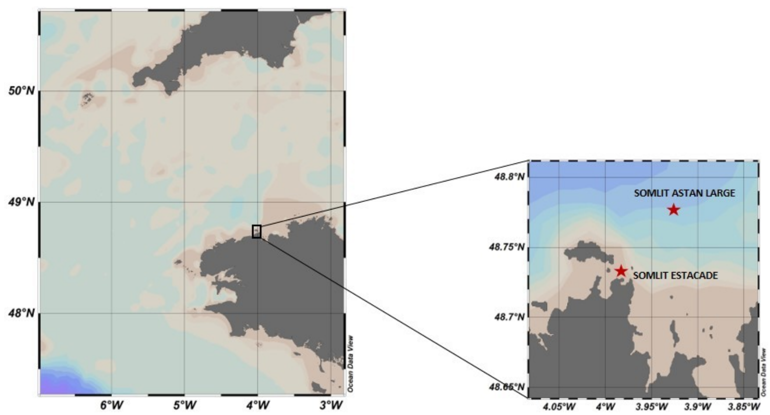
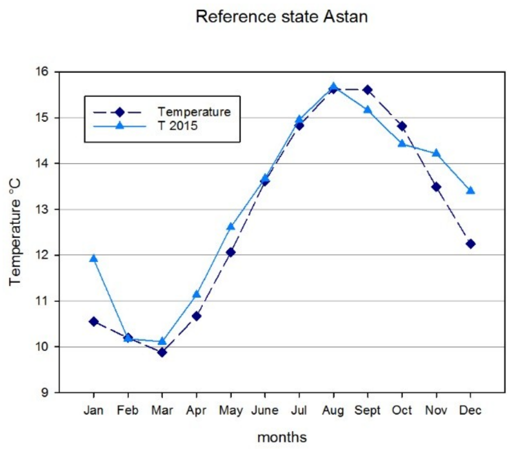


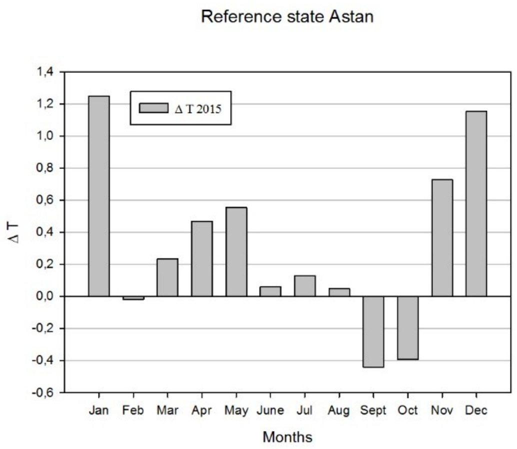
Figure 10: Localisation of Estacade and Astan large sites.

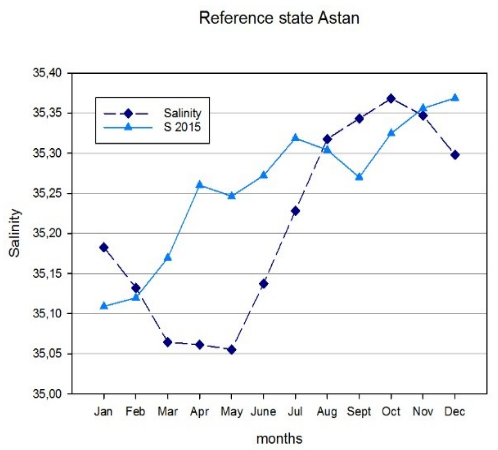
Figures 11 and 12 display the 2015 cycle of temperature, salinity and nitrate in relation to the mean annual cycle at the Astan and Estacade stations. The temperature cycles show different dynamic between the 2 studied stations: At Astan station, for the year 2015, temperatures are higher than the climatology values for the winter, spring, summer (from 1.25°C to 0.05°C) and lower for September and October (respectively -0.44 °C and -0.39°C). Temperature values become higher again in November and December (+0.73°C and +1.15°C). At Estacade station, temperatures are higher than climatology values for the winter and at the beginning of spring (from +1.58°C to +0.48°C) but become lower from June to October with a maximum deviation equal to -0.97°C in July. In the two stations, we can observe that the temperature values become suddenly higher in November and December predicting a warmer 2015-2016 winter than the global average values of this season. The annual average and global values are given in Tables 1 and 2.

