ICES WGOH REPORT 2009

ICES OCEANOGRAPHIC COMMITTEE

ICES CM 2009/OCC:04

REF. SCICOM, ACOM

Report of the Working Group on Oceanic Hydrography (WGOH)

10–12 March 2009

Texel, The Netherlands

ICES International Council for the Exploration of the Sea
CIEM Conseil International pour l'Exploration de la Mer

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Contents

Executive summary

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

IROC Highlights for 2008

- The upper layers of the North Atlantic and Nordic Seas were warm and saline in 2008 compared with the long-term average.
- In the Labrador and Irminger Seas a cold winter led to enhanced convection and cooler intermediate waters compared to 2007.
- Ice cover in the Baltic Sea was the lowest on record.
- In the Nordic Seas the shallow winter convection observed in the last two decades persisted in 2008, continuing the warming and increasing salinity of the deep water.
- A subgroup was formed for writing on key questions on climate change for the ICES steering group on climate change.

The WGOH also fulfils the Terms of Reference for the group including strengthening the role of WGOH and physical oceanography within ICES, exploring areas of mutual interest with international climate monitoring programmes and providing expert knowledge and guidance to ICES Data Centre. WGOH will contribute to the evolving ICES Climate Change position paper by writing chapters on:

1) Warming trends in the North Atlantic
2) Sea ice cover changes in "hot spots" chapter
3) Physical properties and circulation in the North Atlantic.

Approach taken at the meeting

A structured agenda was used for this WGOH meeting (see Annex 2). A mini-symposium was held prior to the formal meeting on day one which included a combination of talks from the host institution and invited WGOH members. Almost 50% of the meeting was spent reporting findings from each of the ICES standard oceanographic sections. The combined area reports are included as Annexes 6 to 16 of this report. The remainder of the meeting was spent working through the other ToRs for the WGOH.

Description of the structure of the report

This report describes the discussion and outcomes relating to the individual terms of reference of the WGOH. The bulk of the report is contained in the area reports (included as Annexes to the report), which is turn form the major contribution to the ICES Report on Ocean Climate.

Solid progress towards the WGOH Terms of Reference were made during this meeting. The ICES Report on Ocean Climate will be completed and submitted to ICES in early May 2009 where many of the Expert Groups key findings are presented.

Key recommendations

ICES should make more hard copies of the IROC report available to WGOH members (10–15 per member) so that such reports can be distributed for lobbying purposes at the national level and to enhance the profile of the IROC report.

ICES should support the maintenance of a weather ship at the Ocean Weather Station Mike location in the Norwegian Sea.

Greater contact should be made between the ICES data centre and NODCs to ensure the ICES database is as comprehensive as possible

1 Opening of the meeting

The Working Group on Oceanic Hydrography met in at the Netherlands Institute for Sea Research, Texel, Netherlands between 10 and 12 March 2009.

Chairs: Glenn Nolan (Ireland) and Hedinn Valdimarsson (Iceland)

18 WGOH members attended (Annex 1) representing 14 ICES nations.

Local host Hendrik Van Aken welcomed all WGOH participants to the meeting and provided all relevant logistical information to those present. The WGOH then proceeded to the nearby lecture theatre for the mini-symposium.

1.1 Mini Symposium 2009

Mini-symposium presentations :

1) Jan Boon (NIOZ PR officer) Introduction into the activities of NIOZ (15 min.)
2) Hendrik van Aken (NIOZ) on climate of the western Wadden Sea and global warming.
3) Toby Sherwin (SAMS) on hydrographic observations along the Ellett line
4) Femke de Jong on the comparison of climate models with observational data in the Irminger and Labrador Seas
5) Bob Pickart (WHOI) on convection in the Labrador and Irminger Sea.
6) Alicia Lavín (IEO) on large changes in the hydrographic structure of the Bay of Biscay after the extreme mixing of winter 2005.
7) The Gerkema (NIOZ) on NIOZ internal wave studies

2 Adoption of the agenda and key discussion points

2.1 Membership and Introductions

Member introductions took place and the agenda was formally adopted. The group welcomed two new members Alexander Trofimov and Robert Pickart

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

The following members of the WGOH presented their respective area reports: Hendrik Van Aken, Holger Klein, Kjell Arne Mork, Alexander Trofimov, Bob Pickart, Bert Rudels, Waldemar Walcowski, Ross Hendry, Agnieszka Beszczynska-Möller, Fabienne Gaillard, Karen Borenas, Hedinn Valdimarsson, Glenn Nolan and Sarah Hughes.

All area reports are included as annexes to this report (Annexes 6–16)

2.3 IROC (update from Sarah Hughes)

- Review of 2008 Atmospheric conditions
- Initial overview of contents and contributions received so far
- Suggestions for improvements and any new time-series or products

2.4 2011 Decadal Symposium on Hydrobiological Variability in the first decade of 21 century

Discussion led by Alicia Lavin

To build on the previous 2 symposia, Alicia Lavin of IEO will host this in Santander in 2011.

WGOH has met with ICES during ASC 2008. Motion to host this approved in late 2008 and €10k given in support. Letter also sent to NAFO (Don Power) to co-sponsor the meeting. They require further information from ICES prior to their June 2009 council meeting including financial support and the commitment required from NAFO. WGOH should talk to Manfred Stein on Ecosystem and Fisheries group within NAFO.

A structure has evolved for this (developed by Sarah Hughes) as follows:

Planning Committee

- Project management role
- Set out timetable for symposium and delegate tasks
- Drive initial organisation
- Draft budget, liaise with ICES and NAFO
- Draft text for theme sessions,
- Invite members to SSC
- Define roles of SSC and LOC
- Liaise between SSC and LOC
- Draft and propose budget sponsorship details

Scientific Steering Committee

- Finalise and agree theme sessions, text of poster flyer
- Invite keynote speakers
- Select papers and posters, organise into theme sessions
- Review and edit submissions (editorial subgroup)
- Appoint theme session chairs
- Arrange honorary speeches at conference/dinner
- Write introductory talks and text

Local Organising Committee

- Hotels, Logistics, Venue, Decorations, Gifts
- Deal with bookings/registration fees
- Arrange details of reception/dinner

A group has been established to move forward the symposium planning including: Alicia Lavin (Convenor), Sarah Hughes, Alicia Lavin, Glenn Nolan, Steven Dye, Agnieszka Beszczynska-Möller, Victor Valencia, Hjalmar Hatun, Penny Holliday, Bert Rudels, and Ken Drinkwater. The group needs to recruit some biological scientists also over the coming months.

2.5 ICES Matters: Improving interaction between WGOH and other Expert Groups

IGSG should try to coordinate meetings with this SG and invite SG chair to next WGOH meeting.

WKOOP (see ToRs 2007) has evolved into WGOOFE (Bee Berx is a member). Get potential users involved and ask them to specify products. Holger Klein has produced a list of products for fisheries with Manfred Stein. WGOOFE will meet again twice in 2009. Holger Klein will act as main link to WGOOFE for 2009.

2.6 Steering Group on Climate Change.

Discussion on: WGOH contribution to ICES Climate Change position paper including:

- Warming trends in the North Atlantic
- Sea ice cover changes in "hot spots" chapter
- Physical properties and circulation in the North Atlantic.

WGOH will form a subgroup comprising Penny Holliday (Lead), Toby Sherwin, Bob Pickart, Bert Rudels, Glenn Nolan and Alicia Lavin to address this request.

Glenn Nolan will ask about SGCC meeting date so that plans can be advanced.

2.7 ICES Data Centre (invitation to be sent to Neil Holdsworth)

Review of recent activities and future plans.

Ross Hendry: Working off Greenland: Danes: "hope you will contribute data to ICES data bank". Canada sends data to NODC where a formal MoU exists. Questions were raised as to whether ICES gets data from the Canadian NODC. Agreed to take the matter to the ICES data centre. What is status of relationship between NODCs and ICES data centre?

ICES do not request data from elsewhere. GN to send email to data centre and respond to group.

2.8 Relations with international climate monitoring programmes

OceanObs 09: Vision for ocean observing for the next 10 years. Kate Larkin approached Penny Holliday to include ICES WGOH contribution to ocean observations. Community to produce (5 page) white papers and a series of plenaries to follow at the conference. WGOH to review Penny's paper and give feedback.

Connection with the CLIVAR project. The WGOH edited and contributed a CLIVAR newsletter published in January 2007 ,which raised awareness. Some WGOH members contribute data to the CLIVAR data centre. IROC is sent to CLIVAR.

THOR: An EU project started formally in January 2009. Many ICES WGOH scientists involved. Focus on Thermohaline Overturning at Risk. The project consists of a large modelling package and a smaller observation package for monitoring the inflows and outflows in the North-Atlantic. Will have cooperation with Canada and US.

Labrador Sea workshop (John Calder and BIO): Participants from Canada, US and Europe. Report available at the end of March 2009 with plan for future measurements.

Arctic Ocean Sciences Board: Oceanographic expert group being formed. Will hold large symposium every second year. AOSB homepage has all of this information.

OOI in the US. Stimulus package may accelerate progress in rolling this out. Irminger Sea is one of the major sites. Major development over the next 4 years.

In connection with the Irminger Sea mooring, CIS, a test is taking place in sea off the Scripps Institute of robust moored profiler for open ocean use.

The ASOF project is planning to produce a document outlining their findings at relevant ocean gateways to the wider community including the NSF and others. ASOF is also contemplating their connections with other organisations. Robert Pickart will explore the prospect of a link-up with ASOF through Tom Haine in the US (Co-Chair of ASOF). WGOH will invite him to the next meeting.

2.9 ICES Annual Science Conference theme sessions

Last theme session proposed by WGOH was biophysical modelling session in 2007.

Hendrik Van Aken had previously proposed a session on ocean turbulence but uptake was limited.

Charles Hannah (WGPBI) has a session proposed in 2010 (title to be confirmed).

Proposed session for 2010:

Bert Rudels will propose the following theme session for 2010. The Arctic Ocean – North Atlantic connection – a vital and fatal link in the Atlantic meridional circulation. WGOH will request sign-off for this at the 2009 ASC.

2.10 WGOH website

Penny Holliday offered kindly to maintain and host the webpage for the working group at NOCS in Southampton for the time being.

2.11 OWS Mike discussion

After consulting with the Geophysical Institute in Bergen, Norway which has been responsible for the oceanography part of the ship, the group agreed to draft a supporting letter stating how valuable the observations on the Ocean Weather Ship Mike (deep open ocean, high frequency, long-term time-series) are for the international community in climate related research. This letter was to be sent to directors of the Geophysical Institute signed by WGOH chairs. Penny Holliday was willing to provide draft to WGOH.

Letter was subsequently sent to the Norwegian authorities on behalf of WGOH.

2.12 Next Meeting

Brest, France, 9–11 March 2010.

2.13 IROC Final review

Robert Pickart offered to contact Ken Moore at University of Toronto and ask him to look at atmospheric section in IROC with a view to re-writing this.

IROC to be sent around by end of April 2009 with comments expected.

WGOH thanked Hendrik Van Aken for hosting the meeting and excellent preparations.

Annex 1: List of participants

Name	Institute	Phone/Fax	Email
Hendrik van Aken	NIOZ		aken@nioz.nl
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Karin Borenäs	SMHI		karin.borenas@smhi.se

Annex 2: Agenda

Agenda WGOH

10–12 March 2009, Texel

Day 1, Tuesday 10 March

Start at 09.00

Mini-symposium (TBC) 09.00–13.00

Jan Boon (NIOZ PR officer) Introduction into the activities of NIOZ (15 min.)

Hendrik van Aken (NIOZ) on climate of the western Wadden Sea and global warming.

Toby Sherwin (SAMS) on hydrographic observations along the Ellett line

Femke de Jong on the comparison of climate models with observational data in the Irminger and Labrador Seas

Bob Pickart (WHOI) on convection in the Labrador and Irminger Sea.

Alicia Lavín (IEO) on large changes in the hydrographic structure of the Bay of Biscay after the extreme mixing of winter 2005.

The Gerkema (NIOZ) on NIOZ internal wave studies

PM

1. Membership and Introductions

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

Day 2, Wednesday 11 March

Start at 09.00

Continue area reports (if symposium takes place on day 1)

3. IROC (15–25 minutes update from Sarah Hughes)

- Review of 2008 Atmospheric conditions
- Initial overview of contents and contributions received so far
- Suggestions for improvements and any new time-series or products

4. 2011 Decadal Symposium on Hydrobiological Variability in the 2000s

Discussion led by Alicia Lavin

5. ICES Matters: Improving interaction between WGOH and other EGs

IGSG

WKOOP (see ToRs 2007).

6. Steering Group on Climate Change

Discussion on: WGOH contribution to ICES Climate Change position paper including:

- Warming trends in the North Atlantic
- Sea ice cover changes in "hot spots" chapter
- Physical properties and circulation in the North Atlantic.

Day 3 (morning only), Thursday 12 March

Start at 09.00

7. ICES Data Centre (invitation to be sent to Neil Holdsworth)

Review of recent activities and future plans

8. Relations with international climate monitoring programmes

- OceanObs 09
- Others

9. ASC theme sessions

- Proposed session for 2009
- Proposed session for 2010

10. IROC Final review

11. WGOH website

12. Next Meeting

13. AOB

Annex 3: WGOH terms of reference 2008

2008/2/OCC04 The **Working Group on Oceanic Hydrography** [WGOH] (Co-Chairs: Glenn Nolan*, Ireland, and Hedinn Valdimarsson*, Iceland) will meet in Texel, The Netherlands from 10–12 March 2009 to:

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

b) consolidate inputs from Member Countries to, and continue development of, the ICES Report on Ocean Climate (IROC), and align data source acknowledgements in IROC with ICES policy; archive data used to compile report;

c) provide support to other Expert Groups requiring information on oceanic hydrography in support of their responses to the OSPAR request on 'An assessment of the changes in the distribution and abundance of marine species in the OSPAR maritime area in relation to changes in hydrodynamics and sea temperature;

d) take action for strengthening the role of WGOH and physical oceanography within ICES; such as IGSG and explore areas of mutual interest with international climate monitoring programmes;

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

f) contribute to ICES Climate Change position paper including:

1) Warming trends in the North Atlantic

2) Sea ice cover changes in "hot spots" chapter

3) Physical properties and circulation in the North Atlantic.

g) prepare draft/outline report for consideration of SGCC at spring meeting 2009.

WGOH will report by 30 April 2009 to the attention of the SCICOM and ACOM.

Annex 4: WGOH terms of reference for the next meeting

The **Working Group on Oceanic Hydrography** (Chair: G. Nolan, Ireland and H. Valdimarsson, Iceland) will meet in Brest, France on 9–11 March 2010 to:

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

b) consolidate inputs from Member Countries to, and continue development of, the ICES Report on Ocean Climate (IROC), and align data source acknowledgements in IROC with ICES policy; archive data used to compile report;

c) provide support to other Expert Groups requiring information on oceanic hydrography;

d) take action for strengthening the role of WGOH and physical oceanography within ICES; such as IGSG and WGOOFE and explore areas of mutual interest with international climate monitoring programmes;

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

f) contribute to ICES Climate Change position paper including:

1) Warming trends in the North Atlantic
2) Sea ice cover changes in "hot spots" chapter
3) Physical properties and circulation in the North Atlantic.

WGOH will report by 30 April 2010 to the attention of SCICOM and ACOM.

Supporting Information

Priority:	The activities of this Group are fundamental to the work of the Oceanography Committee.
Scientific Justification and relation to Action Plan	This is a repeating task established by the Working Group to closely monitor the ocean conditions in the ICES area. The materials presented under this item will be utilised to prepare an overview of the state-of-the-environment in the North Atlantic for 2009. The Working Group recognises the need for disseminating climate information in a timely and appropriate manner. This agenda item will allow WGOH members to prepare the document during the meeting, thus avoiding delays in the dissemination of the information. We will review proposed new developments in IROC content. Links have been made with the CLIVAR programme; it would be of benefit both to ICES and the international programmes to enhance internal information exchange. To follow up on the ICES General Secretary's suggestions for increasing the visibility of WGOH within ICES. To improve communications between working groups under the ICES system. This is in compliance with a request from the ICES Data Centre The work of the proposed Expert Group will be relevant for WGOH.
Resource Requirements:	No extraordinary additional resources
Participants:	WGOH members; Chair of Oceanography Committee.
Secretariat Facilities:	N/A

Financial:	Publication and reproduction costs for the IROC.
Linkages to Advisory Committees:	Advisory Committees on Fishery Management, Marine Environment, and Ecosystem
Linkages to Other Committees or Groups	Publications Committee; Consultative Committee; IGSG
Linkages to Other Organisations:	IOC, JCOMM, CLIVAR

Annex 5: Recommendations

Recommendation	For follow up by:
1. ICES should make more hard copies of the IROC report available to WGOH members (10–15 per member) so that such reports can be distributed for lobbying purposes at the national level and to enhance the profile of the IROC report.	G. Nolan to discuss with ICES Secretariat and Adi Kellerman
2. ICES should support the maintenance of a weather ship at the Ocean Weather Station Mike location in the Norwegian Sea.	Co-Chairs of WGOH
3. WGOH will propose the following theme session for the ASC 2010: The Arctic Ocean – North Atlantic connection – a vital, and fatal link in the Atlantic meridional circulation.	Co-Chairs to raise this at ASC 2009 in Berlin.
4. Greater contact should be made between the ICES data centre and NODCs to ensure the ICES database is as comprehensive as possible.	Co-Chairs of WGOH

Annex 6: Regional Report – Area 9b – Skagerrak, Kattegat and the Baltic

Karin Borenäs and Jan Piechura

Owing to its central location relative to the Skagerrak, Kattegat, and Baltic, the weather in Sweden can be taken as representative for the area. The mean air temperature during 2008 was 1–2ºC above normal in most parts of Sweden and the overall mean was higher than 2007 but not as high as in 2006. The start of the year was mild with winter conditions beginning in March. The first part of June and the end of July were warm with a cool and rainy period in between. A normal fall was followed by another warm December. The precipitation was above average in most parts of Sweden and it was somewhat sunnier and less windy than normal.

Annual cycles of surface temperature and salinity

A large number of hydrographic stations are regularly visited in the Baltic Sea, the Kattegat and the Skagerrak, as exemplified in Figure 1. From six of these stations the annual cycles of surface temperature and salinity are presented in Figure2. Sea surface temperature was above normal in January and February in the whole area. Higher than normal temperatures were also observed in June and at the end of July, with the highest anomalies in Kattegat and Skagerrak. For the rest of the year temperatures were close to normal. In Skagerrak the sea surface salinity was very low in the beginning of June with a strong halocline found at 5 m depth.

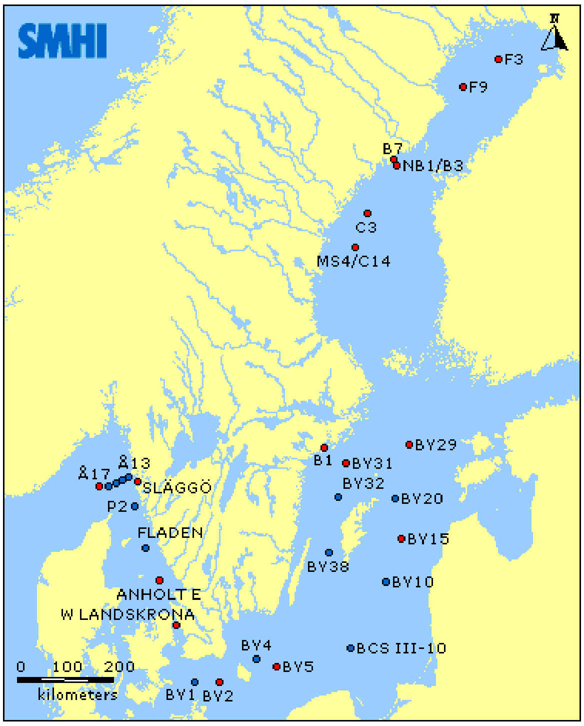
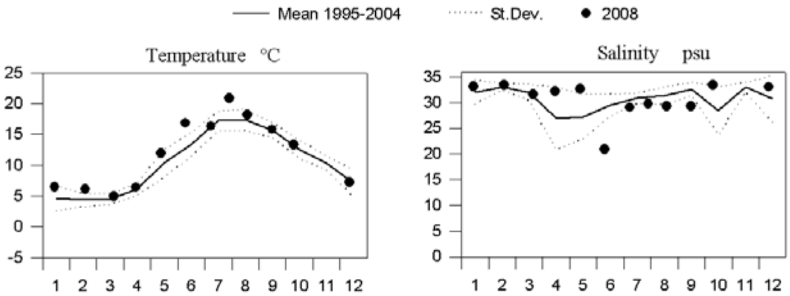
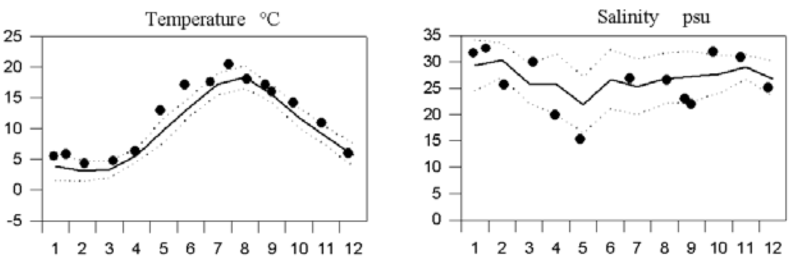


Figure 1. Position of stations visited on a regular basis. Stations marked with red pertain to the Swedish National Monitoring Programme while stations in blue are additional stations sampled by SMHI.

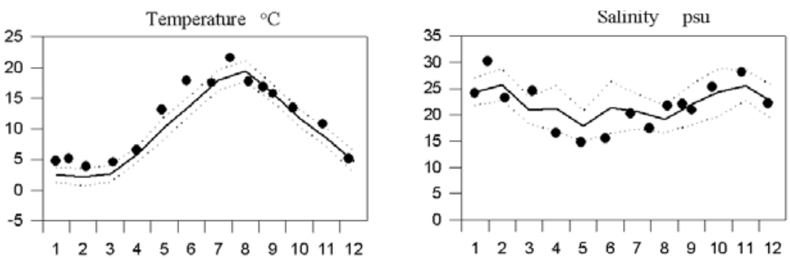
STATION Å17



STATION P2



STATION FLADEN



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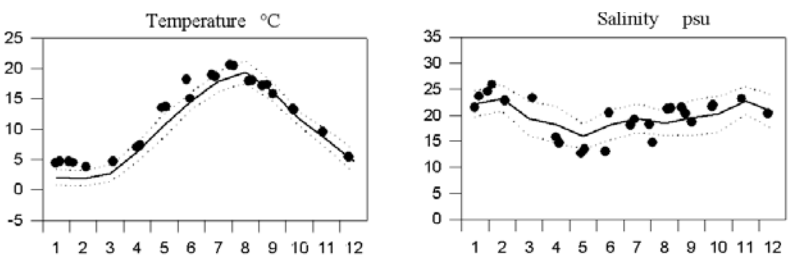

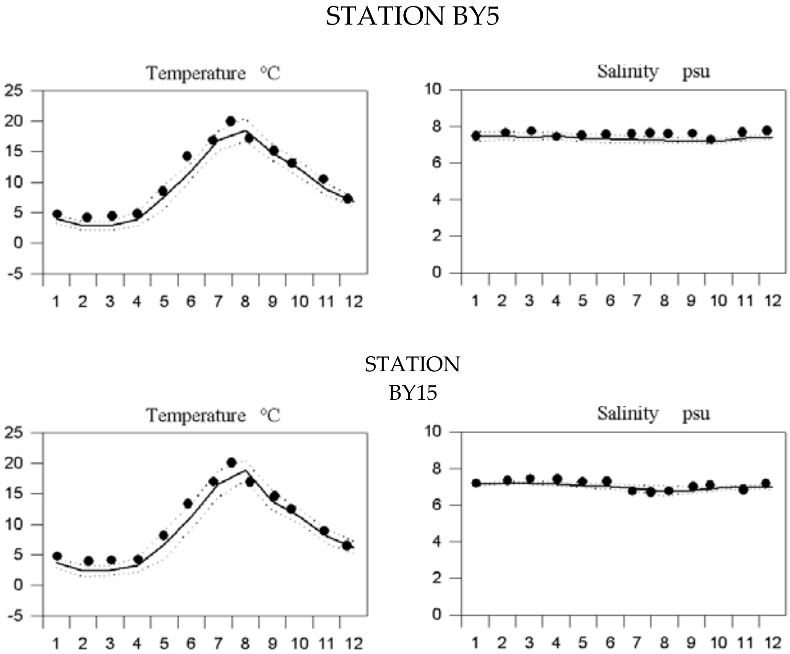

Figure 2. Annual cycles of surface temperature and salinity, see Figure 2 for station positions.

Quarterly transects using towed CTD in the Southern Baltic

The Institute of Oceanology of the Polish Academy of Sciences (IO-PAN) carries out 4 surveys a year in the Southern Baltic using a towed CTD. Figures 3 and 4 show temperature and salinity sections from the summer, respectively winter cruise. The transect runs from the Arkona Basin to the Gdansk deep. The observations obtained from these transects suggest that the Southern Baltic Sea hydrography in 2008 can be characterized as typical for a stagnation period. Surface layer temperature showed seasonal variation from 4–5°C minimum in January to≈ 18 °C in August with a uniform salinity of about 7.5. Very high winter temperatures were caused by mild meteorological conditions during this period.

In the deep layer only minor changes were observed (about 8°C of temperature and 12–16 of salinity) except during the December cruise (see section on water exchange). Very slow eastward movements of near-bottom waters, Figure 3 being a typical picture of such conditions, were seen.

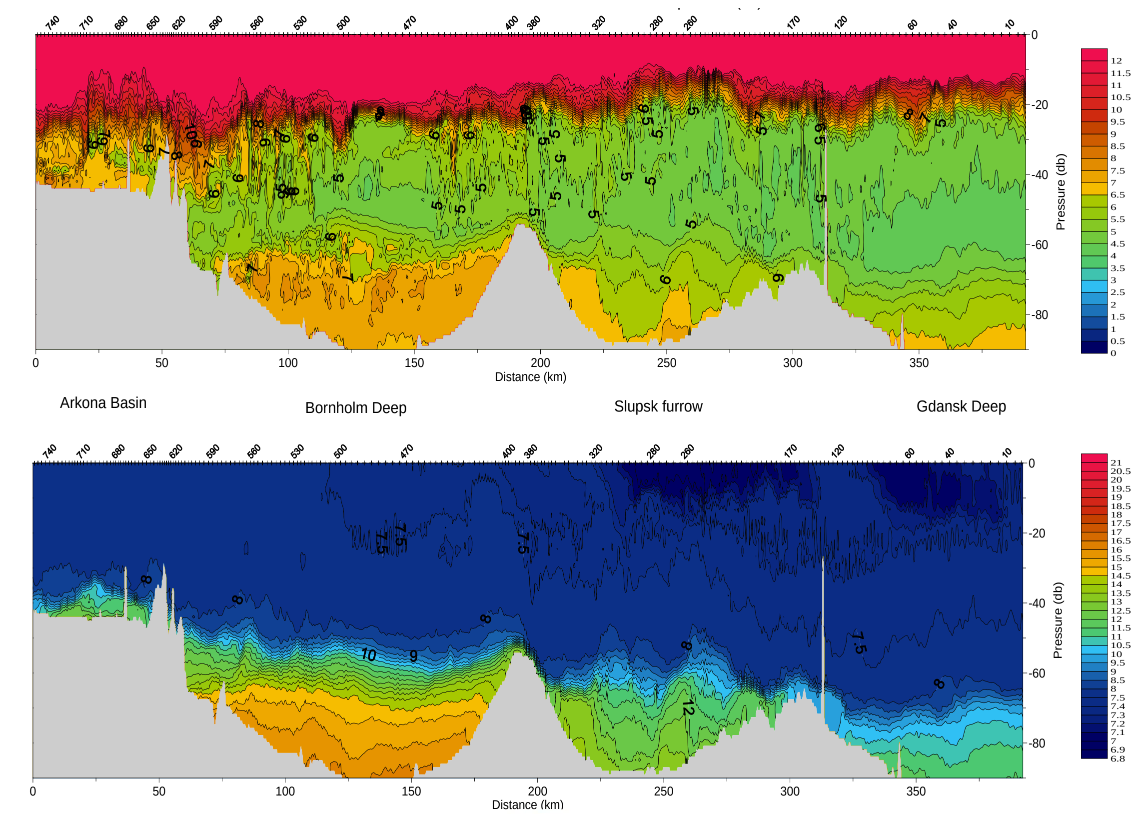

Figure 3. Temperature (upper panel) and salinity (lower panel) in the southern Baltic Sea in June 2008.

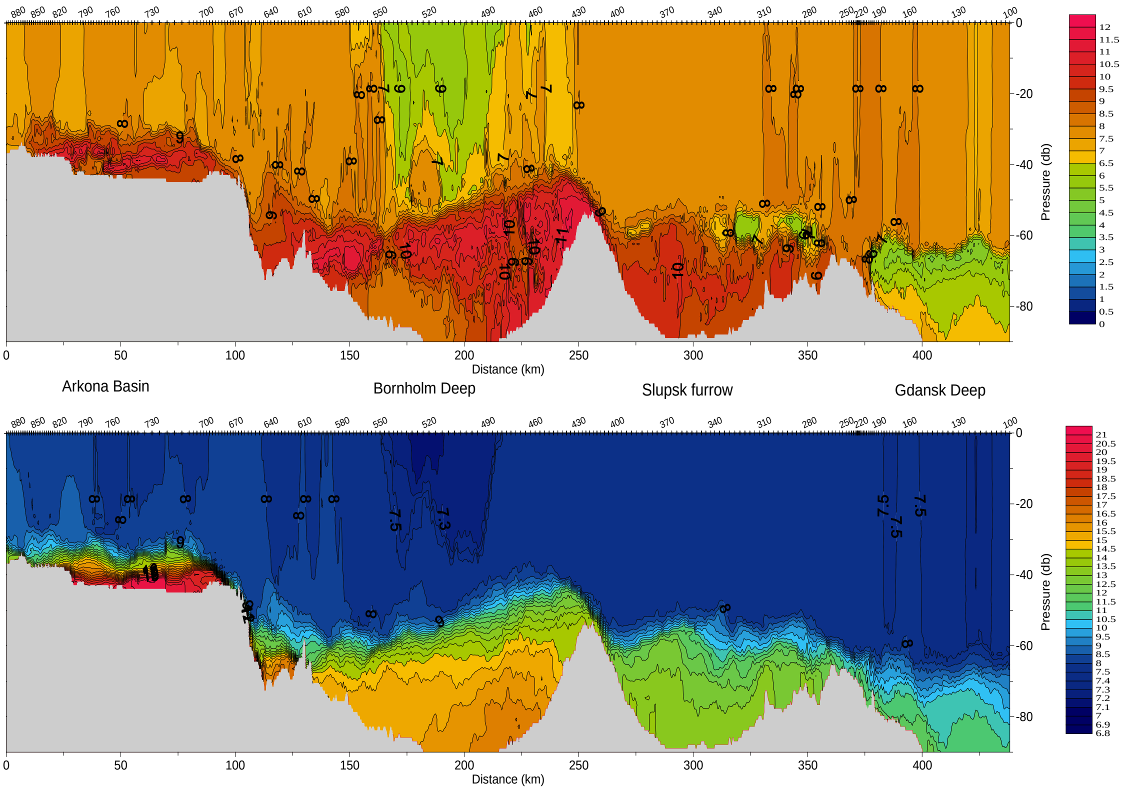

Figure 4. Temperature (upper panel) and salinity (lower panel) in the southern Baltic Sea in December 2008.

Long term observations

At station BY15, east of Gotland, the mean surface temperature for 2008 was lower compared to 2007 (Figure 5, left panel). The decrease was, however, small and for the last 3 years the mean surface temperature has remained fairly constant with an anomaly relative to the 10-year period 1990–1999 being close to +2 °C. The mean surface salinity at BY15 also showed a slight decrease but the five-year running mean still demonstrates a weak positive trend (Figure 5, right panel).

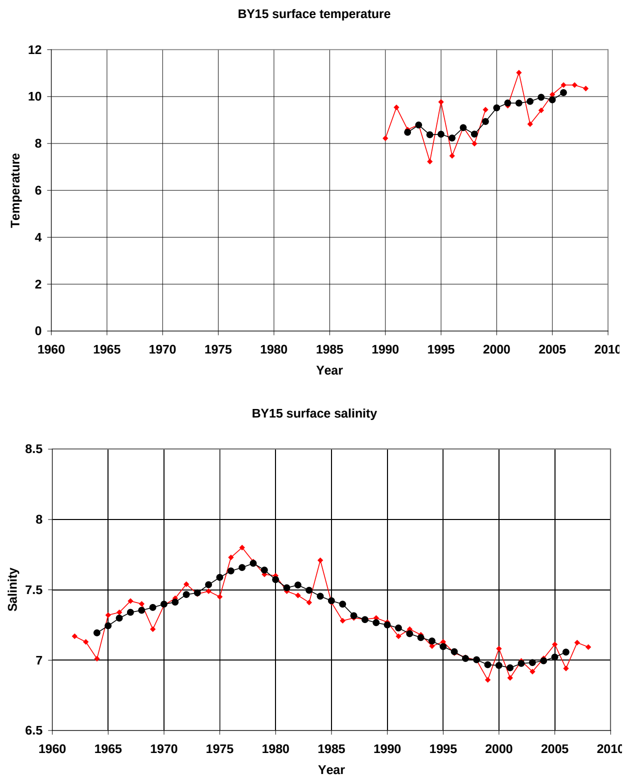

Figure 5. Sea surface temperature (left panel) and salinity (right panel) at BY15 (see Figure 2) in the Baltic proper. Yearly mean (red curve) and 5-year running mean (black curve). SMHI

Water exchange

There were a few inflow events to the Baltic during 2008, but they were only minor. The accumulated inflow through Öresund is presented in Figure 6 and it shows that inflows took place at the end of January, in March, June, October and November. The inflows during the late autumn were manifested in the data from the December cruise by IO-PAN, previously mentioned (Figure 4). These data indicate more dynamic processes with warmer (10–11^{o}C) and more saline waters (20–21) in the Arkona Basin moving towards the east in a near bottom layer through the Bornholm Gate. In the Bornholm Deep and Słupsk Channel this water moved in the intermediate layer due to its low salinity.

The effects on the oxygen conditions in the deep water of the Arkona and Bornholm Basins due to the inflows were of short duration.

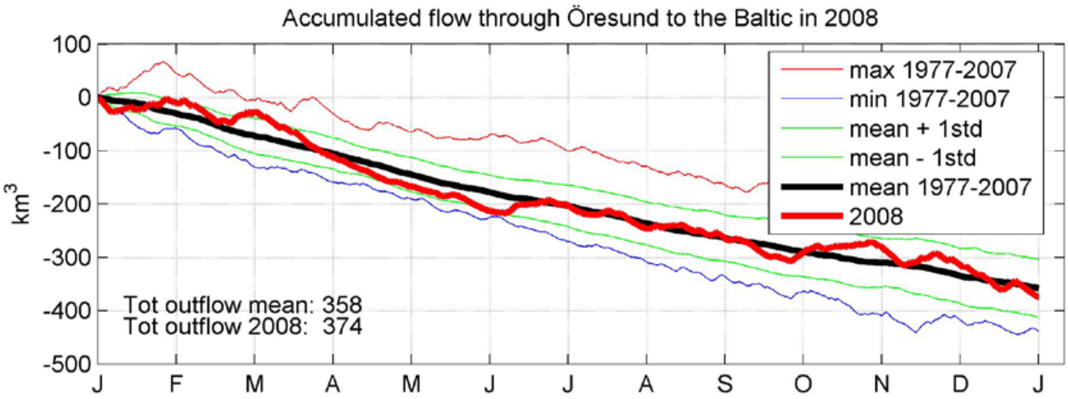

Figure 6. Accumulated inflow (km³) through the Öresund to the Baltic in 2008 compared to 1977–2007 (SMHI).

Ice conditions

The freeze-up was unusually late during the winter 2007/2008, even later than in the previous ice seasons. During the first two months of the year there was very little ice and it was not until the last weeks of March that the Bothnian Bay was ice covered. Maximum ice extent occurred on 24 March (Figure 7) and its value was record low as is demonstrated in Figure 8. In fact, one has to go back before 1900 to find a maximum ice cover that was smaller than the one observed during the winter 2007/2008.

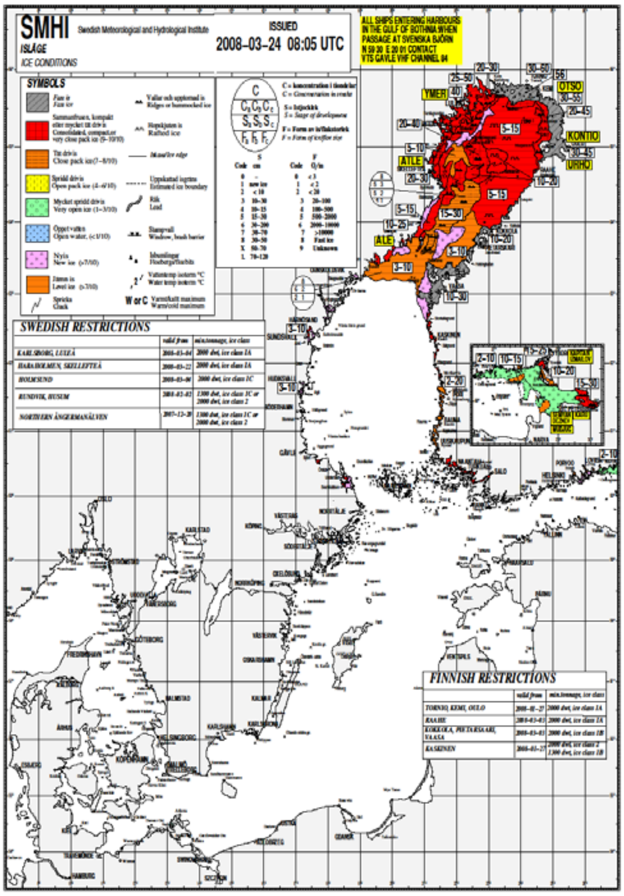

Figure 7. The maximum ice extent in the Baltic Sea during the winter 2007/2008. The map was constructed by the Ice Service at SMHI.

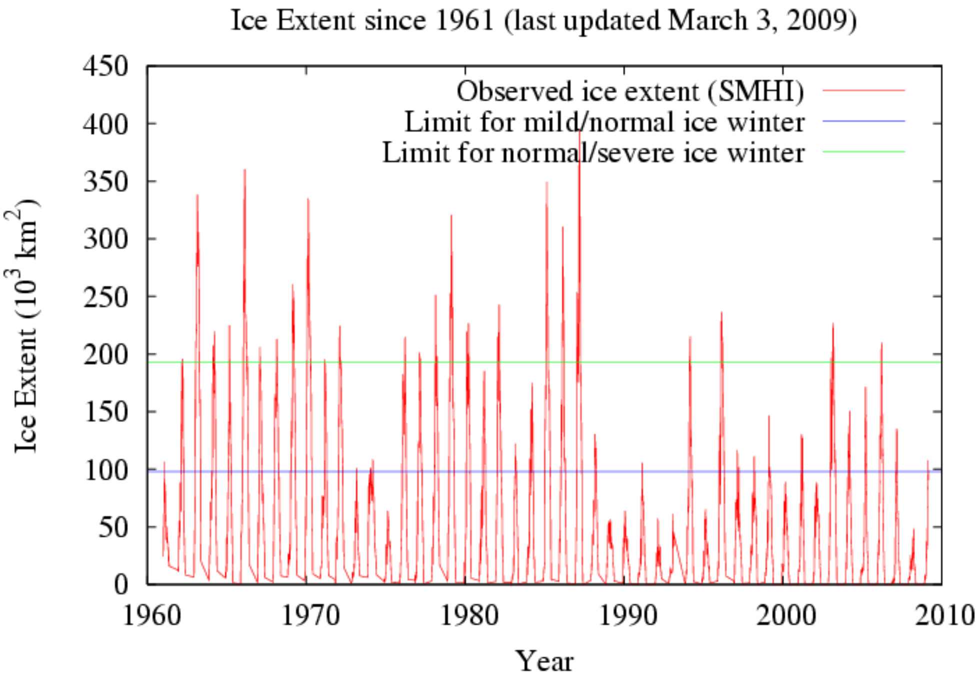

Figure 8. The ice extent in the Baltic starting from 1961. The last value is from 03 March 2009. Graph constructed by Lars Axell (SMHI).

Annex 7: Northern Baltic. Finnish national report

Pekka Alenius, Bert Rudels

Finnish Meteorological Institute

The winter 2007/2008 was the mildest measured in terms of the largest annual ice extent. Only 49000 km² of the Baltic Sea was ice covered. The length of the ice season was 5 to 7 weeks shorter than the average. For the first time ice breaker assistance was not needed in winter navigation in Finnish waters.

The annual course of sea surface temperature was such that the winter and early autumn temperatures were higher than normal, but the summer and autumn were normal. In late summer and early autumn there were upwelling periods because of strong winds.

The summer was exceptionally windy, leading to new seasonal record significant wave heights. In the Northern Baltic Proper the significant wave height in August was 4.7 m and in the Gulf of Finland 3.5 m. Also in the autumn, in October, seasonal maximum significant wave heights, 6m, were measured in the Northern Baltic Sea Proper. The effect of these high waves extends down to the bottom in the local shallow sea areas and thus they have environmental significance.

In the northernmost part of the Baltic Sea, the Bay of Bothnia, the surface and deep water salinities remained at the same level as they have been in the recent years. The temperature in the near bottom waters varied considerably and was going towards lower temperatures.

In the Bothnian Sea the deep water temperature is slowly rising but no significant changes in salinity are observed. The same tendency of warming deep waters are seen in the Northern Baltic Sea proper and in the Gulf of Finland.

The deep water oxygen depletion is a persistent problem in the deep areas of the Baltic Sea proper and western Gulf of Finland. The situation remained serious also in 2008.

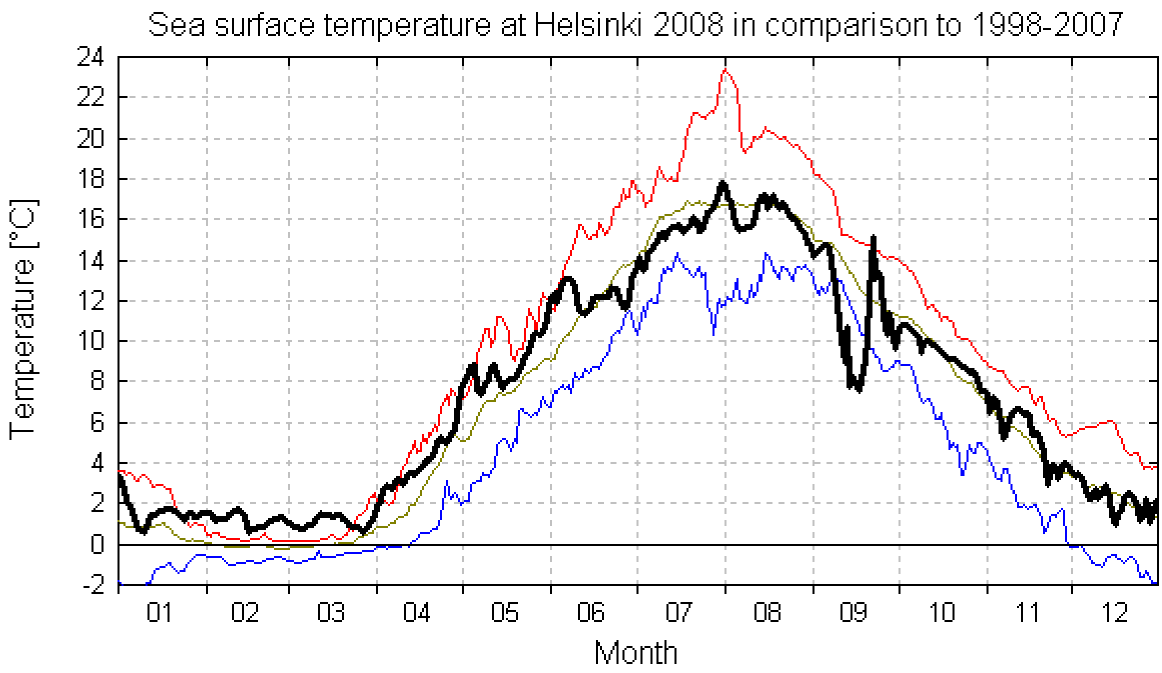

Figure 1. The annual sea surface temperature variation at Helsinki 2008, black, the 1998–2007 mean, the 1998–2007 maximum, the 1998–2007 minimum.

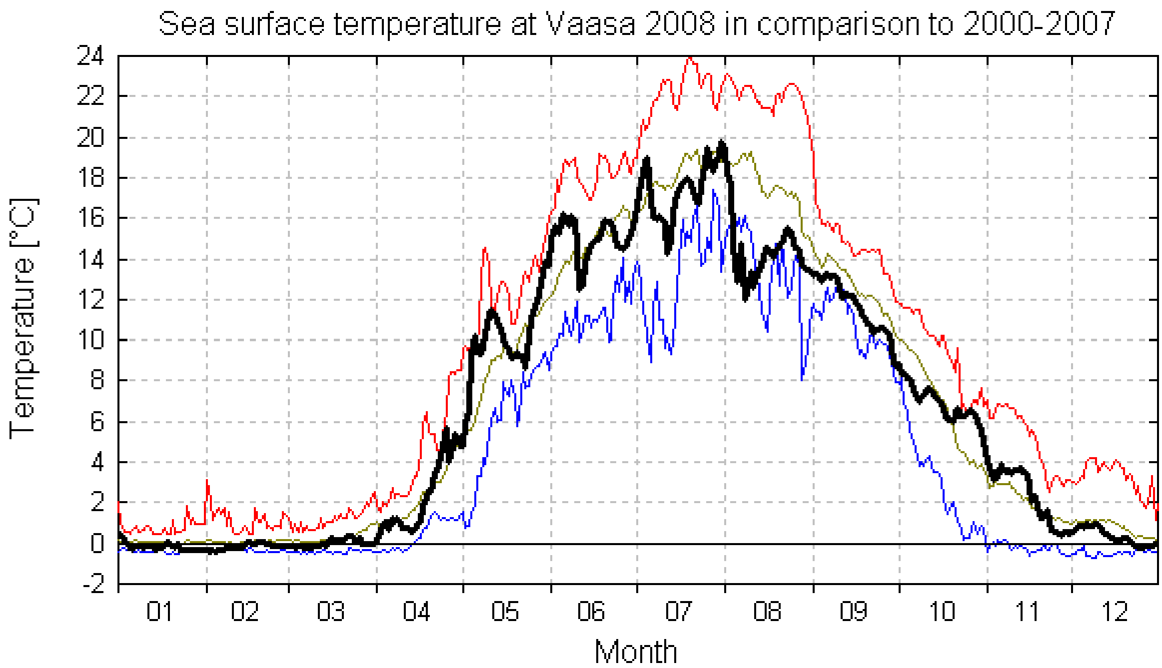

Figure 2. The annual sea surface temperature variation at Vaasa 2008, the 2000–2007 mean, the 2000–2007 maximum, the 2000–2007 minimum.

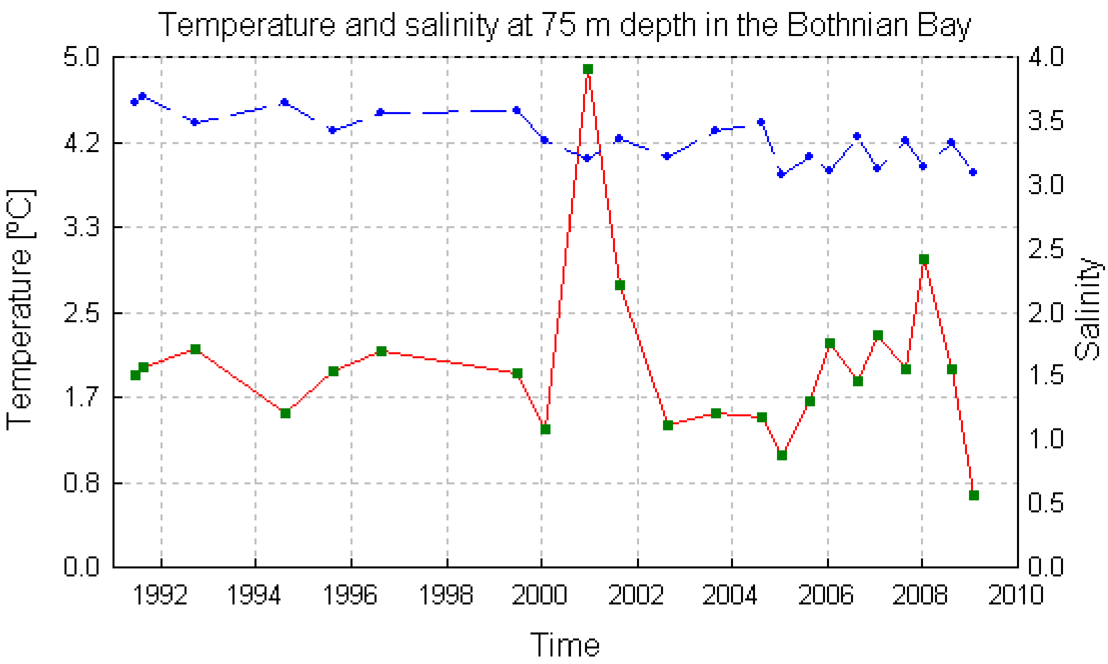

Figure 3. The temperature and salinity at 75m depth in the Bothnian Bay.

