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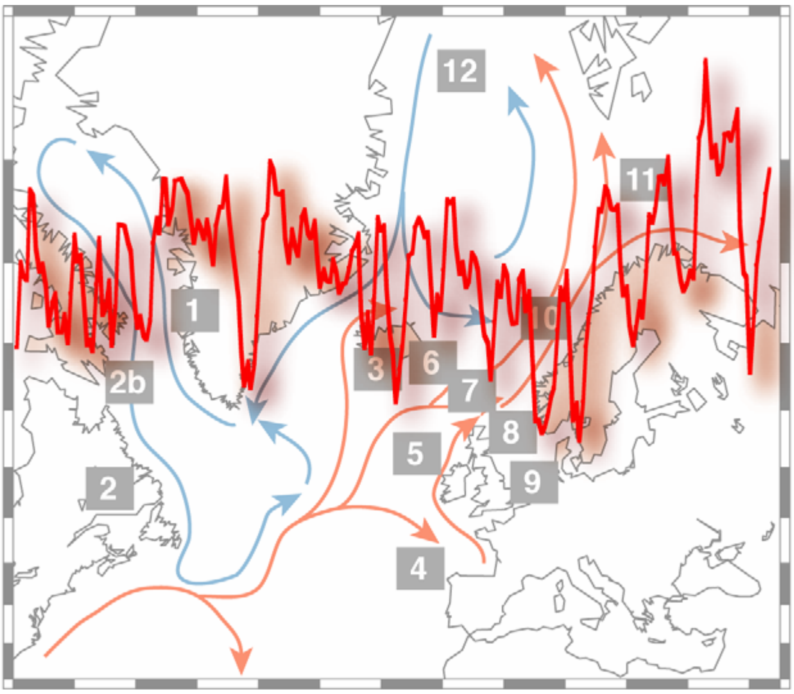

International Council for the Exploration of the Sea

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1 IROC 2005 highlights

The ICES Report on Ocean Climate (IROC 2005) provides a view of environmental conditions in the North Atlantic in 2005 by summarizing results from long-term observations at standard sections and stations. The IROC (formerly known as the ICES Annual Ocean Climate Status Summary) is an annual publication by the ICES Working Group on Oceanic Hydrography.

The North Atlantic Ocean in 2005

The upper layers of the North Atlantic and Nordic Seas were warmer and more saline than the long-term average.

The warm surface anomaly located between the UK and Iceland in 2004 moved into the Norwegian and Barents Seas.

The trend in the last decade (1995–2005) has been of warming and increasing salinity in the upper ocean.

The North Atlantic atmosphere in winter 2004/2005

The North Atlantic Oscillation index during winter 2005 (December 2004–March 2005) was in neutral mode and did not have a strong influence on oceanic variability.

Unusually high pressure developed over the mid-latitude North Atlantic, leading to warmer conditions around the Labrador Sea and cooler conditions in the eastern USA and western Europe.

2 North Atlantic upper ocean temperature overview

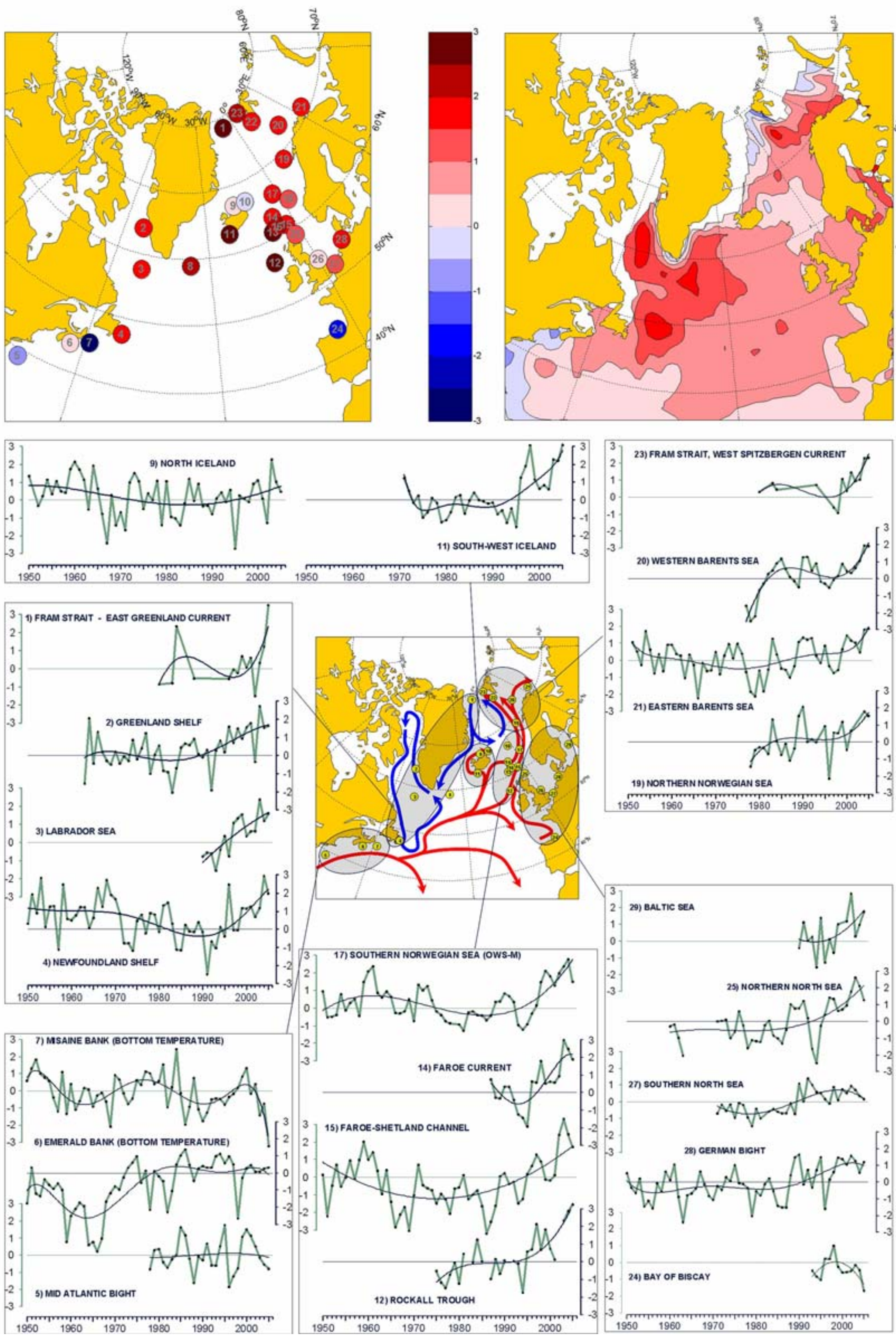


Figure 1: Upper ocean temperature anomalies across the North Atlantic. Temperature data are presented as anomalies from the long-term mean; section and station anomalies are normalised with respect to the standard deviation, e.g. a value of +2 indicates 2 standard deviations above normal (top-left map (see Figure 3 for a legible version) and curves); sea surface temperature data are anomalies in °C (top-right map). The maps show conditions in 2005 (colour intervals 0.5, reds are positive/warm and blues are negative/cool).