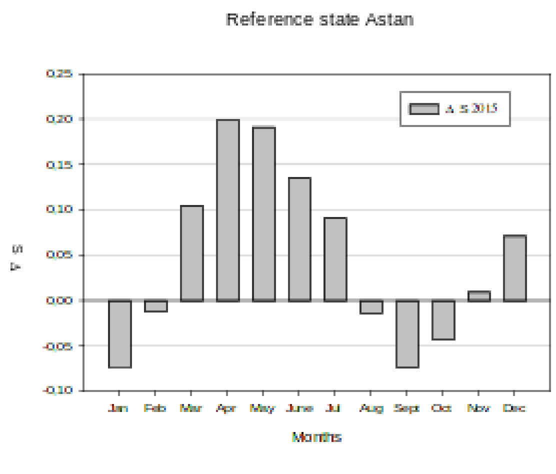
The mean Salinity cycles at the two stations are characterized by an important seasonality with minimum values in spring and maximum in fall. The salinity seasonal cycle is starts one month earlier at the Astan station compared to the Estacade station. In 2015, the salinity cycle is atypical in comparison with the global average cycle. Indeed, there are no low values in winter and spring and we can observe a constant increase all along the year (we observed a maximum deviation in salinity equal to +0.265 at Estacade and +0.199 at Astan, in April). Salinity values are just lower than the average for August, September and October. Minimum salinity values weren't observed in 2015 because of a dry winter with low water precipitations reducing the river inputs in the Western Channel. We have observed the same kind of cycle with no spring salinity low values in 2005, 2007 and 2012.

During 2015, at Astan station, nitrate concentrations were significantly lower than the averaged values excepted from August to October where they are close to the mean values. At the Estacade station, we observed a different evolution than in the Astan station. Nitrate concentrations were almost totally exhausted at Estacade contrary to Astan where the nutrients stock is spread over the well-mixed water column and not totally consumed by the phytoplankton development. The low levels of nitrate concentrations are linked to the high levels of salinity for 2015. The weaker river inputs contributed less to the nutrients supplies.