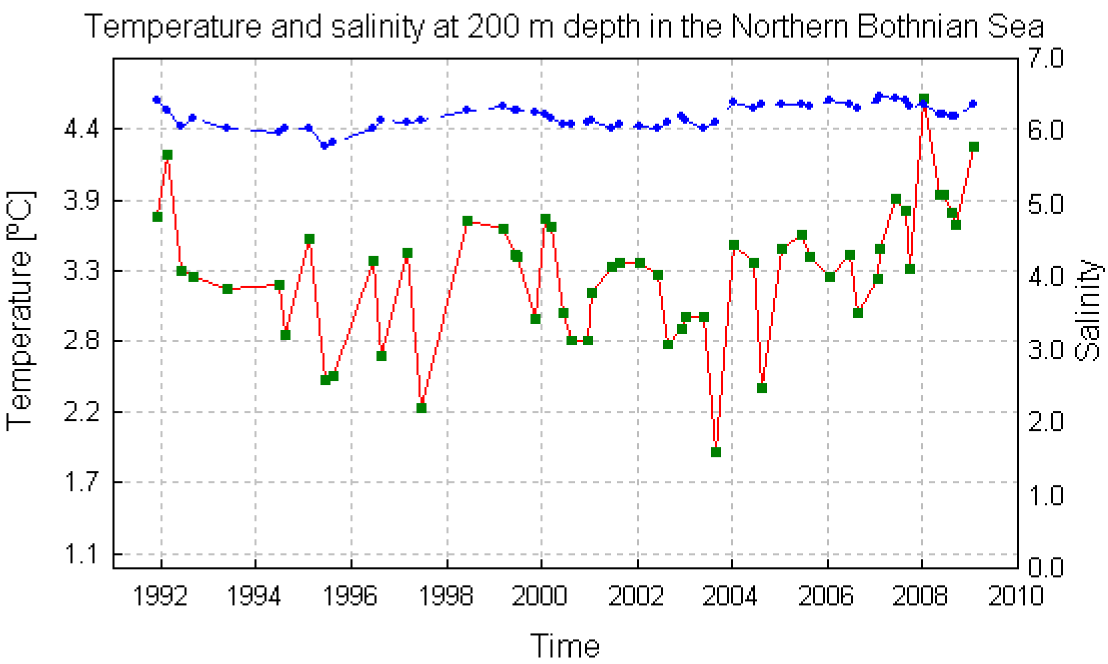

Figure 4. The temperature and salinity at 200m depth in the northern Bothnian Sea.

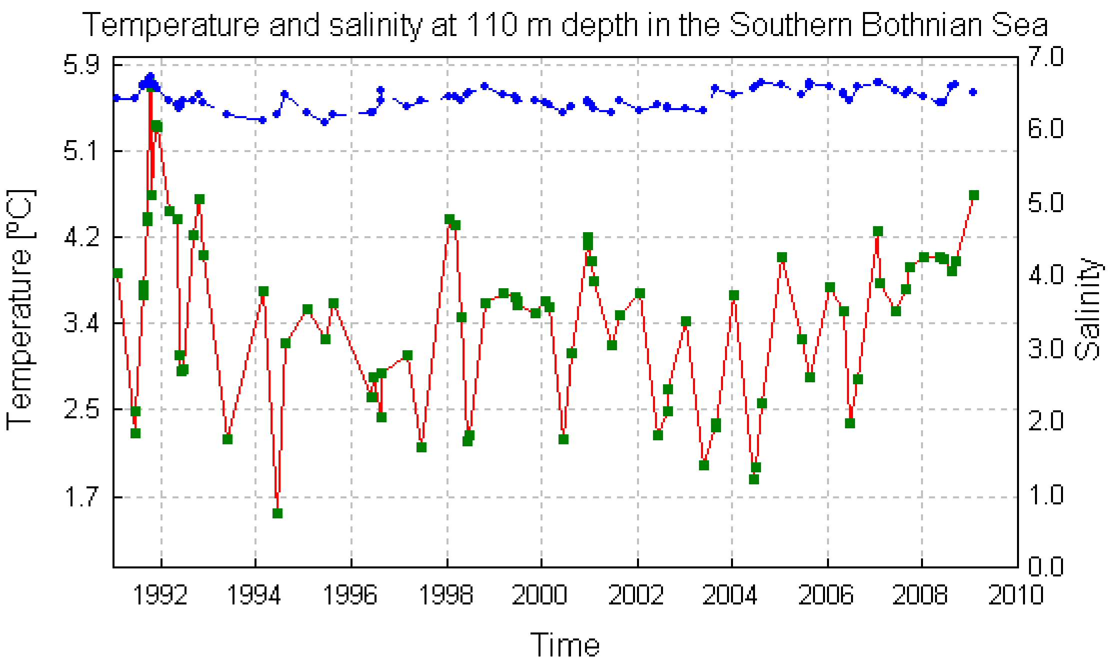

Figure 5. The temperature and salinity at 110m depth in the southern Bothnian Sea.

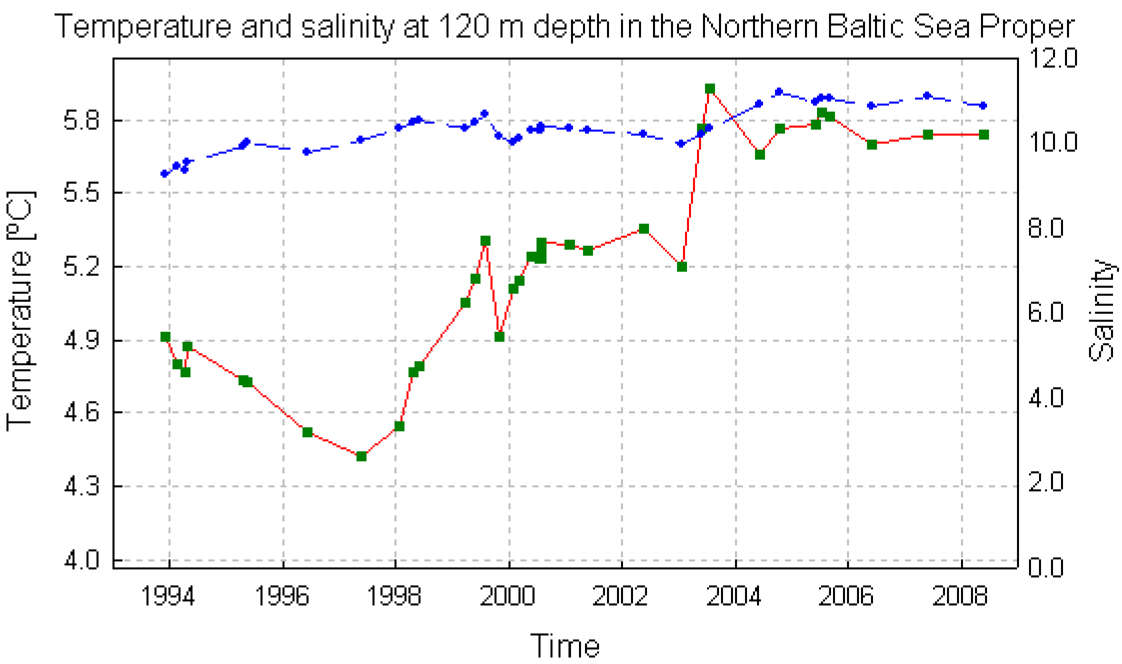

Figure 6. The temperature and salinity at 120m depth in the northern Baltic Sea.

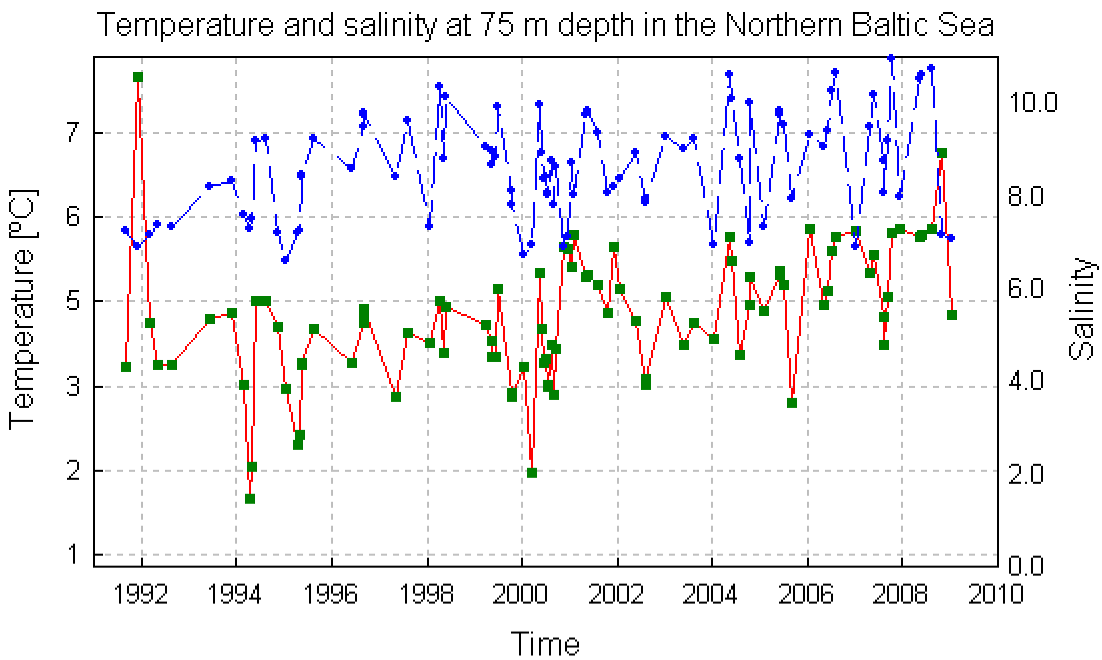

Figure 7. The temperature and salinity at 75m depth in the northern Baltic Sea.

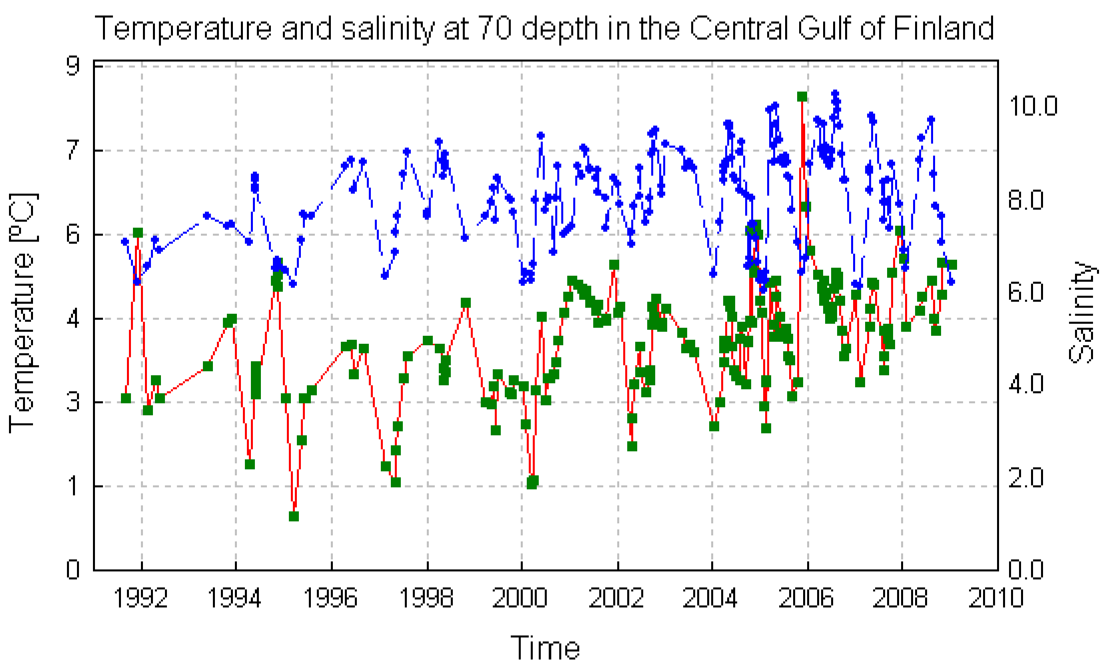

Figure 8. The temperature and salinity at 70m depth in the central Gulf of Finland.

Annex 8:French national report

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1. Ships of opportunity

Near surface temperature and salinity measurements are collected from ships of opportunity in the North Atlantic. Six merchant vessels equipped with thermosalinographs, contributing to the French ORE SSS (sea surface salinity research observatory, http://www.legos.obs-mip.fr/observations/sss) are part of this network, which includes also vessels equipped for the CARBOCEAN EU FP6 project and by NOAA, and complement along-way data collected from research vessels (GOSUD project, http://www.ifremer.fr/gosud). On some of the vessels, ancillary data are also obtained to study inorganic carbon in the upper ocean. All the vessels have been active in 2008, and most of them have reported useful data, although with a return rate of usable data that can be as low as 50%. The ORE SSS vessels include the Nuka Arctica, usually between Denmark and west Greenland, the Nokwanda between France and South Africa, the Monte Olivia between the Channel and eastern South America, and two vessels (Toucan and Colibri) on an irregular basis between the Channel, north-western Mediterranean and French Guyana. There is also one vessel (Matisse) between France, North America and Panama, crossing the North Atlantic 6 times each year. Water samples are collected on a nearly-daily basis on all the vessels, and comparison with nearby ARGO near-surface temperature-salinity data is also done, in order to correct the salinity data from the TSGs. In addition, water samples are collected on the Skogafoss between Iceland and north-east North America four times a year as part of a project to study ocean inorganic carbon changes.

Here, we report data from the Nuka Arctica TSG that are available since June 1997, and for which quality control and validation have been completed. The TSG was initially installed in the bow of the ship, but different operation problems, in particular since it was coupled with a pCO2 equilibrator system (University of Bergen), have induced us to change it to a new location since early 2006 by mid-ship. The depth of intake is a little deeper than before, but the intake is less prone to be in the air during bad weather. Since late 2006, we have had sufficient flow through the TSG with a temperature difference of the TSG with respect to the intake temperature (University of Bergen) on the order of 0.1°C, which is corrected. Data have been collected through most of 2008, missing data only in February and from March 16 to April 10. They are usually of good quality, except during periods of bad weather when air entering in the TSG is still a problem.

The route most commonly sampled by the Nuka Arctica is across the subpolar gyre between Cape Farewell and the Shetlands Islands near 59°N–60°N, and then across the North Sea. Anomaly salinity data after removal of an average seasonal cycle in 1996–2008 (Figure 1) show that the higher-than-usual salinities found in late 2007 have usually persisted through 2008, in particular in the western part of the section, whereas salinity anomalies have decreased in the eastern part of the gyre. The seasonal cycle remains more pronounced, except in the western Irminger Sea, in 2008, compared to the early part of the record. Close to the Greenland shelf, deviations from the seasonal cycle are very large and tended to be positive in 2006–2008. However, this region is not always sampled at the same latitude (depending on the presence of ice on the Greenland shelves), so the salinity data are prone to a large variability, related to the latitude of the section. Temperature anomalies are not presented, but they are mostly coherent with the SST maps produced by NOAA (OI SST product http://www.emc.ncep.noaa.gov/research/cmb/sst_analysis/), although these are independent data. They illustrate a continuation of the positive SST anomalies which have tended to be present along that latitude in recent years, even in the Irminger Sea, where atmospheric forcing in winter 2007/2008 were however favourable to more cooling, resulting in increased vertical mixing and deeper mixed layer than in previous years (Vage *et al*., 2009)

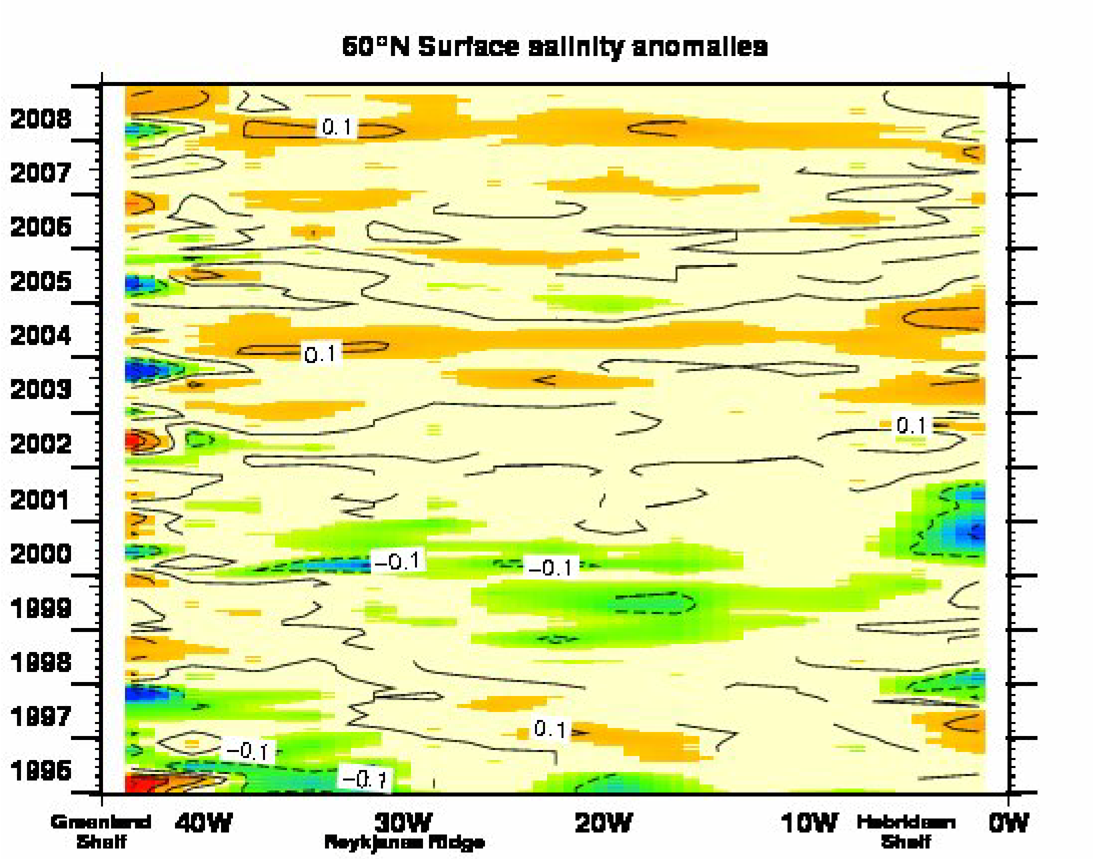

Figure 1. Salinity anomalies with respect to the average seasonal cycle in 1996–2008 mapped near 60°W between the vicinity of the southern Greenland shelf and the Orkney Islands. Based mostly on TSG data from the Nuka Arctica.

2. Gridded fields (ARGO)

ISAS (In Situ Analysis System) is an analysis tool for the temperature and salinity fields, originally designed for the synthesis of ARGO dataset. It is developed and maintained at LPO (Laboratoire de Physique des Océans) within the CREST-Argo project (http://wwz.ifremer.fr/lpo/observation/crest_argo). The latest version, ISAS_V4.2 (Gaillard et Charaudeau, 2008 and Gaillard *et al*., 2009) has been used to perform the monthly analysis presented in this report. The datasets are the standard files prepared by Coriolis for the operational users. They contain mostly ARGO profiles, but CTDs, buoys and mooring data are also included. We did not use XBTs, first because of the question that recently raised about the fall rate error, and second because we prefer to have consistent temperature and salinity fields in order to later compute density. The results are monthly gridded fields of temperature and salinity on depth levels from 0 to 2000m.

2.1 Maps

The monthly fields are shown Figure 2, only for the near surface temperature and for the extreme month of each season (February, May, August and November). The annual means are presented Figure 3 for both variables and at four levels: 10m, 300m, 1000m and 1600m. The state of the ocean is evaluated by comparison with a reference climatology. The anomalies are computed relative to the latest World Ocean Atlas (WOA-05) (Figure 4). The short term tendency is given by the change with respect to the previous year (2007) that we call increment in Figure 5.

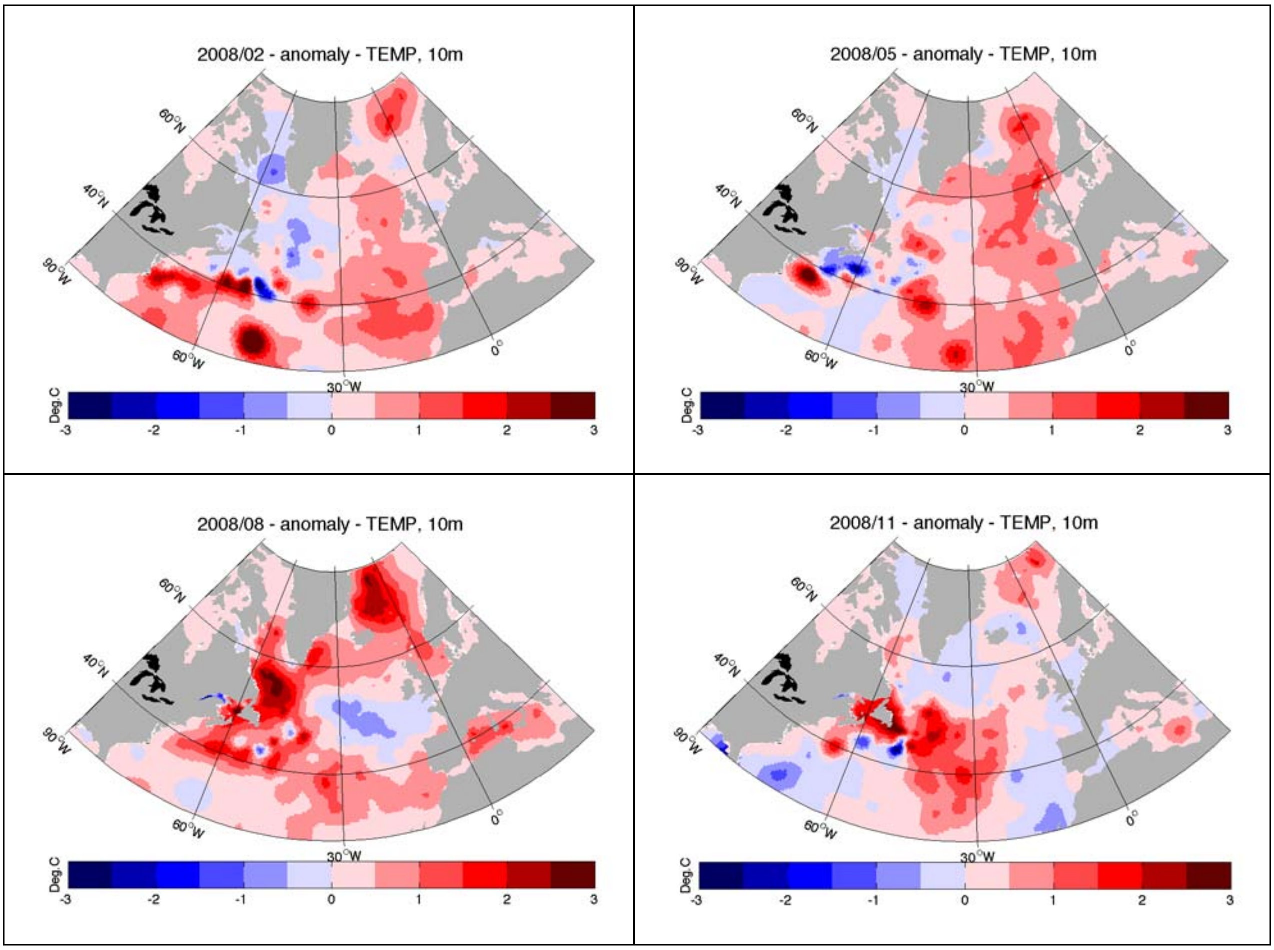

Figure 2. Near surface temperature (10m) for February, May, August and November 2008.

The surface conditions in 2008 have been marked by slightly cooler than normal temperatures in the North-Western part of the basin during winter and spring while the rest of the basin was warmer than normal. Summer was warmer than normal in particular in the Greenland and Labrador seas, it was colder in the North-East Atlantic (south of 60N).

In average over the year 2008 the North Atlantic has been mostly warmer and saltier than the climatology in the near surface layer (10 m). However, we note three areas that tend to be cooler and fresher: the northern part of the Labrador sea, a small area south of New-Foundland and the area centred at 55N–30W. In fact relative to 2007 the cooling of the centre of the gyre is marked and the freshening of the Labrador see extends further south.

The cooling is even more extended at the level of the mode waters (300m), the only area showing a marked warming (and saltening) lies at 40N along the North American shelf

At depth (1000 and 1600 m) the Greenland sea is warmer, Irminger and Labrador seas are warmer and saltier. The signal associated with the Mediterranean water varies with depth. Near the core of the Med water (at 1000 m) the water is warmer and saltier while it is colder and fresher at its lower boundary (1600 m). Interannual change from 2007 to 2008 is low in the northern part and a slight cooling is noted in Labradror/Irminger seas at 1000m. South of 45–50N, the changes show strong space variability.

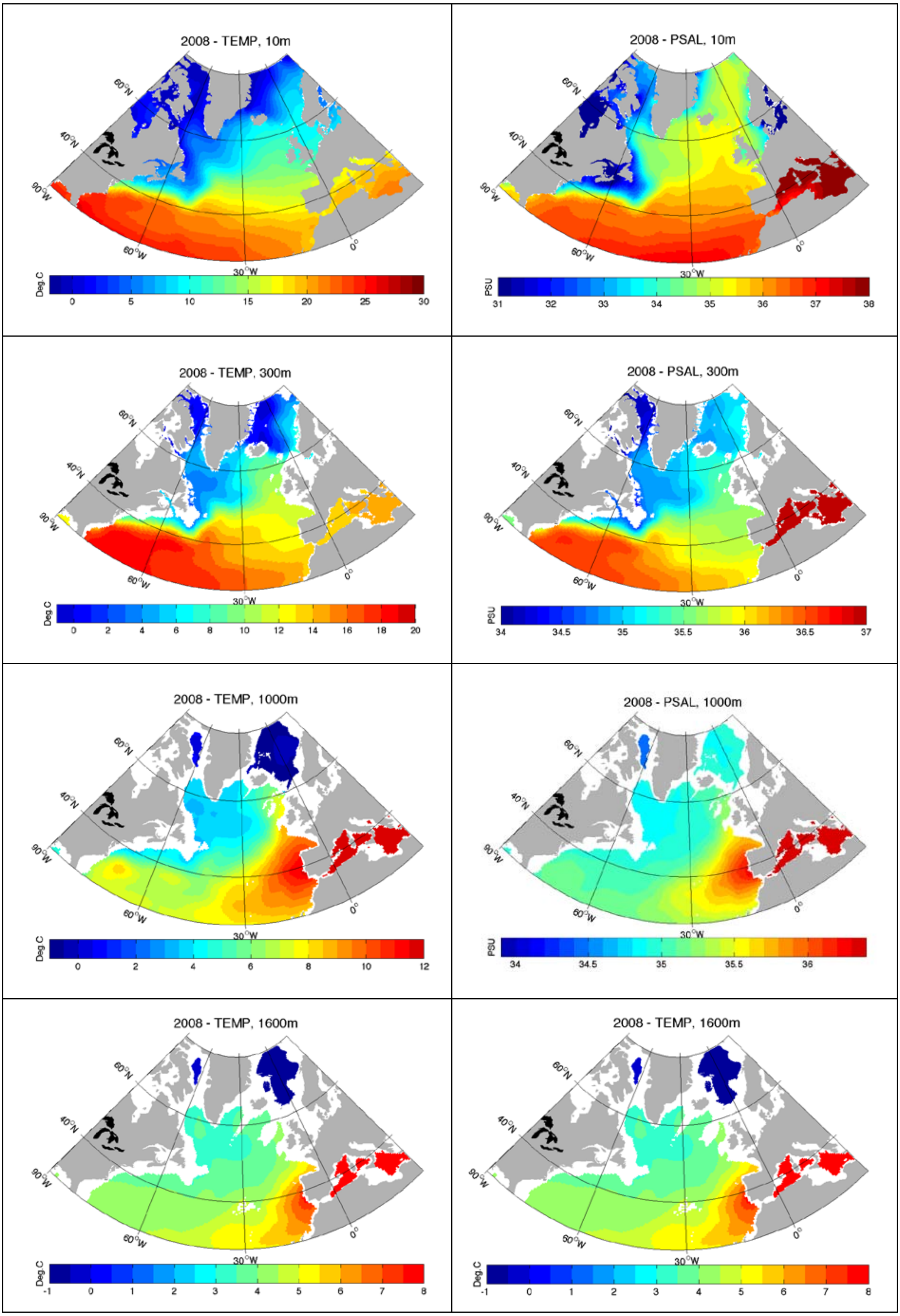

Figure 3. Annual mean temperature (left) and salinity (right) at three depth levels for the year 2008, deduced from the monthly analysis (ISAS).

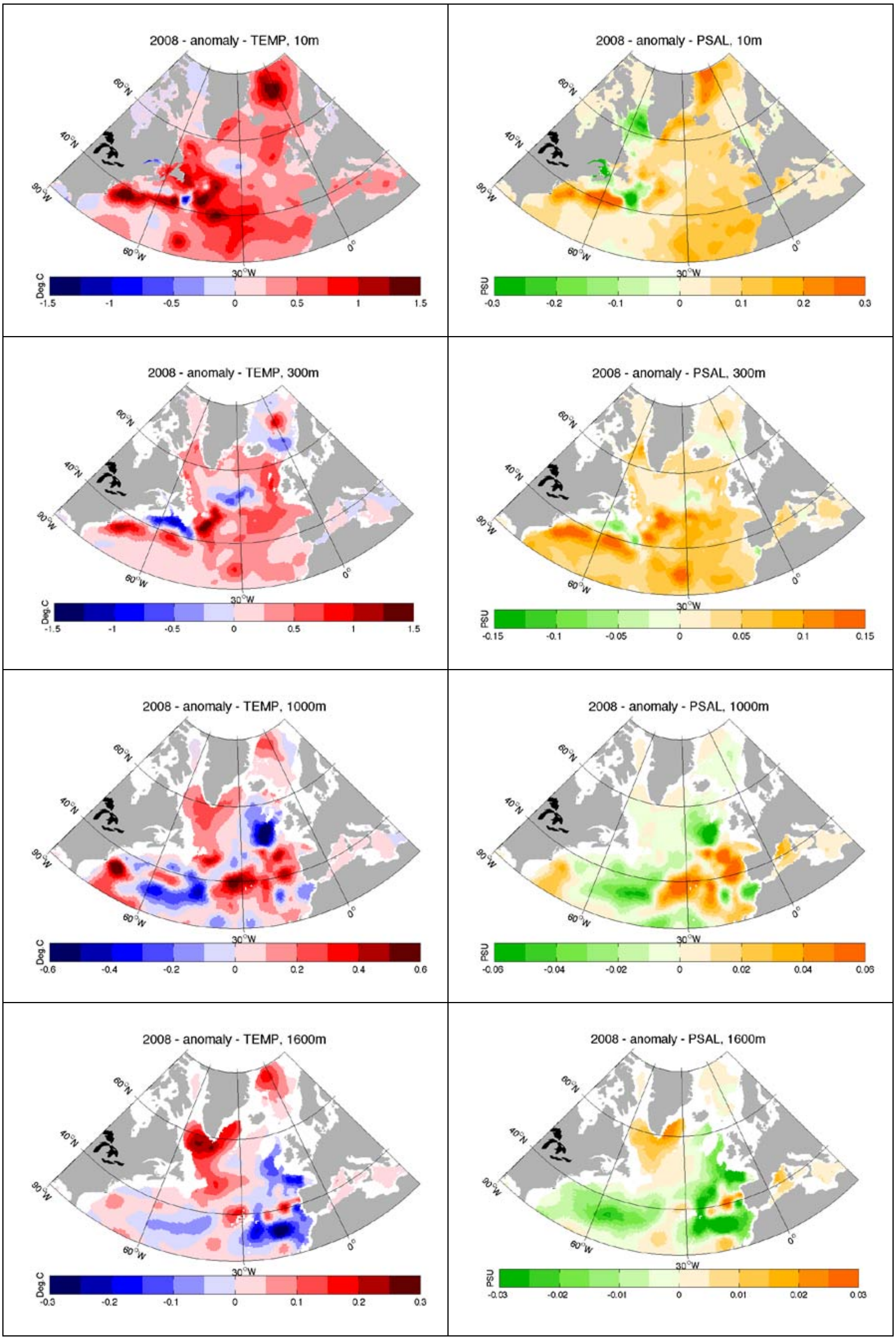

Figure 4. Anomalies of the annual means relative to the reference climatology (WOA-05).

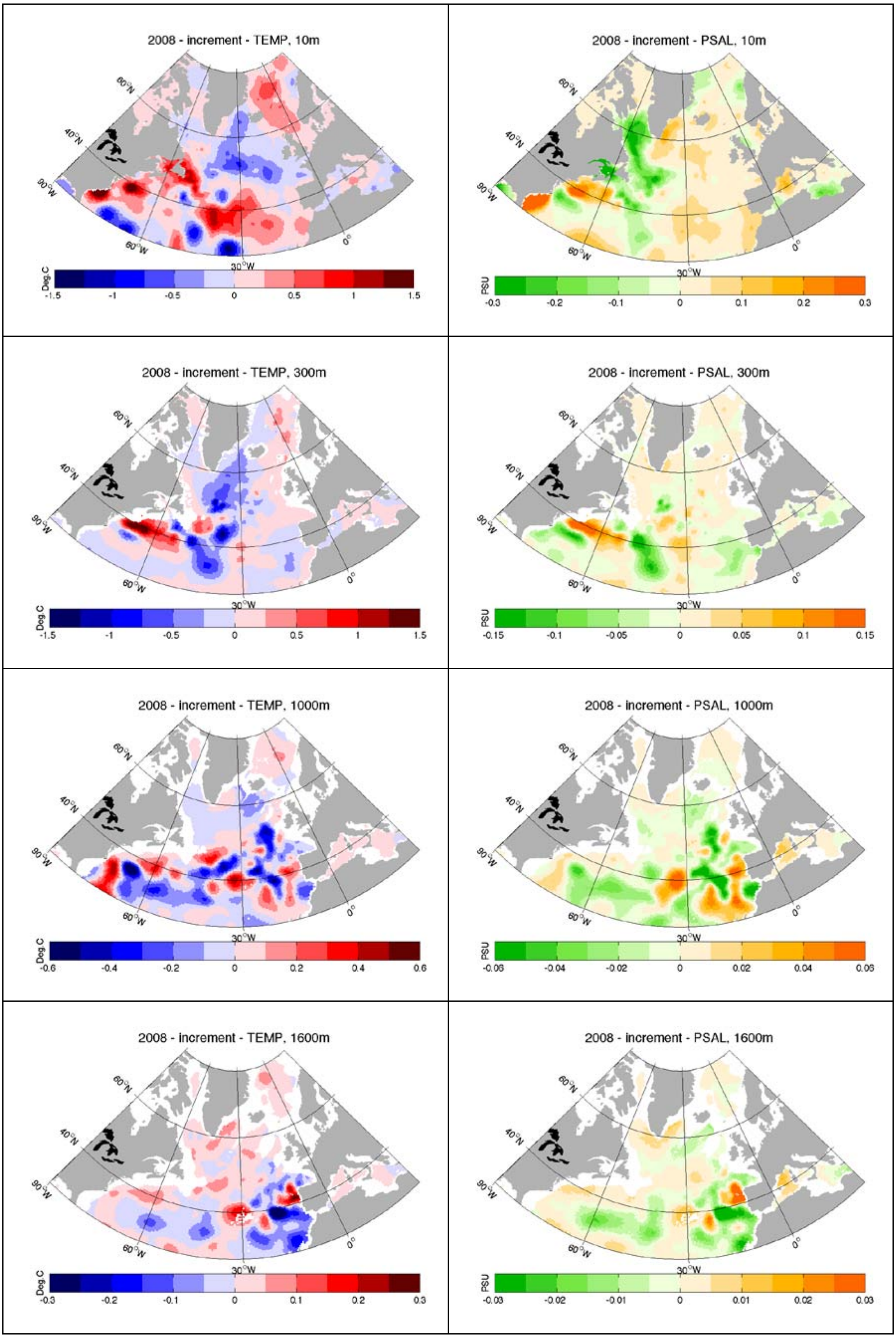

Figure 5. Increment, or change observed in 2008 relative to 2007.

2.2 Time-series

Time-series of temperature and salinity have been extracted from the monthly 3D fields at 12 selected points (Figure 6).

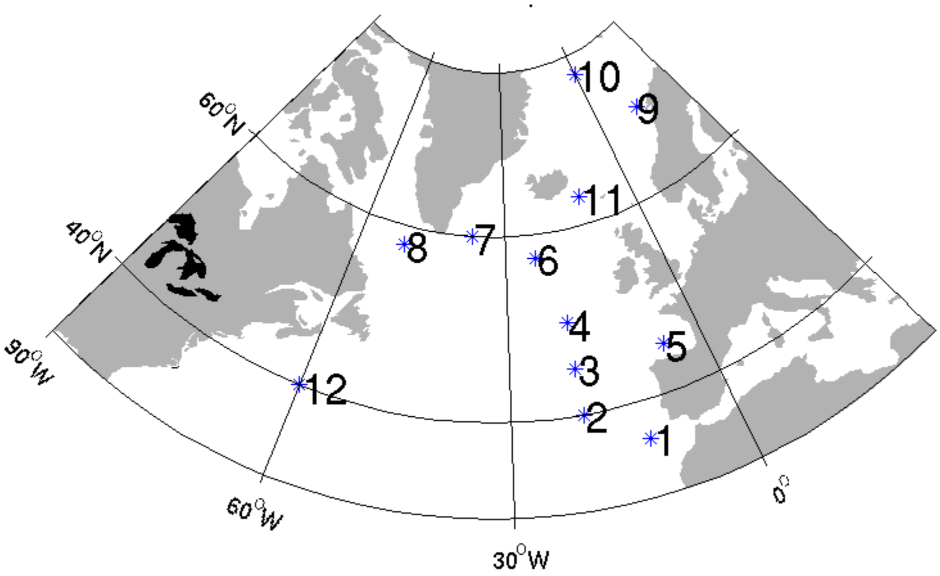

Figure 6. Position of points selected to present the seasonal cycle and interannual variability

2.2.1 Seasonal cycle

The seasonal cycle is shown Figure 7 and Figure 8. The main features at the most representative points are :

- Mediterranean outflow (1) : Winter was 1° warmer than climatology and the warmest of the period. Summer was 0.7° warmer than climatology and second warmest summer.
- Bay of Biscay (5) : Slightly warmer than climatology in winter and spring, Summer was near climatology and the coldest of the period.
- 50N–20W (4) : Winter slightly above climatology, coldest summer of the period, with August/ September below climatology.
- Iceland basin (6) : 0.5° warmer than climatology, except in fall.
- Irminger sea (7) : Winter is similar to climatology, and coldest of the period. Summer 1.5° above climatology, autumn slightly colder than climatology.
- Labrador Sea (8) : Winter was cold, but similar to climatology. Summer was warm (1.8° above climatology). Autumn was cold.
- Greenland Sea (10) : This basin was nearly 2° warmer than climatology but slightly cooler than the two previous years.

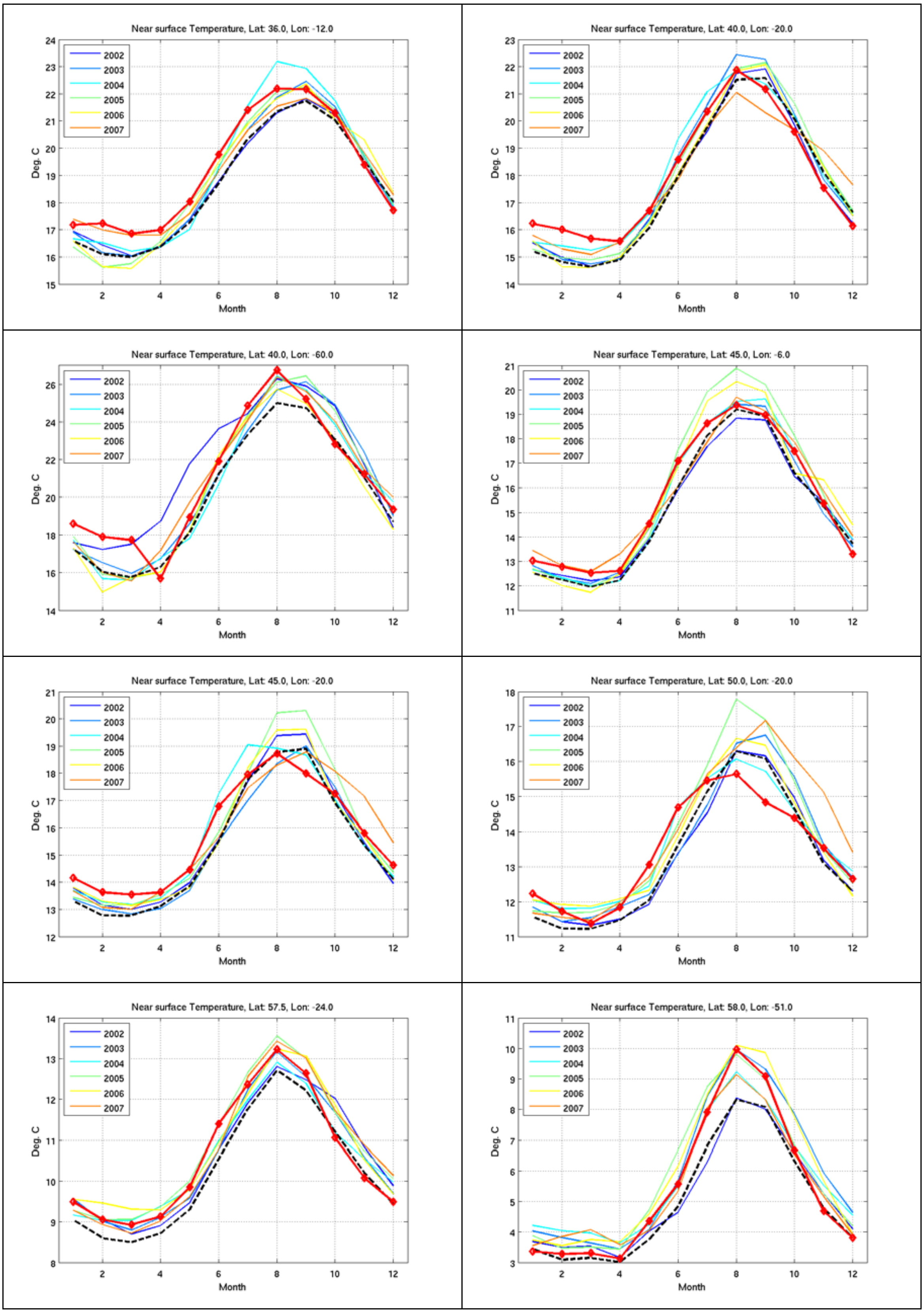

Figure 7. Seasonal cycle at different points (1)

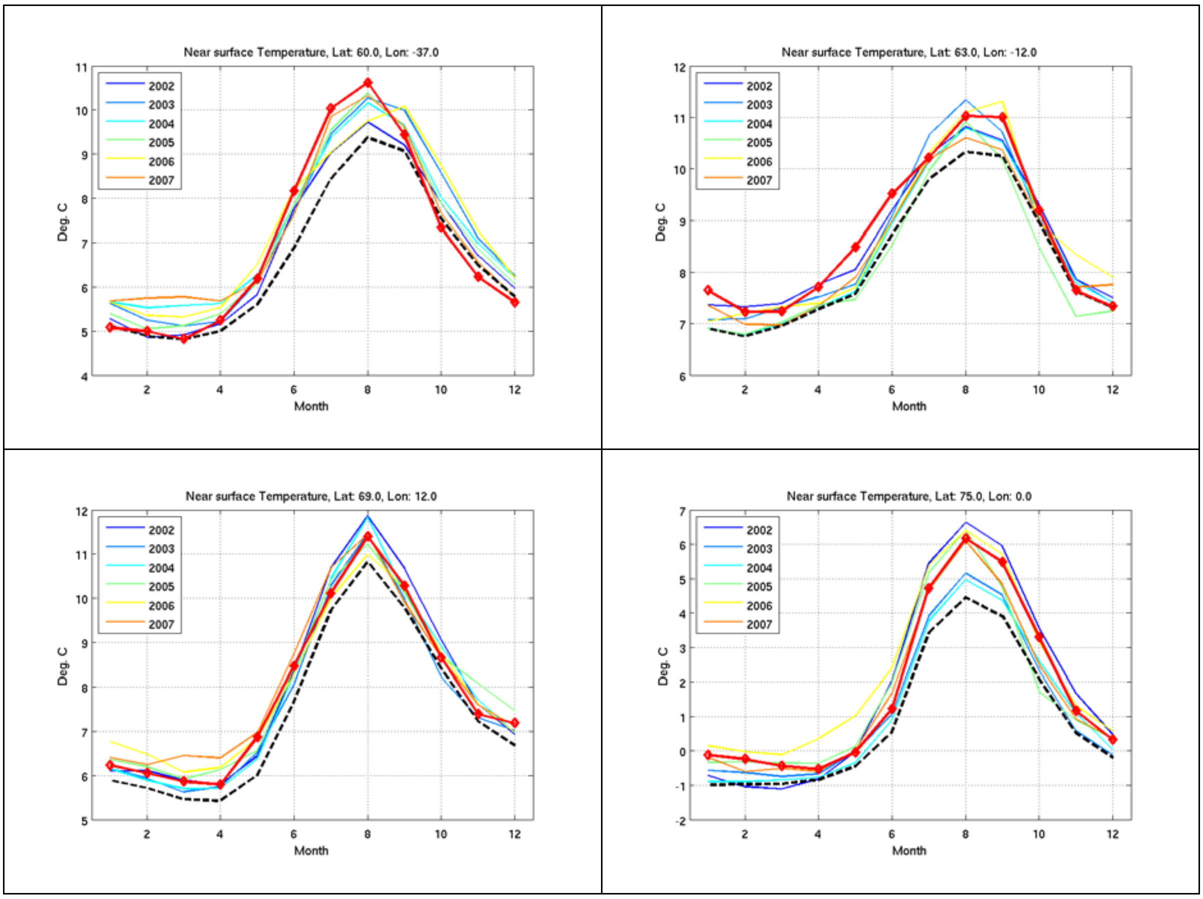

Figure 8. Seasonal cycle at different points (2).

2.2.2 Interannual variability

- Mediterranean outflow (1) : There is a tendency toward warming and saltening in the 200–400m layer. At depth interannual variability is hard to distinguished and might not be correctly sampled because of the meddies.
- Bay of Biscay (5) : The same tendency for warming and saltenig is observed in the 200–400m layer. The period 2004–2008 appears warmer and saltier at 800–1200m and colder and fresher below (as was the case in the Med outflow).
- 50N–20W (4) : A clear cooling/freshening is seen at 800–1200m in 2006–2008.
- Iceland basin (6) : A slow warming-saltening is observed in the 1600–1900m layer over the whole period (2002–2008). In the 200–400m layer cooling is observed since 2006.
- Irminger sea (7) : The warming/saltening of the deep layers is significant (0.3°/year and .007PSS/year) . We also note the cold event without salinity signal at the mode water level at the beginning of 2008.
- Labrador Sea (8) : The warming-saltening tendency is observed in all layers. The convection that occurred at the beginning of 2008 appears as a cold/fresh anomaly down to 1200m.
- Greenland Sea (10) : The warming tendency is clearly seen in the 800–1200 layer. Deeper, the sampling is not sufficient to track interannual variability. In the 200–400 layer strong interannual variability dominates.