3 North Atlantic upper ocean salinity overview

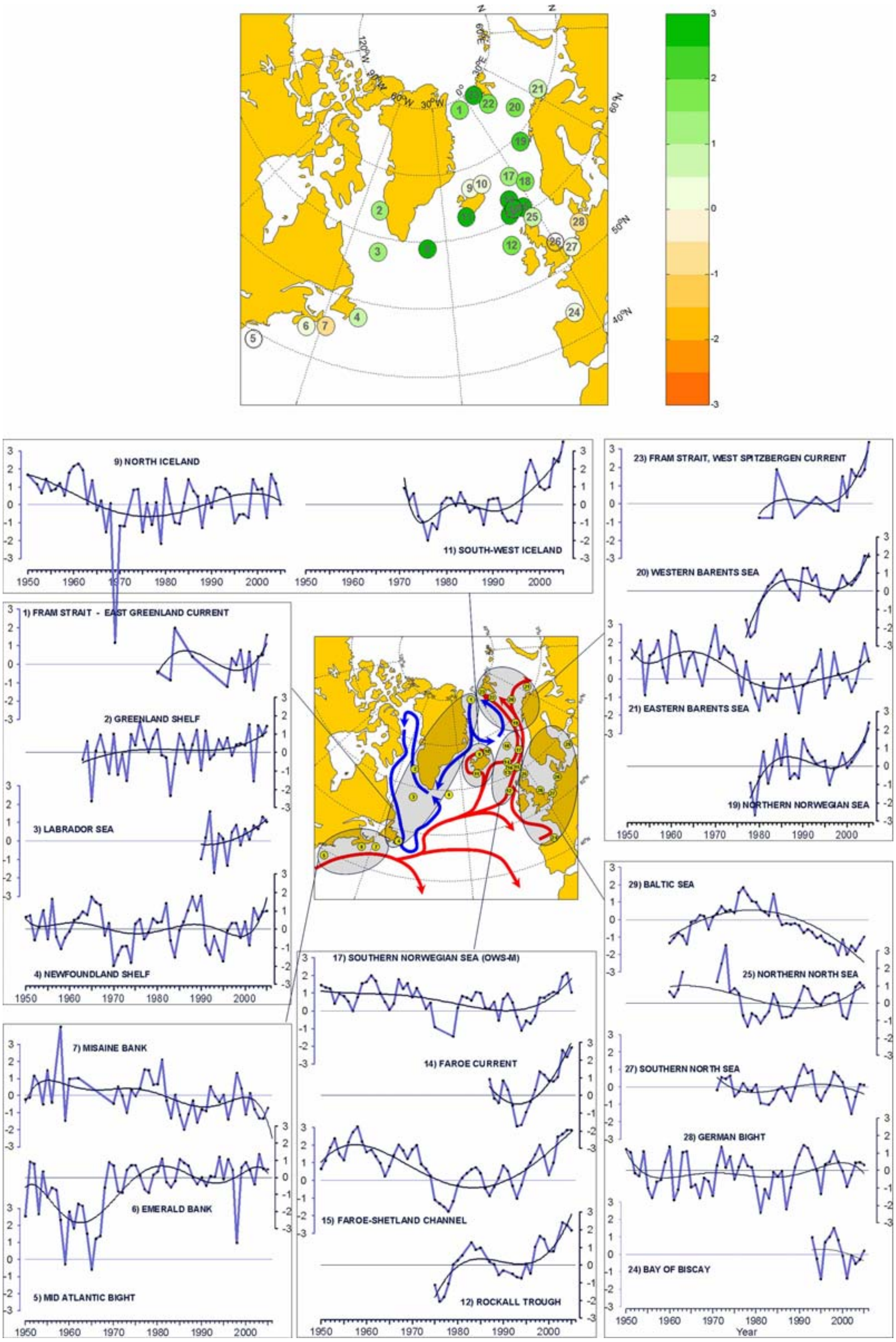


Figure 2: Upper ocean salinity anomalies across the North Atlantic. Salinity data are presented as anomalies from the long-term mean; for consistency, anomalies are normalized with respect to the standard deviation, e.g. a value of +2 indicates 2 standard deviations above normal. The maps show conditions in 2005 (colour intervals of 0.5, greens are positive/saline, orange are negative/fresh); the curves show selected time-series. See Figure 3 for a legible version of the top map.

4 Summary of sustained observations

Ocean climate data from around the North Atlantic are summarized in the present ICES Report on Ocean Climate. Observations in 2005 are compared with the average conditions and with long-term trends in each data set. The key parameters described are seawater temperature and salinity, and less frequently, air temperature.

The data presented have usually been collected as part of a standard oceanographic section, repeated annually or more frequently. The time-series have been extracted from larger data sets as indicators of the conditions in a particular area.

Where appropriate, data in this report are presented as anomalies to show how the values compare with the average or "normal" conditions (usually the long-term average of each parameter during the period 1971–2000). For data sets that do not extend as far back as 1971, the average conditions have been calculated from the start of the data set up to 2000.