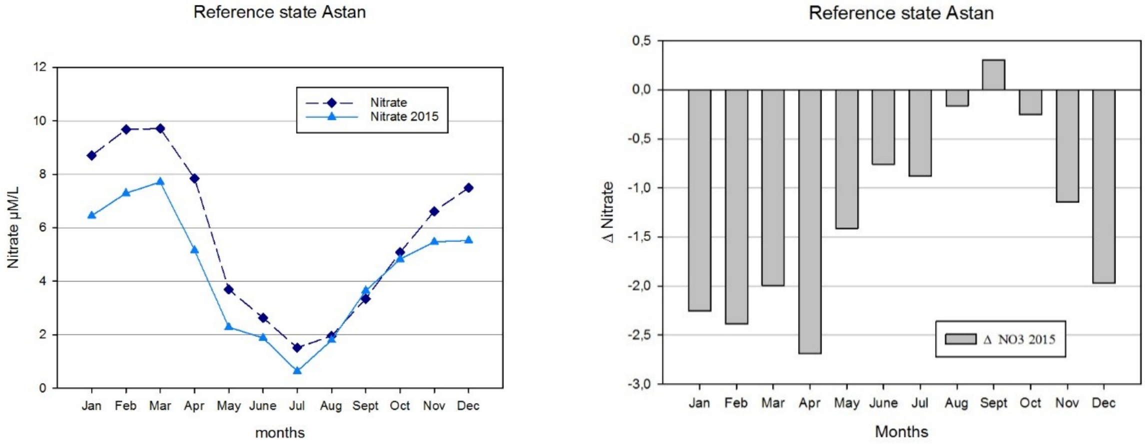
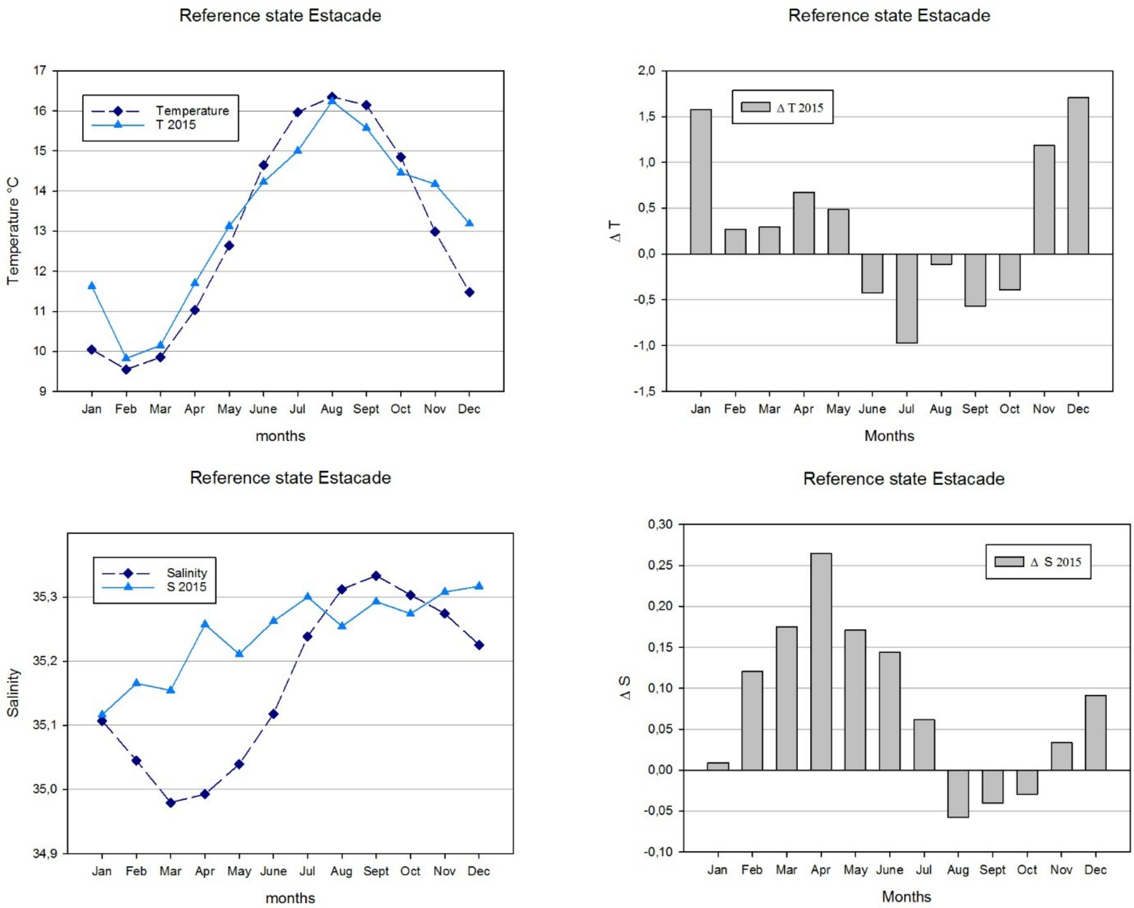


Figure 11: comparison between time series of temperature (upper), salinity (middle) and nitrate (lower) at Astan site in 2015 with the climatological cycle (average over the 2000-2015 period). (Left panels) Dark blue line represents the mean annual cycle and the light blue line represent 2015 data. (Right panels) 2015 deviation to mean values.