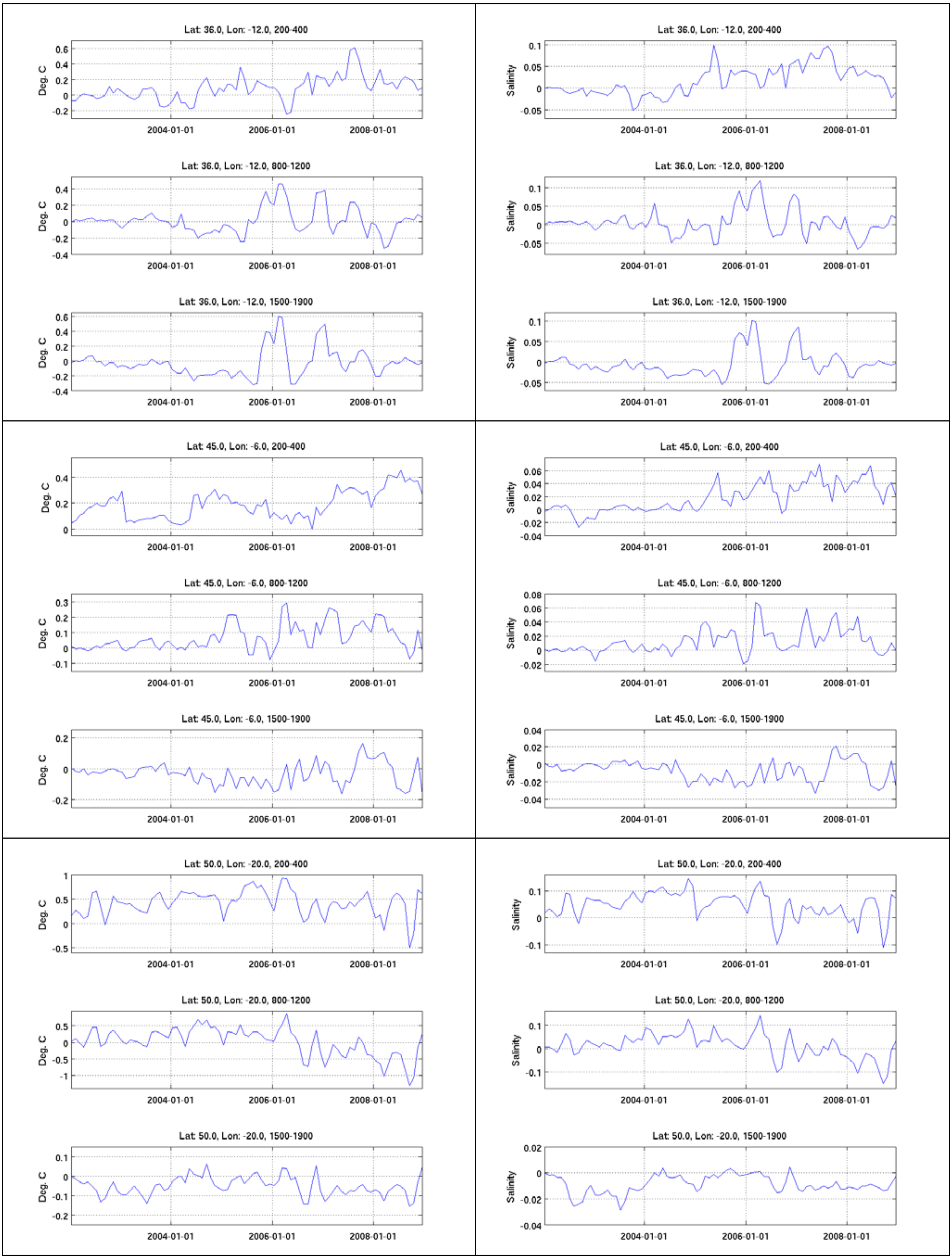

Figure 9. Time-series of temperature (left) and salinity (right) averaged over layers. 200–400m (top), 800–1200 (middle) and 1500–1900 (bottom). Points 1, 5, 4.

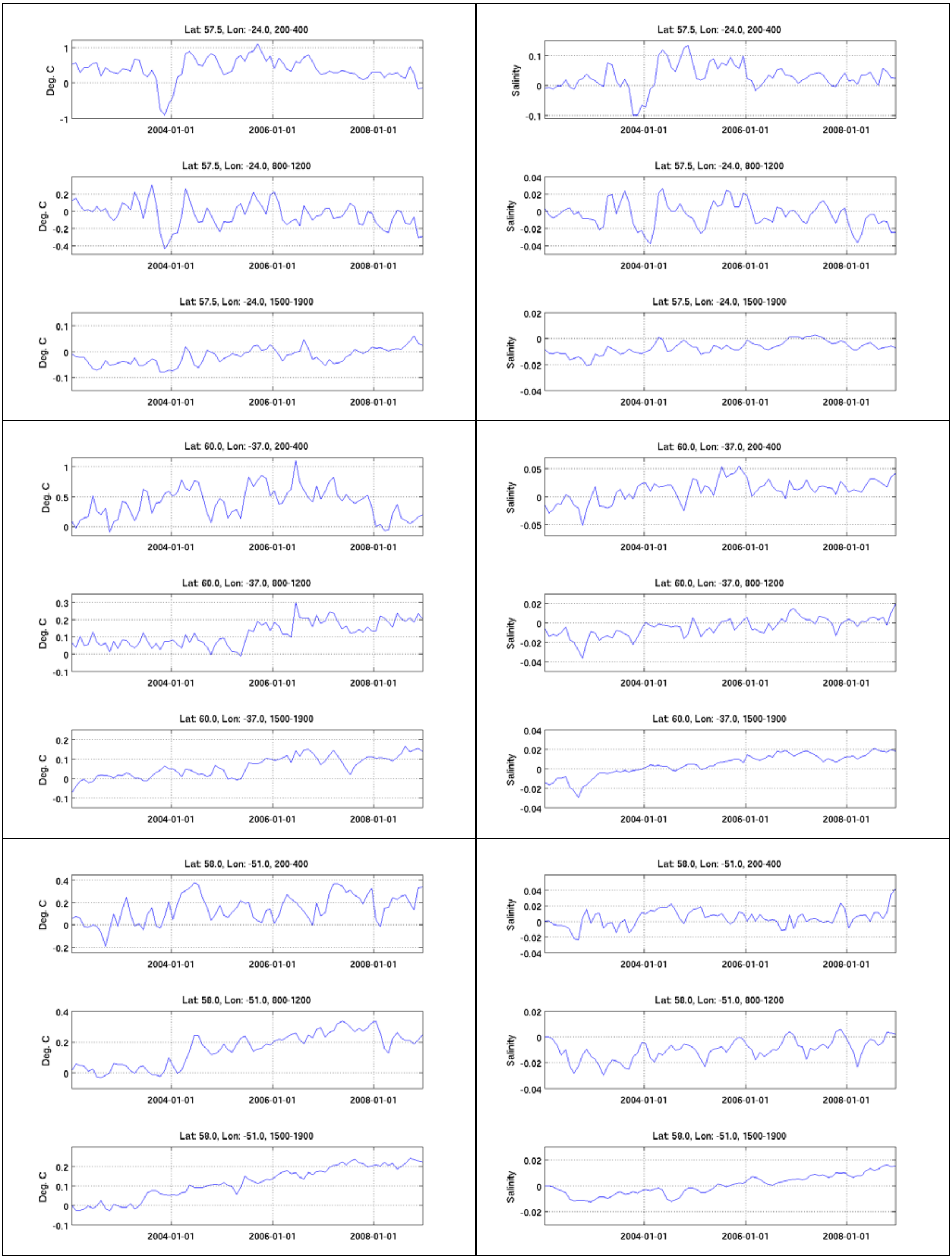

Figure 10. Time-series of temperature (left) and salinity (right) averaged over layers. 200–400m (top), 800–1200 (middle) and 1500–1900 (bottom). Points 6, 7, 8.

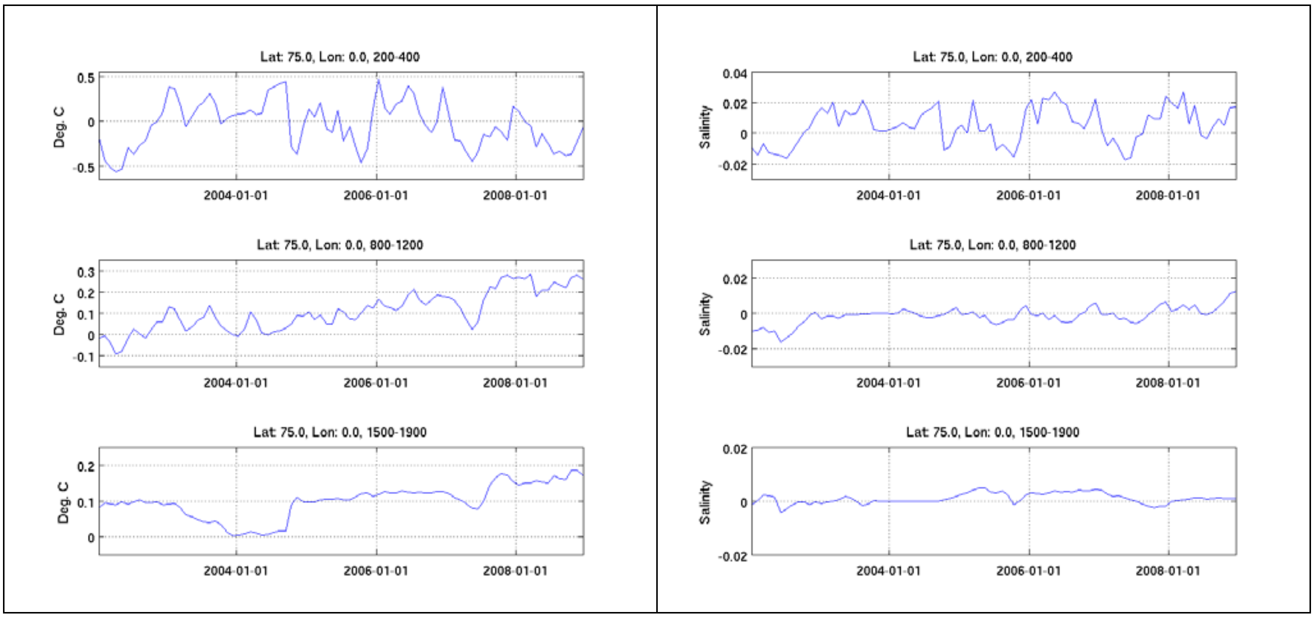

Figure 11. Time-series of temperature (left) and salinity (right) averaged over layers. 200–400m (top), 800–1200 (middle) and 1500–1900 (bottom). Point 10.

3. Coastal time-series

3.1 Astan and Estacade sites (Western English Channel)

Measurements collected twice a month at two stations located on the coastal area on the north coast of Brittany in France are presented here (red point on Figure 12). The Estacade site is located at the end of a peer in the city of Roscoff (France) where the bottom depth varies from 3 to 12 m depending on the tides. Measurements began in 1985. They are collected at 1 m depth. Its exact location is 3°58′58W and 48°43′56N. The Astan site is located 3.5 kilometres offshore from the Estacade site and measurements began in 2000 at 3°56′15W and 48°46′40N. Properties at this site are typical of the Channel water. Bottom depth is at about 60 m depth and the water column is nearly homogenous for most of the surveys. More details can be found at http://www.domino.u-bordeaux.fr/somlit_national/.

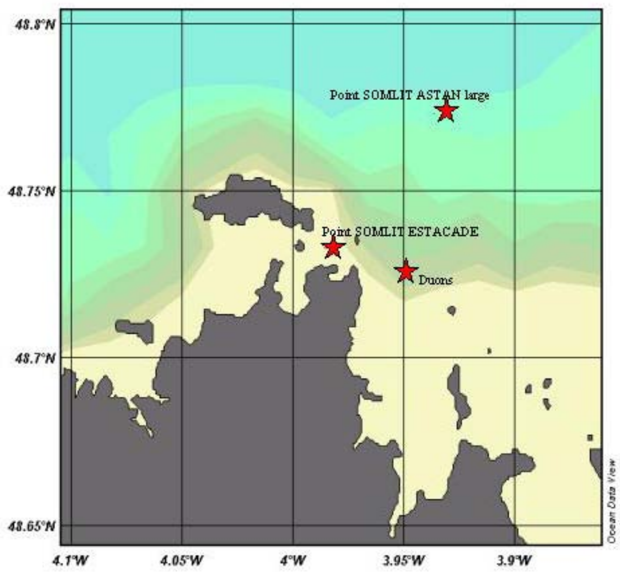

Figure 12. Location of the ESTACADE and ASTAN sites

The first panels (Figure 13) present the 2008 cycle of temperature, salinity and nitrate compared to the mean annual cycle. Both stations show that temperatures during 2008 were close to the mean temperature cycle at the two points. Between March and June, temperatures were higher (+ 0.64 °C) than the averaged values at Astan site station. From august to December, temperatures were lower than averaged values. Excepted from July to October when temperatures were close to the average, temperatures were generally warmer with a maximum in December (+1.74°C). Salinity annual cycles at the two sites were characterized in 2008 by two minimums observed in march and June. Year 2007 was characterized by salinity values which were higher than the averaged values and by the absence of the classical salinity minimum. This explains the positive salinity anomalies (> 0.2) observed in January and February at the two sites. During the second part of the year, salinity values were generally lower than the averaged values. Winter 2007/2008 nitrate concentrations were lower than the averaged values corresponding to the more pronounced oceanic influence. During spring, nitrate concentrations were close to the averaged values. During summer and autumn, nitrate concentrations were not exhausted by phytoplankton development and concentrations were higher than usually observed with positive anomalies (> 1 µM/l^{-1}).

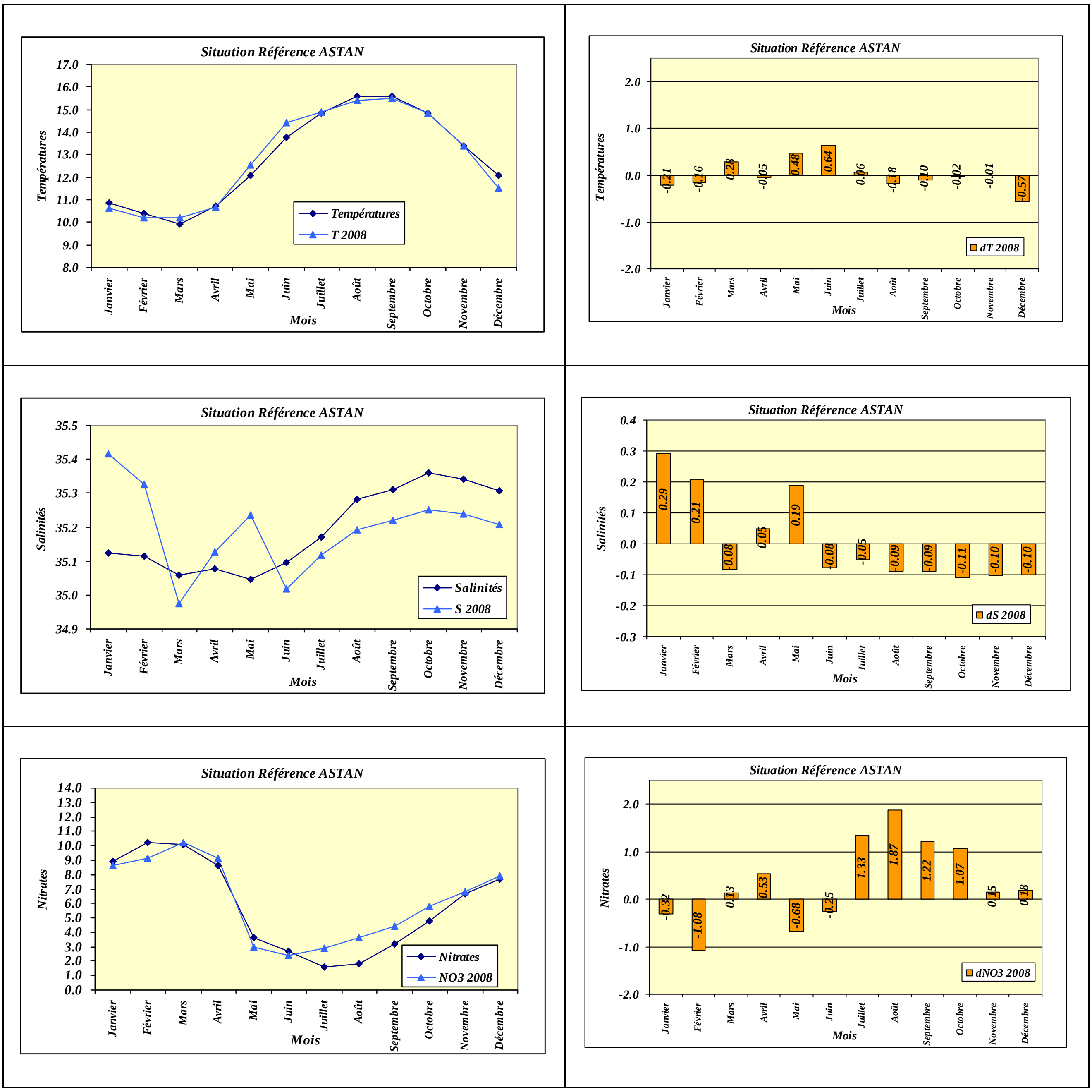

Figure 13. Comparison between times series of temperature (upper), salinity (middle) and nitrate (lower) at the Astan site in 2008 with the climatological cycle. (Left panels) 2008 values. Dark blue line represents the mean annual cycle and light blue line represent 2008 data. (Right panels) 2008 anomalies.

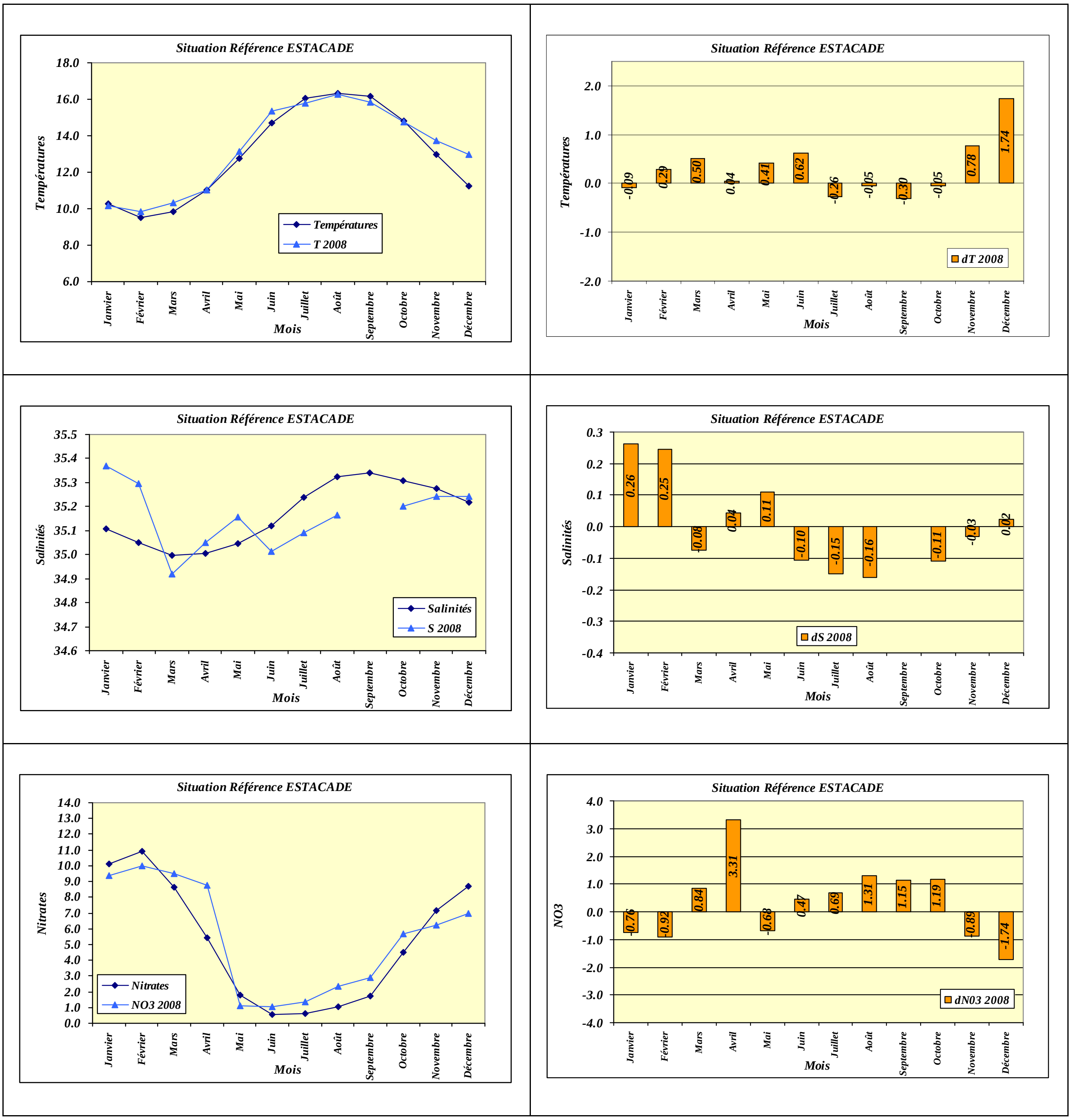

Figure 14. Comparison between times series of temperature (upper), salinity (middle) and nitrate (lower) at the Estacade site in 2008 with the climatological cycle. (Left panels) 2008 values. Dark blue line represents the mean annual cycle and light blue line represent 2008 data. (Right panels) 2008 anomalies.

Figure 14 show time-series of temperature, salinity and nitrate at Astan over the period 2000–2008 and at Estacade over the period 1985–2008 with a large gap from 1992 through 2000. At the Astan site, winter 2008 minimum temperatures were close to the values observed in the early 2000s. In summer 2008, Western Channel waters were well-mixed over the entire water column since no temperature differences between surface and bottom waters were observed. In 2008, salinity cycle is characterized as mentioned above by two seasonal minimums that were rarely observed before. Nitrate concentrations as salinity 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. Year 2008 was characterized by high residual summer nitrate values which may be explained by a lower phytoplankton uptake due to the existence of less favourable environmental conditions than usual during a rainy summer.

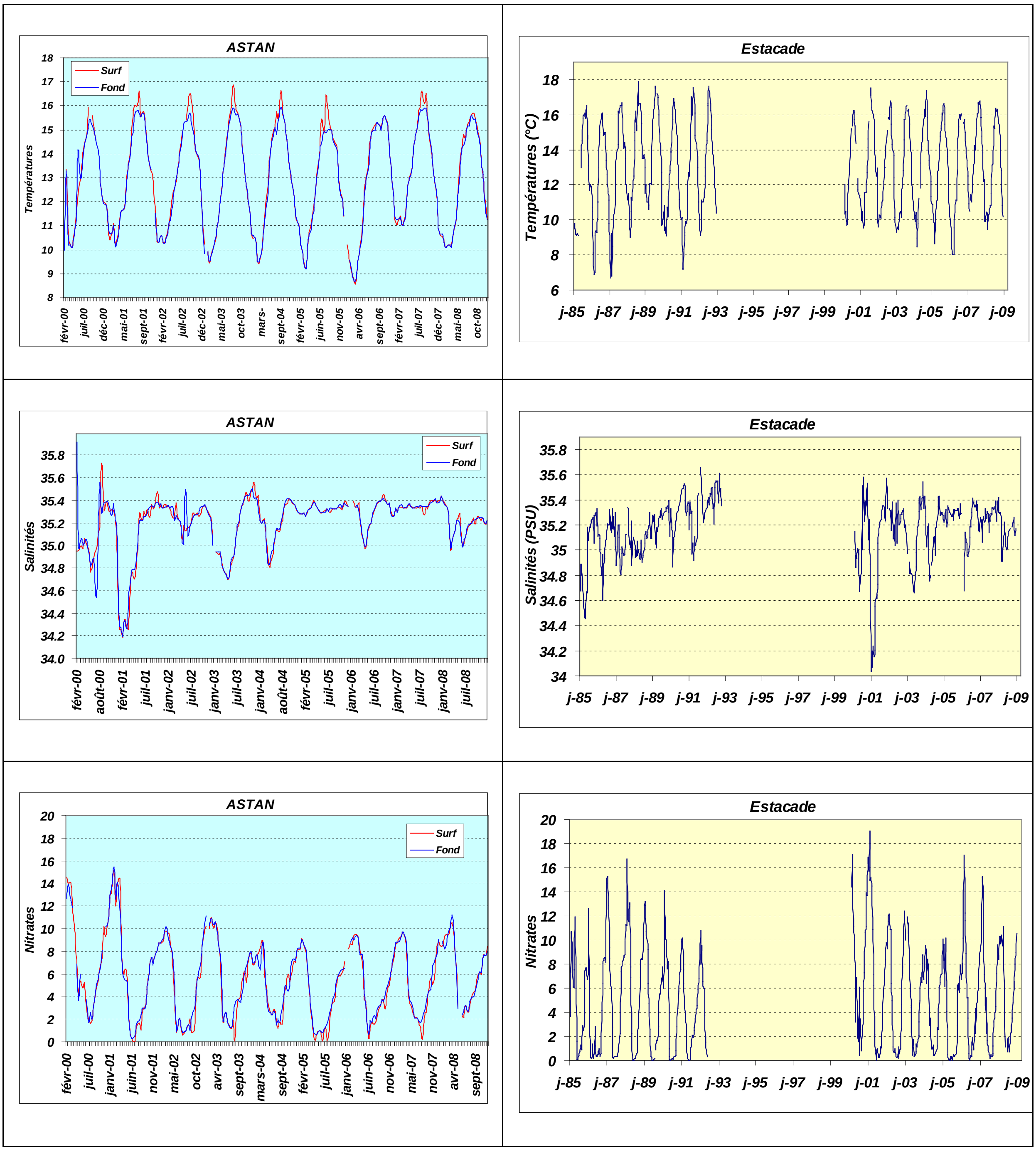

Figure 15. Interannual variability of the temperature, salinity and nitrate at the Astan site over 2000–2008 (left panels) and at the Estacade site over 1985–2008 (right panels).

4. References

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Annex 9 : Icelandic Waters

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

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

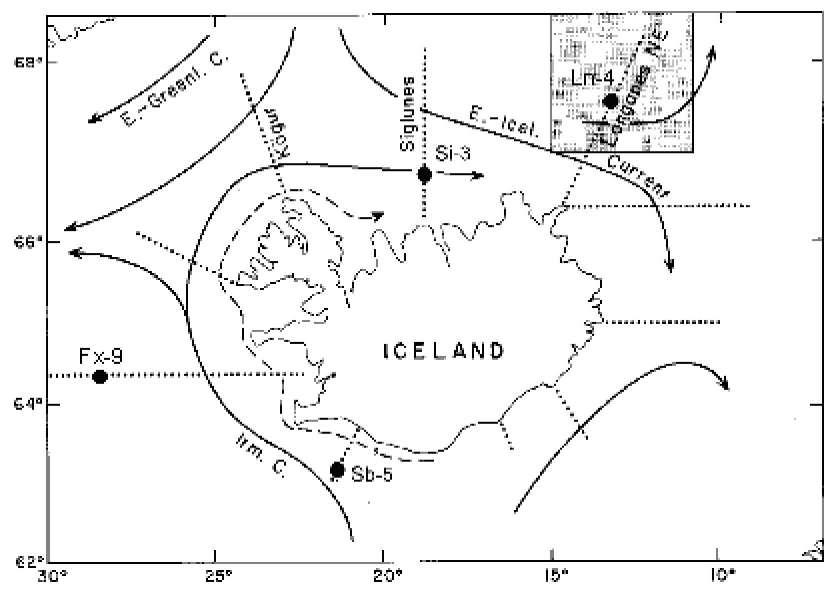

Figure 1. Main currents and location of standard hydrobiological sections in Icelandic waters. Selected areas and stations dealt with in this report are indicated.

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

In 2008 mean air temperature in the south (Reykjavik) and north (Akureyri) were above long time average (Figure 2a).

The salinity and temperature in the Atlantic water from the south remained at high levels similar to previous years (Figures 3.b, 5 and 7). The salinity in the East Icelandic Current in spring 2008 was well above average and temperature was slightly above long term mean (Figures 3a, 6 and 7).

Extremely cold conditions in the northern area 1995, improving in 1996 and 1997, and continued to do so in 1998 and 1999 to 2001 mild but showed a slight decrease in 2002 (Figure 2b) and were then followed by the mild conditions for all seasons in 2003 and 2004. Lower temperatures were seen in the north and east areas in 2005 and 2006. However south and west of Iceland temperatures and salinities have remained high since 1997 and this continued in 2008. In 2008 summer and autumn surface layers temperatures and salinities were higher in the north than they were in 2007.

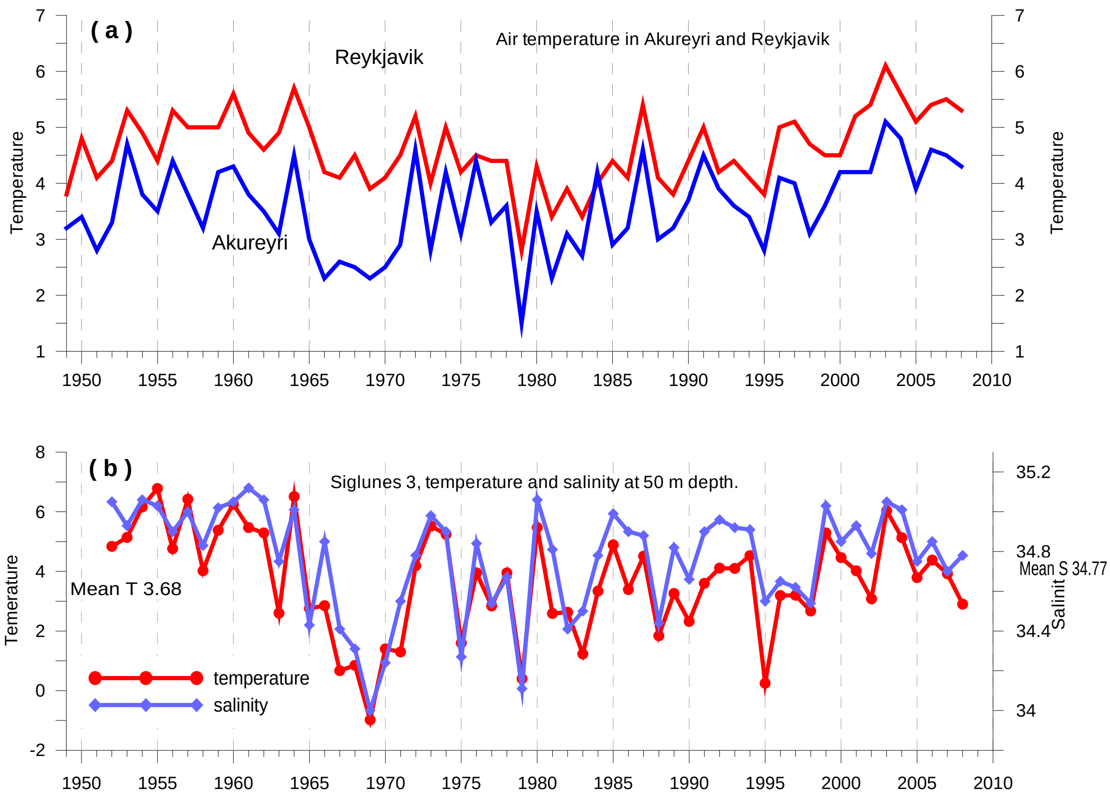

Figure 2.

a. Mean annual air temperatures in Reykjavík and Akureyri 1949–2008

b. Temperature and salinity at 50 m depth in spring at Station Si-3 in North Icelandic waters 1952–2008

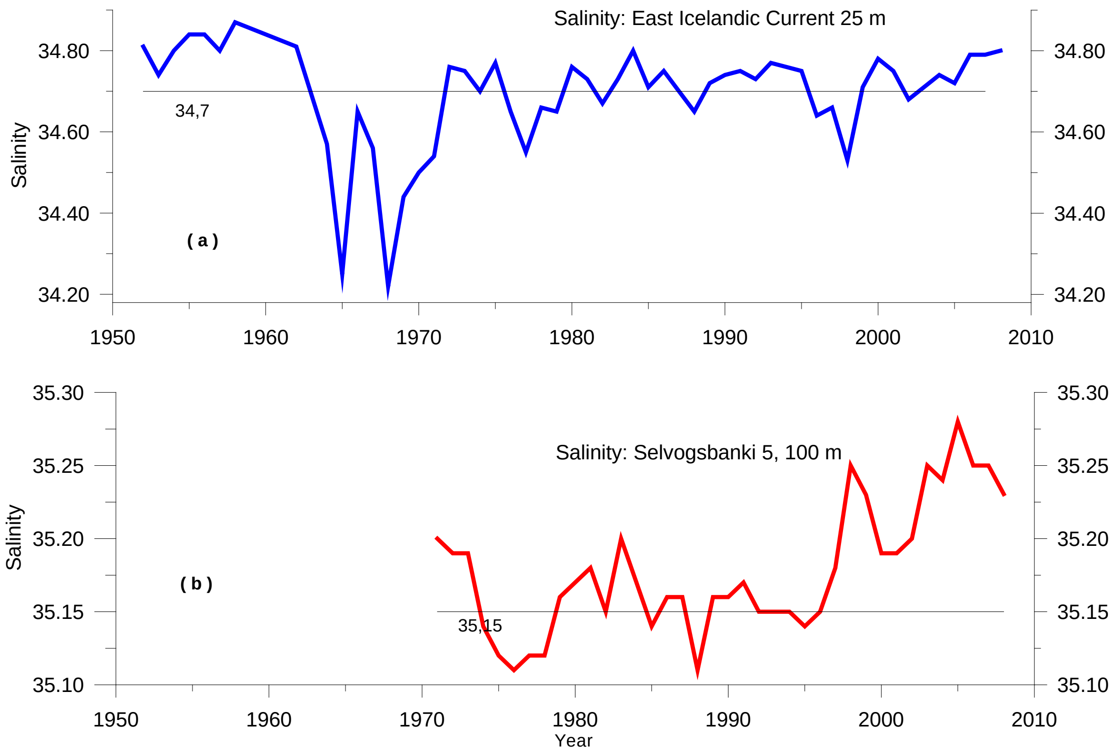

Figure 3. Salinity in spring at:

a. 100 m depth in the Irminger Current south of Iceland (Sb-5) 1971–2008.

b. 25 m depth in the East Icelandic Current north-east of Iceland 1952–2008, mean from shaded area in Figure 1.

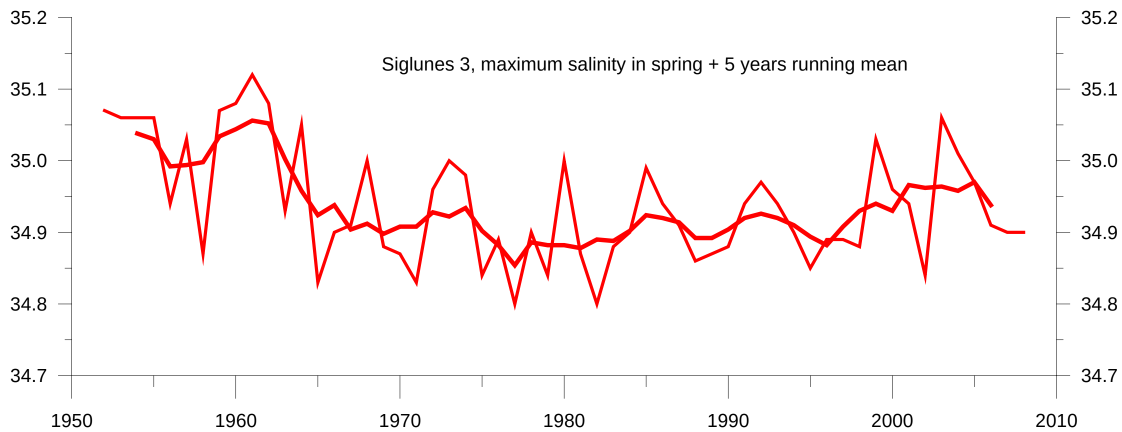

Figure 4. Maximum salinity in the upper 300 m in spring at station Si-3 in North Icelandic waters 1952–2008 and 5 years running mean.

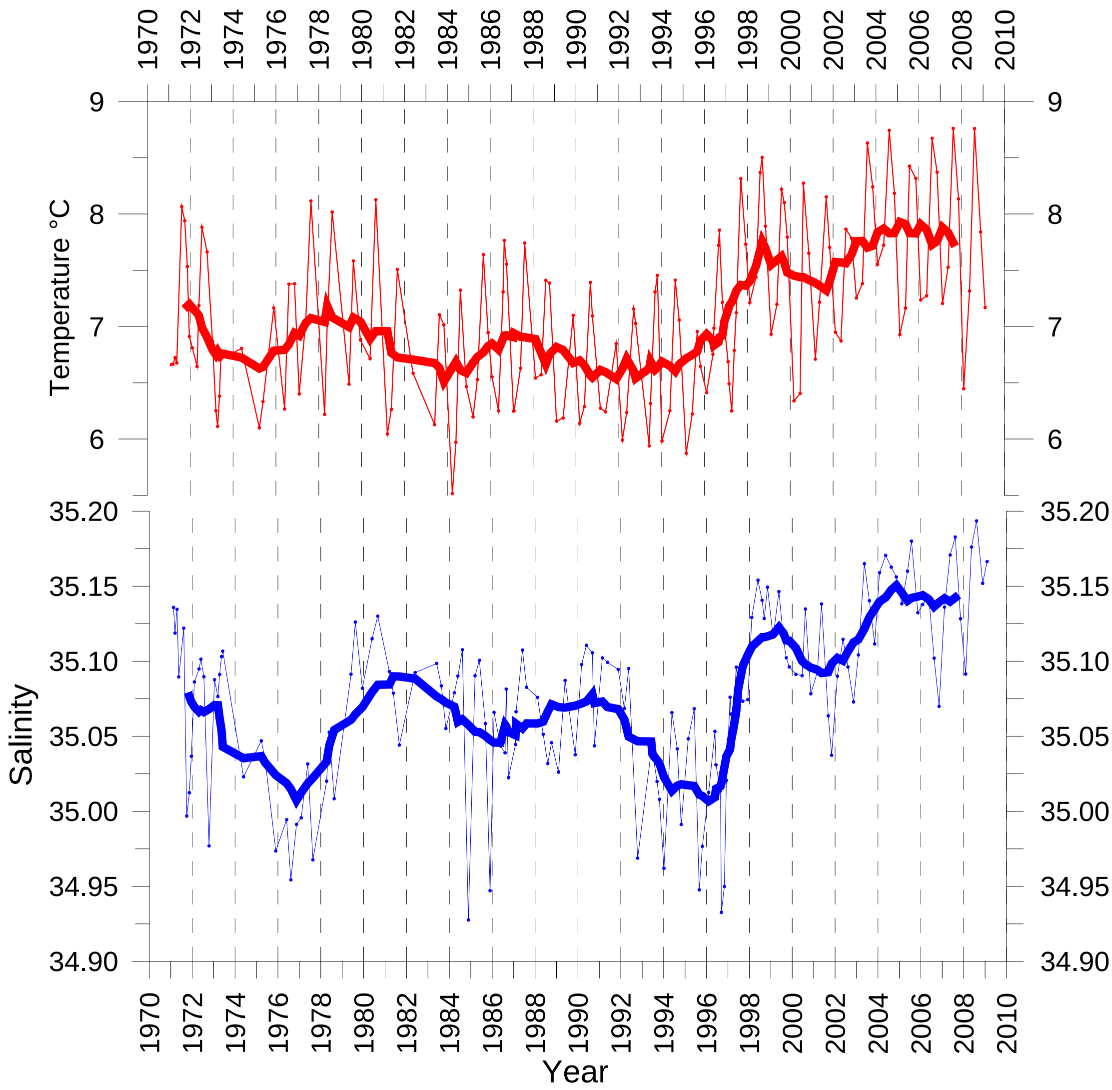

Figure 5. Mean temperature 0–200 m at the shelf brake west of Iceland, 1971–2009. Combined data from stations RE8 (1971–1984) and FX9 (1984–2009), 20 nm apart. Thick line is approx. 3 years running mean.

Annex 10: Spanish standard sections

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Vigo Spain

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The Spanish Standard Sections cover the area of the shelf and shelf-break of the Eastern Atlantic and North Iberian Peninsula. Five sections are sampled monthly by the Instituto Español de Oceanografía, located in Santander (43.5ºN, 3.8ºW), which is the largest, two in Asturias (43.6ºN, 6.2ºW) and from 2001 (43.6ºN, 5.6ºW), A Coruña (43.40ºN, 8.3ºW) and Vigo (42.1ºN, 9.0ºW). Additionally to the area covered by the Instituto Español de Oceanografía, AZTI collected oceanographic data at 43.30ºN, 2ºW (San Sebastián Section) over the continental shelf of the SE Bay of Biscay from 1986 (Figure 1).

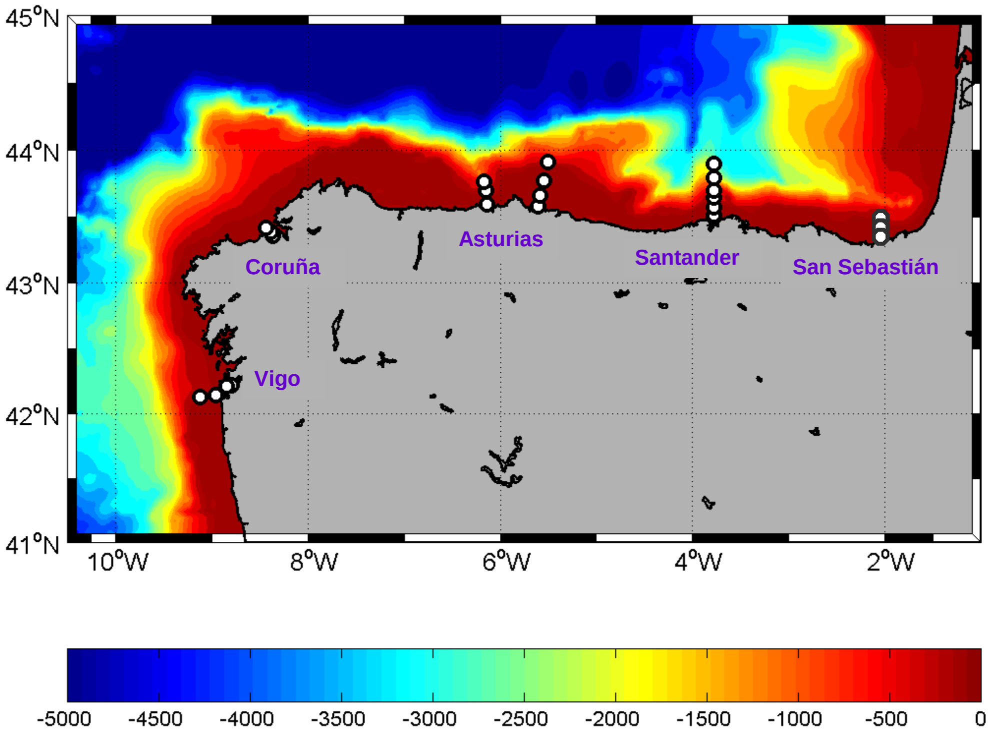


Figure 1. Spanish Standard Sections from the 'Instituto Español de Oceanografía' (Vigo, Coruña, Asturias, Santander) and from AZTI (San Sebastián).

The Bay of Biscay lies almost adjacent to the Atlantic, located between the eastern part of the subpolar and subtropical gyres. The region is affected by both gyres, depending upon latitude. However, the general water circulation in the area follows mainly the subtropical anticyclonic gyre, in a relatively weak manner (1–2 cm·s^{-1}). Because of the east to west orientation of the Basque coast, together with the north to south orientation of the French coast, onshore Ekman transport dominates clearly in autumn and winter due to the westerly and southerly winds. In spring and summer, easterly winds produce weak coastal upwelling events that compensate partly the convergence and downwelling

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).

1. Meteorological Conditions

1.1 Atmospheric temperature

Meteorological conditions in the north of the Iberian Peninsula in 2008 (source: Delegación en Cantabria de la Agencia Estatal de Meteorología) indicate that it was an average year relative to the period 1961–2007. The annual mean air temperature over the southern Bay of Biscay during 2008 was 14.6°C, practically the same than the 1961–2008 average, but well down the last twenty-year mean, being only 1991 and 1992 colder than 2008. Figure 2a shows the plot of the annual means and total average.

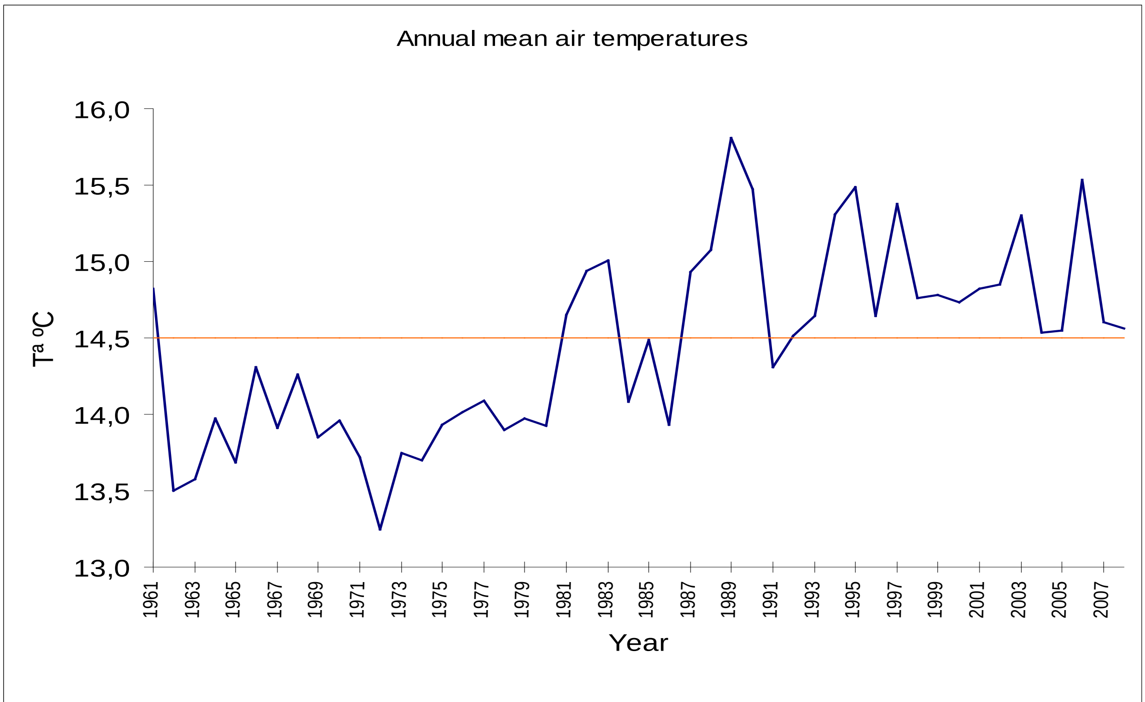


Figure 2. Annual mean temperatures in Santander (43.5ºN, 3.8ºW). Courtesy of the 'Agencia Estatal de Meteorología'.

In the annual cycle (Figure 3a) can be seen positive anomalies appearing in the winter (January–February), and spring (April to June) and negative anomalies for the rest of the year beginning in July and finishing in December. Especially important are the positive anomalies in January and February more than one standard deviation and the negative between September and December around half standard deviation. The seasonal cycle amplitude was 10.2º C from August (19.9ºC) to December (9.7ºC).

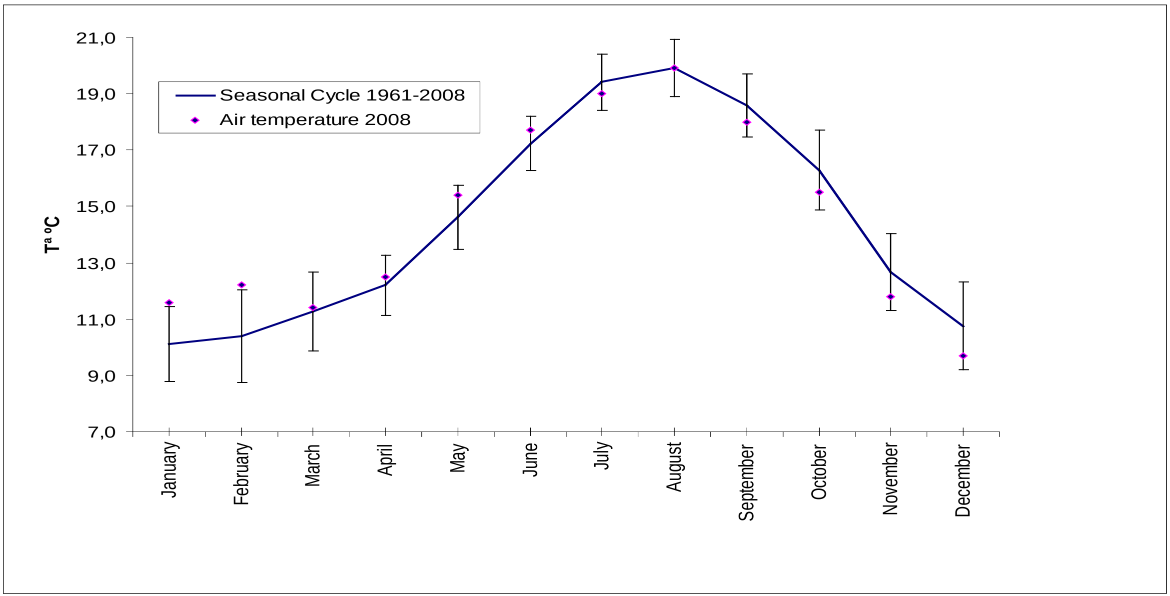


Figure 3a. Air temperatures in 2007 in Santander (43.5ºN, 3.8ºW) and mean value (1961–2007) and standard deviation.). Courtesy of the 'Agencia Estatal de Meteorología'.