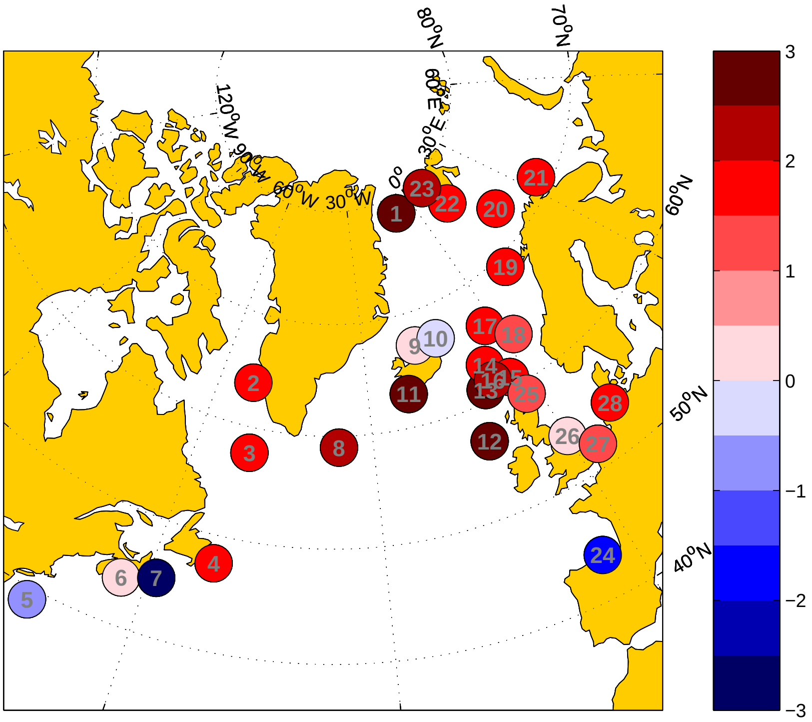
In places, the seasonal cycle has been removed from a data set, either by calculating the average seasonal cycle during the period 1971–2000 or drawing on other sources such as regional climatological data sets. Smoothed versions of most time-series are included, using a Loess smoother, a locally weighted regression with a two- or five-year window.

In the summary tables and figures, normalized anomalies have been presented to allow intercomparison of trends in the data from different regions (Figures 1–3 and Table 1). The anomalies have been normalized by dividing the values by the standard deviation of the data during the period 1971–2000. A value of +2 thus represents data (temperature or salinity) at 2 standard deviations higher than normal.

Sea surface temperature (SST) across the whole North Atlantic can also be obtained from a combined satellite and *in situ* gridded data set. Figure 4 shows the annual and seasonal SST anomaly for 2005 extracted from the Optimum Interpolation SSTv2 data set, provided by the NOAA-CIRES Climate Diagnostics Center in the USA. In high latitudes where *in situ* data are sparse and satellite data are hindered by cloud cover, the data may be less reliable. Regions with ice cover for >50% of averaging period are left blank.

The annual pattern of SST anomaly for 2005 matches very closely that from the *in situ* data. There is a large band of positive anomalies stretching across both sides of the North Atlantic Ocean.

Temperature



Salinity

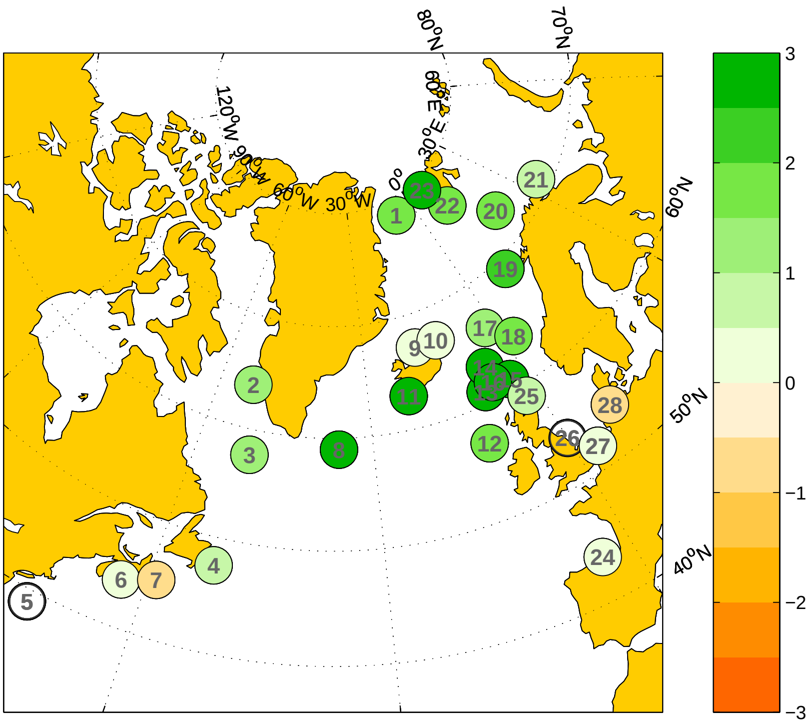


Figure 3: Annual anomalies in 2005 of temperature (upper panel) and salinity (lower panel) over the North Atlantic region. The index number can be used to cross reference each point with information in Tables 1 and 2. Unless specified (in Table 2), these are upper layer anomalies. The anomalies are normalized with respect to the standard deviation, e.g. a value of +2 indicates that the data (temperature or salinity) for that year was 2 standard deviations above normal. Open circles indicate that no data were available for 2005 at the time of publication.

Table 1: Changes in temperature (upper panel) and salinity (lower panel) at selected stations in the North Atlantic region during the past decade. The index number can be used to cross reference each point with information in Figures 1–3 and Table 2. Unless specified, these are upper layer anomalies. The anomalies are normalized with respect to the standard deviation, e.g. a value of +2 indicates that the data (temperature or salinity) for that year was 2 standard deviations above normal. Blank boxes indicate that no data were available for that particular year at the time of publication. Note that no salinity data at all were available for regions 5, 6, 7, and 26.