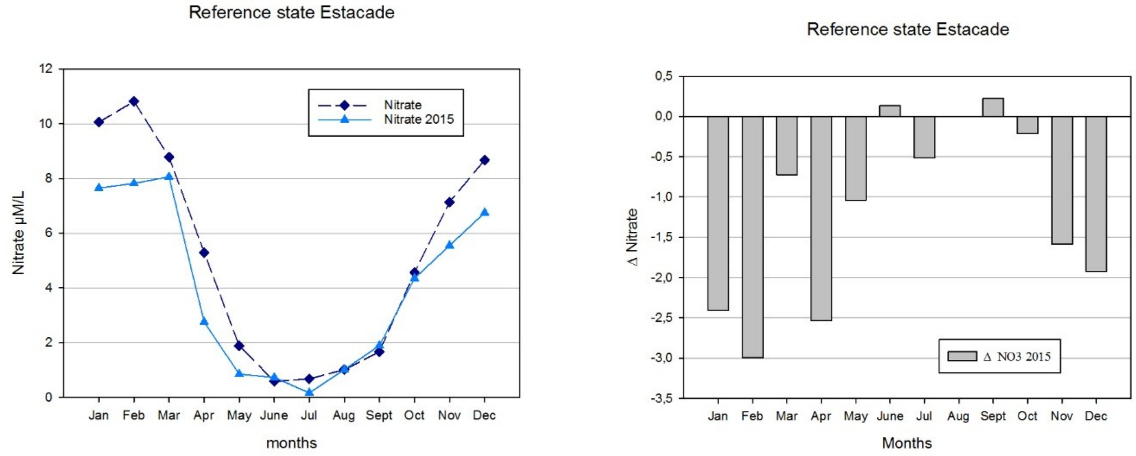


Figure 12: comparison between time series of temperature (upper), salinity (middle) and nitrate (lower) at Estacade site in 2015 with the climatological cycle (average over the 2000-2015 period). (Left panels) Dark blue line represents the mean annual cycle and the light blue line represent 2015 data. (Right panels) 2015 deviation to mean values.

Estacade	Temperature (°C)	Salinity	Nitrate (µmole/l)
Global average	12.94	35.171	5.1
2015	13.27	35.243	3.9

Table 1: Global mean for the period 1985-2015 and 2015 values at Estacade station.

Astan	Temperature (°C)	Salinity	Nitrate (µmole/l)
Global average	12.83	35.211	5.6
2015	13.12	35.260	4.4

Table 2: Global mean for the period 2000-2015 and 2015 values at Astan station.

3.2 Water column properties

As usually observed in this area, the Western Channel waters were well-mixed over the entire water column during the whole year with no significant gradient observed between the surface and the bottom (Fig. 13). The low vertical temperature gradient observed episodically in late summer (late august- early September) during low wind-neap tides period was not observed in 2015. As for temperature Western Channel waters were generally well-mixed over the entire water column since no salinity differences between surface and bottom waters were observed even during the late summer surface heating.

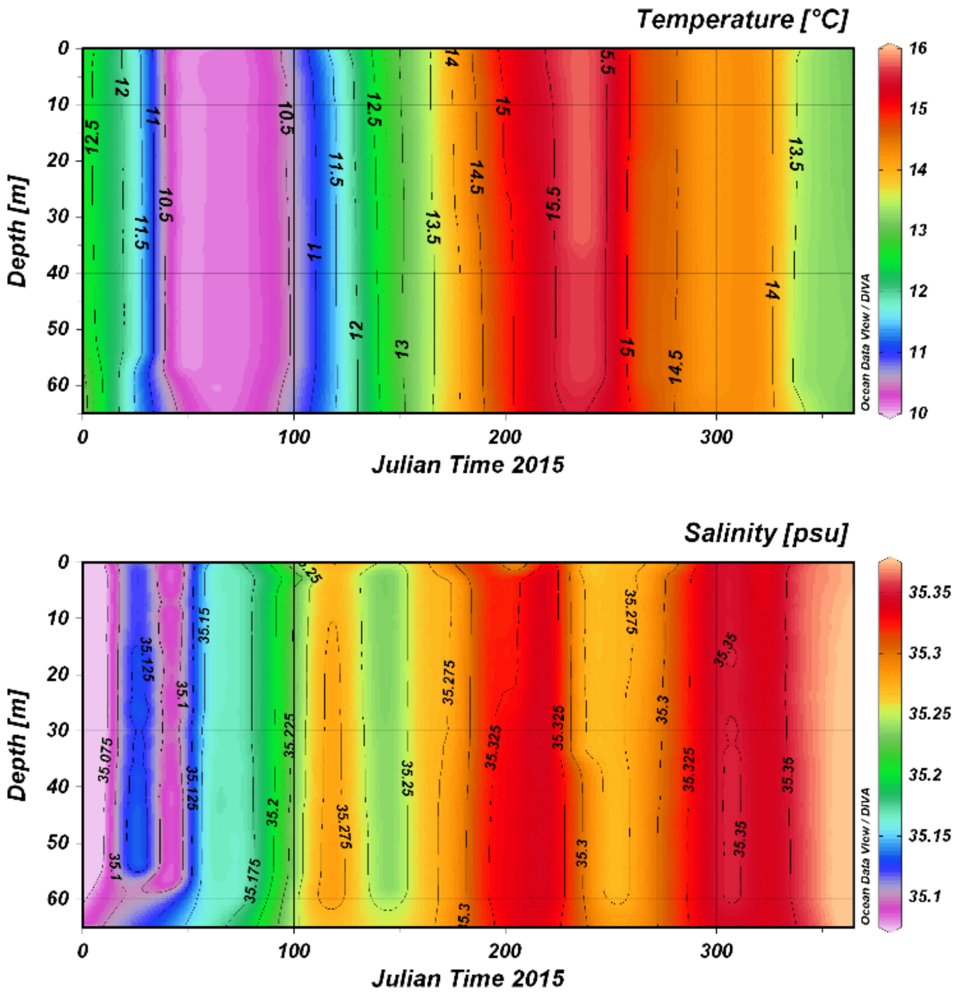
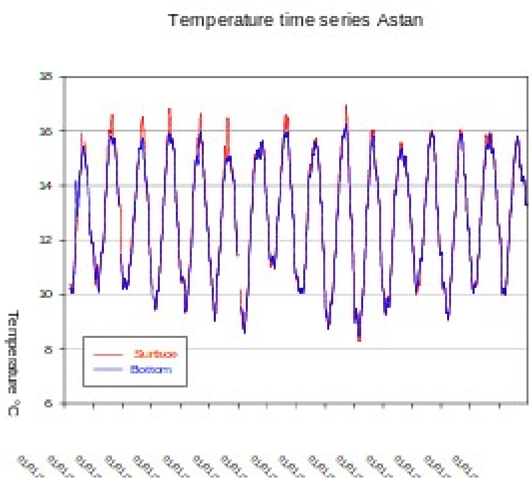