Meteorological conditions in the SE Bay of Biscay in 2008 (Observatorio Meteorológico de Igeldo, San Sebastián, Agencia Estatal de Meteorología) were characterised by a warm winter (around the mean + standard deviation for 1986–2008 period), with the exception of March; a warm spring; and a cold summer and autumn (around the mean - standard deviation for 1986–2008) (Figure 3b). The annual mean air temperature was 13.41º C, 0.22º C below the 1986–2008 average.

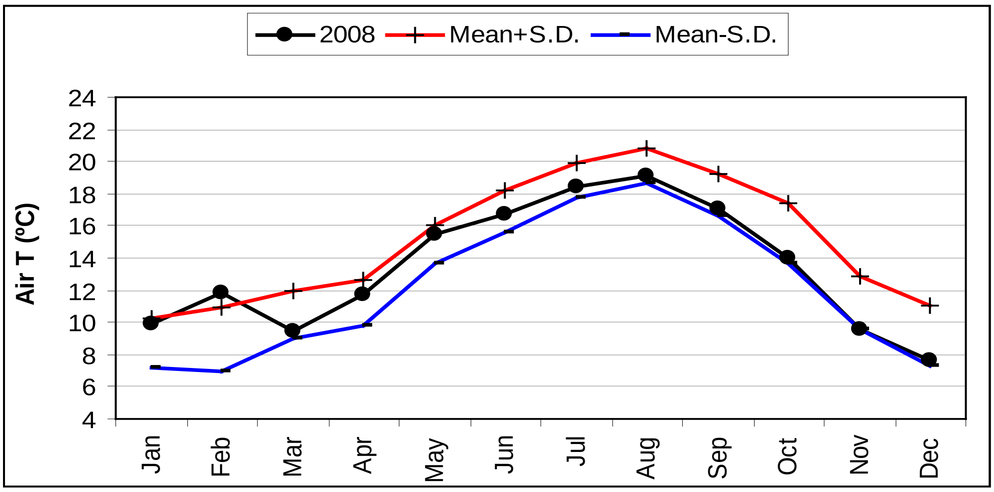


Figure 3b. Monthly mean air temperature (°C) in San Sebastián (43°18.5'N, 02°2.37'W) in 2008 compared with the mean ± standard deviation for the period 1986–2008. Courtesy of the 'Agencia Estatal de Meteorología'.

The peculiarities of the air temperature in 2008 can be observed in the context of the monthly mean temperatures of the period (1986–2008) and the evolution of the accumulated anomalies (Figure 4).

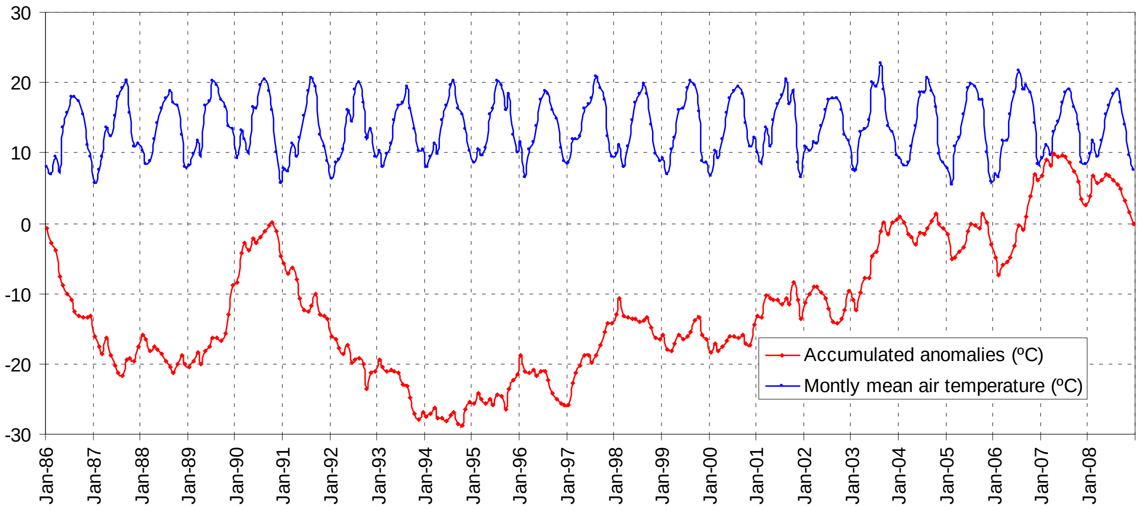


Figure 4. Monthly mean temperatures in San Sebastián (43°18.5′N, 02°2.37′W) in 1986–2008 and accumulated anomalies. Data Courtesy of the 'Agencia Estatal de Meteorología'.

1.2 Precipitation and evaporation

Strong rainfall was measured in the Santander AEMet Observatory during 2008 (Figure 5a), the higher in the last 12 years and the second from 1982.This circumstance has imported large amount of freshwater from the Cantabric and French rivers as well as direct rainfall over the sea surface. Looking at the seasonal pattern, (Figure 5b) we detected a high variability pattern with low rainfall on winter (January and February and July), high in March and the autumn October, November and December. The rest of the month's rainfall has been around the mean seasonal value. The autumn rainfall represent near half of the yearly rainfall and the conditions resulting will be looking deeply next year.

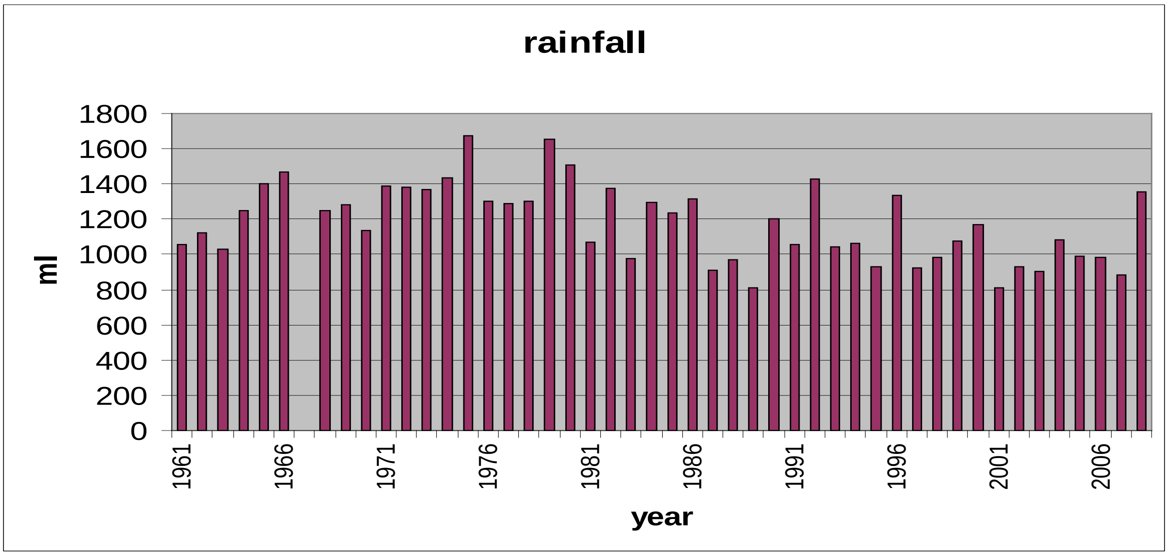


Figure 5a. Annual accumulated rainfall in Santander (43.5ºN, 3.8ºW) Courtesy of the 'Agencia Estatal de Meteorología'.

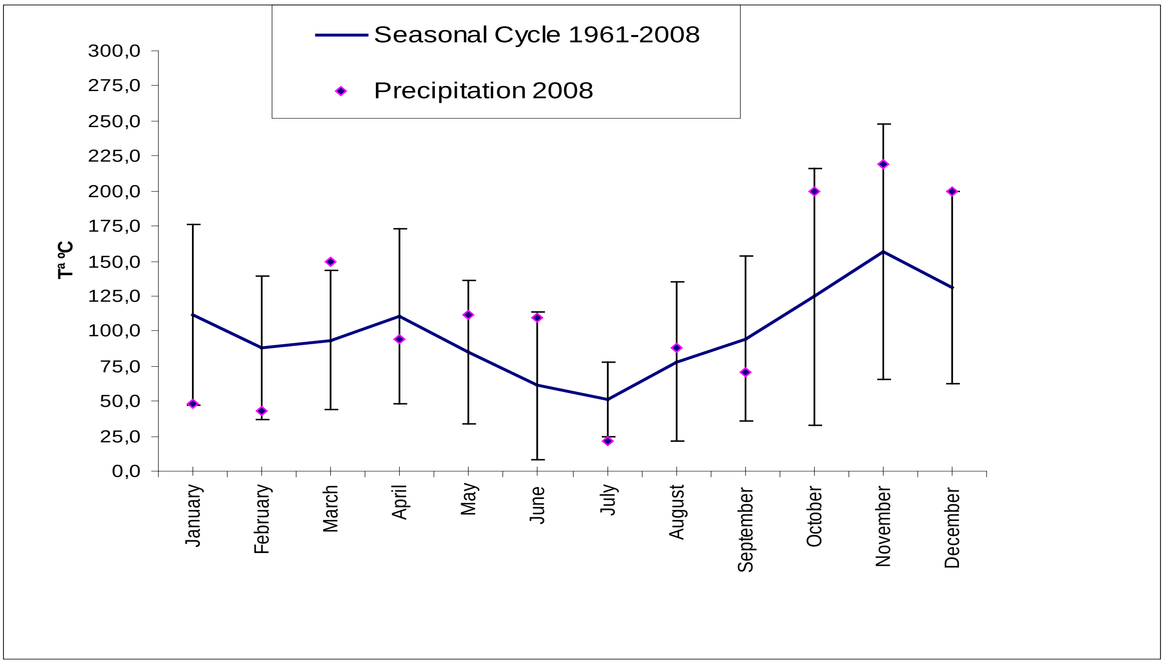


Figure 5b. Accumulated rainfall in 2008 in Santander (43.5ºN, 3.8ºW) and mean accumulated value (1961–2008) and standard deviation. Courtesy of the 'Agencia Estatal de Meteorología'.

In San Sebastián, 2008 can be characterised for being a wet year, concerning the precipitation regime. Thus, only February and September were around the mean minus standard deviation for the period 1986–2008; conversely, March, May and autumn 2008, as a whole, were over the mean plus standard deviation for the period 1986–2008 (Figure 5c). The annual mean precipitation was 159 mm, 36 mm over the 1986–2008 average.

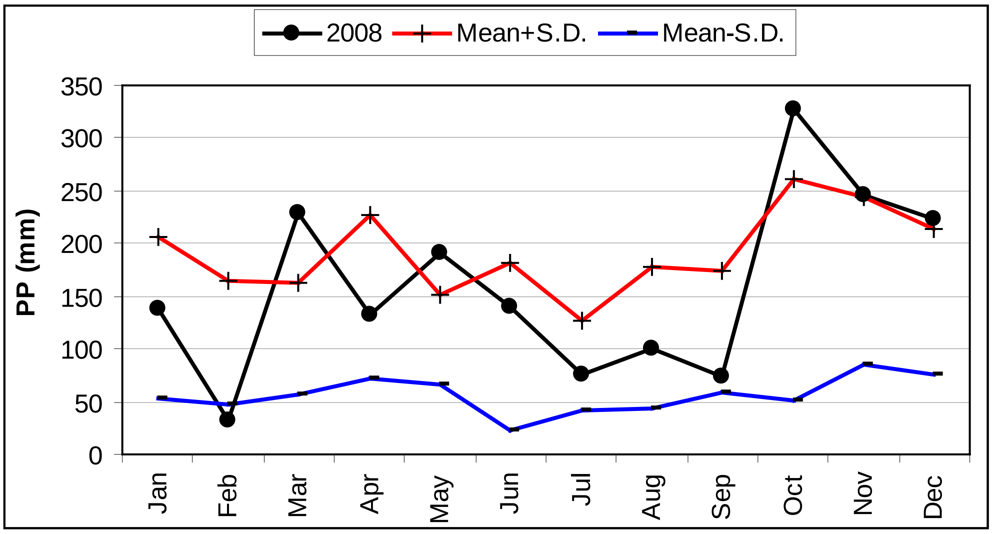


Figure 5c. Monthly precipitation (mm) in San Sebastián (43°18.5′N 02°2.37′W) in 2008 compared with the mean ± standard deviation for the period 1986–2007. Data Courtesy of the 'Agencia Estatal de Meteorología'.

With regard to water balance, the year 2008, within the context of the previous years, shows an increase in the precipitation, in terms of accumulated anomalies (Figure 6).

In addition, the precipitation minus evaporation balance shows an increasing trend, in terms of water balance (Figure 7).

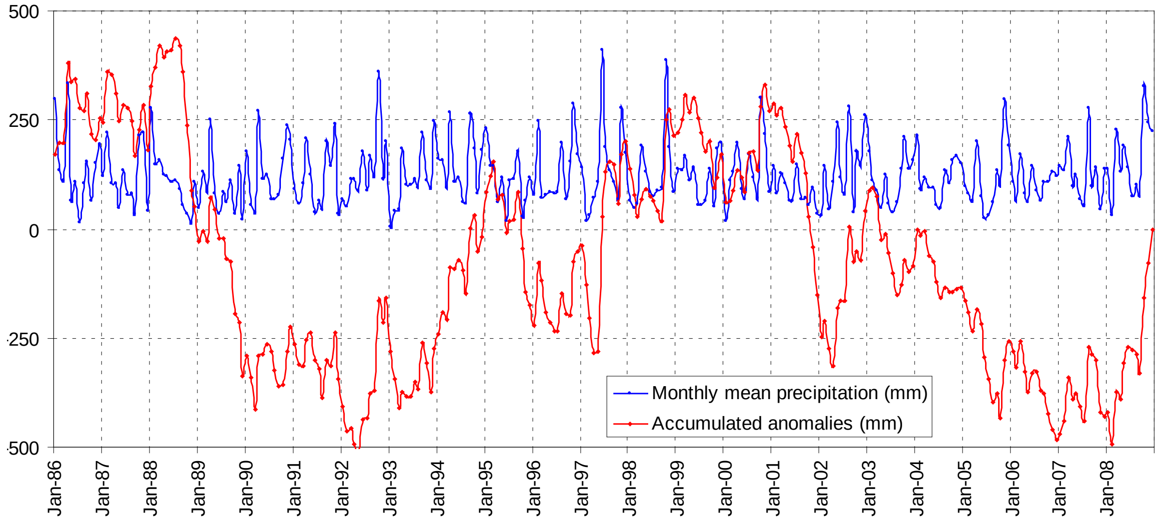


Figure 6. Monthly precipitation (mm) in San Sebastián (43°18.5′N 02°2.37′W) in 1986–2008 and accumulated anomalies. Data Courtesy of the 'Agencia Estatal de Meteorología'.

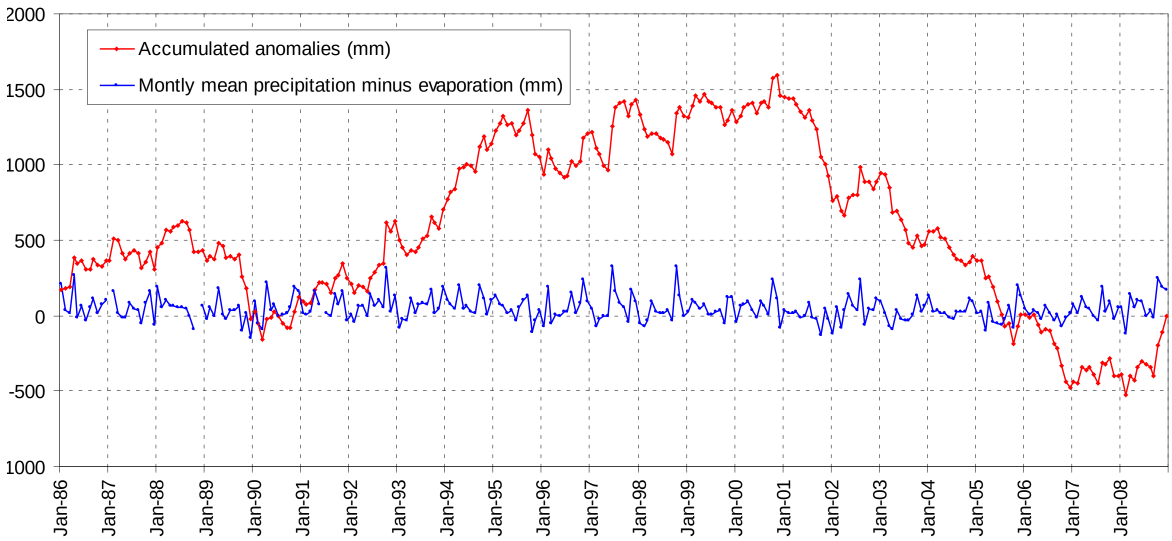


Figure 7. Monthly precipitation minus evaporation (mm) in San Sebastián (43°18.5′N 02°2.37′W) in 1986–2008 and accumulated anomalies. Data Courtesy of the 'Agencia Estatal de Meteorología'.

2. 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 Adour River and 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 in San Sebastián (PP-EV) in a quarterly basis, for the period 1986–2008. NS: not significant; *P=0.01; **P=0.005 ***P=0.001.

	FLOW WINTER	FLOW SPRING	FLOW SUMMER	FLOW AUTUMN
PP WINTER	0.69***			
PP-EV WINTER	0.69***			
PP SPRING		NS		
PP-EV SPRING		NS		
PP SUMMER			0.61**	
PP-EV SUMMER			0.58**	
PP AUTUMN				0.57**
PP-EV AUTUMN				0.59**

The Gironde River flow in 2008 was around the 1986–2008 average; the annual mean River flow was 859 $m^3 \cdot s^{-1}$, only 21 $m^3 \cdot s^{-1}$ over the 1986–2008 average. In spring, the flow was over the monthly mean + the standard deviation for the period 1986–2008, in response to the increase of precipitations as well as spring thaw. In this context, the Gironde River flow is in agreement with the precipitation in San Sebastián except for the local precipitation events during October (Figures 5 and 8).

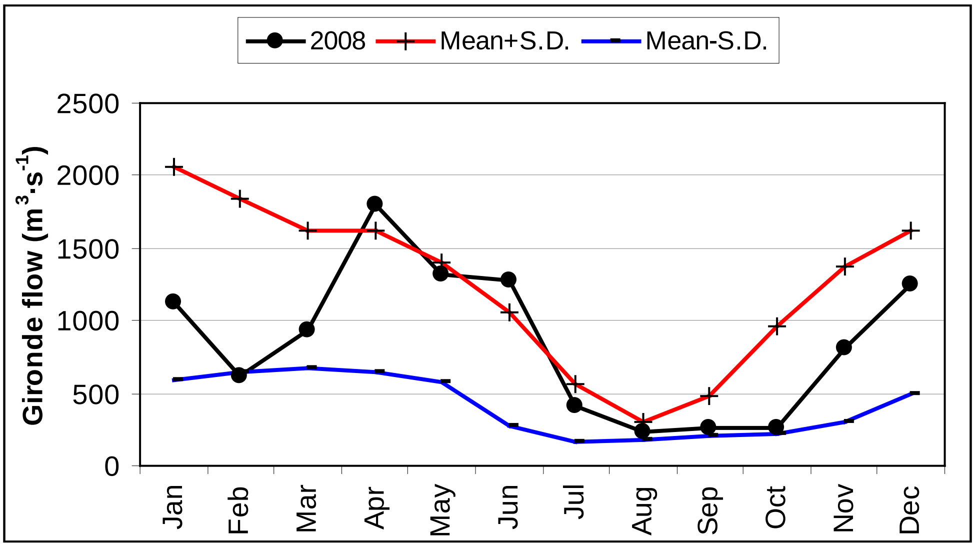


Figure 8. Monthly mean flow (m^3 s^{-1}) of the Gironde River in 2008 compared with the mean ± standard deviation for the period 1986–2008. Data Courtesy of the 'Bordeaux Harbour Authority'.

The peculiarities of the Gironde river flow in 2008 can be observed in the context of the monthly mean values of the reference period (1986–2008) and the evolution of the accumulated anomalies (Figure 9).

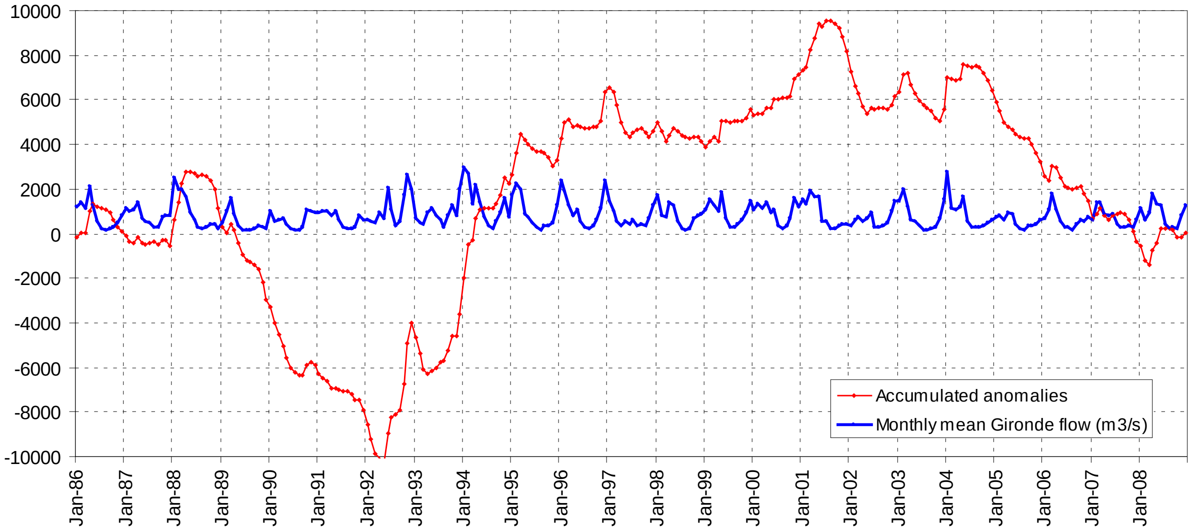


Figure 9. Monthly mean flow of the Gironde river ($m^3 \cdot s^{-1}$) in 1986–2008 period and accumulated anomalies. Data Courtesy of the 'Bordeaux Harbour Authority'.

3. Hydrography

3.1 Coastal and shelf waters

In order to obtain a first approximation of the hydrographic conditions in 2008, a TS diagram representing the waters over the continental shelf of the Bay of Biscay (43°30'N 02°00'W) is shown in Figure 10.

The response of temperature and salinity of the upper layers to the meteorological factors described above is clearly observable in Figure 10. February and March are characterised by thermohaline homogeneity of the water column, as a result of vertical mixing. April is characterised by relatively high precipitation and river runoff (Figure 5 and Figure 8), contributing to the development of haline stratification. Thermal stratification develops between May and October. Finally, the TS diagram is characterised by a thermal inversion in December, according to the high precipitation and river runoff (Figure 5 and Figure 8). The TS diagram shows also the variability in the temperature and salinity values and in the T-S relationships for the waters located below the seasonal thermocline.

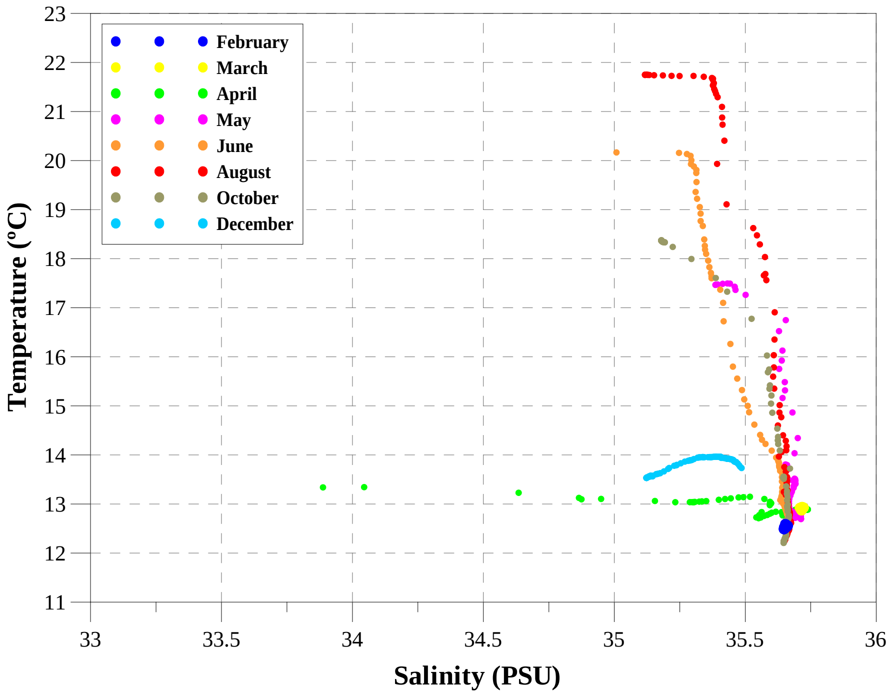


Figure 10. TS diagram of the waters over the continental shelf of the SE Bay of Biscay (43°30′N 02°00′W) in 2008.

Figure 11 shows the evolution of the monthly averaged sea surface temperature (SST) in 2008 (on the basis of a time-series obtained from the Aquarium of the Sociedad Oceanográfica de Gipuzkoa). In general, medium sea surface temperatures (around the mean 1986–2008 average) can be observed in winter and summer, warm temperatures in spring and cold waters in autumn. The annual averaged SST in San Sebastián in 2008 (16.08°C) was below to that of the 1986–2008 period (16.14°C).

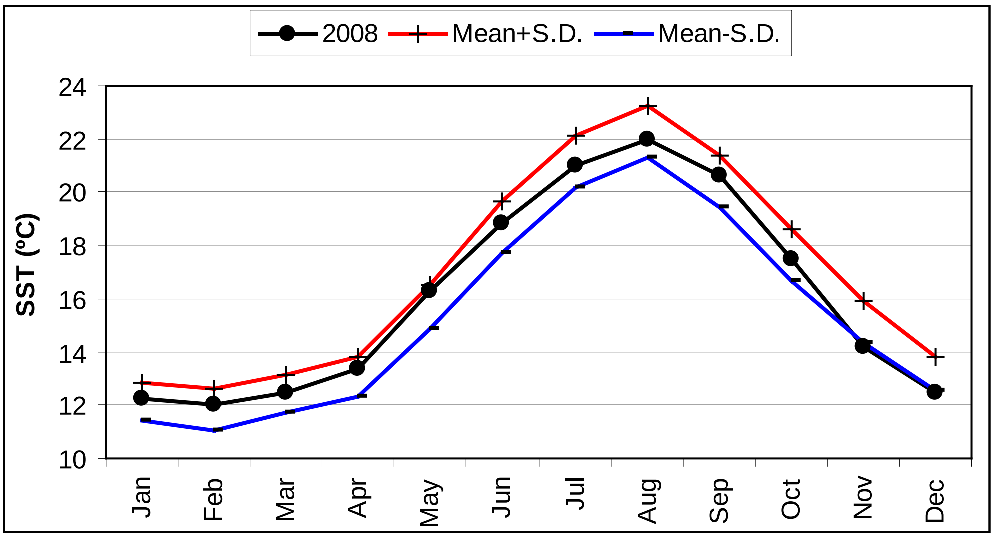


Figure 11. Monthly averaged sea surface temperature (°C) in San Sebastián (43°20′N 02°00′W) in 2008 in comparison with the mean ± standard deviation for the period 1986-2008 period. Data Courtesy of the 'Sociedad Oceanográfica de Gipuzkoa'.

The peculiarities of the SST in 2008 can be observed within the context of the monthly mean temperatures of the reference period (1986–2008) and the evolution of the accumulated anomalies (Figure 12).

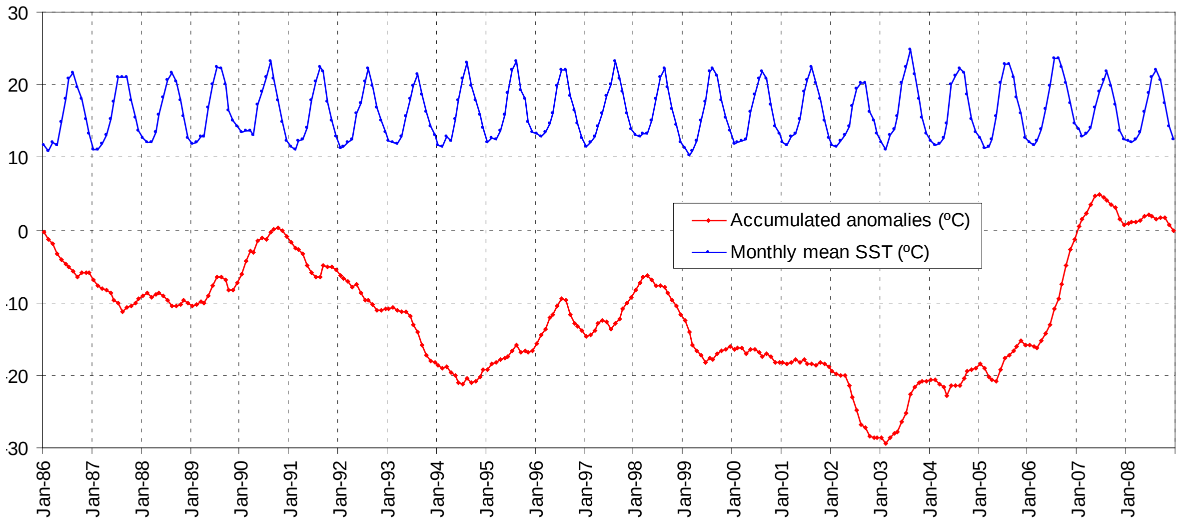


Figure 12. Monthly averaged SST (°C) in San Sebastián (43°20′N 02°00′W) during the 1986–2008 period, together with accumulated anomalies. Data Courtesy of the 'Sociedad Oceanográfica de Gipuzkoa'.

In a similar way, the evolution of the heat content (in terms of mean temperature) and the salt content (in terms of mean salinity minus 35) of the water column (100 m) over the continental shelf of the SE Bay of Biscay can be observed in Figures 13 and 14, respectively.

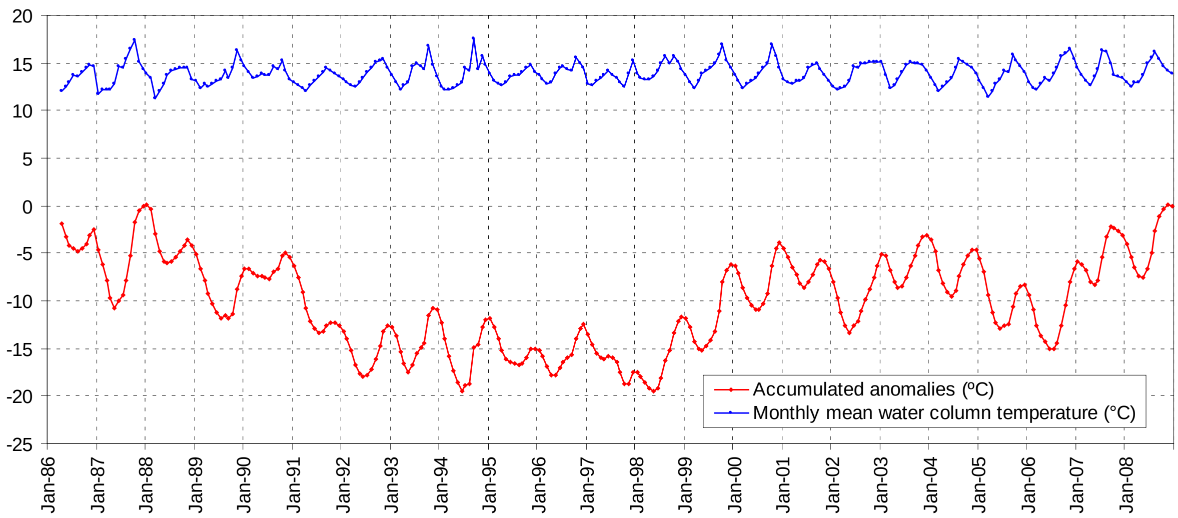


Figure 13. Monthly averaged water column temperature (°C) in San Sebastián (43°30′N 02°00′W) in the period 1986–2008, together with accumulated anomalies.

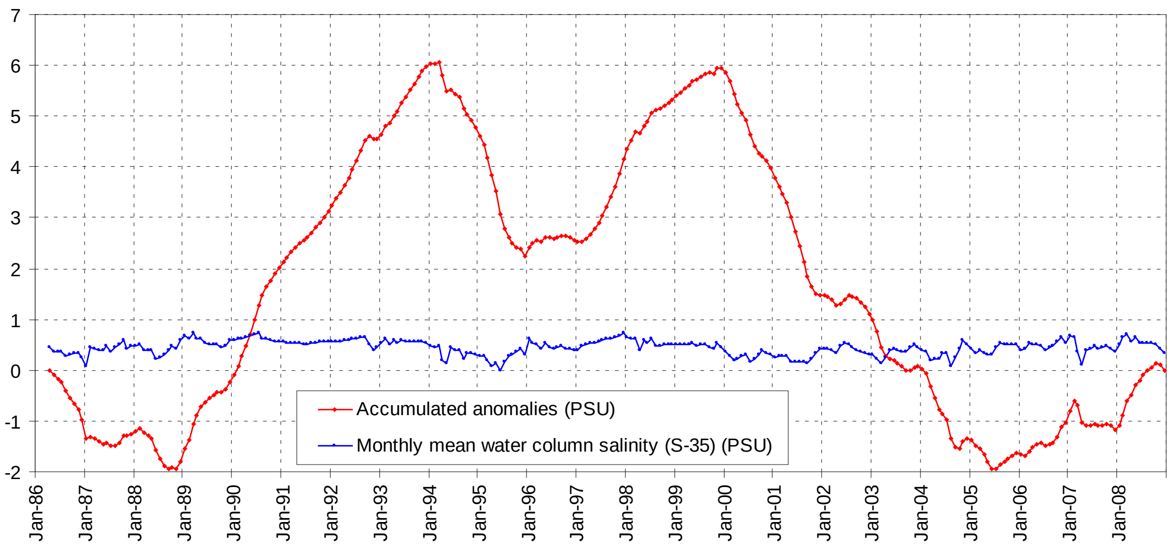


Figure 14. Monthly averaged corrected salinity (S-35) in 100 m water column in San Sebastián (43°30′N 02°00′W) in the period 1986–2008, together with accumulated anomalies.

Aspects related to the hydro-meteorological conditions during 2008, over the SE Bay of Biscay, are listed in Table 2. The SST in winter 2008 remains around the average for the period 1986–2008 (Figure 11), with relatively high air temperatures for this period. In spring 2008, the SST is around the mean plus standard deviation for the period 1986–2008, as a result of the high air temperature (Figure 3b). In contrast, this pattern changed in summer and autumn, from SST around the 1986–2008 average in summer to SST around the mean minus standard deviation in autumn. This pattern is consistent with the atmospheric temperatures for the same period (Figure 3b).

Table 2. Hydrometeorological data in the shelf waters of San Sebastián (43°30′N 02°00′W) in 2008. Mean temperature and salinity calculated for 100 m water column.

2008	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	9.9	139	1324	12.28		12.98	35.510			
February	11.8	33	1240	12.02	35.655	12.53	35.654	12.50	35.651	T<14
March	9.5	229	1148	12.44	35.708	12.91	35.718	12.87	35.715	T<14
April	11.7	133	1138	13.37	33.888	12.93	35.556	12.89	35.738	T<14
May	15.5	191	983	16.25	35.386	13.70	35.656	12.75	35.711	20
June	16.7	140	667	18.83	35.008	14.89	35.542	12.52	35.665	42
July	18.4	76	362	21.04		15.55	35.537			
August	19.1	100	238	21.95	35.117	16.21	35.532	12.28	35.653	55
September	17.1	74	346	20.61		15.43	35.523			
October	14	328	589	17.49	35.180	14.66	35.515	12.25	35.648	44
November	9.6	246	840	14.22		14.25	35.423			
December	7.6	223	1058	12.48	35.123	13.84	35.331	13.79	35.477	T<14

February and March are characterised by homogeneous water columns due to the vertical mixing (Figure 10). April is characterised by haline stratification of the water column, resulting from the presence of cold waters of continental origin. After the increase in air temperature in April, the warming of the sea surface and the water column began to be evident in May. Thermal stratification remains until October 2008 due to weak winds favourable for upwelling. In November, cooling and some increase of turbulence develop the vertical mixing. December is characterised by a thermal inversion, related to the conjunction of cooling and freshwater inputs.

In the SE Bay of Biscay, the 14°C isotherm represents the mean annual temperature and also the lower layer of the thermocline, during the spring and summer stratification. In May, the 14°C isotherm depth was 20 m; from June to August, this layer was placed at around 42–55 m; and, in October it was placed at 44 m. This is consistent with the relatively high dominance of downwelling processes throughout almost all the year (Table 2, Figure 10).

Contours of temperature and salinity (over the shelf, 100 m depth) in the Santander section are shown in Figure 11a and b. The seasonal cycle in temperature is clearly marked in the upper layers. Stratification develops between April/May and October/November, and during the rest of the period the water column is mixed. 2008 presents a long but not too cold winter period and sort but deep (50m) warm summer similar to 1999. Deep water over the shelf is quite warmer.

Salinity contours show high salinity all through the winter due to a strong poleward current with the higher salinity detected in the area over all the time-series. All the rest of the year salinity values are reduced in a large amount, mainly in the upper 20m in spring and nearly over all the shelf at the autumn. This low salinity signal in the upper layers could be due to the advection from the east of warm surface water from river discharges in the corner of the Bay of Biscay as well as for strong rain over the Spanish coast. The strong high salinity signal appears all over the water column due to a strong episode of Iberian Poleward Current saltier than the developed in December 2006 and January 2007.

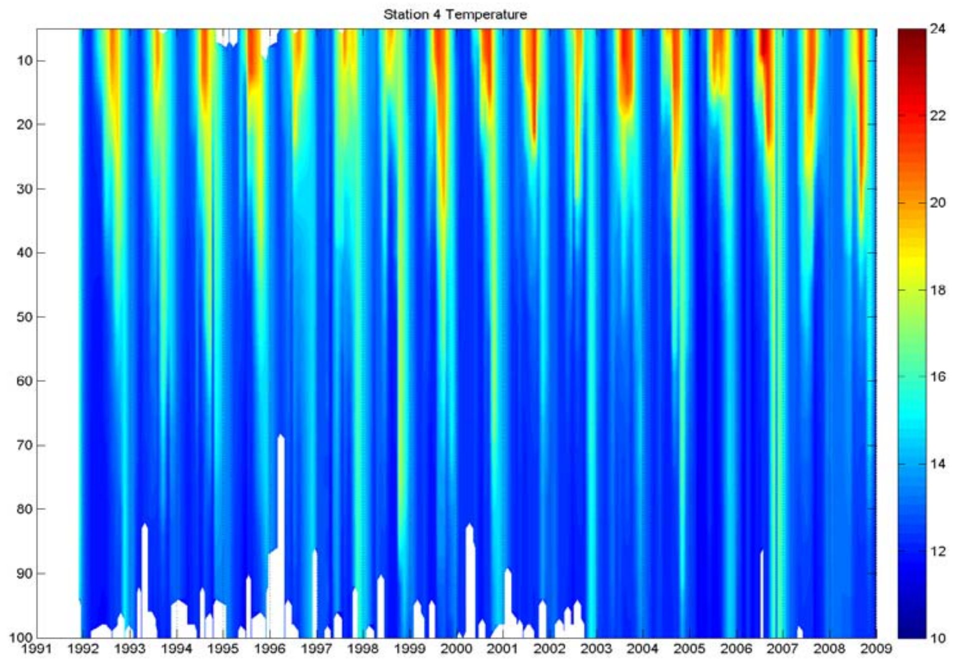


Figure 11a. Temperature evolution at Santander station 4 (shelf).

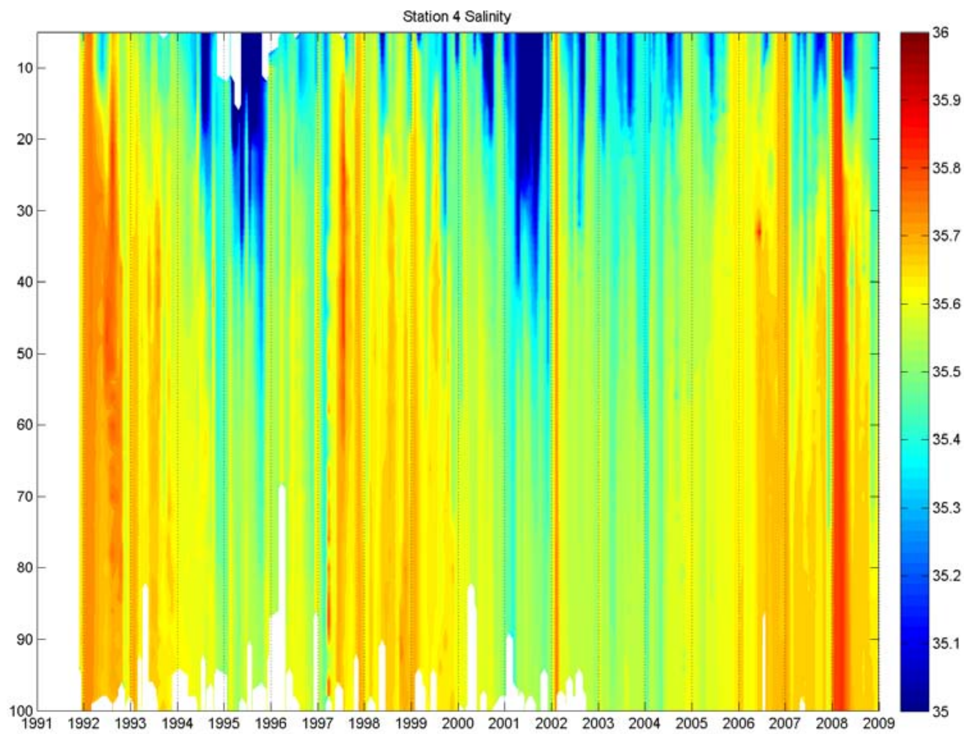


Figure 11b. Salinity evolution at Santander station 4 (shelf).

As a consequence of the different geographical location and coast orientation the mean hydrographical features the annual cycle at the Vigo standard section is moderately different of the standard cycles in Santander and San Sebastián. The differences are related mostly with a stronger influence in this area of the main advection mechanisms (winter poleward current and summer upwelling). Anyway, even if the range of the anomalies may be different because of local climatic and morphologic peculiarities, the anomaly patterns and the general trends can be considered referable to those described for the sections located in the southern Bay of Biscay.

Contours of temperature and salinity and fluorescence over the shelf in the Vigo section from 1994 to 2008 are presented in Figure 12. In summer cold waters were present at depth due to upwelling, while warm waters were at the surface in summer due to insulation. In autumn-winter there is a coastal poleward surface current that transports warm water. Salinity contours still continue show above normal values due to Eastern Atlantic general trend to salinity increase and also to the drought year until September.

The year 2008 with respect of the water thermohaline seasonal characteristics may be classified as normal, in the middle of the time-series range; regarding the fluorescence, related to chlorophyll, after 2005 seems to be more productive that the previous years, and 2008 too.

Coastal processes: variability of the Iberian Poleward current strength in winter and the upwelling in summer seem to have more influence in the west of Iberian Peninsula that the general warming trend observed in other areas of the eastern Atlantic.

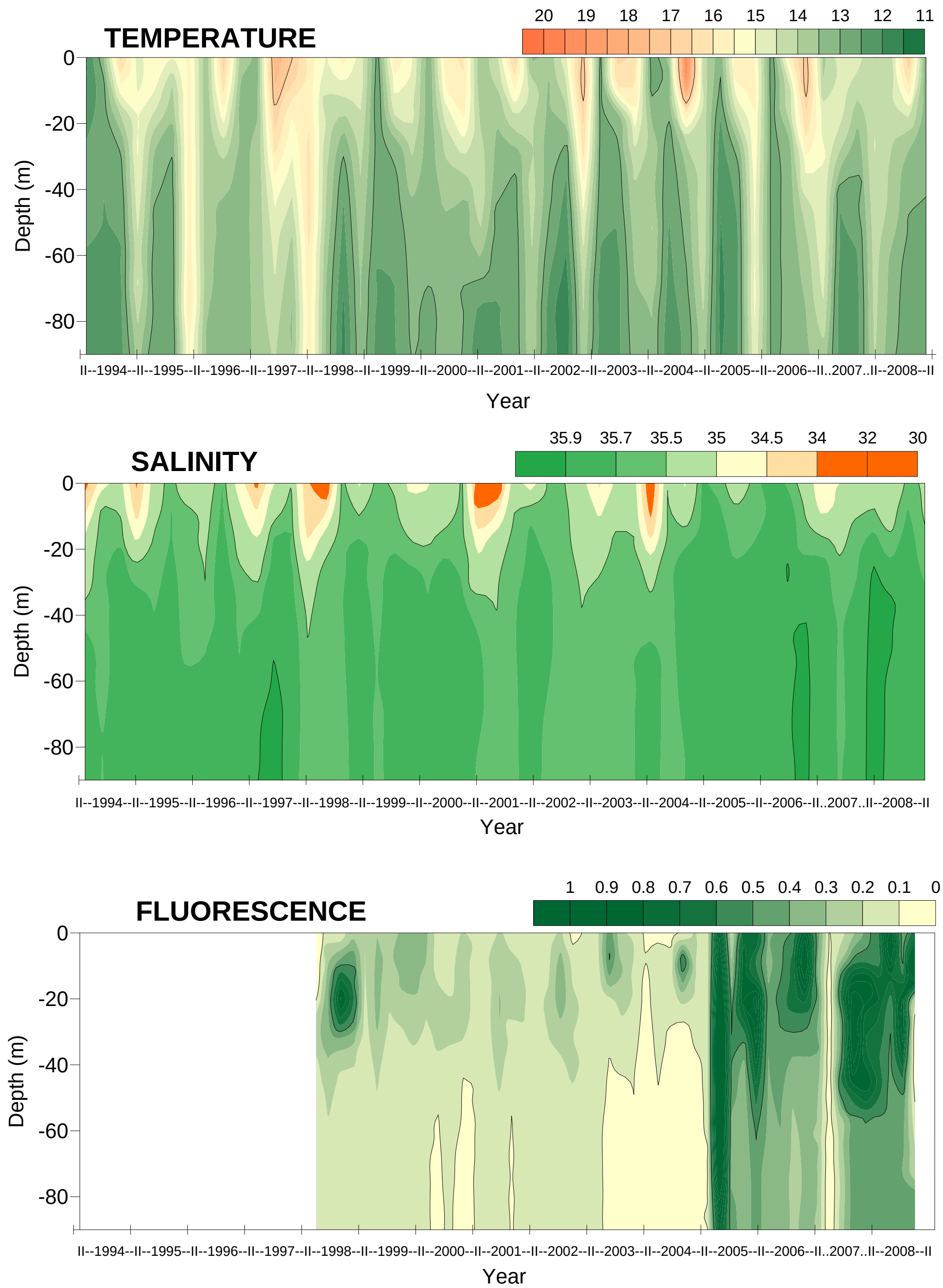
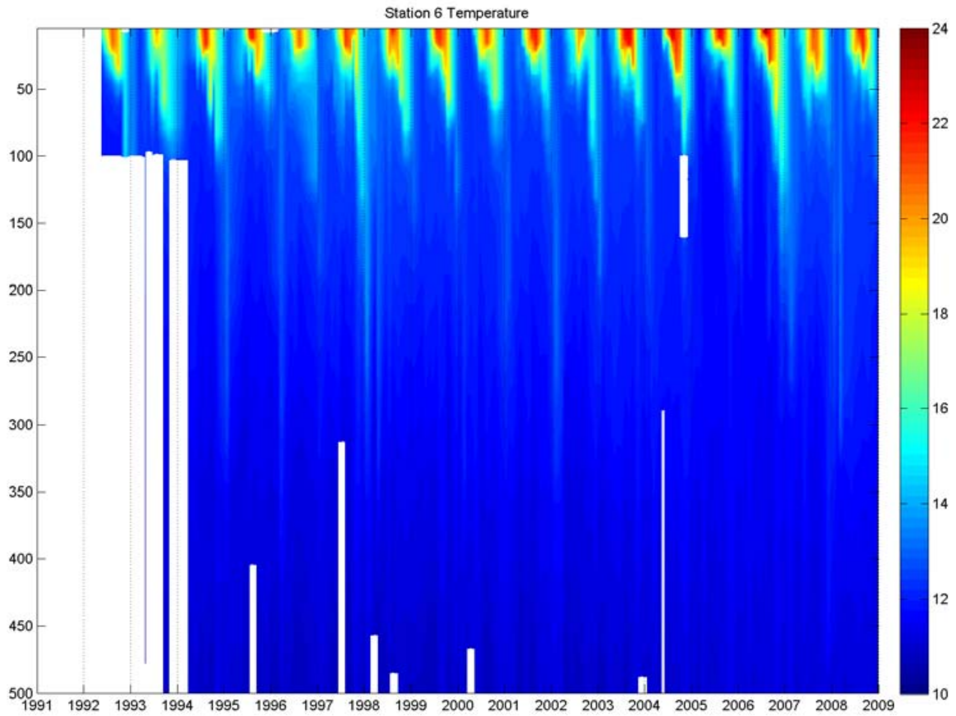
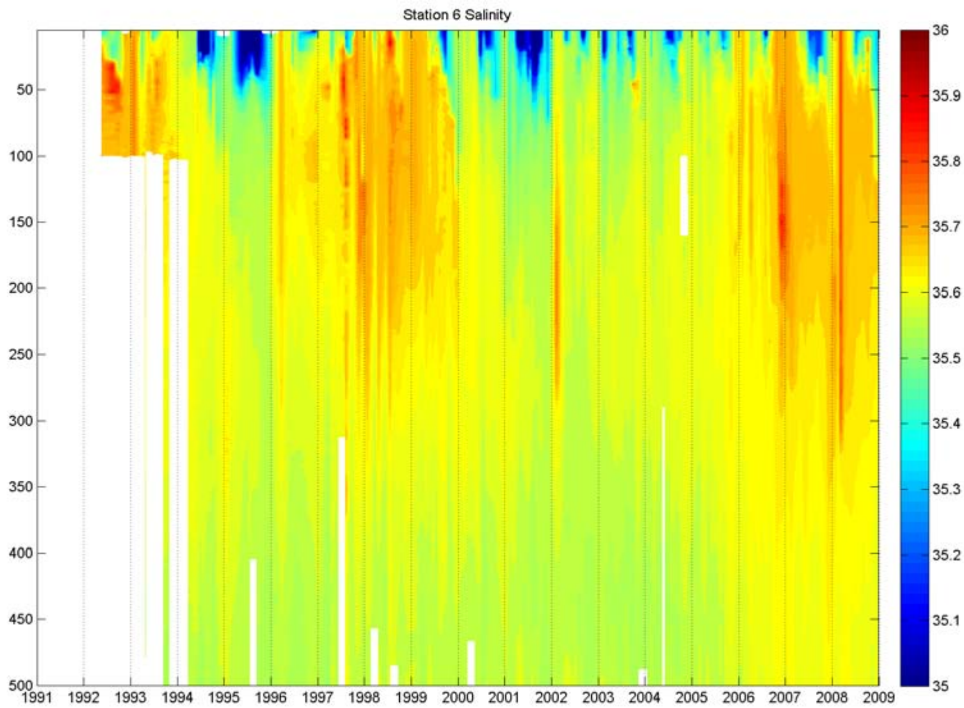


Figure 12 a, b and c. Seawater evolution at Vigo (42.1ºN, 9.0ºW) station of Temperature, salinity and fluorescence.