Temperature

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
1	0.56	0.05	0.25	0.68	0.06	0.60	1.32	0.32	1.22	3.50
2	1.59	0.70	1.49	0.94	1.55	1.78	0.36	2.72	1.52	1.63
3	0.76	1.07	1.33	1.55	0.34	0.61	0.63	2.37	1.18	1.61
4	2.47	0.04	0.04	1.18	1.15	1.25	0.68	1.18	2.94	1.97
5	1.84	1.23	0.76	1.08	1.51	1.14	0.52	0.13	0.54	0.79
6	0.98	0.51	[illegible]	0.28	0.28	0.47	0.07	0.07	0.27	0.33
7	0.35	0.17	0.19	0.84	1.33	0.16	0.40	1.43	0.74	[illegible]
8	0.29	0.39		1.96	0.37	1.78	1.41	1.59	2.95	2.26
9	0.26	0.07	0.12	0.91	1.10	0.08	1.28	2.27	1.01	0.47
10	0.46	1.13	0.47	0.12	0.61	0.68	1.44	2.14	0.55	0.22
11	1.25	1.90	3.07	1.14	0.63	0.84	0.59	2.26	2.20	3.08
12	0.71	2.14	0.70	1.83	0.74	0.14		2.34	2.88	3.24
13	0.45	0.76	2.26	0.13	0.62	1.55	1.62	4.99	4.41	2.77
14	0.64	0.57	1.80	0.51	0.62	0.57	0.94	3.00	2.48	1.90
15	0.64	1.28	0.90	0.11	0.17	0.13	2.41	3.31	2.44	1.72
16	0.09	0.28	0.82	0.87	1.21	1.69	3.21	4.35	3.40	2.14
17	0.31	0.15	1.48	2.12	1.81	1.27	1.98	2.37	2.77	1.50
18	1.11	1.47	1.21	0.23	1.32	0.41	2.92	1.95	2.19	1.26
19	2.16	0.55	0.51	1.18	0.46	0.65			1.80	1.53
20	0.54	0.06	0.16	0.88	0.45	0.33	0.64	1.05	1.95	1.92
21	0.34	0.75	0.57	0.65	1.47	1.16	1.04	0.48	1.80	1.86
22	0.32	0.03	0.17	0.31	0.04	0.54	0.10		0.78	1.55
23		0.60	0.93	1.07	0.34	1.45	0.95	1.03	2.29	2.31
24	0.22	0.21	0.99	0.26	0.59	0.57	0.50	0.15	0.46	1.69
25	0.40	1.42	1.34	0.62	0.72	0.96	1.78	2.61	2.13	1.28
26	0.75	0.57	0.19	0.74	0.60	0.49	0.69	0.84	0.68	0.17
27	0.16	0.11	0.90	0.10	0.74	0.54	0.95	0.70	0.34	0.17
28	1.60	0.16	0.61	1.47	1.38	1.06	1.57	1.27	0.57	1.20
29	1.28	0.13	0.68	1.01		1.20	2.84	0.29	0.98	1.76

Salinity

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
1	1.22	0.33	0.04	0.78	0.94	0.69	1.40	0.42	0.51	1.60
2	0.81	0.16	0.44	0.49	0.41	1.53	1.55	1.47	0.93	1.44
3	1.35	0.48	0.85	0.22	0.65	0.09	0.83	0.66	1.31	1.04
4	0.08	0.33	0.33	0.45	0.41	0.87	1.15	0.54	0.95	0.99
5										
6	1.05	0.44	3.83	0.59	0.87	0.41	0.41	1.37	0.50	0.48
7	1.38	0.28	1.33	0.42	1.12	0.14	0.80	1.33	1.34	0.73
8	1.14	0.57		2.09	0.12	0.97	2.23	0.73	2.73	2.55
9	0.55	0.52	0.72	1.42	0.84	0.91	0.73	1.71	1.21	0.02
10	0.72	1.43	2.24	0.33	1.00	0.57	0.20	0.48	0.59	0.30
11	0.36	1.80	2.50	1.82	1.00	0.84	0.98	2.57	2.40	3.50
12	0.45	1.04	1.65	1.46	0.77	0.79		2.42	2.26	1.97
13	0.97	0.05	1.62	0.89	1.03	0.78	0.84	3.17	3.48	2.81
14	0.36	0.33	1.36	1.18	0.86	0.80	1.05	2.57	2.19	2.73
15	1.01	1.46	2.01	1.38	0.31	1.01	2.46	2.63	2.86	2.84
16	0.43	0.52	1.35	1.63	1.56	1.83	2.62	3.18	2.89	2.71
17	0.72	0.29	0.74	0.73	0.91	1.07	1.02	1.92	2.13	1.04
18	0.78	0.83	1.19	0.33	0.77	0.35	1.37	1.71	1.91	1.97
19	1.01	0.16	0.03	0.72	0.09	0.23			1.34	2.39
20	0.54	0.06	0.16	0.87	0.44	0.33	0.63	1.05	1.95	1.91
21	0.38	1.45	0.28	0.05	0.12	0.72	0.22	0.95	1.95	0.95
22	0.70	0.49	0.63	0.16	0.17	0.55	0.25		0.95	1.80
23		0.38	0.38	1.51	0.38	1.89	1.51	1.51	1.89	3.40
24	0.70	1.01	1.51	0.82	0.09	1.39	0.05	0.54	0.29	0.21
25	0.36	0.45	0.61	0.53	0.71	0.88	0.09	0.95	1.20	0.89
26										
27	0.30	0.12	0.86	0.63	0.28	0.59	1.52	0.56	0.16	0.12
28	0.37	0.52	1.12	0.52	0.03	0.91	0.25	0.46	0.47	0.32
29	1.25	1.37	1.45	2.03	1.12	1.99	1.50	1.78	1.40	0.97

Table 2: Details of the data sets included in Figures 1–3 and Table 1. Blank boxes indicate areas where information was unavailable at the time of publication.