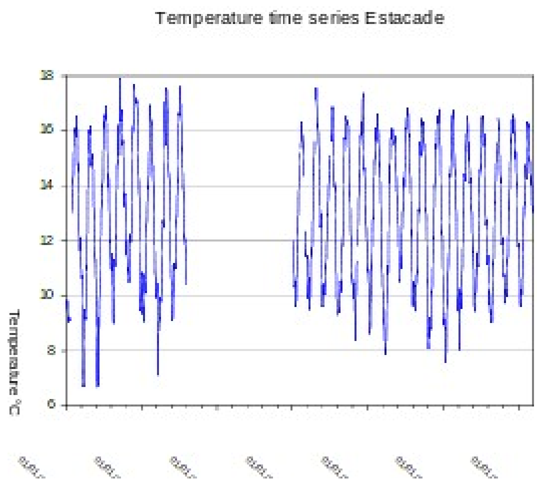
Figure 13: vertical distributions of temperature (top) and salinity (bottom) at Astan site during 2015 (bimonthly CTD profiles). Well-mixed waters were observed during the whole year due to an enhanced vertical mixing by tidal currents.

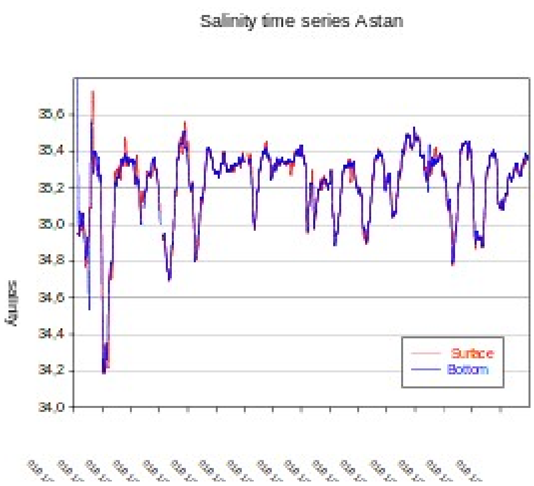
3.3 *Long-term trends*

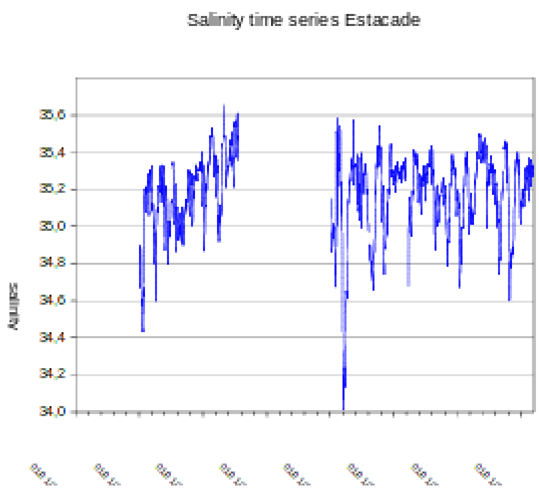
Figure 14 shows the time series of temperature, salinity and nitrate at Astan over the period 2000-2015 and at Estacade over the period 1985-2015 with a large gap from 1992 through 2000 for salinity and nitrate measurements. At the Astan and Estacade sites, winter 2015 minimum temperature were significantly higher than the global mean calculated over the time series.