Contours of temperature and salinity over the shelf-break (600 m depth) in the Santander section are presented in Figure 13a and b. During the first period (1992–1994) only upper layers were sampled.



Figures 6a. Temperature evolution at Santander station 6 (shelf-break).



Figures 13b. Salinity evolution at Santander station 6 (shelf-break).

The warm autumn 2006/ winter 2007 is well represented in the temperature contours where warm water reach nearly 300m depth. This fact is also shown in 2008 with strong episodes in January and March. This fact was only shown in the previous Iberian Poleward Current events of 2002 and 1998. As happened over the shelf and it has been seen in years before, the period of low salinity in the upper waters (1994–1995 and 2000–2001) was reduced in a greater extent from 2002 to 2006 but was increased again in 2007 and 2008.

Below the mixed layer, salinity fell from 1992 to 1995 and increased to 1997/1998 before falling almost continuously until the end of 2004 except for the increase in salinity in the upper 300 m during the 2002 winter. This episode of salinity increase disappeared in spring and was caused by the poleward current observed during that winter. From 2005 to 2007 the causes of the maintaining the increase in salinity could be related to atmospheric forcing at the area of formation of this water mass specially during the extreme cold and dry 2005 winter (Somavilla *et al*, 2009).

The deep winter mixing layer that occurs in the Bay of Biscay on 2005 and 2006 produced an increase of Salinity and decrease of temperature the NACW. But in autumn 2006 winter 2007, a strong IPC reached Santander section with increase salinity in a large amount between surface and 300m depth, with strong signal between 100 and 200m. During 2008 salinity under the mix layer keeps high, but an strong episode occurred mainly in March, but salinity maintains high after the change in mode waters occurred in 2005–2006.

Stratification develops between April/May and October/November, mainly reaching 50 m depth. 2008 stratification concerned both temperature and salinity, but the strong rainy year made a deep low salinity layer of 120m depth at the end of the year.

If we look at thin layer superficial waters, we expect to find an approximate mirror of atmospheric forcing. Due to the thermal inertia of the seawater surface, the temperature seasonal cycle does not follow a sinusoidal cycle but presents a rapid warming period in late spring, whereas the autumn cooling is less abrupt.

Fitting the temperature signal by two harmonic terms plus a linear trend, we can reproduce the signal approximately (Figure 14). Taking this into account, we can compare the year 2008 with the climatological mean for surface waters. SST was around the mean value for the winter and the beginning of the spring, except early March when temperature reach more than 13ºC, 0.5ºC higher than the mean. After that, a rapid increase in temperature it is produced with values lightly over the mean until September, the warmer month of the year with nearly 22ºC. For the rest of the year SST was lower than the average, especially at December, around 13ºC, more than 0.5 under the adjusted value The amplitude of the seasonal cycle of SST was of 8.9 ºC, and the air temperature seasonal cycle for the year (10.2ºC) are both of then close to the long term mean 8.7 and 9.8ºC respectively.

The anomalous warm winter and spring produced a yearly temperature close to the average sea Surface Temperature or slightly higher (Figure 15), but the cold second part of the year (September-December) produced a negative anomaly, more than 1ºC at the end of the year, suggesting a strong winter mix layer for 2009.

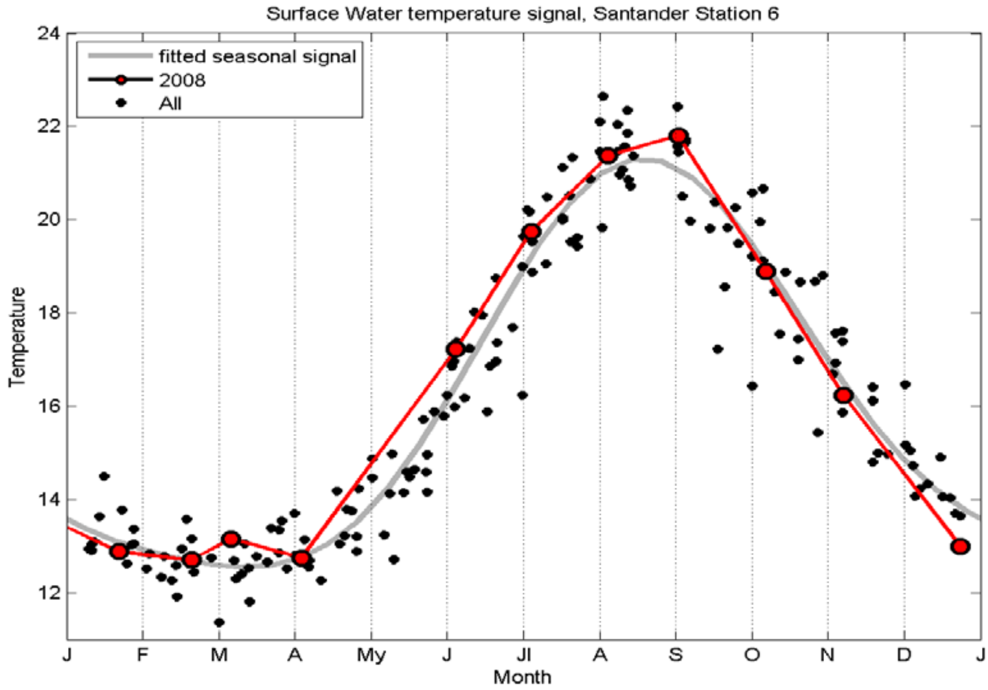


Figure 14. Seawater Surface Temperature at Santander station 6 (shelf-break).

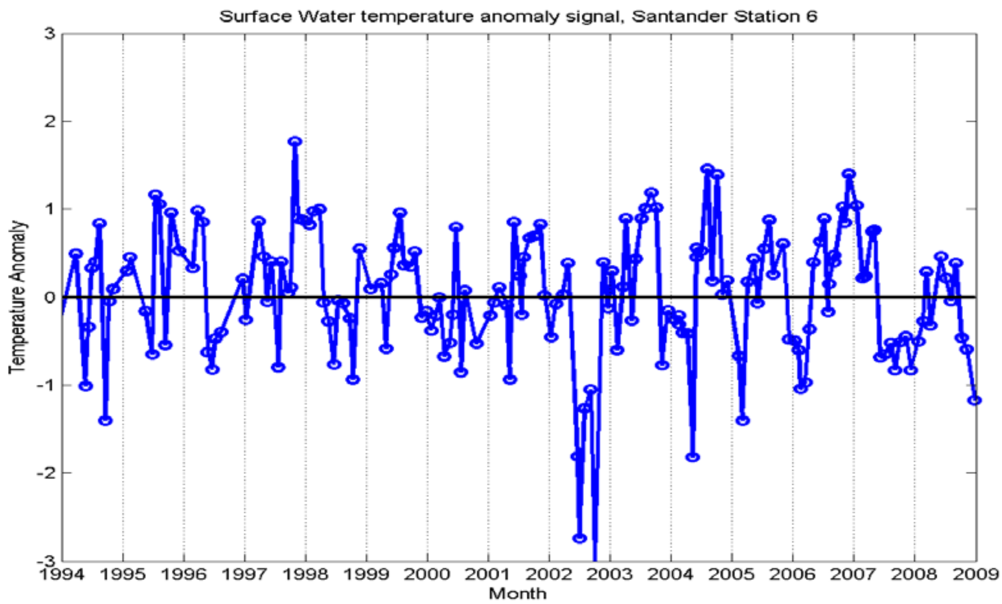


Figure 15. Seawater Surface Temperature anomalies at Santander station 6 (shelf-break).

When the analysis is produced all over the upper waters to 300m depth, 2008 due to the warm winter and the Iberian Poleward Current event present an standard year with a strong temperature signal in March (Figure 16). The mean temperature value was 12.8, the third warmer year after 1998 and 2007. The strong increase in temperature produced by the effect of winter 2005 and 2006 in 2007 has decrease a little and central waters are returning to previous event values.

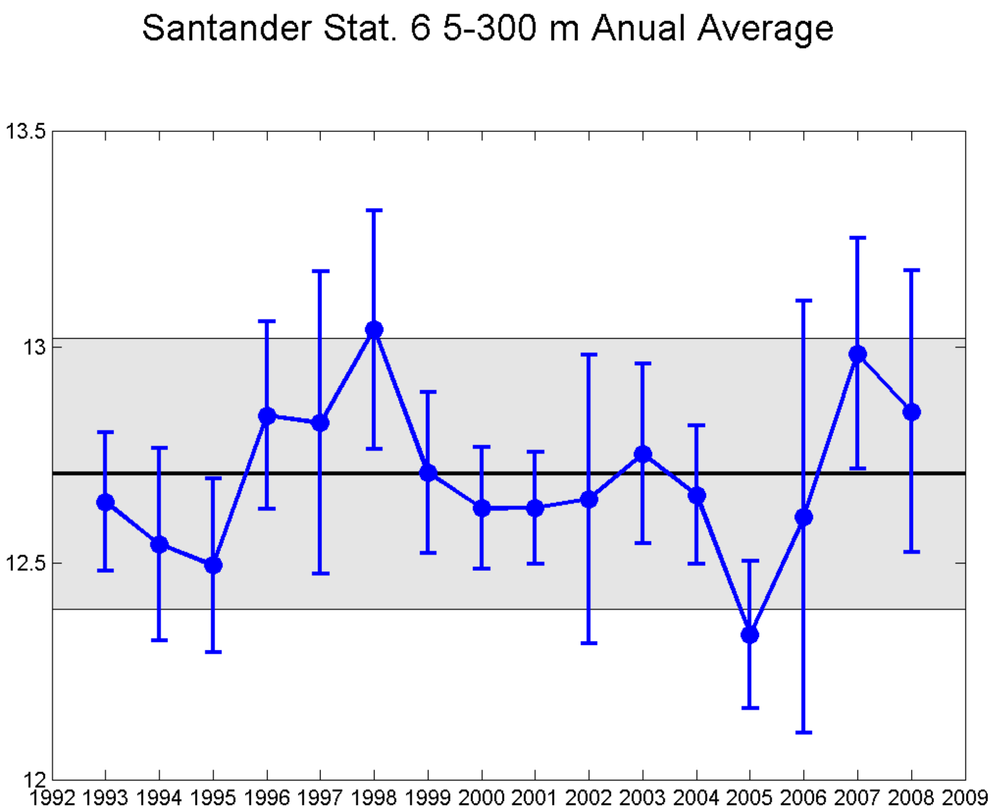


Figure 16. Annual average temperature (5–300)m. at Santander station 6 (shelf-break).

A salinity average of this layer (5–300 m) is shown in Figure 17 for station 6. The 2008 mean value are in the limit of one standard deviation above the mean, only 1998 presented higher salinity. Between 1998 and 2001, evidence of a decline in salinity was found up to a depth of 300 m. In 2002 this trend was inverted, especially during the Iberian Poleward Current episode at the beginning of the year. During the end of 2006 and beginning of 2007 an important increase in salinity has been observed in the upper 300 meters. The strong episode of Iberian Poleward Current detected in 2008, similar to the 2002 one, add more salinity to the water column and made 2008 reach the maximum of the trend started in 2003. But values decreasing during 2008 after the maximum value reached in winter and low values seems to reach in December, due to strong precipitations at the end of the year. The salinity behaviour of the complete time-series seems to be related with the atmospheric forcing in the area of formation of the ENACW, as it has been mentioned before and specifically with the difference between precipitation and evaporation.

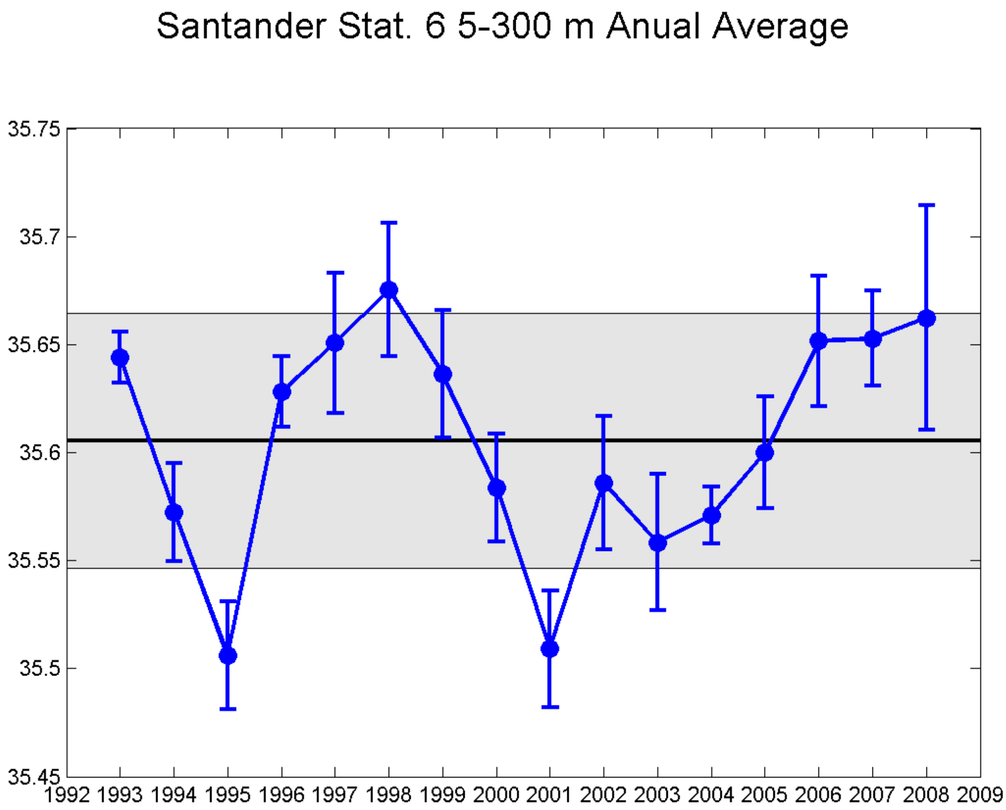


Figure 17. Annual average salinity (5–300m) at Santander station 6 (shelf-break).

In figure 18 distributions of potential temperature between isobars from 200 to 600 meters and 600–1000 meters corresponding to ENACW and MW (Mediterranean Water) respectively is presented at St 7 over the slope. Strong variability is detected upper waters (200–300m) due to the extremely cold and dry winter 2005. A warming trend is observed in ENACW deeper that 300m of around 0.26ºC/dwecade and in between 0.23 and 0.12 ºC/decade in the MW. The inflow of warm water from the cold episode of winter 2005 and 2006 is clearly reflected in water from 400 to 600m depth where potential temperature has increased around 0.28ºC/decade.

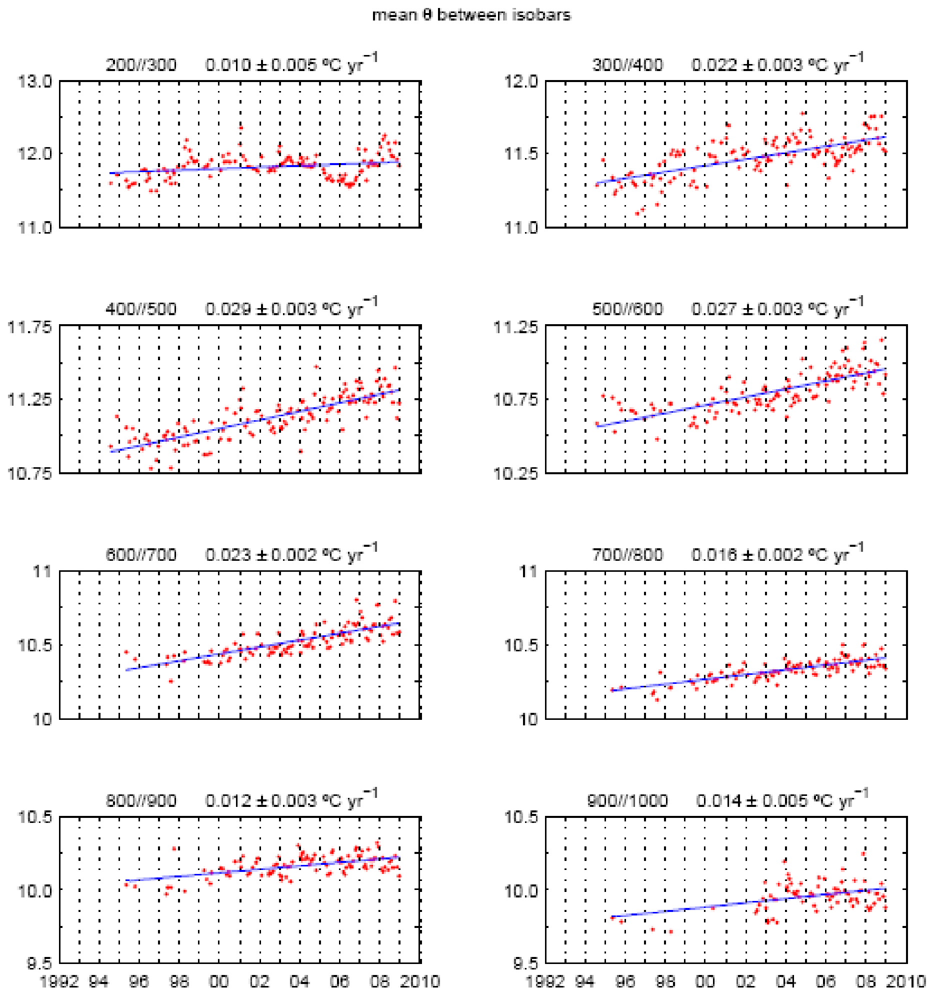


Figure 18. Mean Temperature evolution between isobars of ENACW (200–600m) and MW (600–1000m) water at Santander station 7(43º 48'N, 3º 47'W) (slope)

3.2 Water Masses

The consequences of the deep winter anomaly in the mixed layer and upper Central Waters in 2005 and the 2006 winter was over after the extremely warm summer/autumn 2006 and winter 2007. In 2005 the mixed layer depth was greater than 300 dbar and in winter 2006 the mixed layer reaches practically the same depth. The existence of a very low stratified water column below the seasonal thermocline, developed during the 2005 summer, has favoured the formation of a very deep mixed layer again in winter 2005/2006. The warm winter 2007 has produced again a shallow mixing layer.

In the figure 19 it can be seen the θ/S diagram of water masses at the southern Biscay from the Santander Standard Section data set, the sequential colour code also provides a first approach to the interannual variability. ENACW is found just below the mixed layer (typically less than 200 dbar) and it is described by a straight line which ends in a Salinity Minimum level located about 500 dbar. Below this level it is found progressively the Mediterranean Water (MW) which has its core about 1000 dbar the limit of our sampling. From the data set it can be observed that MW have increased its temperature and salinity compensating its density until 2005/2006 but after seems stabilised, whereas the variability in the ENACW is not so evident in the θ/S diagram. The main changes evident in ENACW are the increase in temperature and salinity since 2005 onwards and the interruption of the θ/S straight line below the 27, in isopycnal level in the last years and the recovering again after the warm winter of 2007. The changes at the minimum level of ENACW are not compensating potential temperature and salinity. A change in water masses in clearly view.

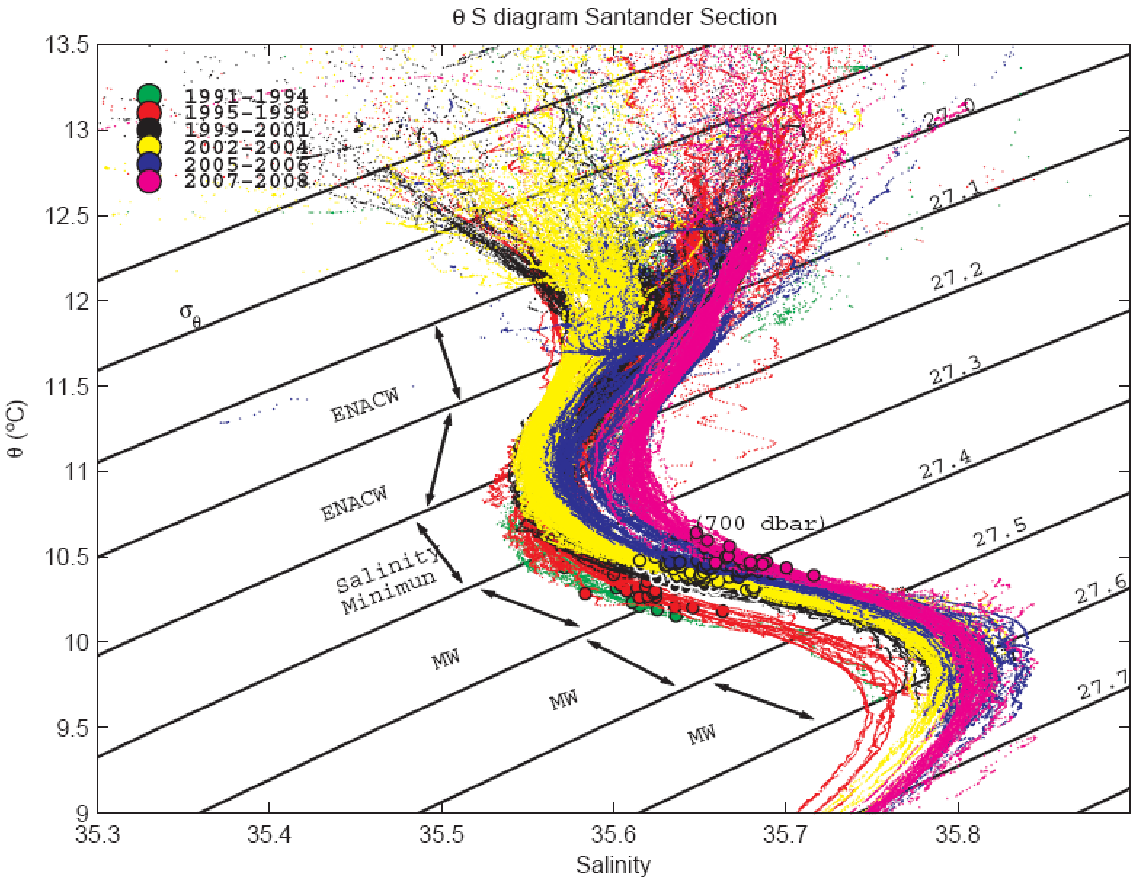


Figure 19. Water masses at Santander stations 6 and 7 presented in a θ/S diagram.

Annex 11: Ireland Area report

Glenn Nolan, Kieran Lyons, Sheena Fennell, Guy Westbrook, Heather Cannaby and Sinan Husrevoglu

Oceanographic Services and Marine Climate Change teams, Marine Institute.

Coastal time-series

Several coastal time-series are maintained around the Irish coast. These include SST measurements at the M3 weather buoy (southwest Ireland) and a longer-term SST record at Malin Head. The locations of these measurements are shown in Figure 1.

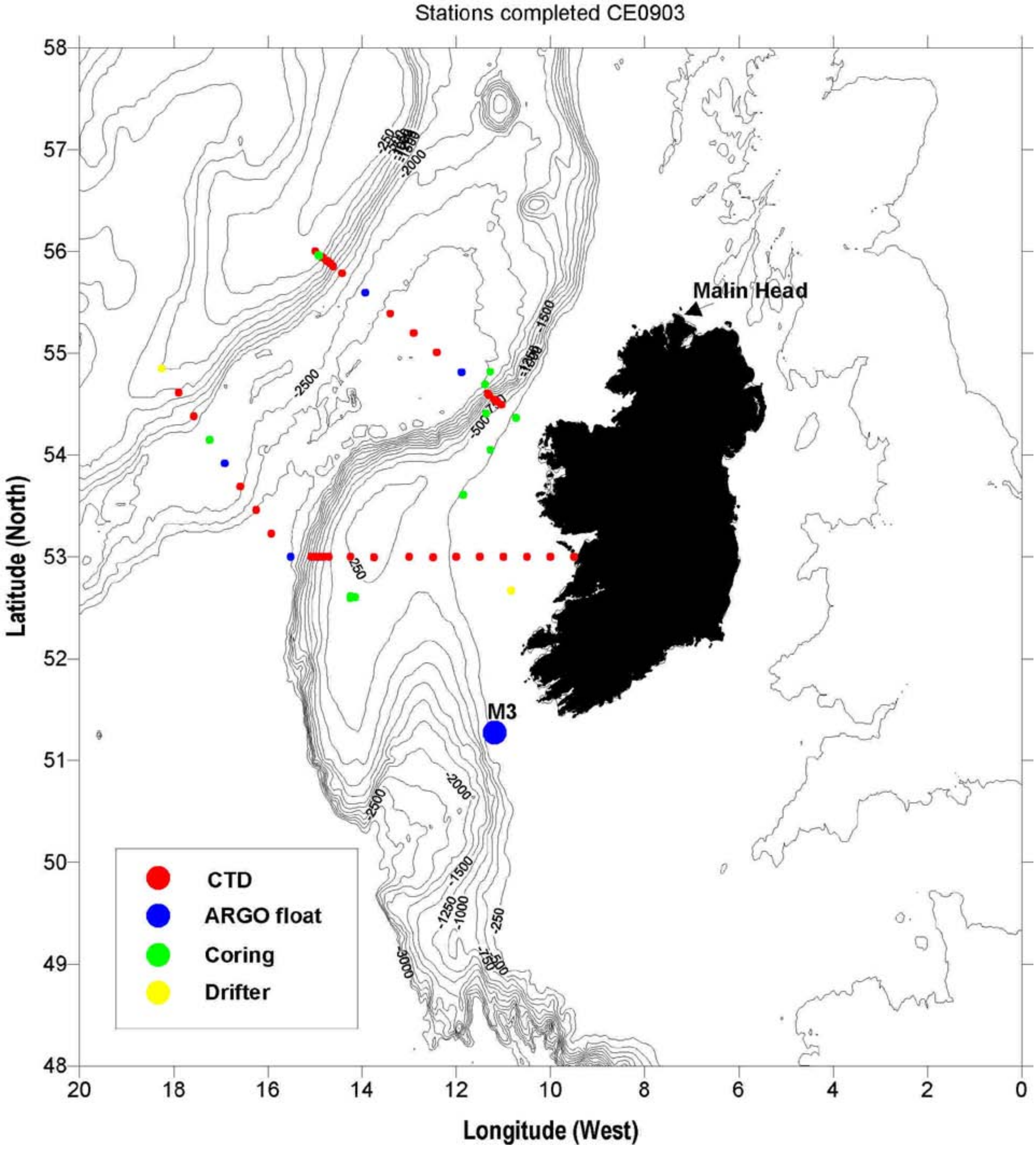


Figure 1. Location of key measurement sites in Irish waters.

Malin Head Sea surface temperature

A long-term sea surface temperature data set has been maintained at Malin Head since 1958. Temporal variability in sampling frequency ranges from hourly to daily over the period. Sea surface temperature anomalies from this station are presented in the figure below.

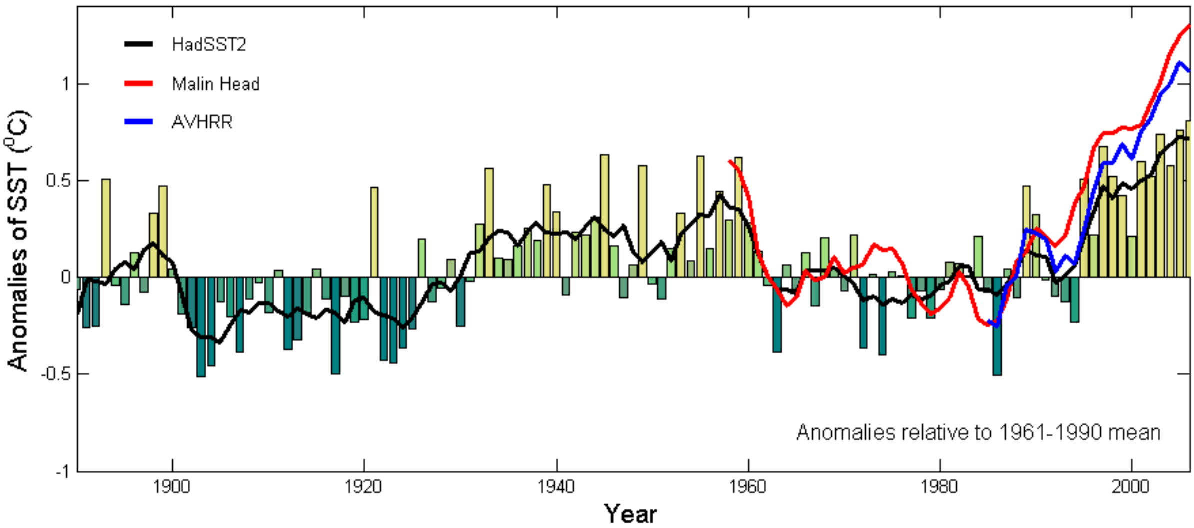


Figure 2. Sea surface temperature from Malin Head (Ireland) 1960–2005 overlaid on the longer term HADSST data set and satellite derived AVHRR SST measurements (from Cannaby and Husrevoglu (2009)).

One of the noteworthy points in this data set is the presence of colder winter SST values in the early part of the record with values between 4°C and 6°C. Where these lower temperatures are observed in winter there is a less pronounced heating season in summer of that year. This is particularly apparent in 1963, 1978, and 1985–86. This can be related to the Atlantic Multidecadal Oscillation (AMO) cool phase. Winter temperatures are typically >6°C since 1990 and summer temperatures are more pronounced in that period also. This corresponds with the more recent warm phase of the AMO.

M3 Buoy

An offshore weather buoy is maintained at 51.22°N 10.55°W off the southwest coast of Ireland since mid-2002. Sea surface temperature data are measured hourly at this location and archived after quality control procedures have been completed. There is considerable interannual variability at this site (Figure 3). 2003 and 2005 saw the warmest summer temperatures of the record while 2007 saw the warmest winter temperatures. 2006 saw winter temperatures below the time-series mean.

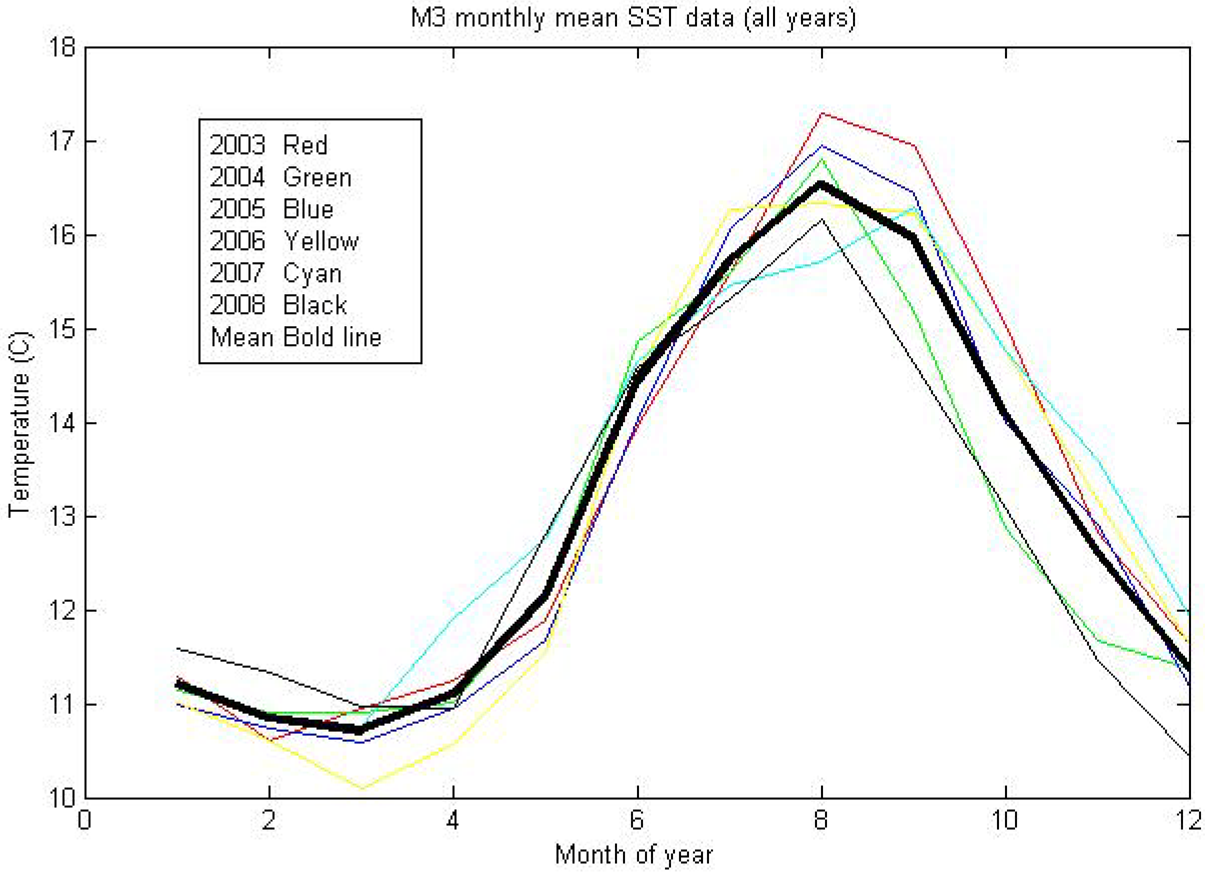


Figure 3. SST at the M3 weather buoy since its deployment in 2002 compared with the time-series mean (black line).

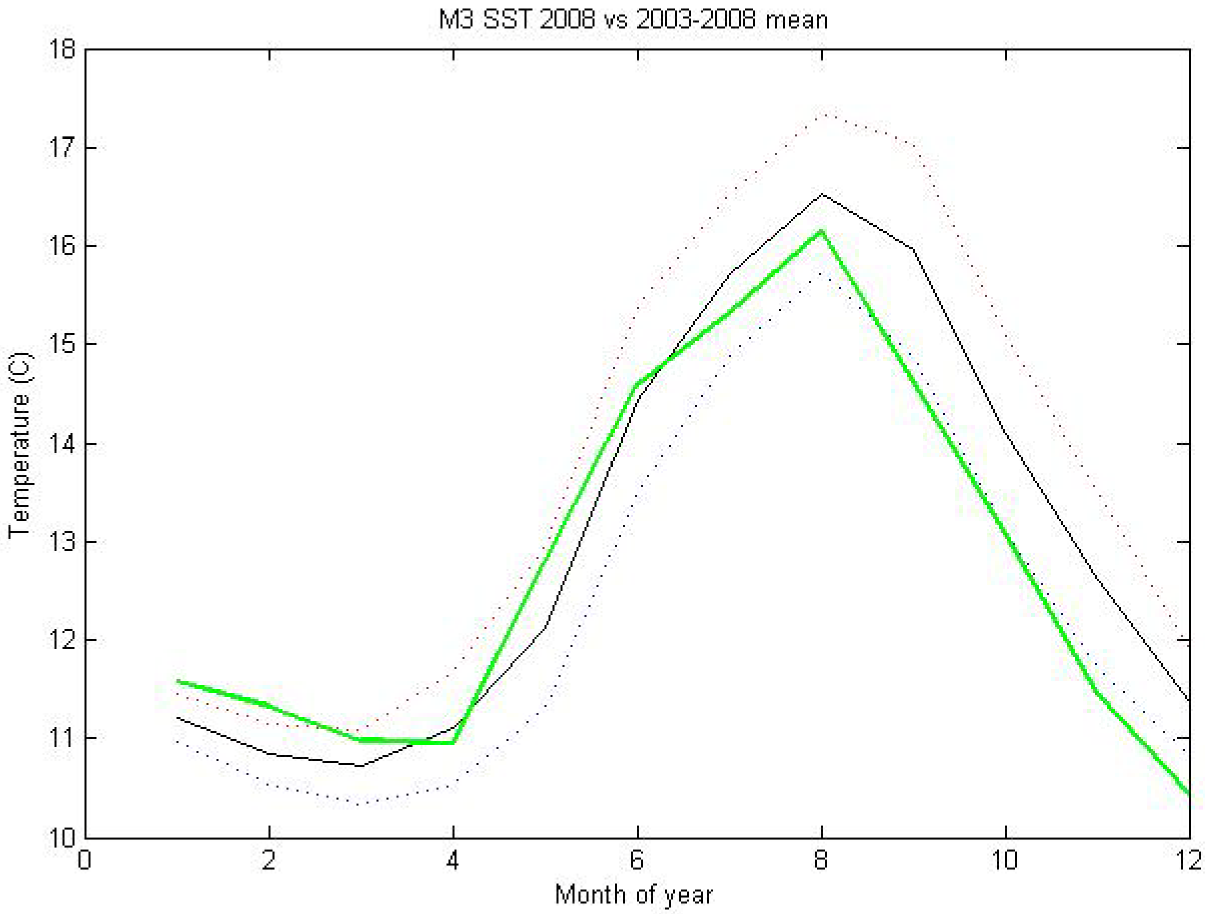


Figure 4. SST at the M3 weather buoy (green line) in 2008 compared with the time-series mean (black line).

Standard deviations also shown.

2008 temperatures started above the time-series mean (2003–2008) until April. From July onwards, temperatures remained well below the time -series mean. Salinity data from this station will be available in April 2009.

Offshore cruise activity

Celtic Explorer cruise CE0903 was conducted in February 2009 to examine hydrographic conditions in Rockall Trough. A total of 43 stations were occupied for a variety of parameters including CTDs, grab samples and cores, nutrients, salinity and phytoplankton. Four ARGO floats were also deployed (see Figure 1 for locations).

South Rockall line

Two transects across the Rockall Trough were completed on cruise CE0903. The first was the South Rockall Line which runs from Porcupine Bank to Southern Rockall Bank. Some stations on this transect exceed 3000m water depth. A warmer saline core is evident on the eastern side of the section reflecting the Shelf Edge Current and some influence from the North Atlantic Current. The thermocline is deeper on the eastern side of the trough also and shoals up as one progresses westward along the section. The salinity plot is more complex with Sub Arctic Intermediate Water and Mediterranean water present as intermediate water masses. The influence of several water masses is evident in the T/S diagram for the section including a strong Mediterranean Water signal at ca. 1000m water depth on the eastern side of the section. Below 1000m the influence of Labrador Sea Water (LSW) is evident.

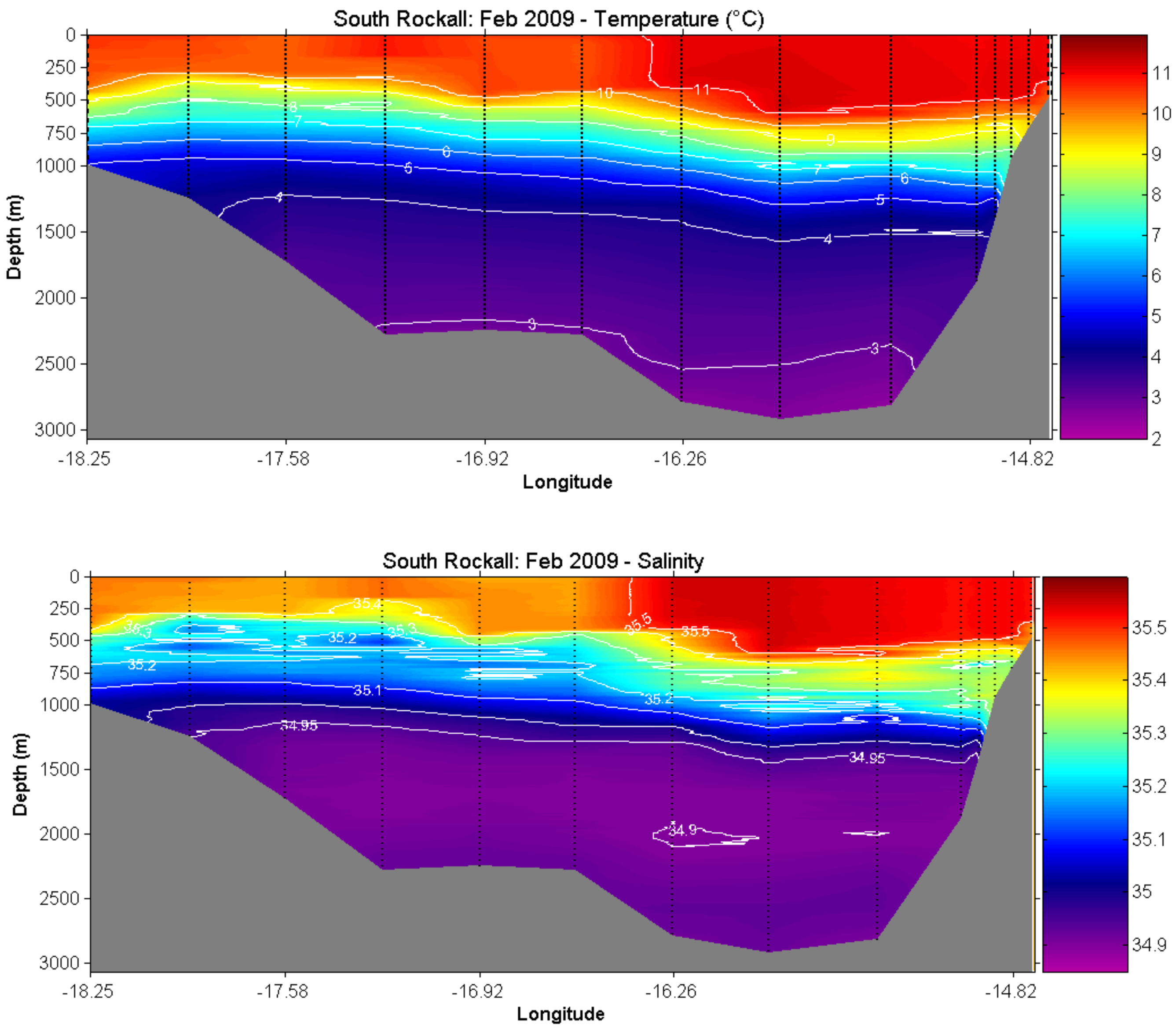


Figure 5. Temperature (upper panel) and salinity (lower panel) sections along the South Rockall Transect in February 2009.

The shelf break near Porcupine Bank (Figure 6) marks a region where various intermediate water masses interact, most notably SAIW and MEDW. A closer look at this region shows a strong SAIW influence in some years (e.g. 2006 and 2008) and other years where this influence is much less pronounced (e.g. 2007 and 2009). Hatun *et al.* (2005) has linked this to changes in the position of the subpolar front. If the subpolar front is located to the southeast of its mean position, SAIW can encroach past Rockall

Bank into Rockall Trough while if the front is further to the northwest, subtropical waters from the south are likely to dominate the upper and intermediate waters of the Rockall Trough.

On the western end of the South Rockall line, the fresher SAIW layer is much shallower than on the section near Porcupine Bank. Typical depth of the salinity minimum is at 400m in 2008 and 500m in 2009 (Figure 7). The SAIW layer is deeper at Porcupine Bank and interacts with MEDW in the 800–1000 m water depth range. The MEDW influence can be seen in the overall T/S plot for the section in 2009 (Figure 8).

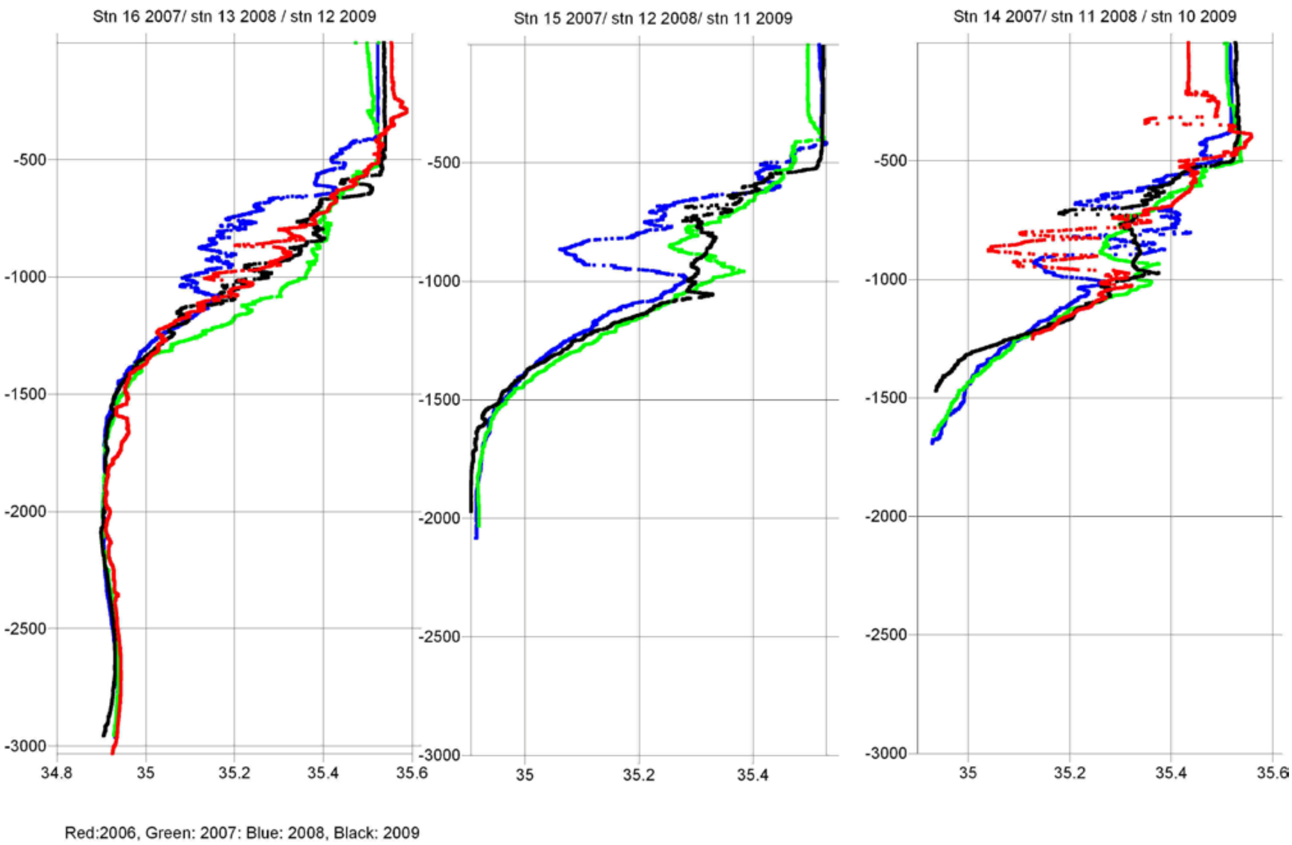


Figure 6. Salinity profiles from 3 stations west of Porcupine Bank between 2006 and 2009 showing strong interannual variability at these sites.