Index	Description	Measurement Depth	Long-term Average	Latitude	Longitude	Mean T	Sdev T	Mean S	Sdev S
1	Fram Strait – East Greenland Current – Section Average 3°W to Shelf edge	50–500 m	1980–2000	78.50	−8.00	0.58	0.39	34.67	0.11
2	Station 4 – Fylla Section – Greenland Shelf	0–200 m	1971–2000	63.88	−53.37	2.70	0.99	33.51	0.33
3	Section AR7 – Central Labrador Sea	0–150 m	1990–2000	57.73	−51.07	3.57	0.43	34.67	0.08
4	Station 27 – Newfoundland Shelf Temperature – Canada	0–175 m	1971–2000	47.55	−52.59		0.28		0.24
5	Oleander Section (120–400 km) – Mid-Atlantic Bight USA	Surface	1978–2000	39.00	−71.50		0.91		
6	Emerald Bank – Central Scotian Shelf – Canada	250 m	1971–2000	44.00	−63.00	9.16	0.83		0.14
7	Misaine Bank – Northeast Scotian Shelf – Canada	100 m	1971–2000	45.00	−59.00	1.57	0.67		0.14
8	Central Irminger Sea Sub-Polar Mode Water	200–400 m	1991–2005	59.00	−36.00	3.99	0.38	34.88	0.02
9	Siglunes Station 2–4 – North Iceland – Irminger Current	50–150 m	1971–2000	67.00	−18.00	3.34	1.01	34.82	0.12
10	Longanes Station 2–6 – Northeast Iceland – East Icelandic Current	0–50 m	1971–2000	67.00	−13.00	1.24	0.69	34.70	0.08
11	Selvogsbanki Station 5 – Southwest Iceland – Irminger Current	0–200 m	1971–2000	63.00	−22.00	7.58	0.39	35.15	0.04
12	Ellet Line – Rockall Trough – UK (Section Average)	0–800 m	1975–2000	56.75	−11.00	9.21	0.22	35.33	0.03
13	Faroe Bank Channel – South Faroe Islands	Upper Layer HSC*	1988–2000	61.00	−8.00	8.23	0.18	35.24	0.03
14	Faroe Current – North Faroe Islands (Modified North Atlantic Water)	Upper Layer HSC*	1988–2000	63.00	−6.00	7.92	0.29	35.22	0.03
15	Faroe Shetland Channel – Shetland Shelf (North Atlantic Water)	Upper Layer HSC*	1971–2000	61.00	−3.00	9.61	0.17	35.36	0.03
16	Faroe Shetland Channel – Faroe Shelf (Modified North Atlantic Water)	Upper Layer HSC*	1971–2000	61.50	−6.00	7.85	0.25	35.21	0.04
17	Ocean Weather Station Mike – 50 m	50 m	1971–2000	66.00	−2.00	7.41	0.31	35.15	0.04
18	Southern Norwegian Sea – Svinøy Section – Atlantic Water	50–200 m	1978–2000	64.00	2.00	8.07	0.40	35.23	0.05
19	Central Norwegian Sea – Gimsøy Section – Atlantic Water	50–200 m	1978–2000	69.00	10.00	6.66	0.37	35.15	0.03
20	Fugløya – Bear Island Section – Western Barents Sea – Atlantic Inflow	50–200 m	1977–2000	73.00	20.00	−0.01	0.04	35.05	0.04
21	Kola Section – Eastern Barents Sea	0–200 m	1971–2000	71.30	33.30	3.92	0.49	34.76	0.06
22	Northern Norwegian Sea – Sørkapp Section – Atlantic Water	50–200 m	1978–2000	76.50	11.00	3.84	0.68	35.06	0.04
23	Fram Strait	50–500 m	1980–2000	79.00	8.00	2.60	0.58	34.99	0.03
24	Santander Station 6 (shelf break) – Bay of Biscay – Spain	5–300 m	1993–2000	43.70	−3.78	12.78	0.26	35.59	0.06

Index	Description	Measure-ment Depth	Long-term Average	Latitude	Longitude	Mean T	Sdev T	Mean S	Sdev S
25	Fair Isle Current Water (waters entering North Sea from Atlantic)	0–100 m	1971–2000	59.00	−2.00	9.84	0.38	34.90	0.11
26	UK Coastal Waters – Southern Bight – North Sea	0–100 m	1971–2000	54.00	0.00				
27	Section Average – Felixstowe – Rotterdam –52°N	Surface	1971–2000	52.00	3.00	12.14	1.12	34.64	0.21
28	Helogoland Roads – Coastal Waters – German Bight North Sea	Surface	1971–2000	54.19	7.90	9.94	0.68	32.11	0.56
29	Baltic Proper – East of Gotland – Baltic Sea	Surface	1971–2000 **	57.50	19.50	8.57	0.86	7.35	0.24