In 2015, salinity cycle is characterized, as mentioned above, by higher values than those usually observed in this area, especially in winter. Means annual salinity at Astan and Estacade are slightly higher than the global average values. The differences are more important during winter explaining the low values of nitrate in the first part of the year. Usually, nitrate concentrations, as salinity and temperature, present a large interannual variability particularly in the winter maximum values which is linked to the interannual variability in the oceanic influence in the Channel waters. Maximum nitrate winter concentrations (7.7 µM/l at Astan and 8.1 µM/l at Estacade) were significantly lower than average winter values due to the reduced influence of the low salinity waters in the Western Channel. The monthly mean nitrate concentrations were the third minimum concentrations observed between January and April since 2000 at Astan. Nitrate winter and early spring stock for the spring phytoplankton development was reduced in 2015 when compared to the previous years. Residual nitrate values (C = 0.6 µMole/l at Astan and C = 0.2 µMole/l at Estacade) observed in summer 2015 are the second lowest measured values since 2000 at the two stations. The available nutrient amounts for the phytoplanktonic production weren't totally exhausted which may be explained by less favorable meteorological conditions.









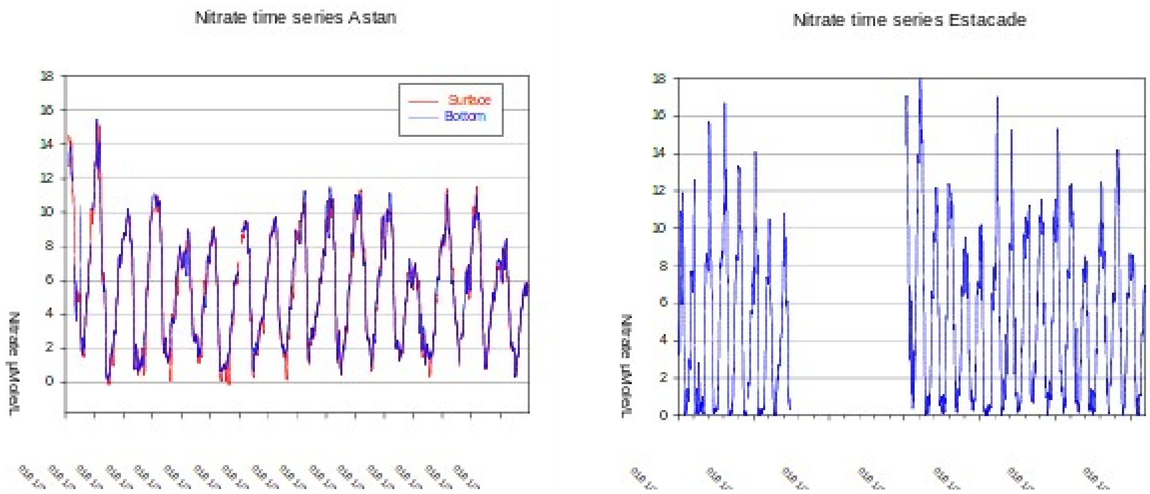


Figure 14: Interannual variability of the temperature, salinity and nitrate at Astan site over 2000-2015 (left panels) and at Estacade site over 1985-2015 (right panels).

We calculated the trends over the time series for the 2 periods mentioned above: At Astan station, we observed an increase of SST (+0.004°C/year), an increase of the SSS (+0.007 pss/year) associated to a decrease of the nutrient concentrations (-0.04 µmole/year).

At Estacade station, we observed an increase of SST (+0.001°C/year), an increase of the SSS (+0.001 pss/year) and an increase of the nutrient concentrations (+0.009 µmole/year). This last result, we would expect that the variation of the nutrient concentrations should be anti-correlated with the salinity variation as at Astan station. Therefore, more statistical and in depth analysis of these time-series will be need to understand the key processes influencing the long-term trends at these 2 coastal sites.