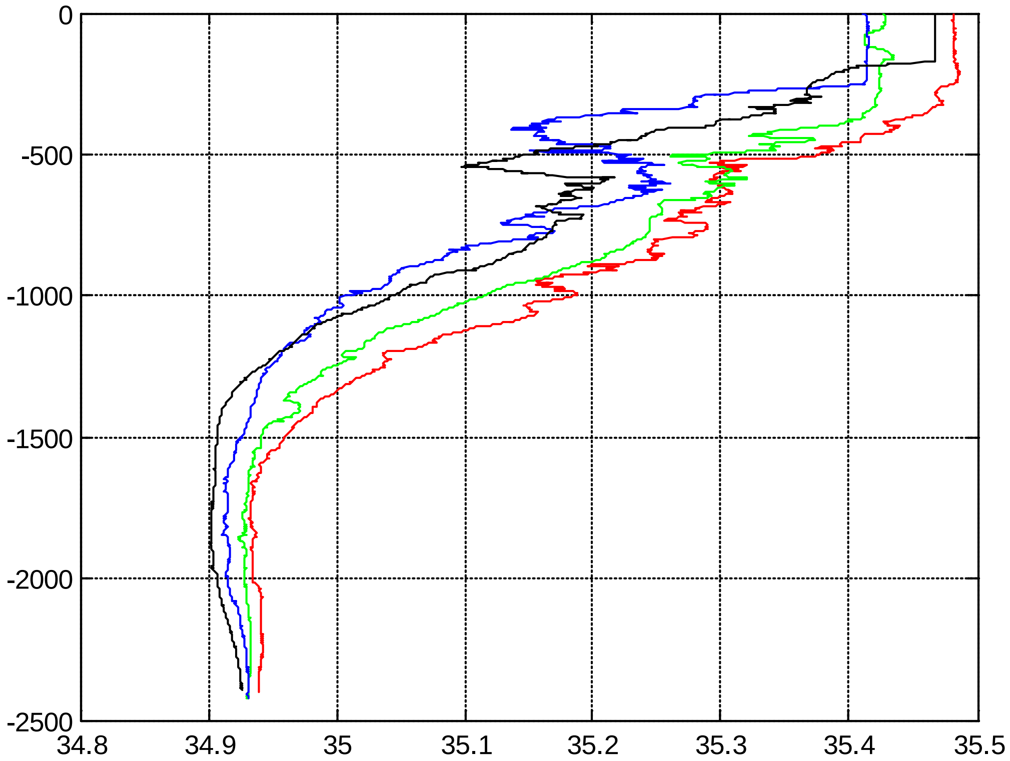


Figure 7. Salinity profiles from a station near Rockall Bank between 2006 and 2009.

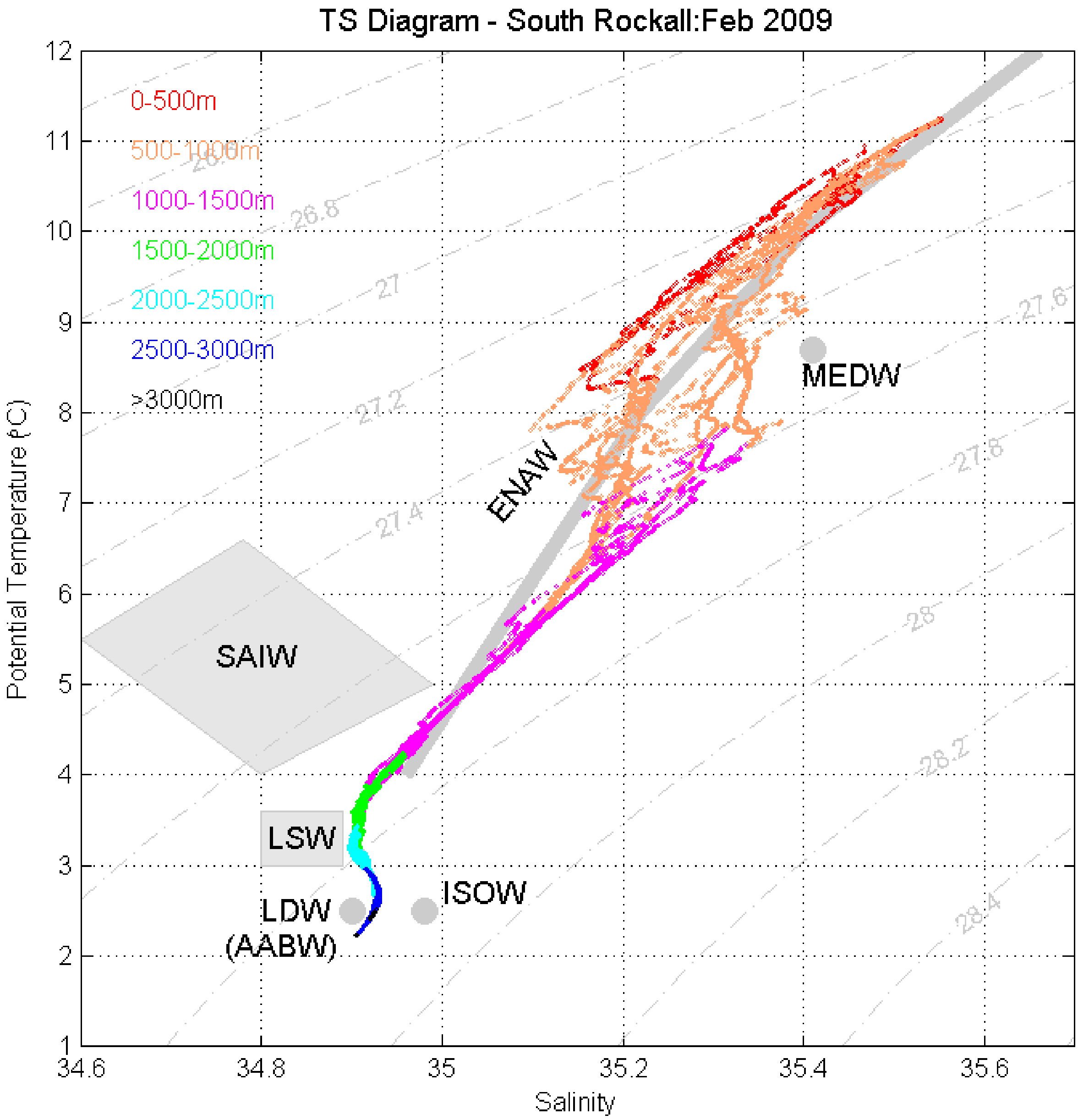


Figure 8. T/S curve for the South Rockall section during 2009.

North Rockall line

The second traverse of the Rockall Trough conducted is the North Rockall line which traverses from Rockall Bank to Erris Head. A shoaling of the permanent thermocline is not evident from east to west on this section, as previously observed in 2006 and 2007 (Figure 9). An eddy is evident at 13.95W along the section which may explain some of the deepening thermocline and halocline in this case. Because this section is further north than the previous section, MEDW is not observed on the North Rockall line.

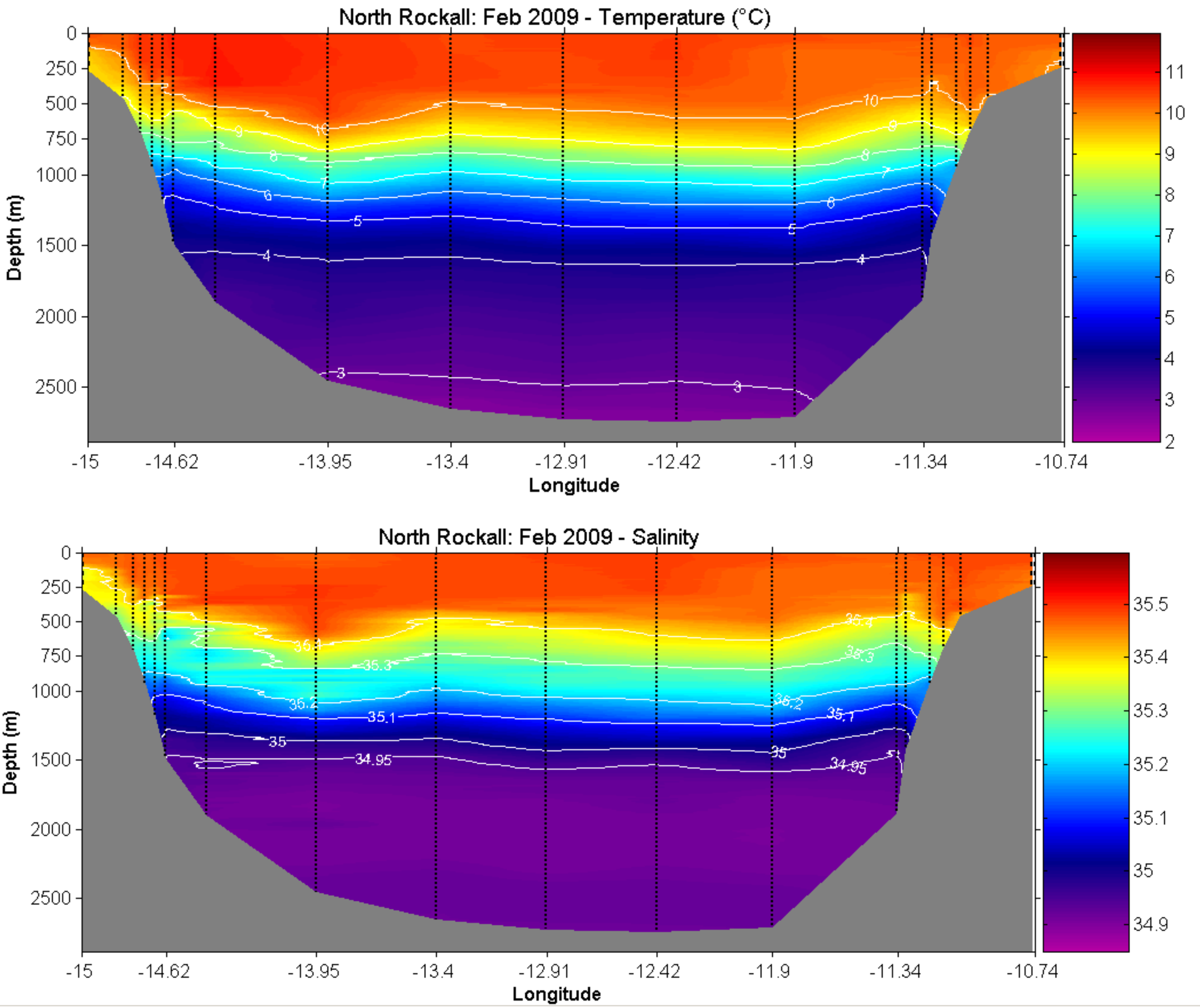


Figure 9. Temperature (upper panel) and salinity (lower panel) sections along the North Rockall Transect in February 2009.

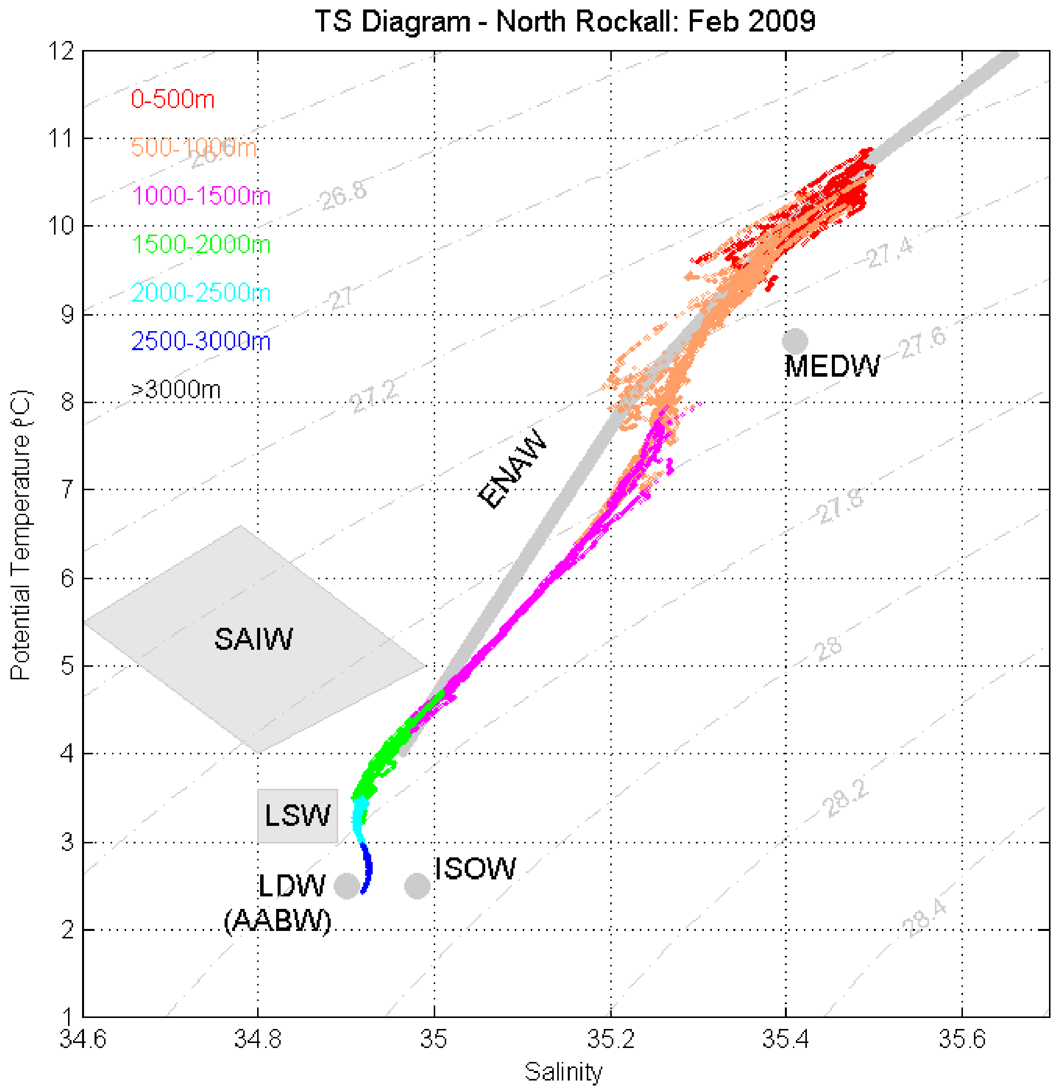


Figure 10. T/S Curve for the North Rockall section during February 2009

A much tighter T/S relationship is apparent on the North Rockall section. There is no MEDW influence here. Characteristics of the surface and deep water masses are similar to South Rockall.

Deep waters of Rockall Trough

The time period between 2006 and 2009 has seen considerable freshening of the Labrador Sea Water (LSW) centred on 1800m in the Rockall Trough (Figure 11). This is conceivably the arrival of LSW formed in the source region in 2000 that has transmitted itself through the deep water pipeline in the North Atlantic to reach the eastern basin. We will continue to monitor this water mass over the coming years to explore its effect on the overall water column, including potential vorticity.

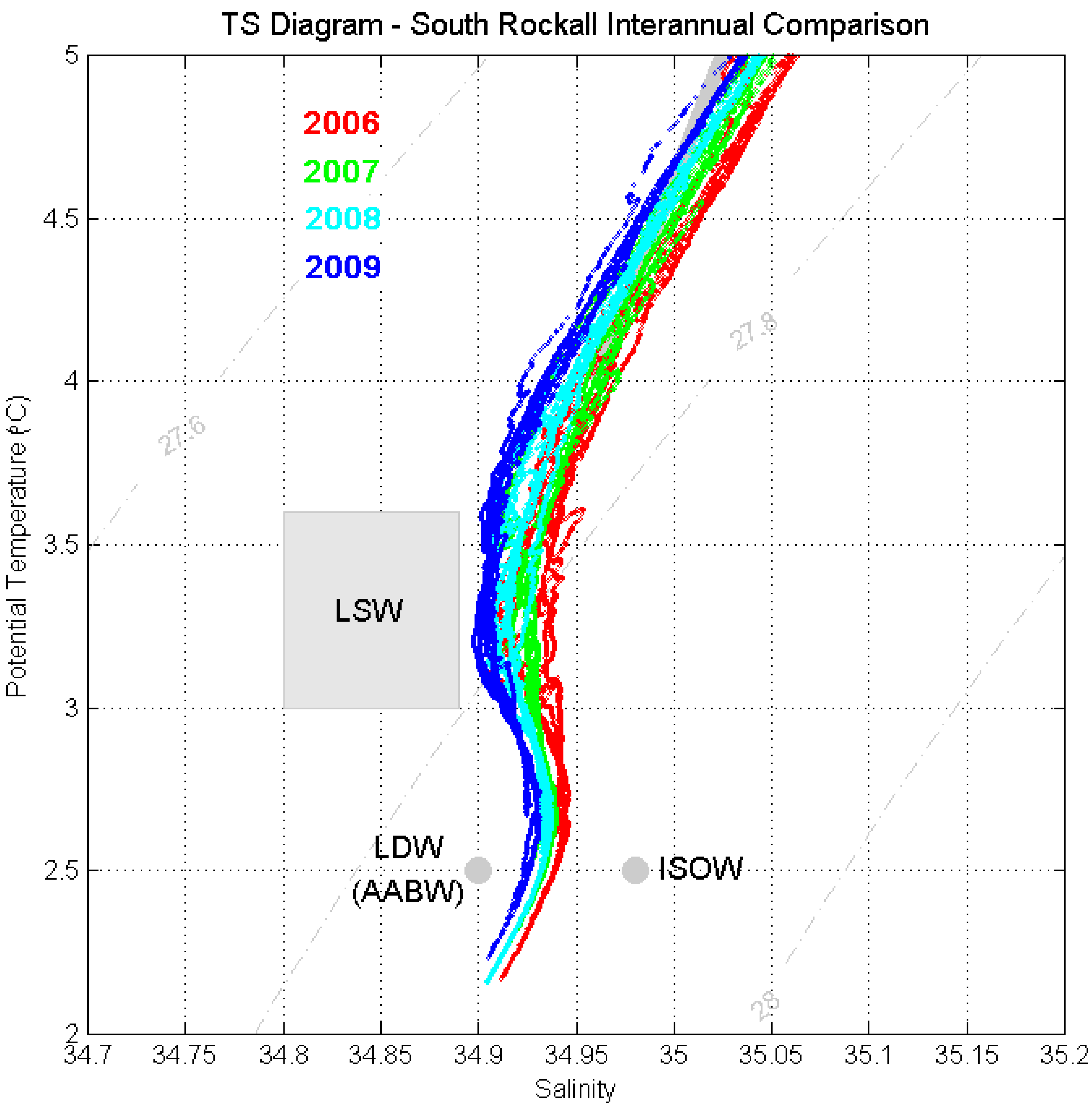


Figure 11. Interannual comparison of the deep water masses in Rockall Trough (2006–2009)

Conclusions

1. Significant interannual variability in the upper and intermediate waters
2. Strong SAIW influence at Porcupine in 2006 and 2008, shallower MLD in West Rockall (SAIW may stabilise water column)
3. LSW (freshening progressively since 2006)
4. Irish coast SST above long-term mean but has decreased in last year or so
5. Shallower MLD in 2009 than 2008

Acknowledgements

We thank the scientists on crew on board the Celtic Explorer for their hard work and commitment. Thanks also to MI technicians Micheal Roper and Kieran Adlum for their work in maintaining buoys and coastal stations around Ireland.

Annex 12: Dutch national report

Henrik Van Aken, NIOZ Royal Netherlands Institute, Netherlands

The NIOZ Royal Netherlands Institute for sea Research participated in the British RSS Discovery cruise 74DI332 to recover the monitoring moorings in the Irminger Sea. Now 5 years of data from these moorings are available. They contain daily TS profiles between about 200 and 2400 m, and high-frequency ADCP data from the upper 600 m and the lower 500 m of the water column, as well as TS data near the bottom. The westernmost mooring near the 3000 M isobath off Greenland has been redeployed.

During the Cruise of RRS Discovery also the AR7E section in the Irminger Sea was surveyed. The CTD data and tracer data are available to extend the time-series from the Irminger Sea to be reported in the annual ICES Report on Ocean Climate (area 5b).

For the late summer of 2009 a cruise with RV Pelagia is scheduled to service the monitoring mooring and to resurvey the AR7E section.

Annex 13: Oceanographic status report North Sea 2008

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Bundesamt für Seeschifffahrt und Hydrographie, Hamburg

(Federal Maritime and Hydrographic Agency)

1. The BSH North Sea Summer Surveys

In 1998 the Federal Maritime and Hydrographic Agency (BSH, Bundesamt für Seeschifffahrt und Hydrographie) started its annual summer surveys which cover the entire North Sea between 52° and 60° N. The surveys were realised at a time when thermal stratification is expected to be at its maximum and phytoplankton production has passed its maximum (see Table 1). The surveys include seven coast to coast East-West sections between 54° and 60° N and additional stations between 54° N and the entrance of the English Channel. With the exception of the first survey in 1998 all surveys served a fixed station grid for vertical CTD and water samples (see dots in Figure 7). Between the fixed CTD-stations a towed CTD-system mounted on the BSH's towfish 'Delphin' oscillated between a depth of 3–5 m and a about 5 metres above the bottom in order to record the 3-dimensional distribution of relevant oceanographic parameters. Both CTD-systems sampled T, S, fluorescence (chlorophyll-a, yellow substance), and oxygen concentration. Additionally, a thermosalinograph and optical sensors were mounted in the ship moon pool at about 4 m depth.

Table 1: H_{tot} and S_{tot} : Total heat and salt content of the North Sea, data from summer cruises with R/V GAUSS (G) and R/V PELAGIA (P). Climatology according to Janssen et al., 1999. SST: area averaged North Sea SST during the observation period.

date of cruise	cruise id	H_{tot} [x10^{21}J]	SST [°C]	S_{tot} [x10^{12}t]
24.06.1998 – 16.07.1998	G317	-	13.5	-
02.07.1999 – 22.07.1999	G335	1.359	15.2	-
09.08.2000 – 23.08.2000	G353	1.497	15.3	1.140
11.07.2001 – 02.08.2001	G370	1.346	15.2	-
16.07.2002 – 31.07.2002	G385	1.517	15.4	1.135
28.07.2003 – 13.08.2003	G405	1.625	17.8	1.138
05.08.2004 – 20.08.2004	G425	1.594	17.1	1.148
10.08.2005 – 29.08.2005	G446	1.550	14.9	1.153
02.08.2006 – 20.08.2006	G463	1.520	17.0	1.138
03.08.2007 – 17.08.2007	P273	1.567	15.3	1.143
21.07.2008 – 05.08.2008	P293	1.550	16.1	1.143
climatology:		1.400	-	1.192

In 2008 the 60° N section was extended westwards to the point of 3° W (1998–2007: 0.5° W) with a small excursion to the South around the southern tip of the Shetlands. Further on, in 2008 the 54° N section is basing on classical CTD data only due to problems with the towed system at the beginning of the cruise which results in a coarser spatial resolution on this section.

2. Global Radiation

During May and June 2008 the monthly means of global radiation at the East Frisian island Norderney (Figure 1) clearly exceeded the long-term mean. The July mean corresponded to the climatology and the August values was lower than the climatology. The rest of the year the global radiation was very close to the long-term mean.

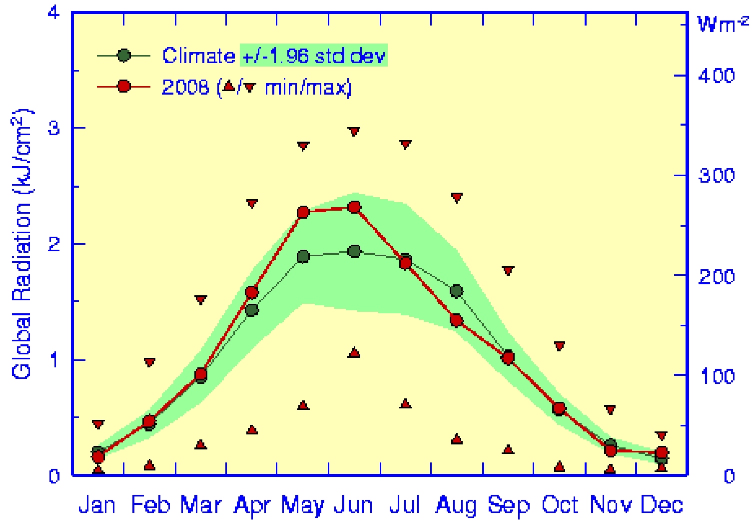

Figure 1. Monthly averaged global radiation at Norderney in 2008 [kJ/cm²]. Data kindly provided by the German Weather Service (DWD).

3. Elbe River Run-Off

Between February and April 2008 the monthly Elbe river run-off was slightly above and from June to December slightly below the long-term mean (Figure 2). The annual averaged run-off decreased from 22 km³/year - which corresponds to the long-term mean - to 20 km³/year (Figure3). The data were kindly provided by the WSA Lauenburg.

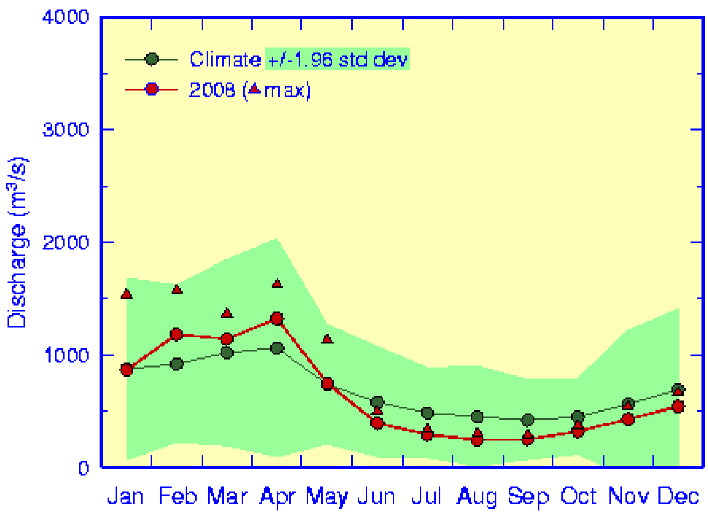

Figure 2. Monthly means of Elbe discharge in 2008 (WSA Lauenburg).

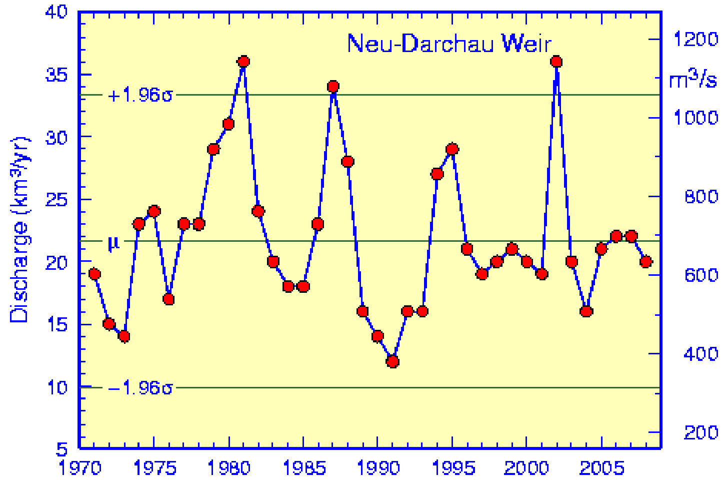

Figure 3. Yearly averaged Elbe run-off 1971–2008 (WSA Lauenburg).

4. North Sea SST

During 2008 the weekly means of area averages SST were slightly above the long-term means. The heat excess from the previous year at the beginning of 2008 was much smaller than in the beginning of 2007 (Figure 4). The anomalies varied between +0.4 and +1.7 °C, in December and January 2009 the SST matched the long-term mean (+0.1 and 0.0 °C respectively). In contrast to the previous years there were no SST records in 2008.

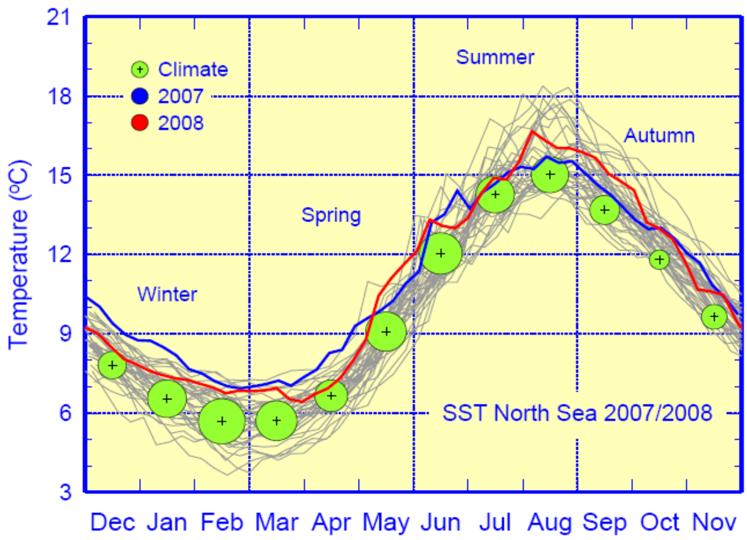

Figure 4. Weekly means of area averaged North Sea SST from December 2007 until November 2008 (red line) and from December 2006 until November 2007 (blue line). The grey lines are the annual cycles back to 1968. The green circles give the long-term monthly mean, the radius gives the interannual standard deviation for the period 1971–1993.

The linear trend of 0.3±0.1 K/decade (dotted line in Figure 5) doesn't describe the real history of the mean SST adequately. In fact, this history is characterised by spontaneous jumps between warm and cold regimes.

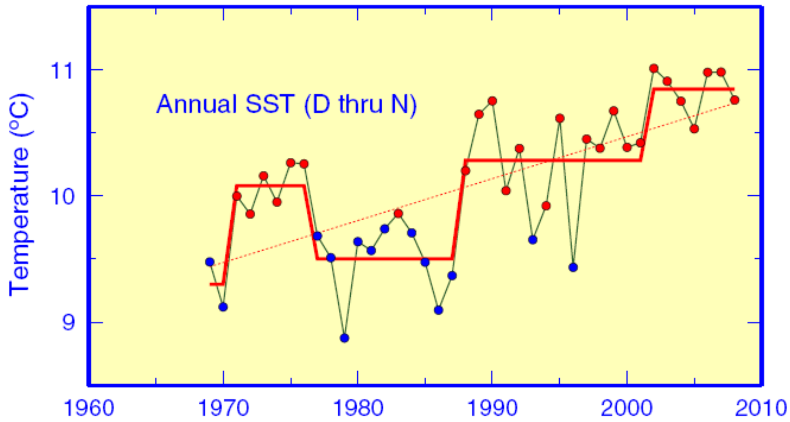

Figure 5. Time-series of annual North Sea SST 1968–2008 (Dec through Nov) together with linear trend and regime shifts. Blue if < 9.86 °C (base period mean 1971–1993), otherwise red.

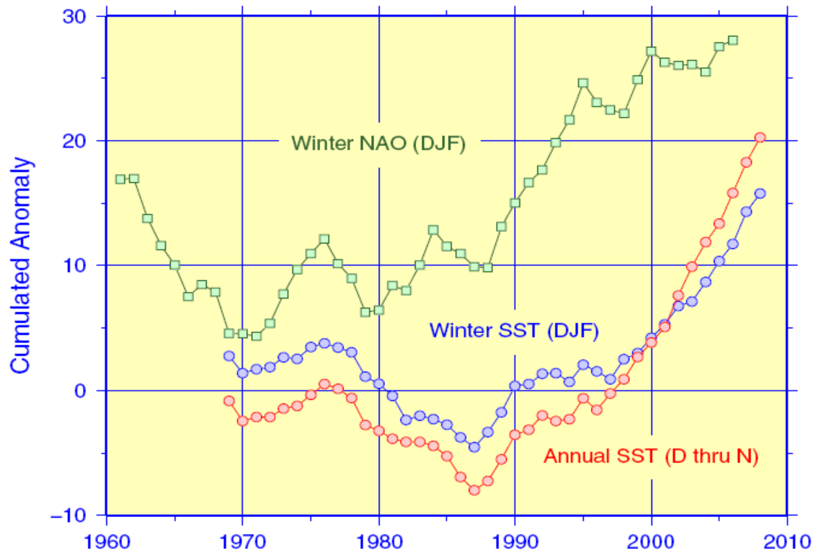

Figure 6. Time-series of cumulated standardised anomalies for winter (DJF) and annual (December through November) North Sea SST and of cumulated winter NAO index (Koslowski and Löwe, 1994).

The cumulated anomalies of the winter NAO (DJF), winter SST (DJF), and annual averaged North Sea SST show no correlation during the last decade.

5. North Sea Summer Temperatures

Normally, the temperature exhibits a typical gradient with increasing temperatures from the open northern boundary towards the inner German Bight with isotherms running approximately from SW to NE. In 2008 the near-surface isotherms are running roughly NNW – SSE with a pronounced warming along the Norwegian and Danish coast (Figure 7, left), though the monthly averaged SST for July 2008 has a positive anomaly of 0.6°C only.

In the bottom layer we still observe the typical gradient with isotherms running approximately from SW to NE. Here temperatures and spatial pattern are comparable to 2007. The area covered by the 8°C-isotherm is larger compared to 2007 and close to the Dutch coast temperatures are locally about 1°C cooler (Figure 7, right).

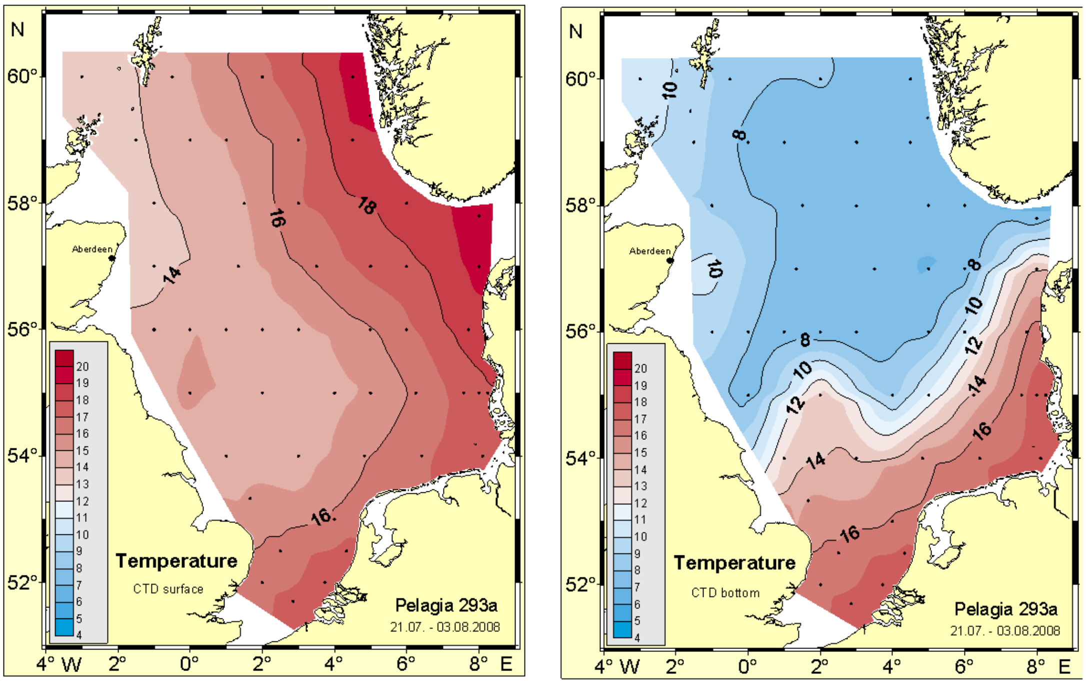

Figure 7. Horizontal surface (left) and bottom (right) temperature distribution [°C], PELAGIA 293a, 21 July – 3 August 2008.

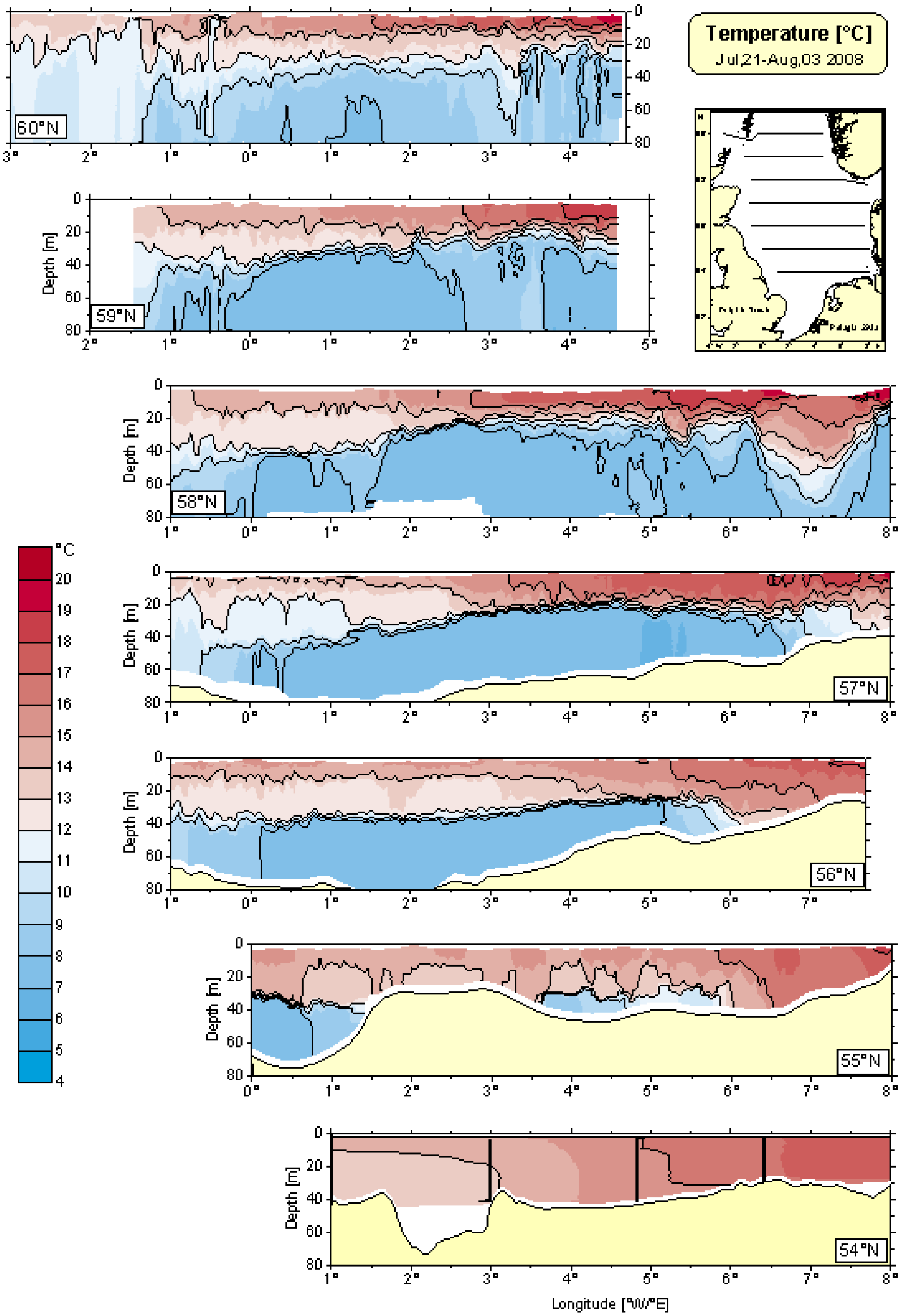

Figure 8. Temperature section from PELAGIA 293a, 21 July – 3 August 2008.

The pronounced warming along the Norwegian and Danish coast in the surface layer compared to 2007 is clearly visible in the temperature sections north of 56° N (Figure 8). In 2008 the vertical gradient was smoother and the W-E gradient was much stronger compared to 2007. Along the English coast north of 56 °N the structure of the upper layer is much thinner and partly fragmented along 57° N. In return, the structure of the colder bottom water is much more stable and the 8°C water fills nearly the whole central North Sea (compare Figure 7). The 54° N section was completely vertically mixed due to tidal mixing and strong winds, the 55° N section was vertically mixed at its eastern section and above the Dogger Bank, respectively weakly stratified only east off 1.5° E.

6. Temperatures at Light Vessel *Ems*

Figure 9 gives a time-series of water temperature recorded at different depths on the unmanned light vessel Ems (54° 10′ N; 6° 21′ E, water depth 35 m). Though the time-series has several gaps due to technical problems or the maintenance of the vessel, it shows clearly the seasonal stratification and its decay during fall. Due to the general warming of the North Sea during the last years, the winter minimum 2006/2007 and 2007/2008 were 3.0 – 3.5 °C above the long-term mean (green line). Like the SST, the winter minimum 2008/2009 at light vessel Ems approached again the long-term mean.

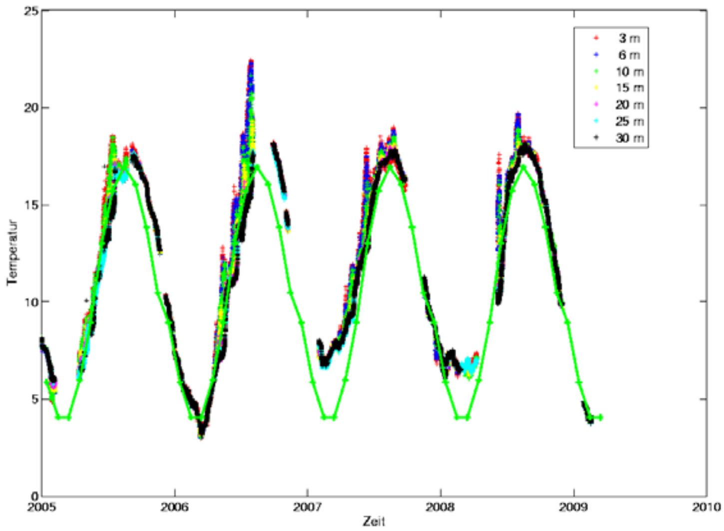

Figure 9. Temperatures at light vessel Ems 2005–2009. Green line climatology according to Janssen *et al.*, 1999[1].

[1] Janssen F., C. Schrumm 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.

7. Total Heat Content

The total heat content is a climate relevant index which integrates the effects of solar radiation, advection of Atlantic Water, seasonal stratification, and atmospheric heat exchange. Figure 10 shows the total North Sea heat content for the summer cruises 1999–2008 related to the masked area in Figure 7. The heat content was steadily decreasing from 2003 until 2006 but rising again between 2006 and 2007. Between 2007 and 2008 the heat content fell back to the 2005 value. The discrete values are given in Table 1.

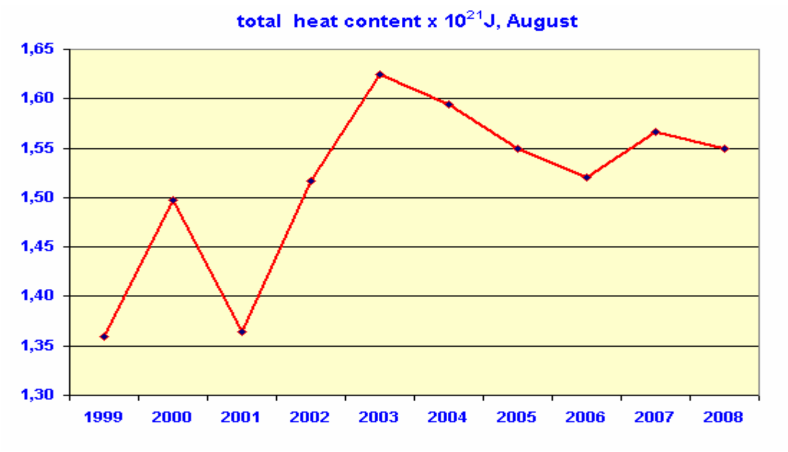

Figure 10. Total heat content in J x 10^{12}, 1999–2008.

Figure 11 shows the monthly mean temperatures of the total North Sea volume between 2000 and 2008 based on results of the operational BSH model 'BSHcmod'. Beside the pronounced warming during the last years the data show the increasing length of the summer season: Seasonal warming starts earlier and cooling much later. This pattern is already known from the SST data, but is also valid for the total North Sea volume. During 2008 this trend is reversing, i.e. in 2008 seasonal warming started later and seasonal cooling earlier as in 2007.

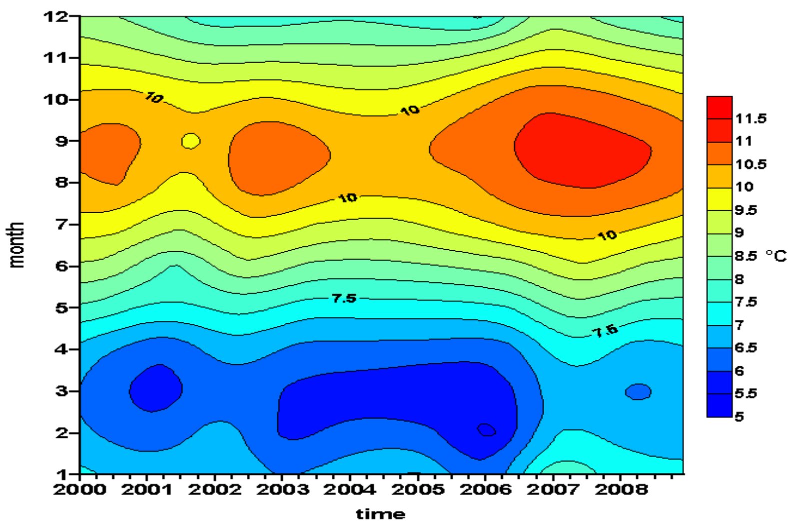

Figure 11. Monthly mean temperature of the total North Sea volume 2000–2008.

(BSHcmod model data)

8. North Sea Salinity and Total Salt Content

Compared to 2007 the salinity concentrations in the surface and bottom layers increased in the northern part of the North Sea, while the southern part became fresher. The tongue of Atlantic Water with salinity S>35 in the near-surface layer reached about half a degree further to the south. In the bottom layer the 35.25-isohaline extended to about 58 °N over the whole North Sea between the Scottish and Norwegian Coast covering a much larger area as in the previous year (Figure 12). The position of the 34-isohaline at the bottom was comparable to 2007. At the surface north of 57° N the 34-isohaline was located about 1° further to the west. The total salt content during the 2008 survey equals that of the 2007 survey (see Table 1 and Figure 13), i.e. the increasing salinity in the northern part was compensated by the freshening in the southern North Sea.