***HSC – High Salinity Core**

****1990–2000 for temperature data**

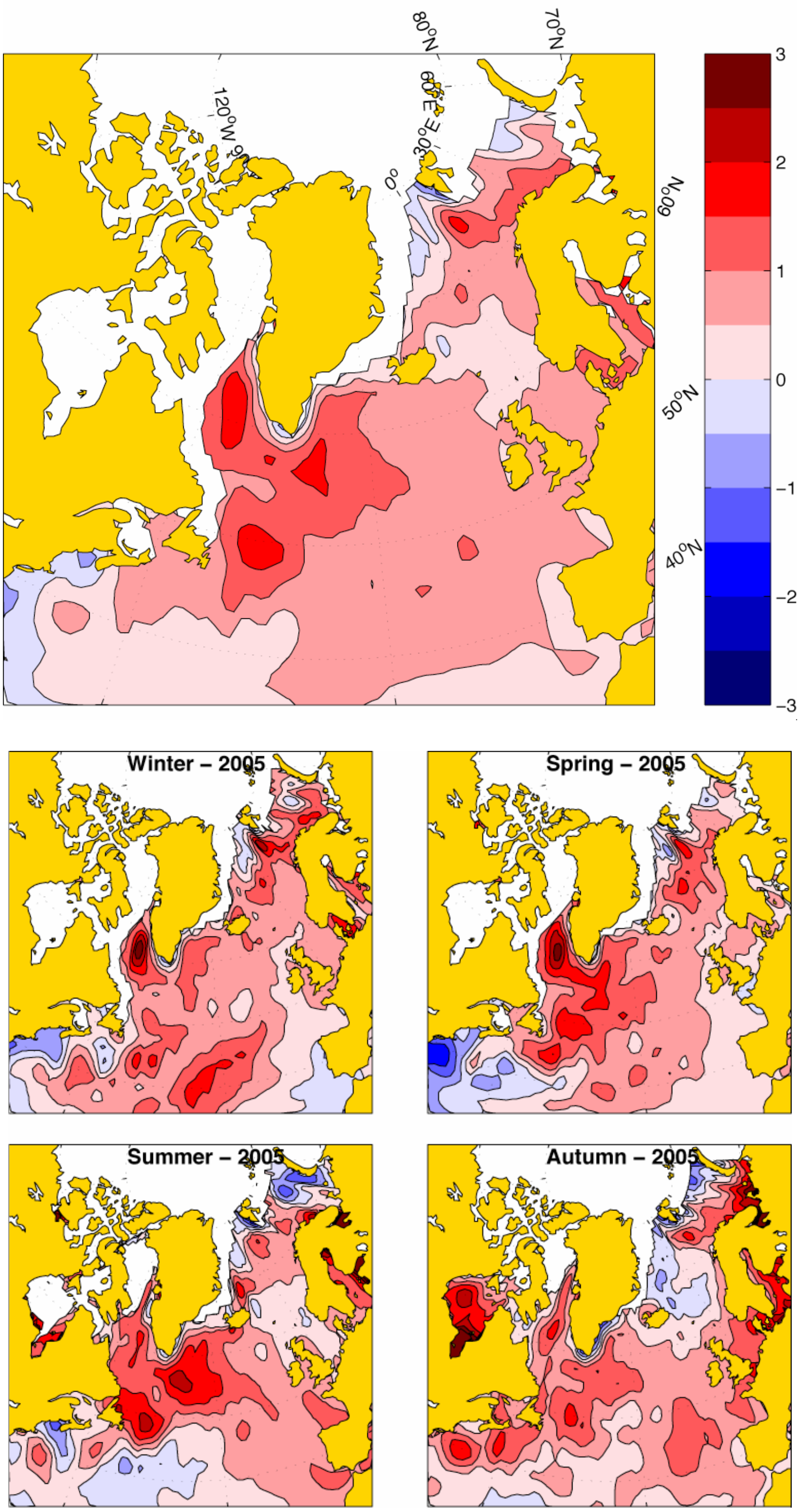


Figure 4: Map of annual (upper panel) and seasonal (lower panel) sea surface temperature anomalies (°C) over the North Atlantic for 2005 from the NOAA Optimum Interpolation SSTv2 data set, provided by the NOAA-CIRES Climate Diagnostics Center, USA. The colour-coded temperature scale is the same in all panels. The anomaly is calculated with respect to normal conditions for the period 1971–2000. The data are produced on a one-degree grid from a combination of satellite and *in situ* temperature data. Regions with ice cover for >50% of averaging period are left blank.

5 The North Atlantic atmosphere

5.1 North Atlantic Oscillation index

The North Atlantic Oscillation index (NAO) is a measure of the difference in normalized sea level pressure between Iceland and the subtropical eastern North Atlantic. When the NAO index is positive there is a strengthening of the Icelandic low and Azores high. This strengthening results in an increased north–south pressure gradient over the North Atlantic, causing colder and drier conditions over the western North Atlantic and warmer and wetter conditions in the eastern North Atlantic. During a negative NAO, a weakening of the Icelandic low and Azores high decreases the pressure gradient across the North Atlantic and tends to reverse these effects.

The NAO index can be useful to describe the climate of the North Atlantic region. In this report, all references to the NAO relate to the extended winter index calculated from sea level pressure data over the winter months. For example, the NAO index for 2005 was calculated from sea level pressure anomalies between December 2004 and March 2005.

Two slightly different versions of the NAO index are referenced here. The Rogers Index is more closely correlated with conditions in the western North Atlantic, while the Hurrell index is more closely correlated with conditions in the eastern North Atlantic. The NAO index is limited in that it can only describe the strength of the north–south dipole in sea level pressure (SLP) anomaly. Although this has been the predominant pattern during the past 30 years, it is not always the case.

Following a long period of increase from an extreme and persistent negative phase in the 1960s to a most extreme and persistent positive phase during the late 1980s and early 1990s, the Hurrell NAO index underwent a large and rapid decrease during the winter preceding 1996. Since 1996, the Hurrell NAO index has been fairly weak, but mainly positive (0.12 in 2005). The Rogers NAO index has followed a similar pattern, with a strong negative phase in the 1960s, becoming more positive in the 1980s and 1990s. It remained mainly negative from 1996 to 2004, but became positive in 2005 (6.7 mbar).

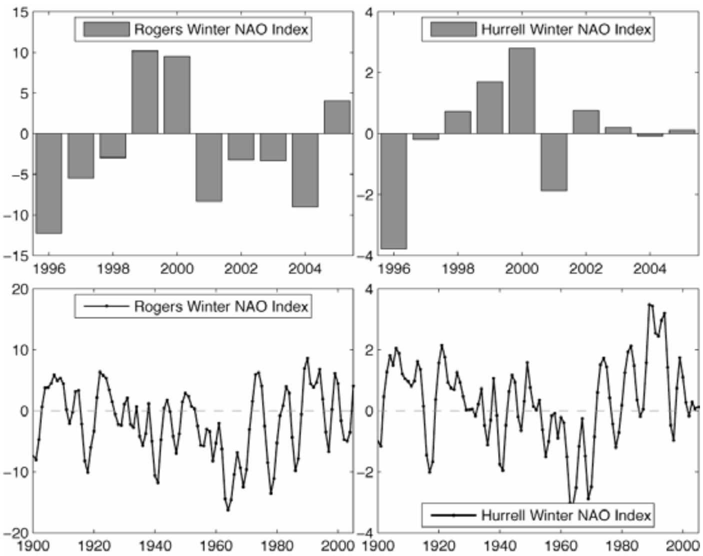


Figure 5: The two winter NAO indices in terms of the current decade (upper panel) and the past 100 years (lower panel: a two-year running mean has been applied).

5.2 North Atlantic sea level pressure

The NAO index is an indicator of the sea level pressure but does not fully describe the effect on windfields. Patterns of sea level pressure anomaly from the long-term mean can provide extra information. Just as winds tend to follow isobars, so wind anomalies follow contours; a positive sea level pressure anomaly produces an anticyclonic anomaly in the windfield.

Between December 2004 and March 2005, a positive sea level pressure anomaly over the mid-latitude North Atlantic lead to weaker westerlies, but increased northerly winds over the eastern region. The result was warmer conditions around the Labrador Sea and cooler conditions in eastern USA and Western Europe.

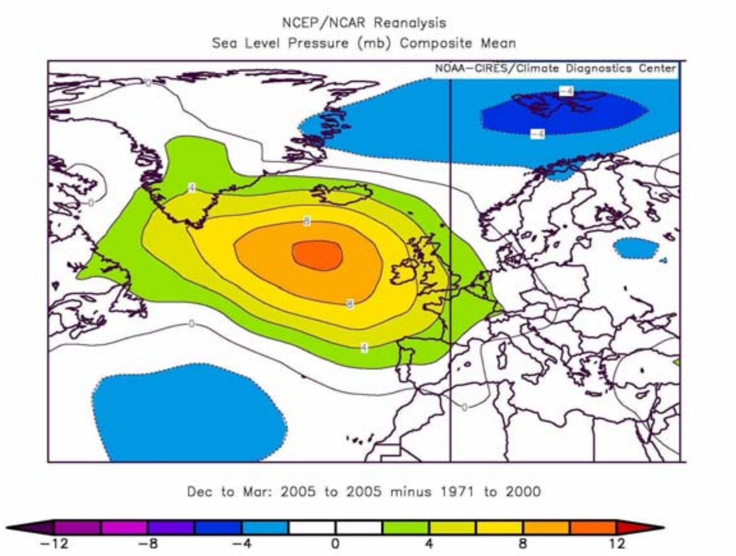


Figure 6: Sea level pressure anomaly between December 2004 and March 2005. (NCEP/NCAR Reanalysis data from NOAA-CIRES Climate Diagnostics Center: www.cdc.noaa.gov/Composites).

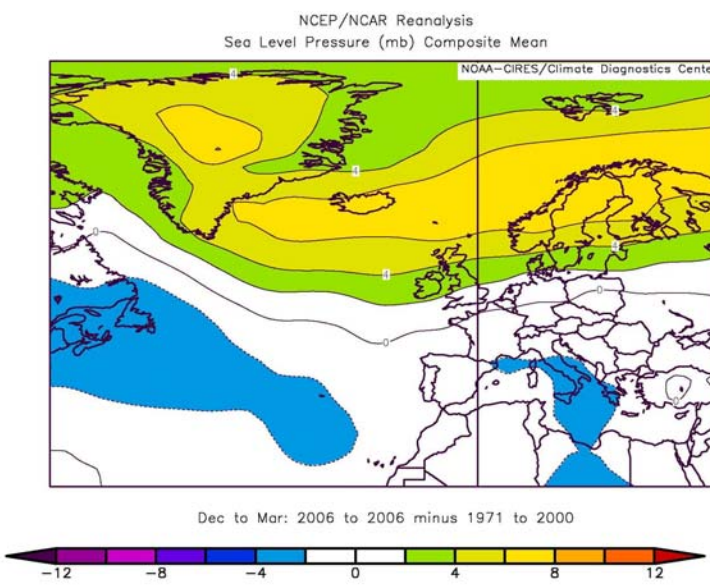


Figure 7: Sea level pressure anomaly between December 2005 and March 2006. (NCEP/NCAR Reanalysis data from NOAA-CIRES Climate Diagnostics Center: www.cdc.noaa.gov/Composites).

6 Detailed area descriptions

6.1 Introduction

The general pattern of oceanic circulation in the North Atlantic, in relation to the areas described here, is given in Figure 8. Information about each area has been distilled from larger data sets which have been collected under programmes of sustained observations.

Most standard sections or stations are repeated annually or more frequently. The text summarizes the regional context of the sections and stations, noting any significant recent events. Key parameters are plotted against time.

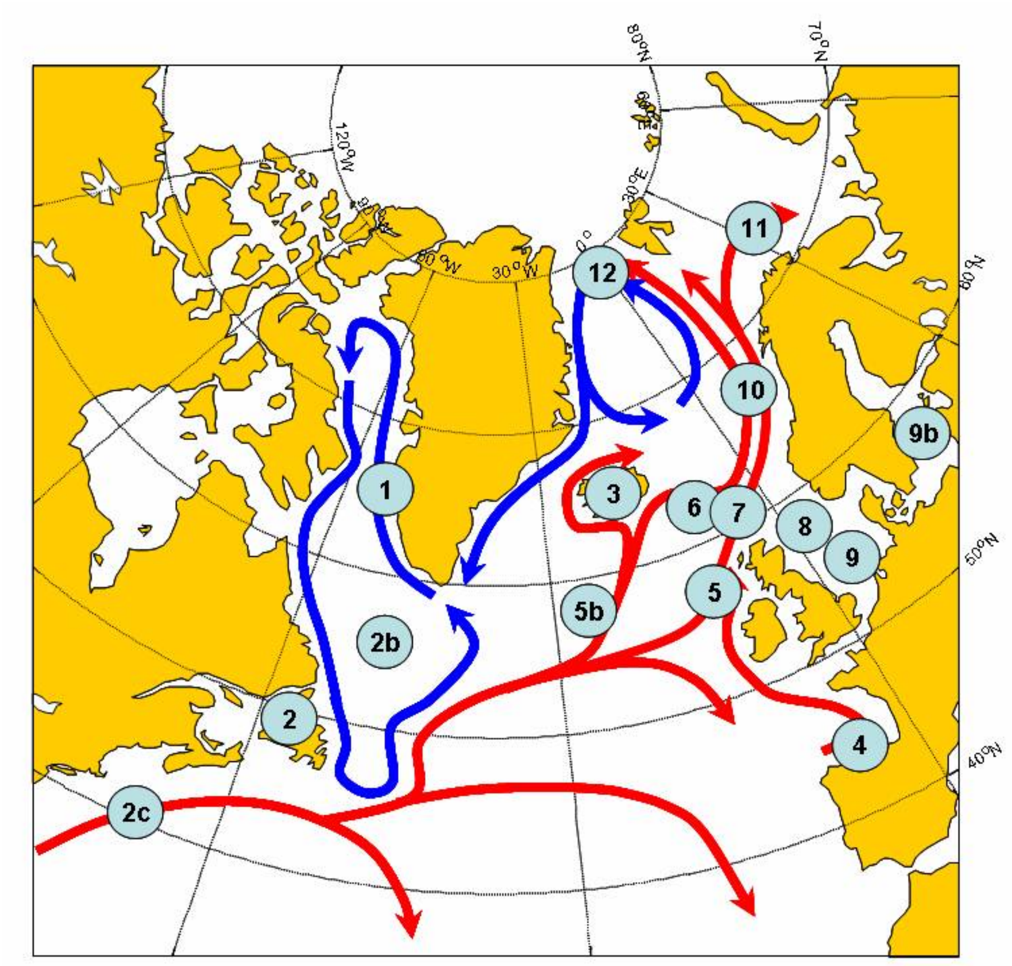


Figure 8: Schematic of the general circulation of the North Atlantic in relation to the numbered areas presented in the ICES Report on Ocean Climate. The blue arrows indicate the cooler waters of the sub-polar gyre. The red arrows show the movement of the warmer waters in the subtropical gyre.

6.2 Area 1 – West Greenland

West Greenland lies within an area that normally experiences cooler conditions when the NAO index is positive. But despite the positive NAO winter 2005 index, air temperature conditions around Greenland continued to be warmer than normal; mean air temperatures at Nuuk show positive anomalies (+1.6°C).

Subsurface autumn water temperatures off West Greenland have a significantly negative correlation (r^2=0.72) with the sea ice cover off Labrador during January–March of the following year. Satellite-derived ice charts showed that in winter 2004/2005, West Greenland sea ice conditions were favourable.