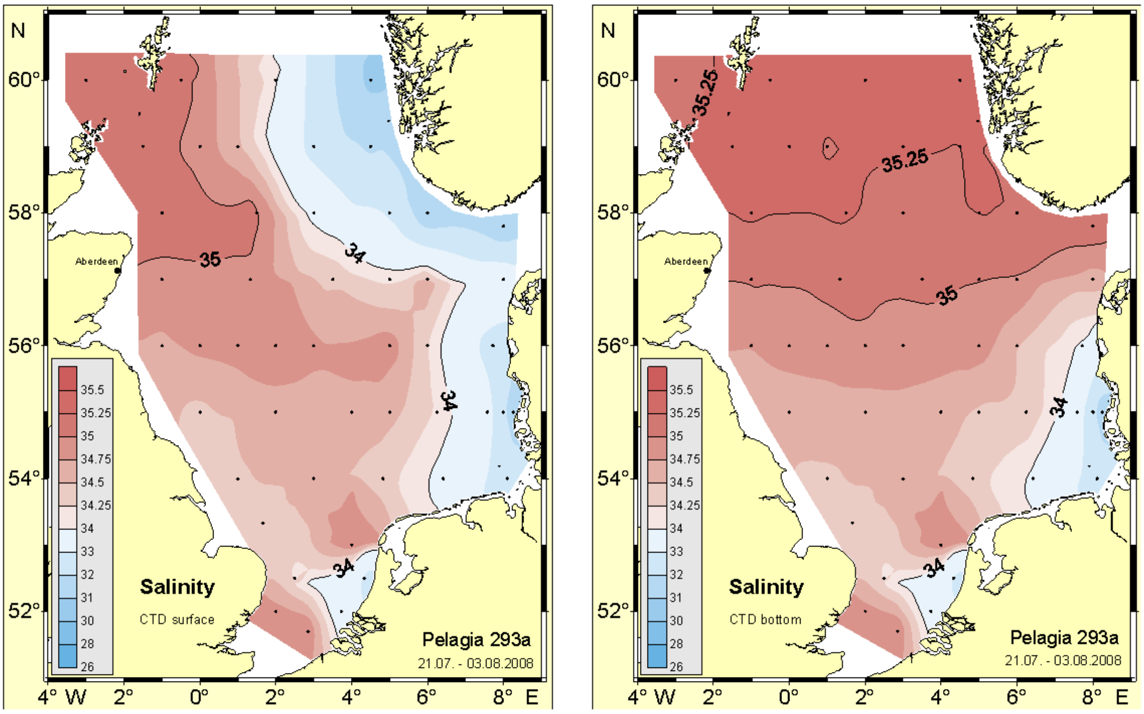

Figure 12. Horizontal surface (left) and bottom (right) salinity distribution.

PELAGIA 293a, 21 July – 3 August 2008.

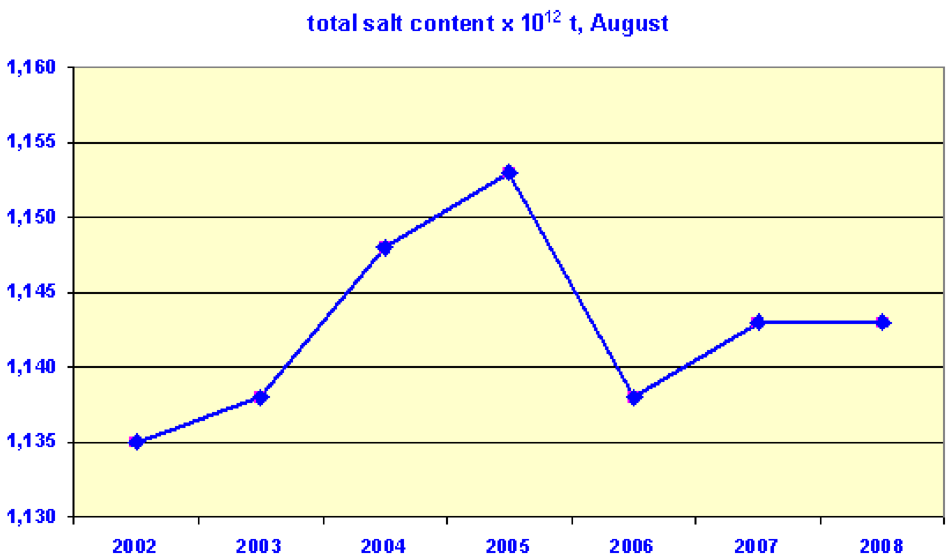

Figure 13. Total salt content in 10^{12} tons from 2002 to 2008.

***(GAUSS* and *PELAGIA* cruise data).**

The salinity sections as in Figure 14 show a distinctive stratification between the fresher Baltic outflow (S<34, 58–60°N) and North Sea water north of 57° N. As mentioned above, the Baltic outflow was spreading about 1° further to the West compared to 2007. At 58° N the fresh water ribbon adapts very close to the Danish coast with some small fresh water ribbons between 4 and 5 °E.

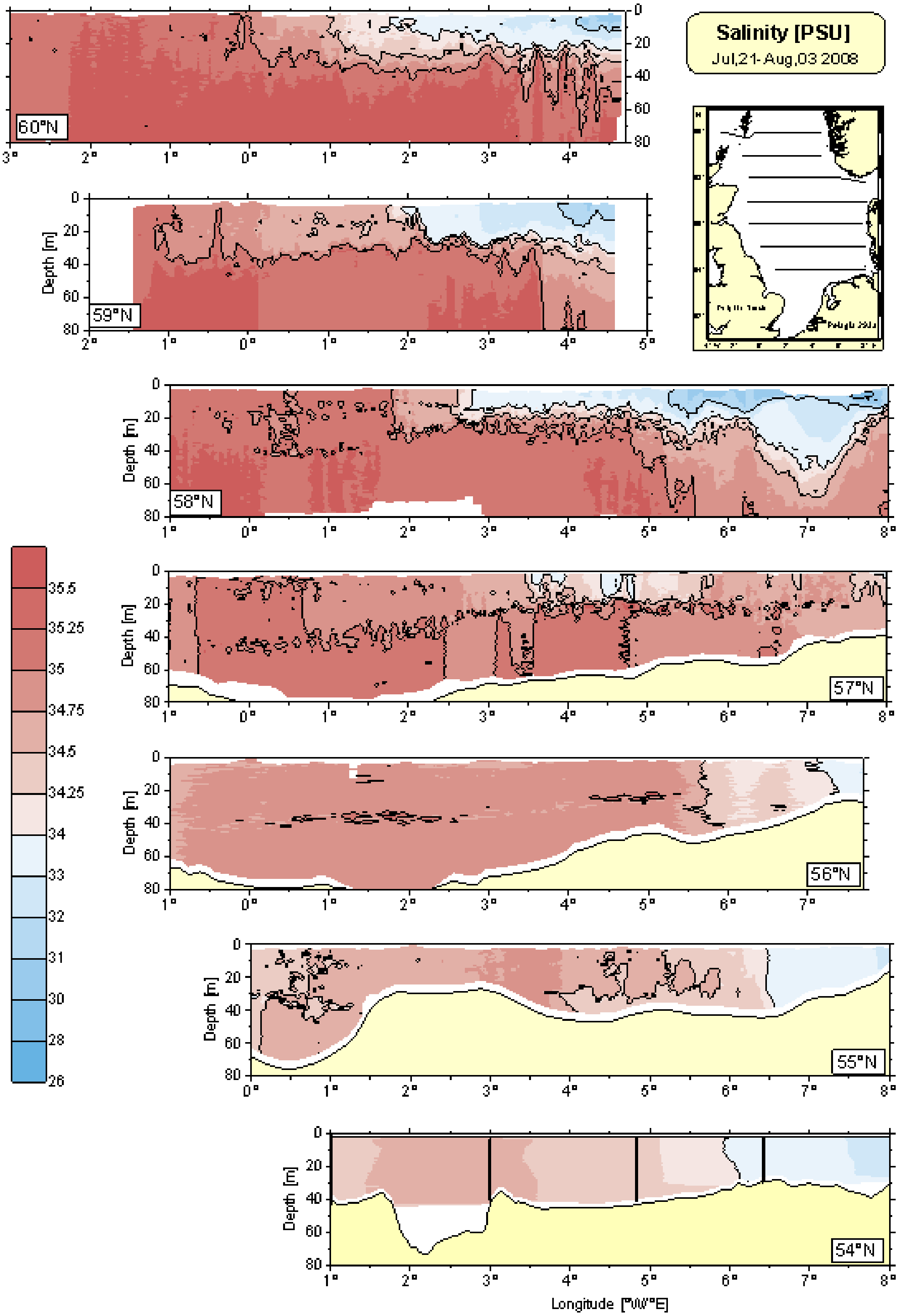

Figure. 14. Salinity sections from PELAGIA 293a, 21 July – 3 August 2008.

9. Oxygen Saturation and Secchi-Depth

The oxygen saturation below the thermocline was high for July. Only small patches west off Jütland exhibit a saturation between 70 and 80 % (Figure 15 left and centre). Not until oxygen saturation falls below 40 % marine life experience substantial stress.

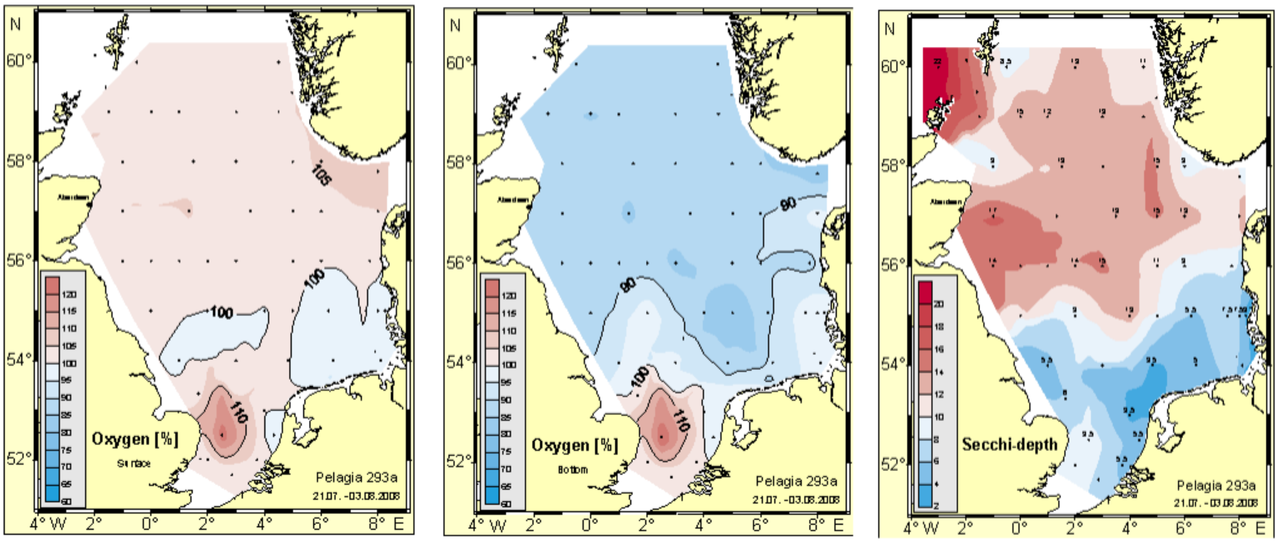

Figure 15. Surface (left) and bottom (centre) oxygen distribution [%].Right: Secchi-depth [m].

PELAGIA 293a, 21 July – 3 August 2008.

10. Secchi-Depth

The right panel in Figures 15 shows the Secchi-depth during the PELAGIA summer cruise. Satellite data reveal, that the area of high Secchi-depths coincide with regions of low chlorophyll, yellow substance, and suspended matter concentrations.

11. Chlorophyll-a Distribution

Figure 16 shows the monthly averaged near-surface chlorophyll-a concentrations of the North Sea for March, April, May, and June. The data are from the Medium Resolution Imaging Spectrometer Instrument (MERIS) of the ENVISAT satellite. To improve the resolution a logarithmic scale is used. Chlorophyll production started during March and reached its maximum during April and May. The status shown for June kept stable until November. There are no data in January and December due to cloud coverage and there are greater spatial gaps due to clouds in February and November.

The vertical distribution of chlorophyll-a along the sections of the summer survey is shown in Figure 17. The chlorophyll maximum is located directly under the thermocline and near the surface where no stratification has established (compare Figures 8 and 14).

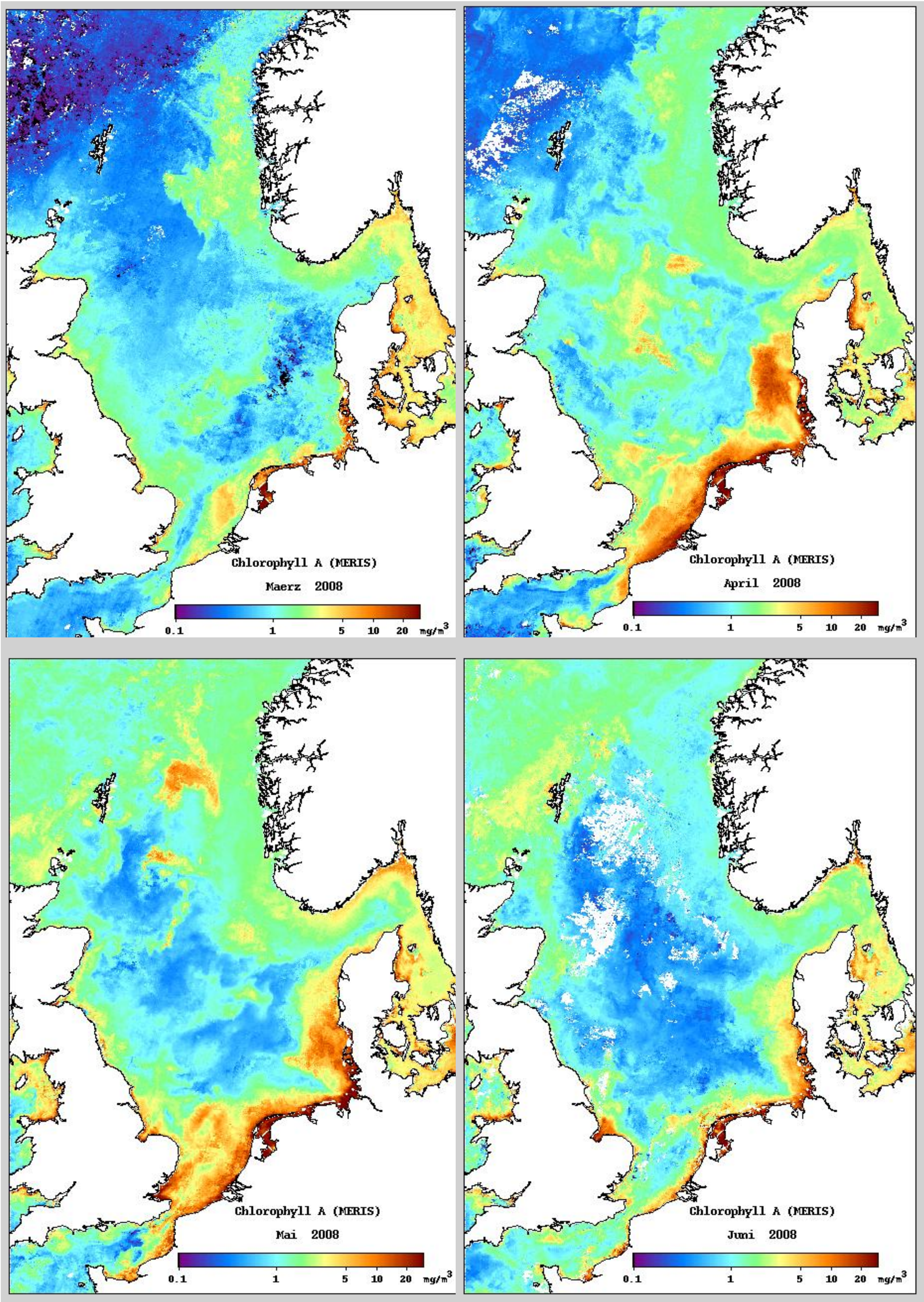

Figure 16. Monthly averaged Chlorphyll-a concentration (MERIS) during March, April, May, and June 2008.

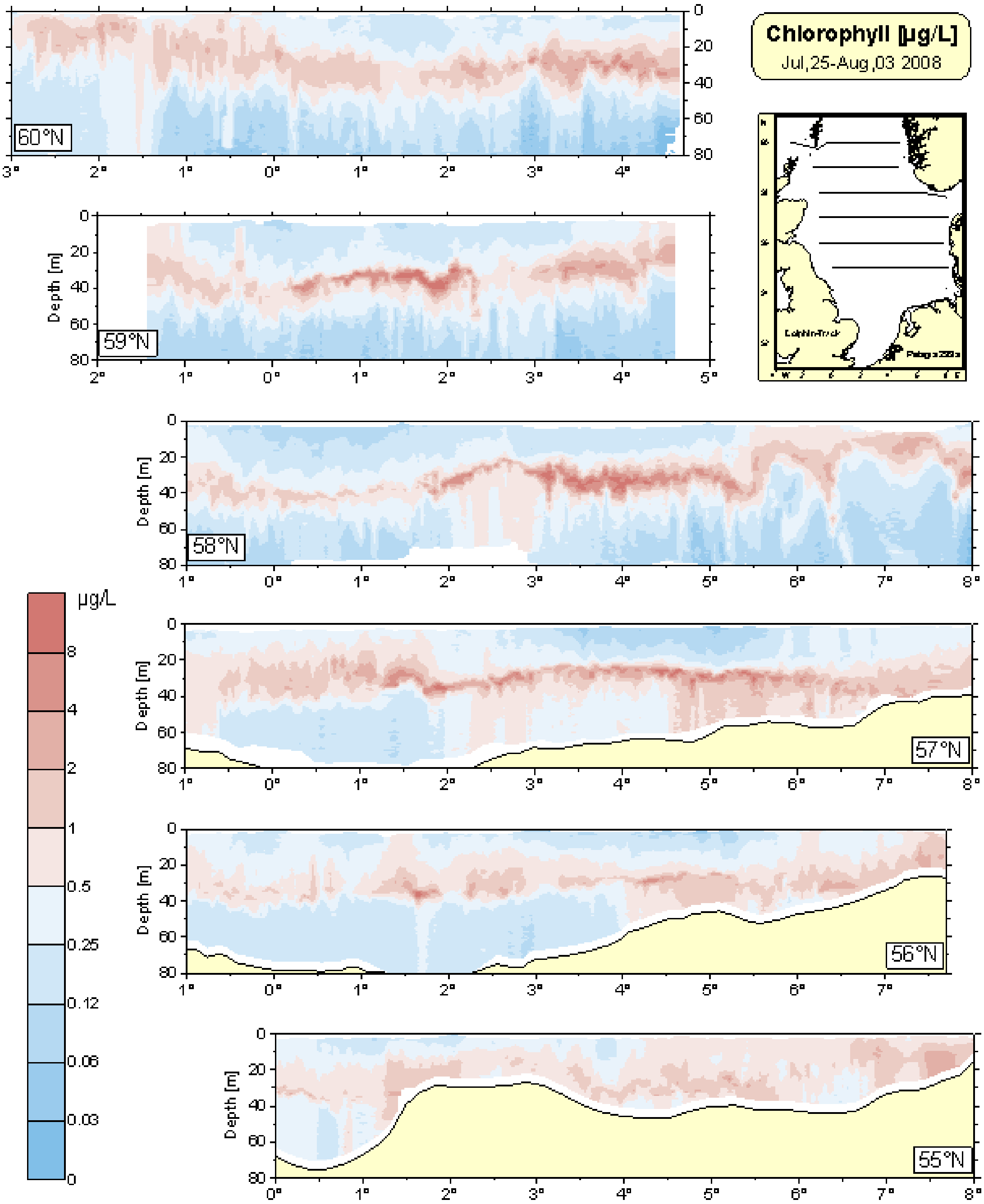

Figure 17: Chlorophyll-a sections from PELAGIA 293a, 21 July – 3 August 2008.

Annex 14: Norwegian Waters

Randi Ingvaldsen, Kjell Arne Mork, Morten Skogen, Henrik Søiland, and Harald Loeng

Institute of Marine Research

Summary

The temperature in the southern Barents Sea was in 2008 above normal but less that in 2007 and the sea-ice cover was less than normal but slightly larger than in 2007. In 2008 the Atlantic water in the Norwegian Sea was only slightly warmer than normal, about 0,1–0,3 °C. The temperatures in the North Sea were in 2008 less than in 2007 but still larger than normal.

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

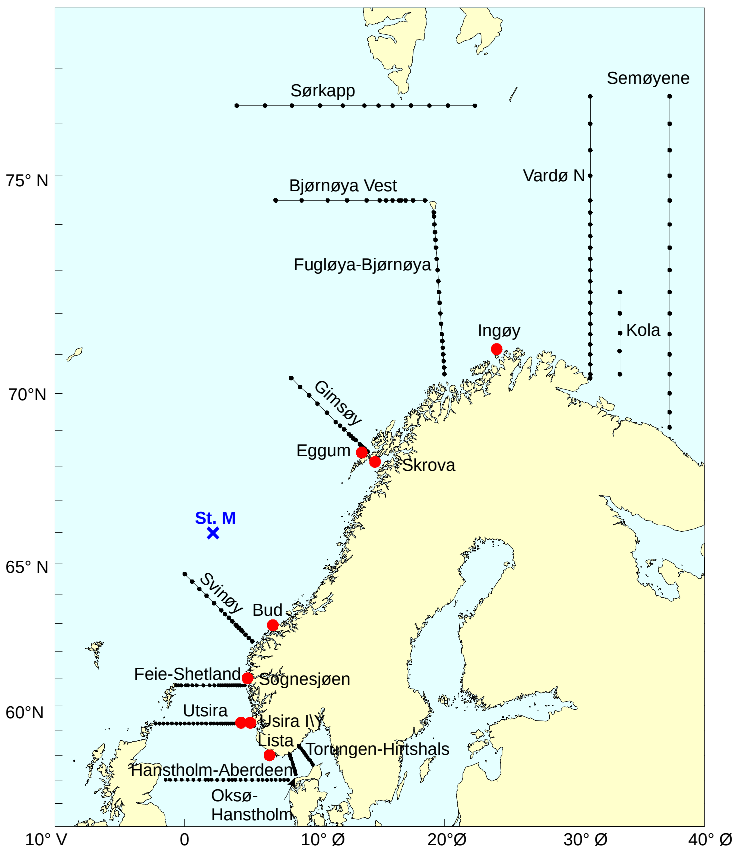

Figure 1. Standard sections and fixed oceanographic station worked by Institute of Marine Research, Bergen. The University of Bergen is responsible for station M, while the Kola section is operated by PINRO, Murmansk (ANON 2002).

The Norwegian Sea

After six years with a relatively extraordinary warm and salt Atlantic water in the eastern Norwegian Sea both temperature and salinity dropped in 2008 and were only slightly larger than the long-term mean.

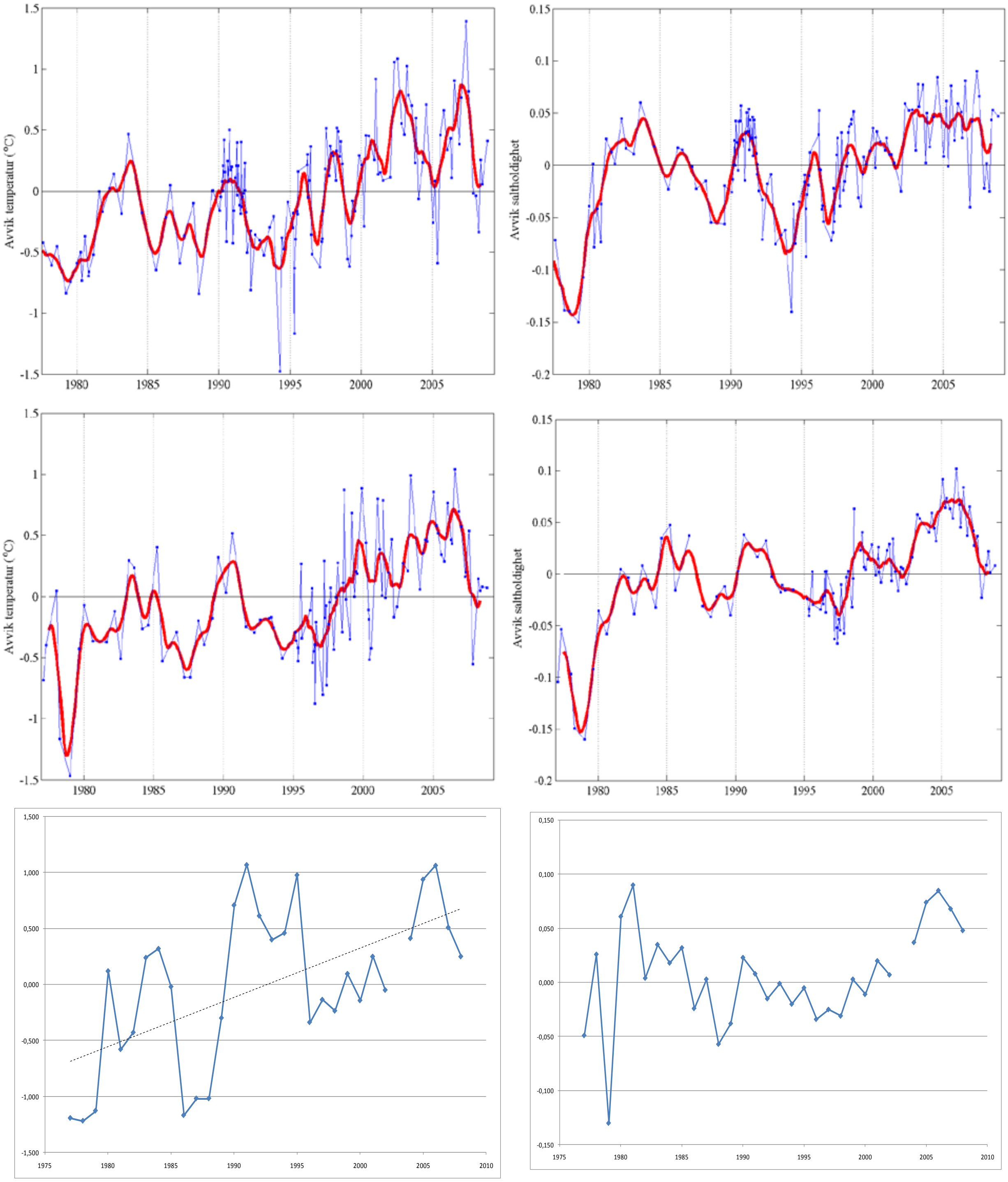

Figure 2. Temperature and salinity anomaly in the core of Atlantic water for the sections Svinøy-NW, Gimsøy-NW and Sørkapp-W, averaged between 50 and 200 m depth. Blue lines are actual values (only summer values in the Sørkapp section) while red lines are one year averages.

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. Figure 2 shows the development in temperature and salinity in the core of Atlantic Water for three different sections from south to north in the eastern Norwegian Sea (Figure 1). There has, in general, been an increase of temperature and salinity in all three sections from the mid-1990s to 2007. From 2000 the annual temperature averages were above normal in both the Svinøy and the Gimsøy section. After the record-high value in the Svinøy section in 2007 the temperatures in both Svinøy and Gimsøy section dropped to near the normal in 2008. As Atlantic water flows northward the temperature increase can also be observed further north, in the Sørkapp section. In 2008, the annual temperature averages were 0,2 °C and 0,1 °C above the long-term-mean for the time-series in Svinøy and Gimsøy sections, respectively. In the Sørkapp section the summer temperature was 0,3 °C above the long term mean. The salinity has the last years also increased in all three sections but it also dropped in 2008. In the Svinøy section the salinity has since 2003 been nearly constant and in 2008 was 0,04 above normal while it in the Gimsøy section decreased and was 0,01 above the mean in 2008. In the Sørkapp section the salinity was in 2008 also above the long term mean, about 0,05.

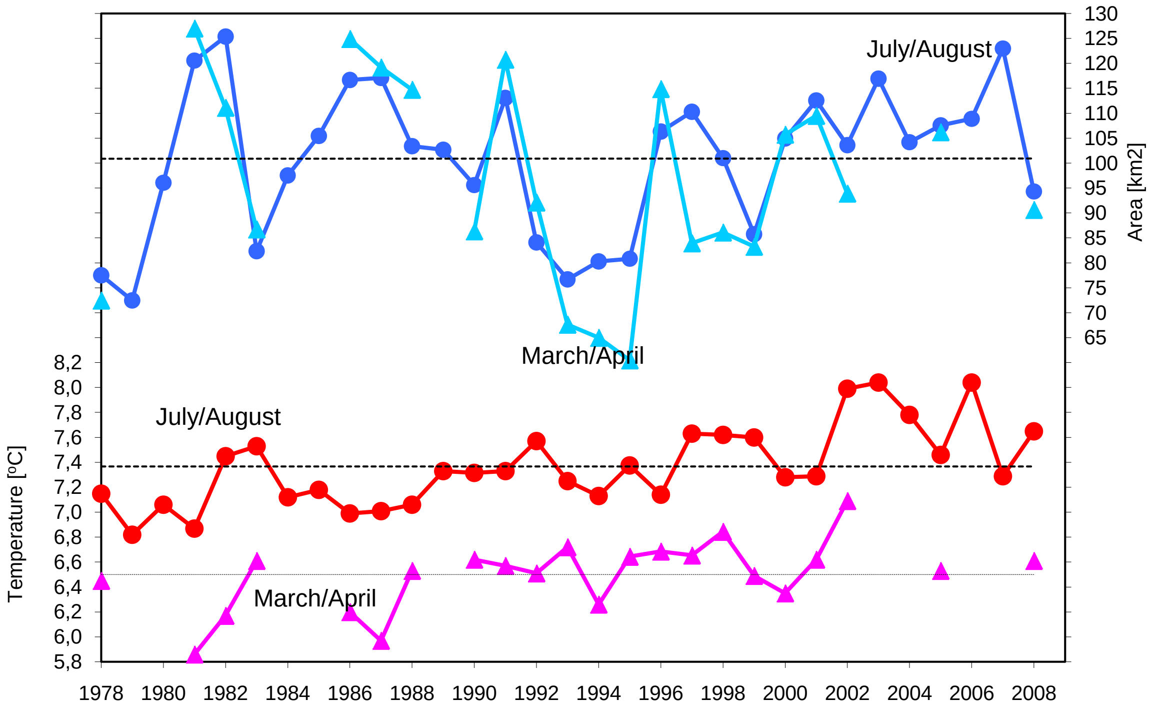

Figure 3. Time-series of area (in km²) and averaged temperature (red) of Atlantic water in the Svinøy section, observed in March/April and July/August, 1978–2007.

The area of Atlantic water (defined with S>35.0) in the Svinøy-section has been calculated. The mean temperature within the limited area has also been calculated, and the results for spring and summer are shown in Figure 3. Large values in the area are due to larger distribution of Atlantic water in the section. This is due to a more westerly or/and vertical distribution of Atlantic water. There are considerable variations both in the area of Atlantic water distribution and its temperature. The distribution area of Atlantic water decreased since the beginning of 1980s to mid-1990s and increased from there to 2007. In 2008, however, there was a considerable drop from 2007 and more Arctic waters occupied the section.

The Barents Sea

The Barents Sea is a shelf area, receiving inflow of Atlantic water from the west. The inflowing water demonstrates considerable interannual fluctuations in water mass properties, particularly in heat content, which again influence on winter ice conditions. The variability in the physical conditions is monitored in two sections. Fugløya-Bear Island is situated where the inflow of Atlantic water takes place; the Vardø-N section represents the central part of the Barents Sea. In both sections there are regular hydrographic observations, and in addition, current measurements have been carried out in the Fugløya- Bear Island section continuously since August 1997. Coastal monitoring is performed at the station Ingøy.

The Fugløya-Bear Island section, which capture all the Atlantic Water entering the Barents Sea from south-west, showed temperatures of 0.8–1°C above the long-term mean in early 2008 (Figure 4). Further east along the 31°13E longitude, at the Vardø-North section, the temperature anomaly during late winter was 1.5°C above the long-term mean, which is an all time high since the time-series started in 1977. The high temperatures were due to higher-than-normal temperatures upstream in the Norwegian Sea in combination with less atmospheric cooling than usual because of the high air temperatures during winter. Due to low air temperatures in spring in combination with weak Atlantic inflow, the ordinary seasonal temperature increase during spring was lower-than-normal, particularly in the south-western Barents Sea, and in August 2008 the temperature in south-west was only 0.5°C above the long-term mean (Figure 4). The strong temperature decrease during the year caused 2008 as a whole to be colder than the previous two years even though it started out with a new record-high temperature. The salinity variations are similar to those in temperature, and the salinity is still high but decreasing since 2006.

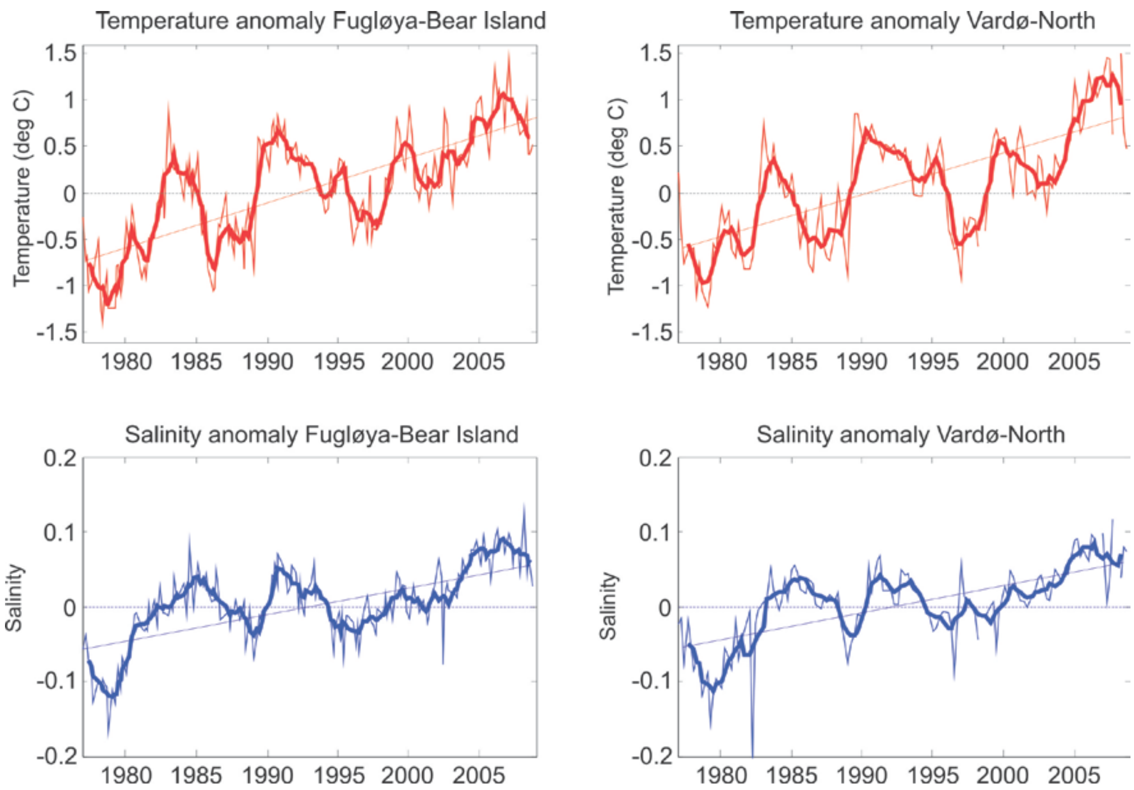

Figure 4. Temperature (upper) and salinity (lower) anomalies in the 50–200 m layer of the Fugløya-Bear Island section (left plates) and Vardø-N section (right plates).

The surface temperatures in the Barents Sea are closely linked to the air temperatures. The time-series from the surface coastal waters at Ingøy show that during the winter of 2007–2008 the surface temperature were above the long-term mean (Figure 5). In spring 2008 the temperatures decreased relative the long-term mean, while in fall 2008 and early winter 2009 they increased to above the long-term mean. The same signal is evident in the deeper waters (at 250 m), but the temperature decrease occurred somewhat later in summer and was stronger. The fall of 2008 was pronounced colder than the 2 years before, particularly at depth, but from December 2008 the temperatures again have been above the long-term mean although lower than during the last 3 winters.

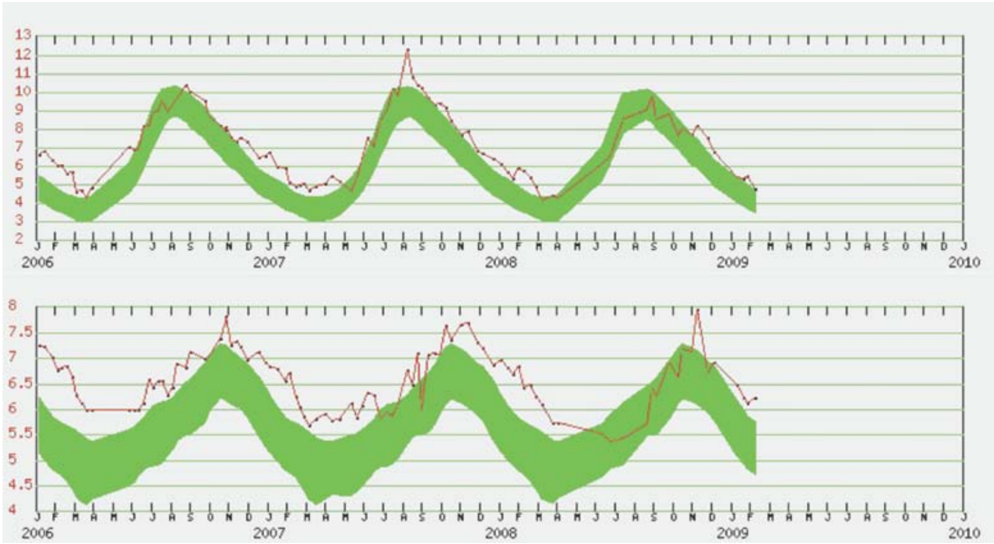

Figure 5. Monthly mean temperature at 1 m and 250 m depth at the fixed station Ingøy, northern Norway, situated in the Coastal Current at the entrance to the Barents Sea. Vertical axis is temperatures (°C) and horizontal axis is month. The green areas are the long-term mean for the period 1936–1944 and 1968–1993 +/- one standard deviation and represent the typical variations.

The variability in the ice coverage in the Barents Sea is linked to the temperature of the inflowing Atlantic water, the northerly winds, and 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), but usually the sea ice distribution in the western Barents Sea respond a bit quicker than in the eastern part. Due to the high temperatures there has been little ice in the last years (Figure 6). During the period 2003–2006 the winter ice edge had a substantial retreat towards north-east, but since then the ice area has increased. In winter 2008 the amount of ice was close to the situation in 2007. During the spring and summer of 2008 the figure implies an increase in ice anomaly in the western area, but this is mainly due to redistribution of ice. During summer northerly winds prevailed and shifted the ice toward the east coast of Spitsbergen. In the eastern parts the ice area was less than the long-term mean, and averaged over the year, 2008 showed less ice than normal but slightly more than in 2007.

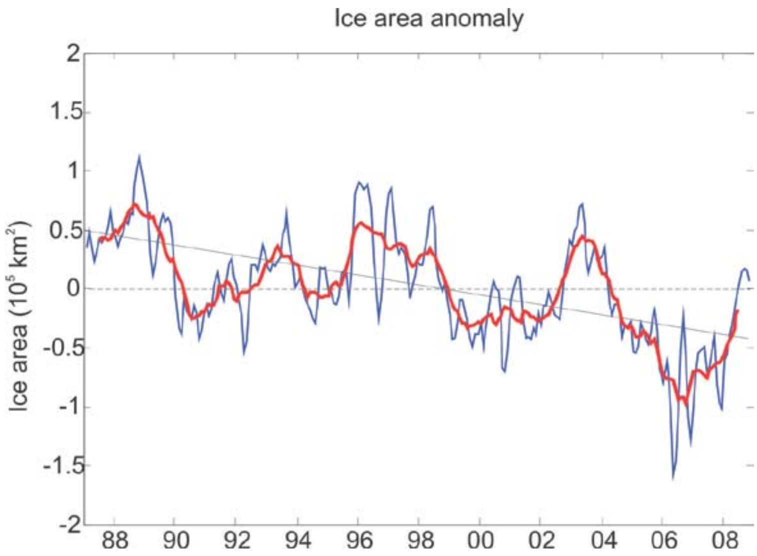

Figure 6. Ice area anomaly for the sector 25–45°E in the Barents Sea, which is the area with the highest variability in ice cover. Monthly mean (blue line) and 1 year moving average (red line) is shown relative to the mean ice area for the period 1995–2008. The strait line indicates the trend line.

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. Southwest wind, which is predominant during winter, accelerates flow of Atlantic Water into the Barents Sea; whereas, weaker and more fluctuating northeast wind common during summer, slows the flow. The mean transport of Atlantic Water into the Barents Sea for the period 1997–2008 is 2 Sv (Sv = 106 m3s-1) with an average of 2.2 Sv during winter and 1.8 Sv during summer. During years in which the Barents Sea changes from cold to warm marine climate, the seasonal cycle can be inverted. Moreover, an annual event of northerly wind causes a pronounced spring minimum inflow to the western Barents Sea; at times even an outward flow.

The time-series of volume transport reveals fluxes with strong variability on time scales ranging from one to several months (Figure 7). The strongest fluctuations, especially in the inflow, occur in late winter and early spring, with both maximum and minimum in this period. The recirculation seems to be more stable at a value of something near 1 Sv, but with interruptions of high outflow episodes.

The volume flux varies with periods of several years, and was significantly lower during 1997–2002 than during 2003–2006 (Figure 7). The year of 2006 was a special year as the volume flux both had a maximum (in winter 2006) and minimum (in fall 2006). Since then the inflow has been low, particularly during spring and summer. The inflow in 2008 was much as in 2007; moderate during winter followed by a strong decrease in spring. In early summer 2008 the flux was close to the average. As the observational series still only have data until summer 2008, it cannot give information about the situation in fall 2008 and early winter 2009. There is no significant trend in the observed volume flux from 1997 to summer 2008.

Heat transport into the Barents Sea is formed by a combination of volume and temperature of inflowing water masses, although those two factors are not necessarily linked. The reason is that while temperature of inflowing water depends on temperatures upstream in the Norwegian Sea, the volume flux depends mainly on the local wind field. This signals the importance of measuring both volume transport and temperature, since volume flux is essential to transport zooplankton, fish eggs, and larvae into the Barents Sea.

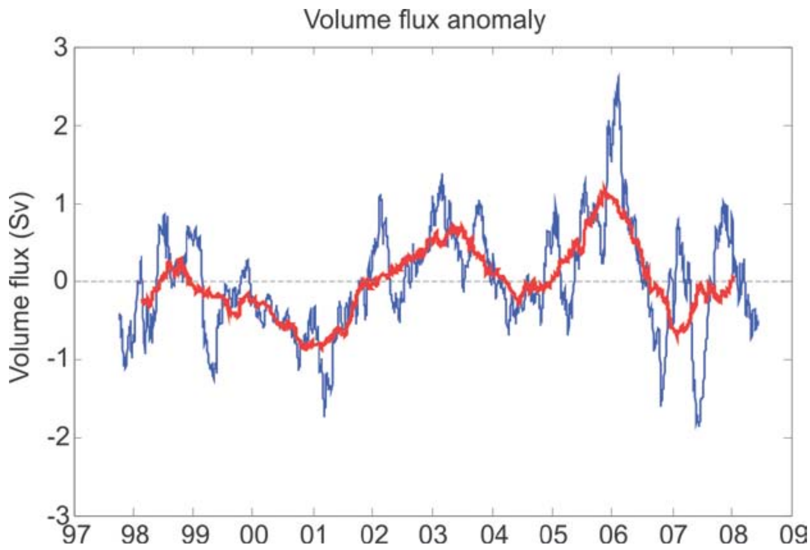

Figure 7. Observed Atlantic Water volume flux through the Fugløya-Bear Island section estimated from current meter moorings. Three months (blue line) and 12-months (red line) running means are shown.

The North Sea

In 2008 the temperatures in the North Sea were higher than normal but less than in 2007. In the northern North Sea the temperature was 0.2–0.7 degrees above the normal.

Figure 8 shows the development of temperature and salinity at two positions, one (A) near bottom in the north-western part of the North Sea and the second (B) in the core of Atlantic water at the western shelf edge of the Norwegian Trench. The measurements are carried out during summer and represent the last winter situation. The average temperature at the plateau is 1–2°C lower than in the core of the inflowing Atlantic water (Figure 8). Also the salinity is slightly lower at the plateau. In both places there was extremely high temperature and salinities in 2004. This is a result of very high salinity in the inflowing Atlantic water and the effect of a mild winter. The relatively cold winters and springs of 2005 and 2006 has lead to quite normal temperatures in the deep layers of the North Sea, while the salinities still are quite high due to high salinities of the inflowing Atlantic water. After a temperature increase in 2007 the temperatures for both locations reduced in 2008 but were still above normal.

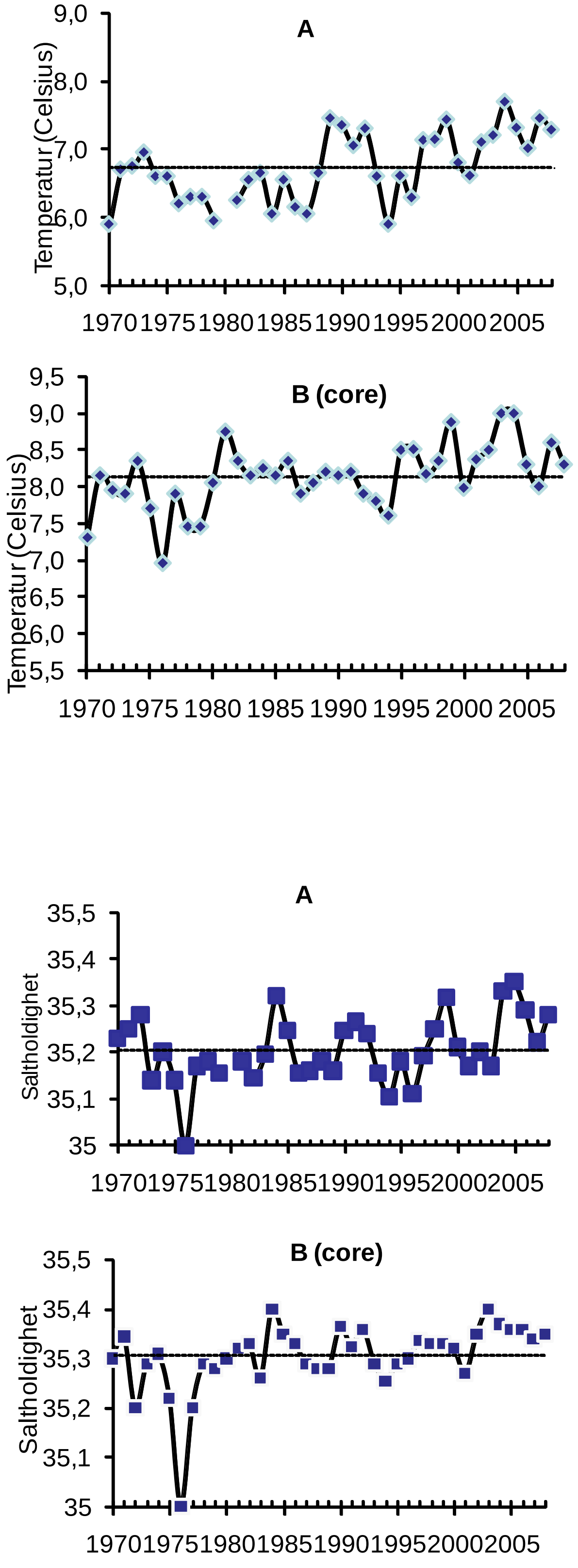

Figure 8. Temperature and salinity near bottom in the north-western part of the North Sea (A) and in the core of Atlantic water (B) at the western shelf edge of the Norwegian Trench during the summers of 1970–2008 (ANON. 2009).

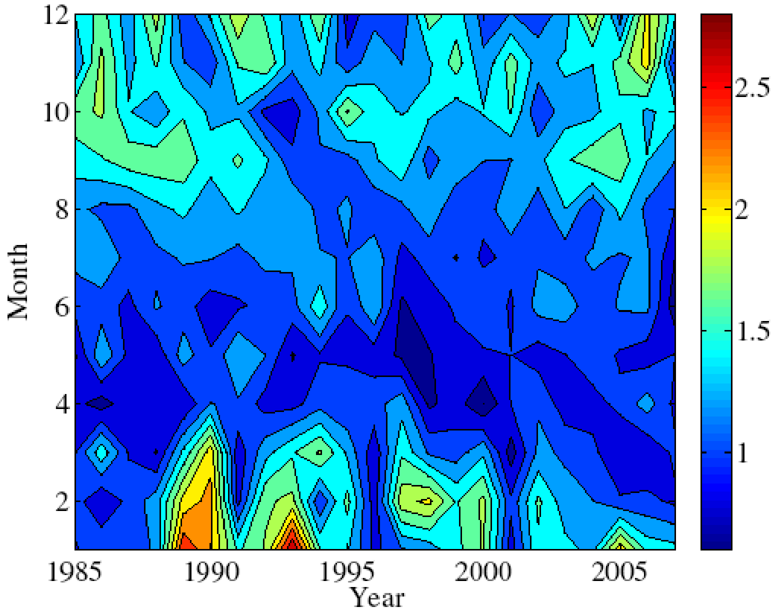

Figure 9. Time-series (1985–2007) of modelled monthly mean volume transport of Atlantic water into the northern and central North Sea southward between the Orkney Islands and Utsira Norway. 1 Sv = $10^6 m^3 s^{-1}$. (ANON. 2007)

Annex 15: Atlantic Domain of the Nordic Seas

Hydrographic conditions in Atlantic Domain of the Nordic Seas (Area 8,10,11) – Summer 2008

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Institute of Oceanology Polish Academy of Sciences, Sopot, Poland

2008 observations

AREX2008 cruise aboard vessel R.V Oceania owned by Institute of Oceanology Polish Academy of Sciences (IOPAS) was performed during period of 08 June 2008 – 23 July 2008. Altogether 199 CTD casts along 11 sections were done (Figure 1). The SBE 9/11 device was used. Currents measurements were done by means of lowered Acoustic Doppler Current Profiler (LADCP). The self-recording 300 kHz RDI device was used to profile entire water column during the standard CTD casts. Continuous currents measurements by the ship-mounted ADCP, RDI 150 kHz were conducted during the whole cruise, as well.

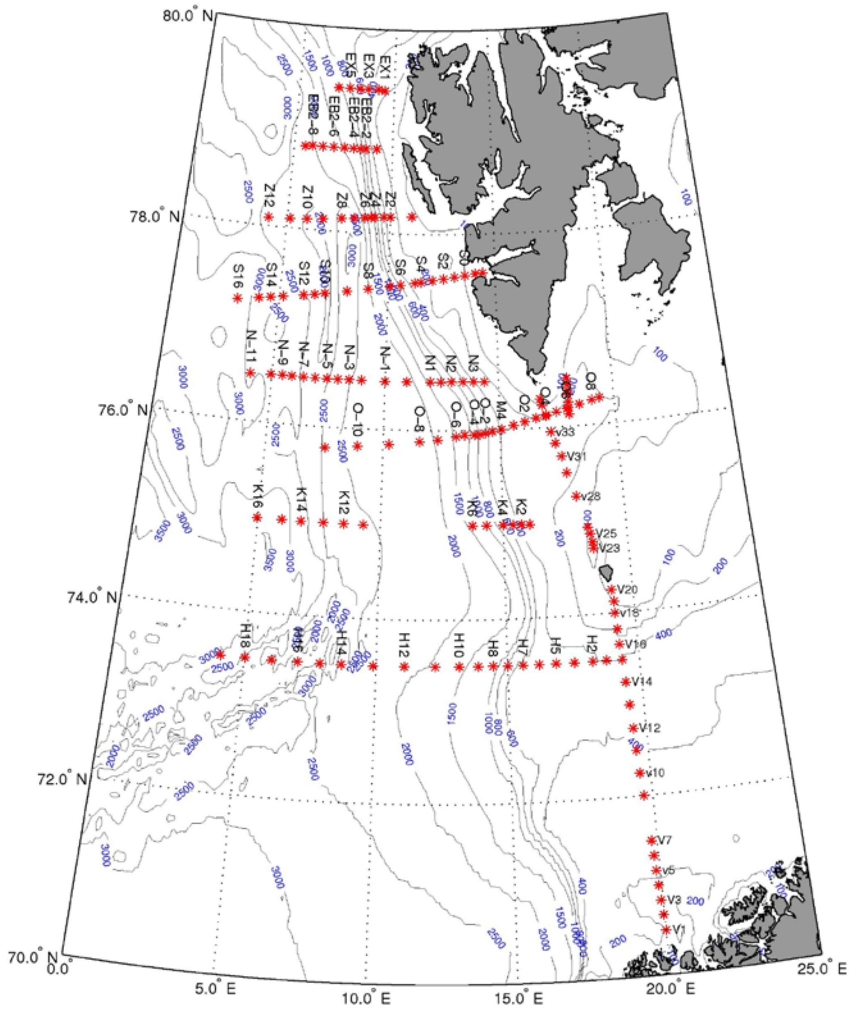


Figure 1. Stations grid performed during R.V 'Oceania' cruise, summer 2008.

Hydrographic conditions

After maximum in 2006, Atlantic Water salinity and temperature has decreased meaningful. At standard section 'N' along the 76°30' latitude, between meridians 009–012°E, mean salinity at 200 dbar has changed from 35.112 in 2007 to 35.075 in summer 2008 (Figure 2a). Mean salinity at this standard section was still higher than 13 years mean (35.053). Changes of temperature were more dramatic. Mean temperature at 200 dbar level has changed from 4.50°C in summer 2006, 3.84°C in summer 2007 to 3.08°C in summer 2008 and was lower than 13 years mean (3.14°C) (Figure 2b). Nevertheless the linear trends of AW temperature and salinity were still positive.

Changes of temperature at standard section 'N' well represents temperature variability of AW layer of entire region.

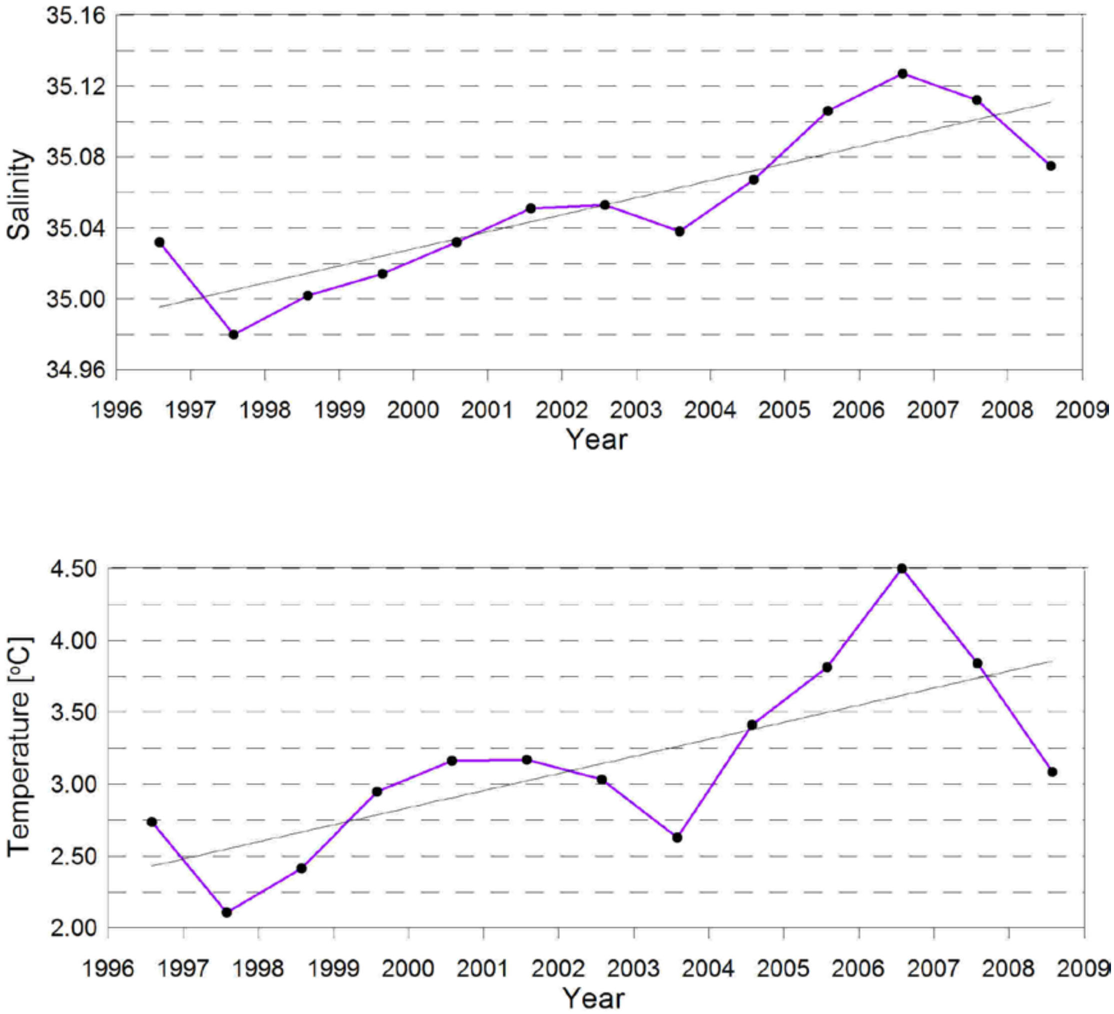


Figure 2. Mean salinity (upper panel) and mean temperature in summer (July) at section 'N' (76°30′ N) at 200 m, between 009°– 012° E. Linear trends are marked.

For a better comparison with other sections, the mean temperature of water layer 50–500 dbar for the same section 'N' (76°30′ N), between 009°–012° E were calculated. The 10 years (summer 1996–2005) mean salinity equals 35.02, salinity 2.70°C.

Deviations from these values are represented in Figure 3.

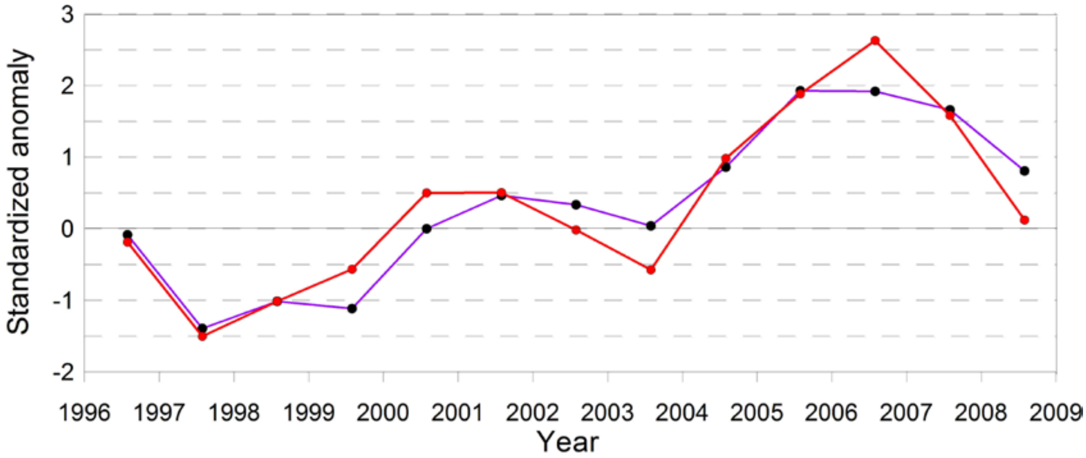


Figure 3. Standardized mean salinity (blue line) and temperature of the 50–500 dbar layer at section 'N' (76°30′ N), between 009°–012° E. Anomalies calculated against the 1996–2005 mean.

Also T-S diagrams show significant changes of water masses properties (Figure 4). Salinity and temperature maximum of Atlantic Water mass (AW) appeared in 2006. The Arctic Atlantic Water was characterized by slightly salinity increasing in 2008, which can be effect of mixing with more saline AW in previous years. Consequence of solarisation is clearly visible in the Warm Surface Water (WSW), especially in 2006. Small changes were noted in the Arctic Intermediate Water (AIW) and the Nordic Sea Deep Water (NDW).

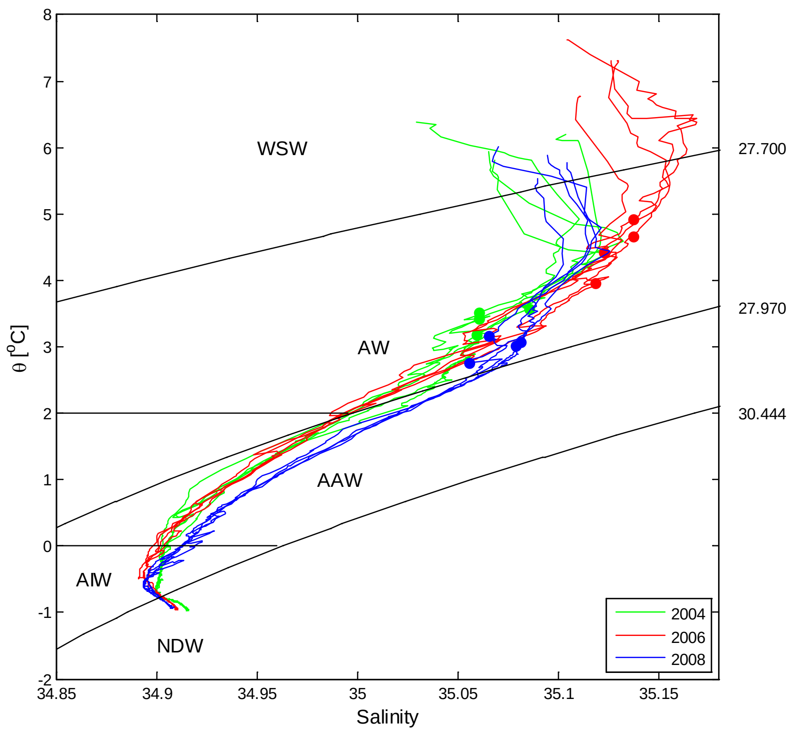
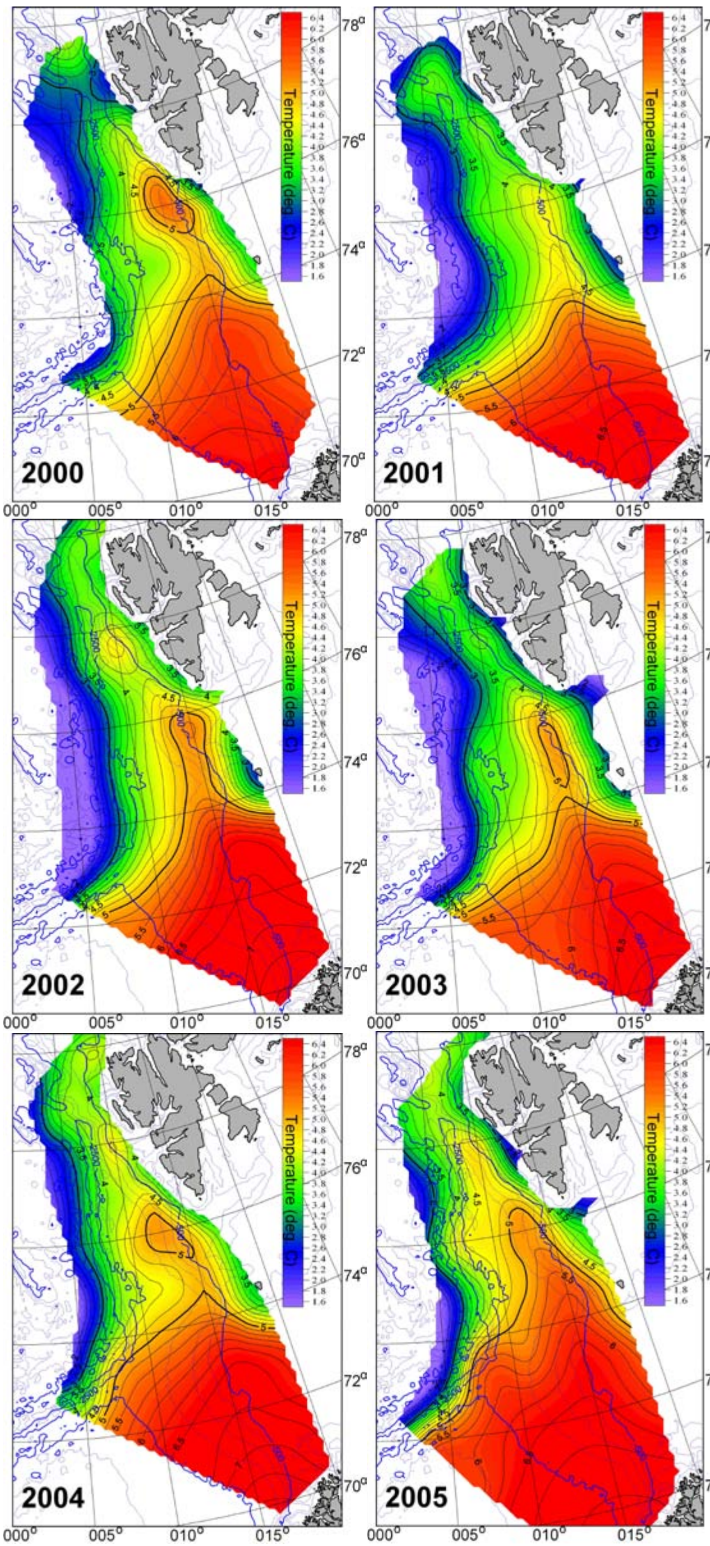


Figure 4. TS diagram for CTD stations performed in 2004 (green lines), 2006 (red lines) and 2008 (blue lines) on the Section 'N' (76°30′ N) between 009°– 012° E. Dots (green-2004, red-2006 and blue-2008) indicate level of 200 dbar.

The northern extension of the 5°C isotherm at 100 dbar (Figure 5) shows cooling of the AW layer in the Greenland Sea as well. After the northernmost extend in 2006, the 5°C isotherm moved back to the south close to the position from summer 2004.



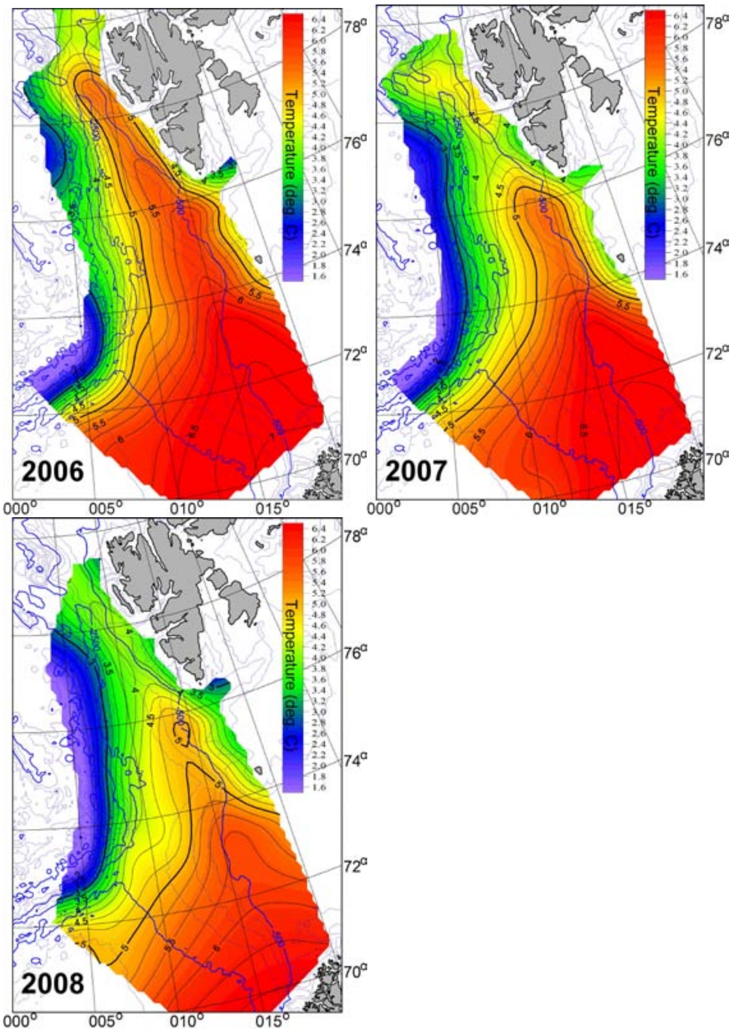


Figure 5. Temperature at 100 dbar in June/July 2000–2008. 5°C isotherm in bold.

Dynamics

Also baroclinic currents and baroclinic currents kinetic energy at 100 dbar (calculated for the reference level of 1000 m.) were lower than in 2006 (Figure 5), and even than in 2007, the level of KE was similar to this from 2004. Two branches of AW in the Greenland Sea were in summer 2008 well visible (Figure 6). Also inflow into the Barents Sea was distinct.

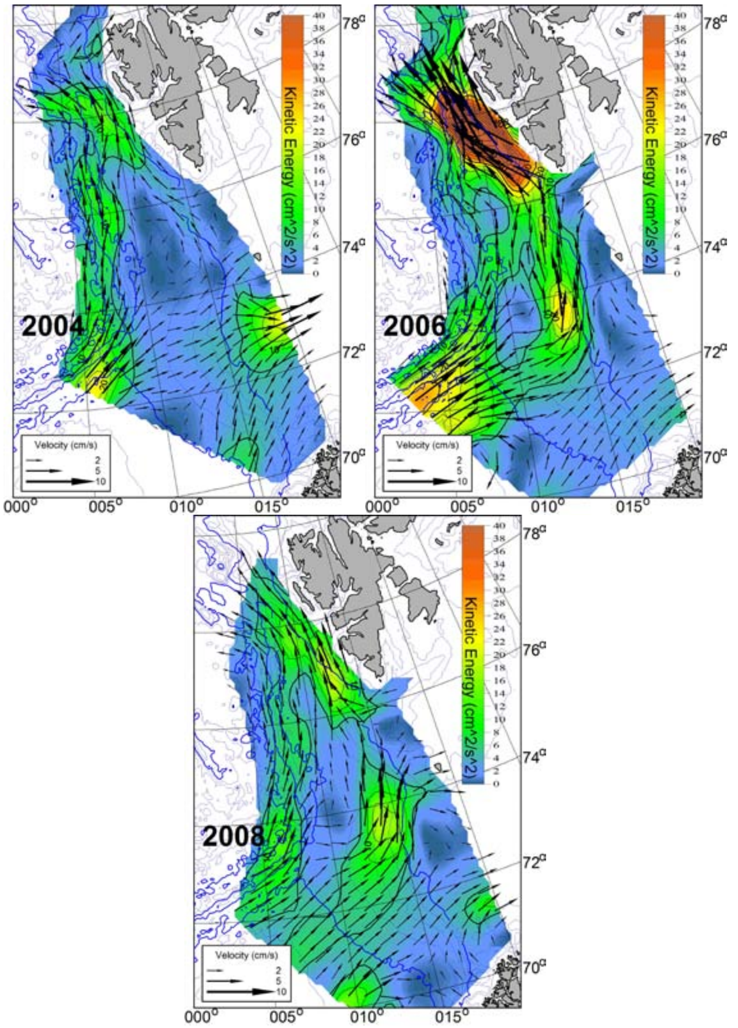
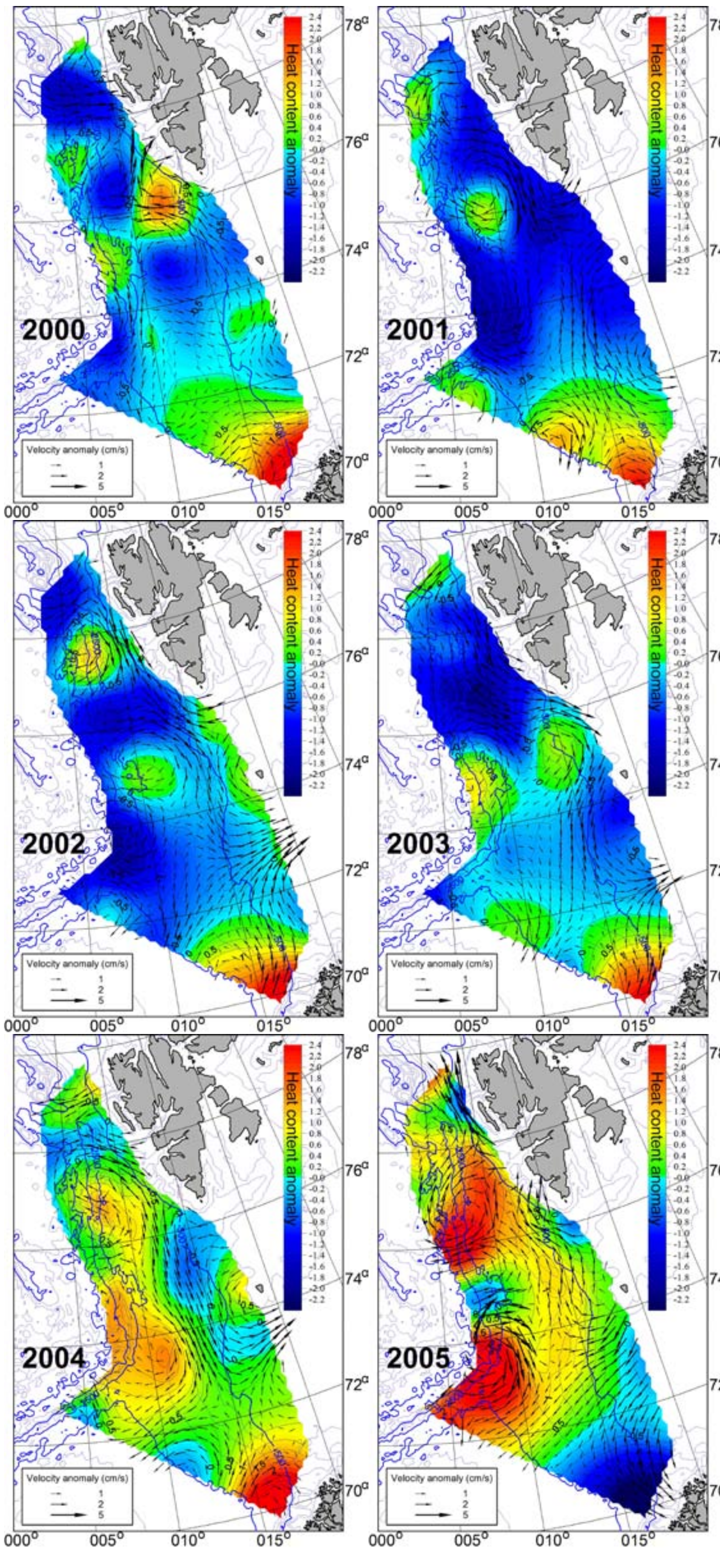


Figure 6. June/July 2004, 2006 and 2008. Baroclinic flow kinetic energy distribution (colour scale), and baroclinic currents at 100 dbar. Reference level 1000 m.

Anomalies of heat content and baroclinic currents present changes of the region dynamics and thermodynamics (Figure 7). Heat content of AW layer was calculated for layer of water with salinity bigger than 34.92 and temperature higher than 0°C. Large heat content anomalies (antycyclonic eddies) were observed in summer 2005 and 2006.


2000
2001
2002
2003
2004
2005
Heat content anomaly
Velocity anomaly (cm/s)
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2
5
78°
76°
74°
72°
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000°
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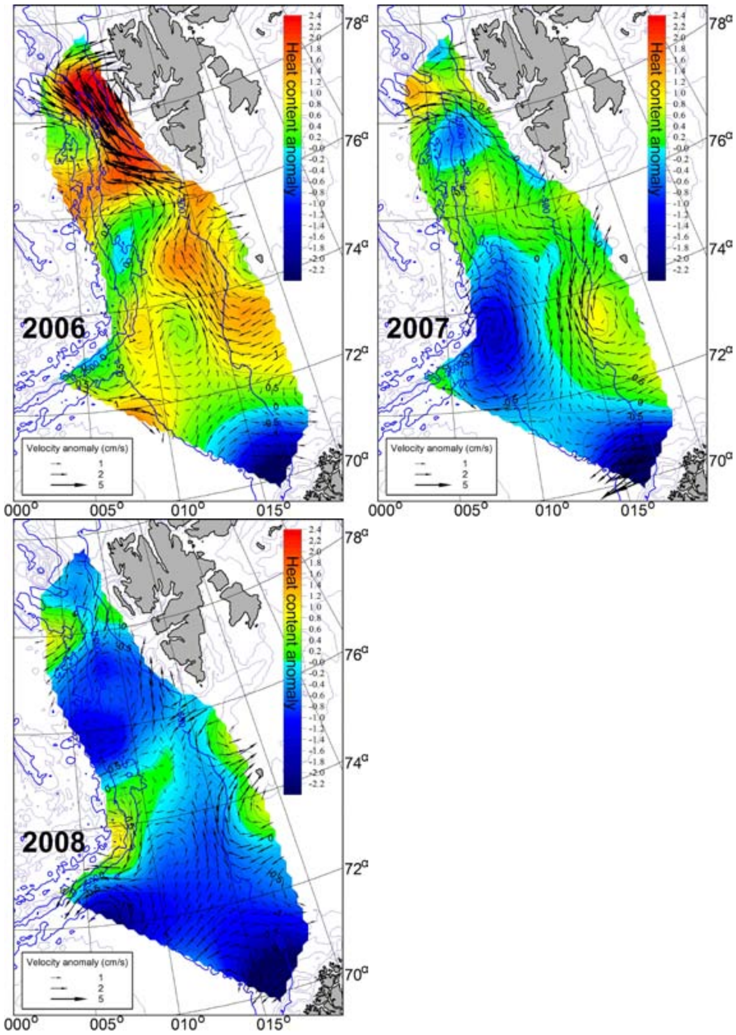

Figure 7. June/July 2000–2008. AW layer heat content anomaly (GJ.m²) – colour scale and baroclinic currents at 100 dbar anomaly. Reference level 1000 m.

Presented data was collected during the EU project cruises ASOF-N and DAMOCLES. For horizontal distributions plots in 2006, 2007 and 2008, data from Gimsoy Section provided by the Institute of Marine Research, Bergen were used.

Annex 16: Russian standard sections in the Barent Sea 2008

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

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 2008 was 1,690 including 276 stations at the standard sections.
Figure 1 presents the main Russian standard sections in the Barents Sea the data from which are discussed further.

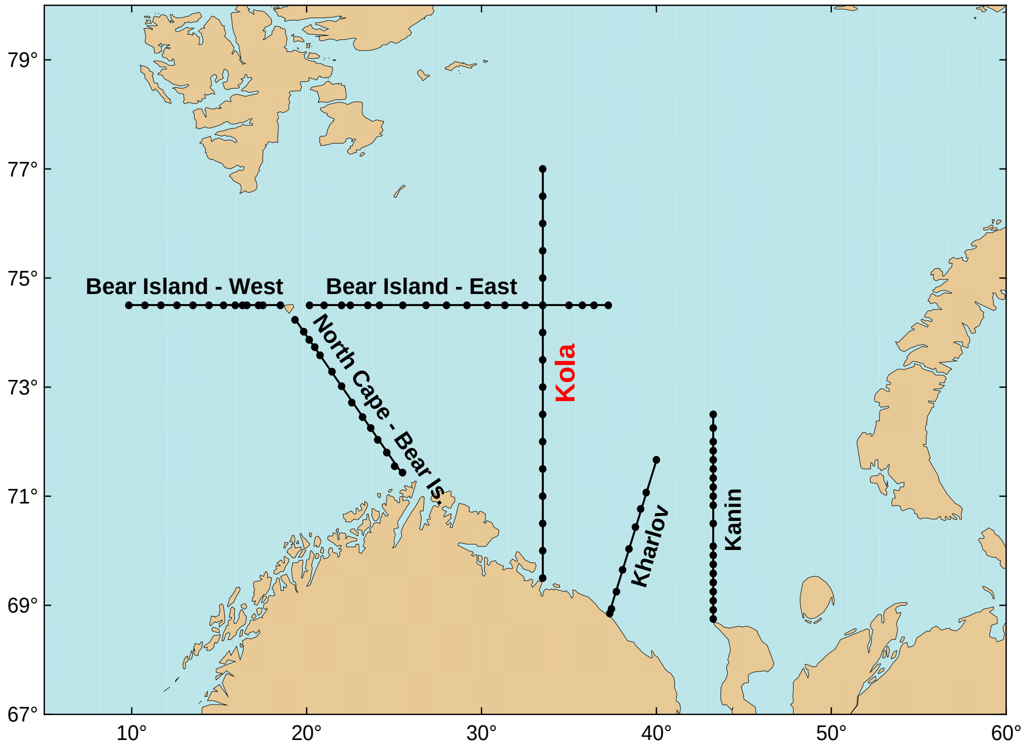

Figure 1. Main Russian standard sections in the Barents Sea.

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 - the Bear Island Section – since 1929, the section Bear Island - West – since 1935, the section Bear Island - East and the Kanin Section – since 1936). The Kola Section has been occupied more than 1,100 times by now.
Published time-series from the main standard sections (Bochkov, 1982; Tereshchenko, 1997, 1999) are also used in this analysis.
The weather over the North Atlantic was determined by cyclonic activity throughout the year, and by an intensification of the Iceland Low during autumn and winter. The distinctive feature of the year of 2008 was an intensification of the Arctic anticyclone during spring and summer, that caused a southward shift of the Island Low. As a result, the usual path of Atlantic cyclones moved southward, and, therefore, northeasterly and easterly winds prevailed over the Norwegian and Barents Seas.

Air temperature data were taken at http://nomad2.ncep.noaa.gov and averaged over the western (70–76°N, 15–35°E) and eastern (69–77ºN, 35–55ºE) parts of the sea. During winter and spring, the air temperature was warmer than normal, with maximum positive anomalies (6.0–7.0 °C) in the eastern Barents Sea in February and March. In April–September, the air temperature was generally close to the long-term means, with prevalence of small negative anomalies (<0.5 °C). In October/November, over most of the sea, the air temperature was, on average, 0.5–1.0 °C higher than normal; and in December, positive anomalies increased to 3.0–4.0 °C.

Sea surface temperature (SST) data were taken at http://iridl.ldeo.columbia.edu and averaged over the Bear Island - Spitsbergen area (74–79ºN, 08–25ºE), central (71–74ºN, 20–40ºE) and south-eastern Barents Sea (69–73ºN, 42–55ºE). The SST shows much of the same variations as the air temperatures. During winter, over most of the Barents Sea, SST was higher than normal, with maximum anomalies of 1.2–1.4 °C in the eastern areas. During spring, positive anomalies of SST decreased to 0.3–0.7 °C in the eastern Barents Sea; whereas negative anomalies of SST (0.2–0.3 °C) dominated in the western sea. During summer and autumn, SST anomalies decreased in most of the Barents Sea; on the whole, SST was near normal, with small (0.2–0.4 °C) negative anomalies. During October–December, positive anomalies of SST were observed in most of the sea; maximum anomalies (up to 1.0 °C) were found in the eastern areas.

Throughout most of the year of 2008, the sea ice extent was less than normal, but more than in 2007 (Figure 2). In comparison with the previous year, the ice coverage (expressed as a percentage of the sea area) was 2–6 % more in January–March and twice as much by June. In May, a polynya started to form south of the Franz Josef Land archipelago and in July the ice massif was finally broken. Come September, the area near Franz Josef Land was ice-free and the main ice massif was in the north-western Barents Sea near the east coast of the Spitsbergen archipelago. Ice formation started in the northernmost sea in October. By the end of the year the ice coverage of the Barents Sea was 5–12 % less than normal and 13–19 % more than in 2007.

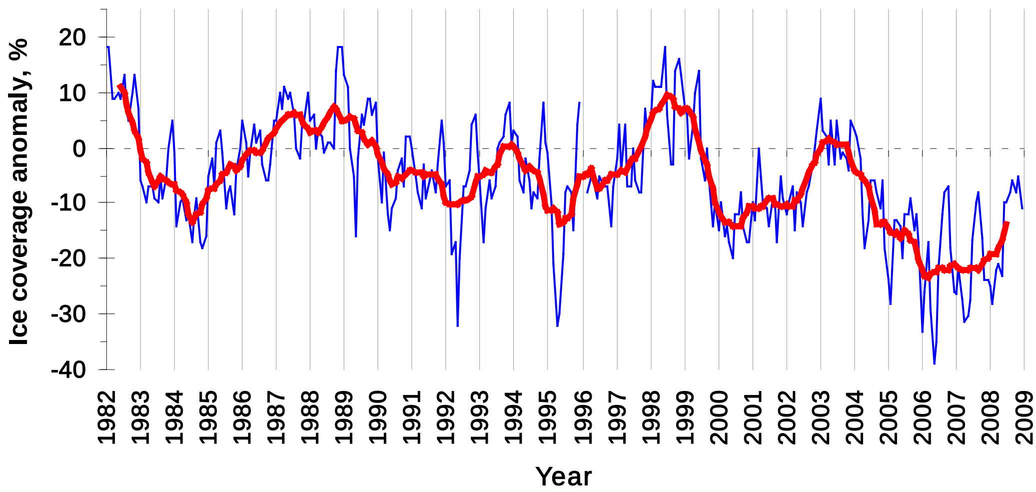

Figure 2. Anomalies of mean monthly ice extent in the Barents Sea in 1982–2008. A blue line shows monthly values, the red one – 11-month moving average values (Anon., 2009).

According to the observations along the Kola Section, which was made 9 times in 2008, sea temperature in the active layer (0–200 m) of the southern Barents Sea was higher than the long-term mean during most of the year (Figure 3). At the beginning of the year, the weaker-than-usual seasonal cooling caused an increase in positive temperature anomalies in the Atlantic Waters compared to December. The temperature anomalies exceeded 1.0 °C through April, and in separate months they were maximum for the period from 1951 to the present. During spring and summer, easterly and north-easterly winds prevailed and the water temperature anomalies were decreasing in most of the surveyed area. In August/September temperature in the Murman Current (St. 3-7) was near normal and the temperature anomalies did not exceeded 0.2 °C (Figure 3). In the coastal waters (St. 1-3), negative temperature anomalies were registered and such cold anomalies have not been observed there in September for the last 10 years. At the end of the year, the weaker-than-usual seasonal cooling of the surface layer caused an increase in the temperature anomalies compared with the second half of September. Compared to the previous year, the water temperature was, on average, 0.3–0.9 °C lower in most of the water column both in the Murman Current and coastal waters (Figure 3).

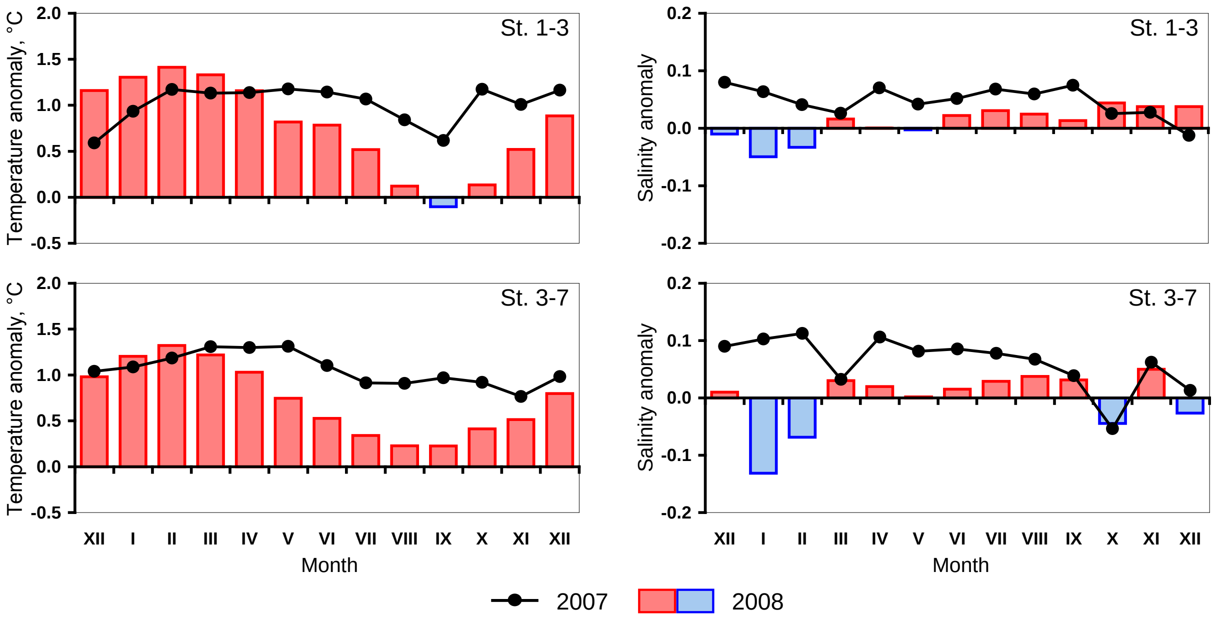

Figure 3. Monthly mean temperature (left) and salinity (right) anomalies in the 0–200 m layer of the Kola Section in 2007 and 2008. St. 1–3 – Coastal waters, St. 3–7 – Murman Current (Anon., 2009).

In the southern Barents Sea in 2008, water salinity was typical for warm years. Negative salinity anomalies were observed during winter; in the second half of the year, some increase in salinity anomalies took place (Figure 3).

On the whole, the annual mean temperature in the 0–200 m layer of the Kola Section was in 2008 typical for anomalous warm years, and lower than in 2007 (Figure 4). Annual mean salinity in the 0–200 m layer of the section was near normal, and also lower than in 2007.

In the North Cape - Bear Island Section, the observations were made in February, April, August and October. Positive anomalies of temperature in the 0–200 m layer of the North Cape Current decreased from 1.3 ºC in February to 0.8 ºC in April and further to 0.4 ºC in August. In October, an increase in positive temperature anomalies (up to 0.6 °C) was observed.

In 2008, the section Bear Island - West (along 74º30′N) was occupied 3 times. Temperature in the 0–200 m layer of the eastern branch of the Norwegian Atlantic Current (74º30′N, 13º30′–15º55′E), was significantly warmer than normal. Positive temperature anomalies decreased from 1.3 °C in March to 0.5 °C in August, and then increased to 1.2 °C in November.

During 2008, the section Bear Island - East (along 74º30′N) was made 4 times. Temperature in the 0–200 m layer of the northern branch of the North Cape Current (74º30′N, 26º50′– 31º20′E), was significantly higher than the long-term average, with the maximum positive anomalies (1.1–1.9 ºC) registered in February, March and April. By October, positive temperature anomalies decreased to 0.5 °C.

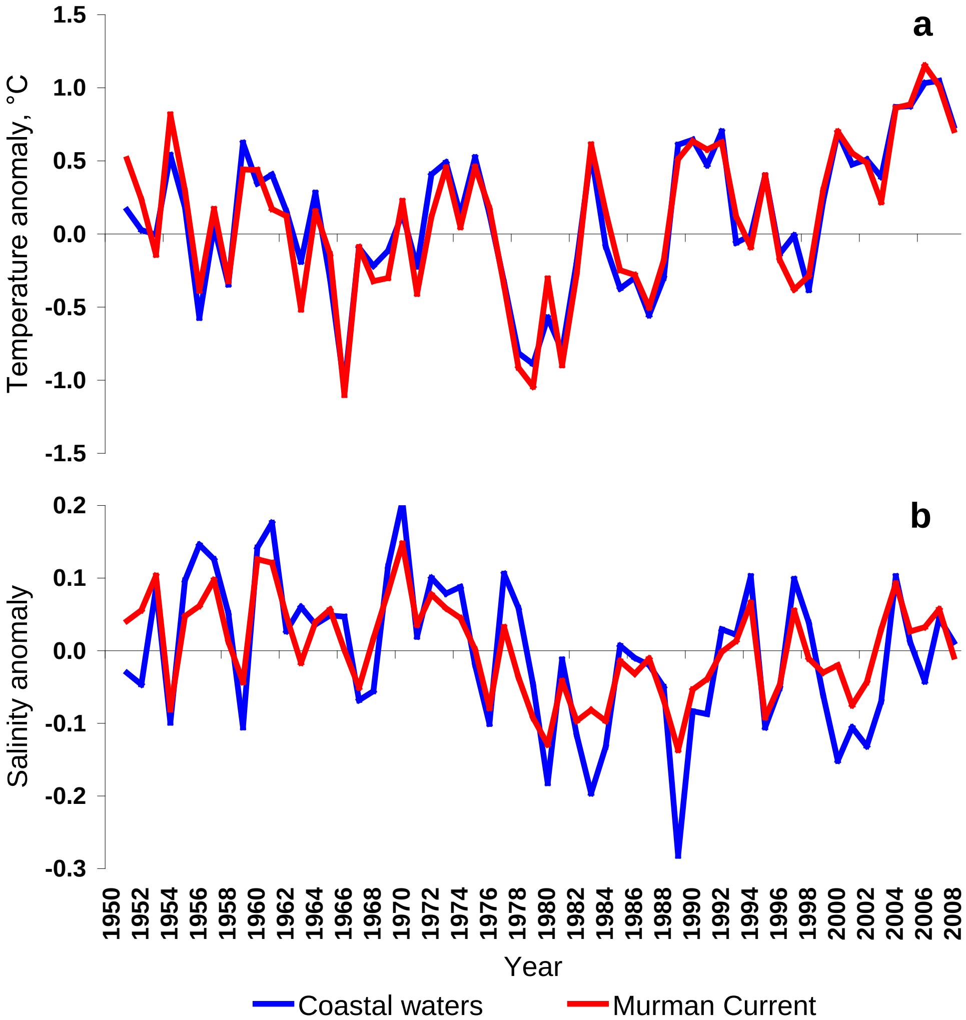

Figure 4. Mean annual temperature (a) and salinity (b) anomalies in the 0–200 m of the Kola Section in 1951–2008. Coastal waters – St. 1-3, Murman Current – St. 3-7 (Anon., 2009).

In the Kanin Section (along 43º15′E) in the eastern Barents Sea, the observations were made in February, May, August and December. In the 0–200 m layer of the Novaya Zemlya Current (71º00′– 71º40′N, 43º15′E), positive temperature anomalies decreased from 2.1 °C in February to 1.1 °C in May, and to 0.8 °C in August. By December, the temperature anomalies increased again to 1.4 °C.

The temperature in the bottom layer in August/September 2008 corresponded to the temperatures of warm and anomalous warm years for most of the Barents Sea, and was close to those of 2007. Positive temperature anomalies were, on average, 0.5–1.5 °C; maximum anomalies (above 1.5 °C) were found in the north-eastern Barents Sea (Figure 5).

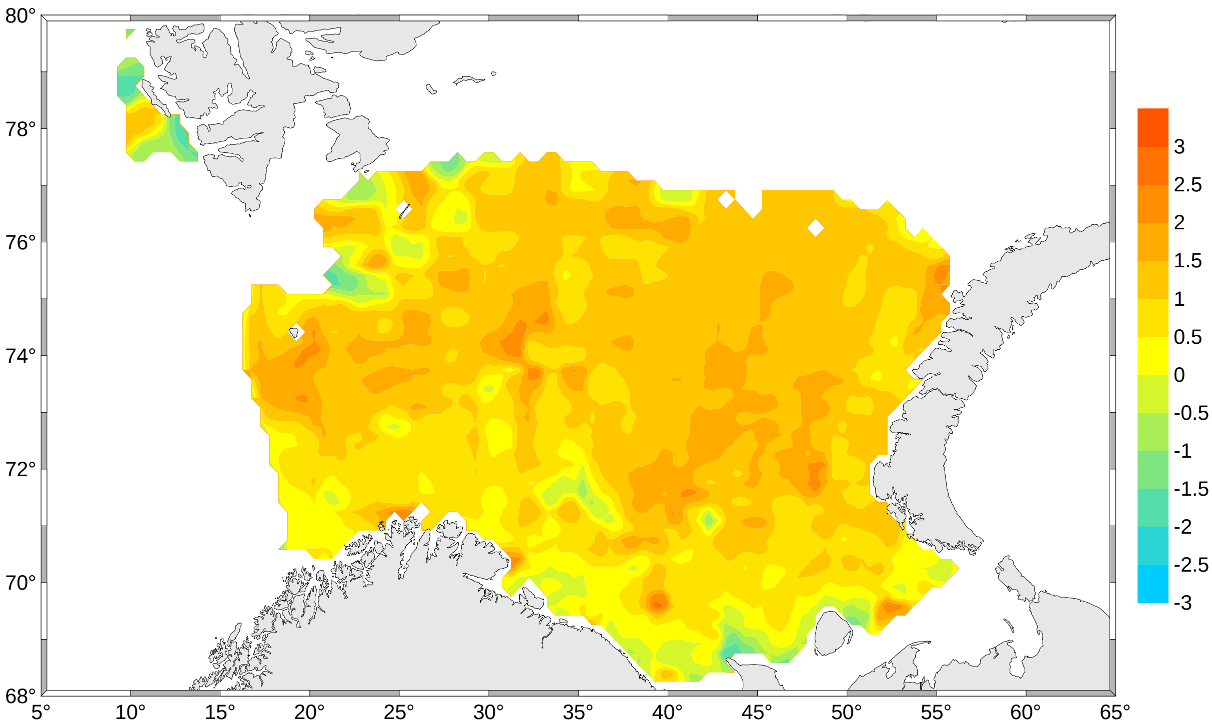

Figure 5. Bottom temperature anomalies in the Barents Sea in August/September 2008 (Anon., 2009).

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