At Fyllas Bank, the 2005 subsurface temperatures were similar to the warm 1960s, but lower than autumn 2003 when temperatures were 2.44°C above normal. The long-term mean for the 0–200 m layer is 2.87°C.

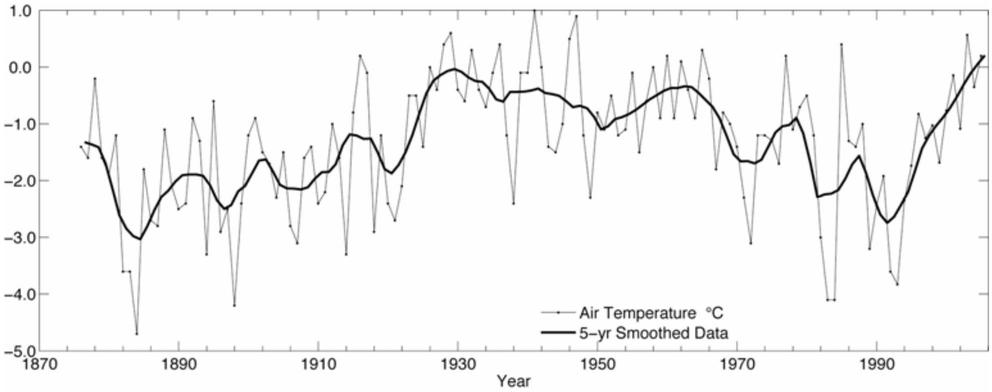


Figure 9: Area 1 – West Greenland. Annual mean air temperature observed at Nuuk.

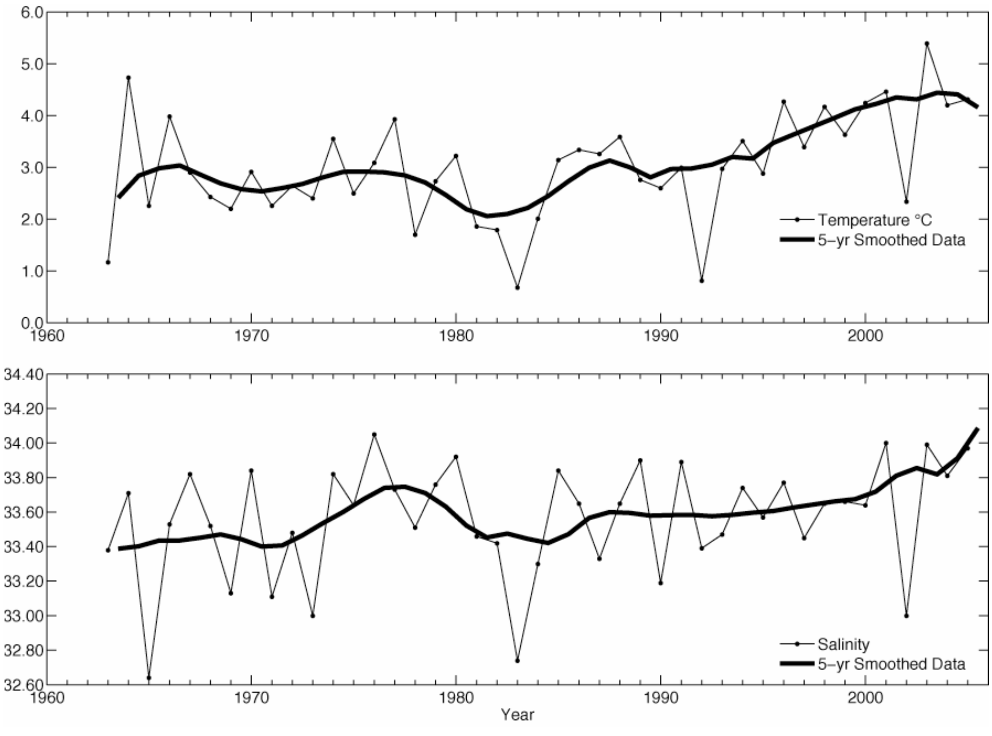


Figure 10: Area 1 – West Greenland. Fyllas Bank Station 4 autumn temperature (upper panel) and salinity (lower panel), 0–200 m.

6.3 Area 2 – Northwest Atlantic: Scotian Shelf and the Newfoundland and Labrador Shelf

Oceanographic conditions in this region are determined to a large degree by the strength of the winter atmospheric circulation over the Northwest Atlantic. In general, when the normal cyclonic circulation is weak during the winter months (usually corresponding to a negative Rogers NAO index), warm and saline ocean conditions predominate.

Scotian Shelf

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

In 2005, annual mean air temperatures over the Scotian Shelf, represented by Sable Island observations, were above average by about 0.7°C (based on 1971–2000 mean values), up nearly 1°C from 2004. West of Sable Island, air temperature anomalies decreased to 0.32°C over the eastern Gulf of Maine.

The amount of sea ice on the Scotian Shelf in 2005, as measured by the area of ice seaward of Cabot Strait between Nova Scotia and Newfoundland, continued to decrease from the exceptionally large coverage in 2003.

Topography separates the northeastern Scotian Shelf from the rest of the Shelf. In the northeast, the bottom tends to be covered by relatively cold waters (1–4°C), whereas the basins in the central and southwestern regions have bottom temperatures that typically are 8–10°C. The origin of the latter is the offshore Slope waters, whereas in the northeast, their source is principally from the Gulf of St Lawrence. The interannual variability of the two water masses differs. Misaine Bank temperatures at 100 m capture the changes in the northeast. They show slightly warmer than normal conditions in 2005 by 0.1°C (not significantly different from 0); this was about a 2°C increase from 2004. In Emerald Basin, temperatures in 2005 were cooler than average at 100 m (up to −1.65°C), but changed linearly to about 0.2°C above average at 250 m. The warmer than average deep temperatures continue a trend that has existed since the mid-1980s, except for the cold year of 1998.

Annual sea surface temperature anomalies were about 1.1°C over the eastern, 0.7°C over the central, and −0.03°C over the western Scotian Shelf during 2005. The Lurcher Shoal area west of Nova Scotia had an annual anomaly of −0.7°C, the Bay of Fundy −0.2°C. The density difference 0–50 m over the Scotian Shelf increased on average in 2005 to above normal, although there was considerable spatial variability with stratification below normal in some areas.

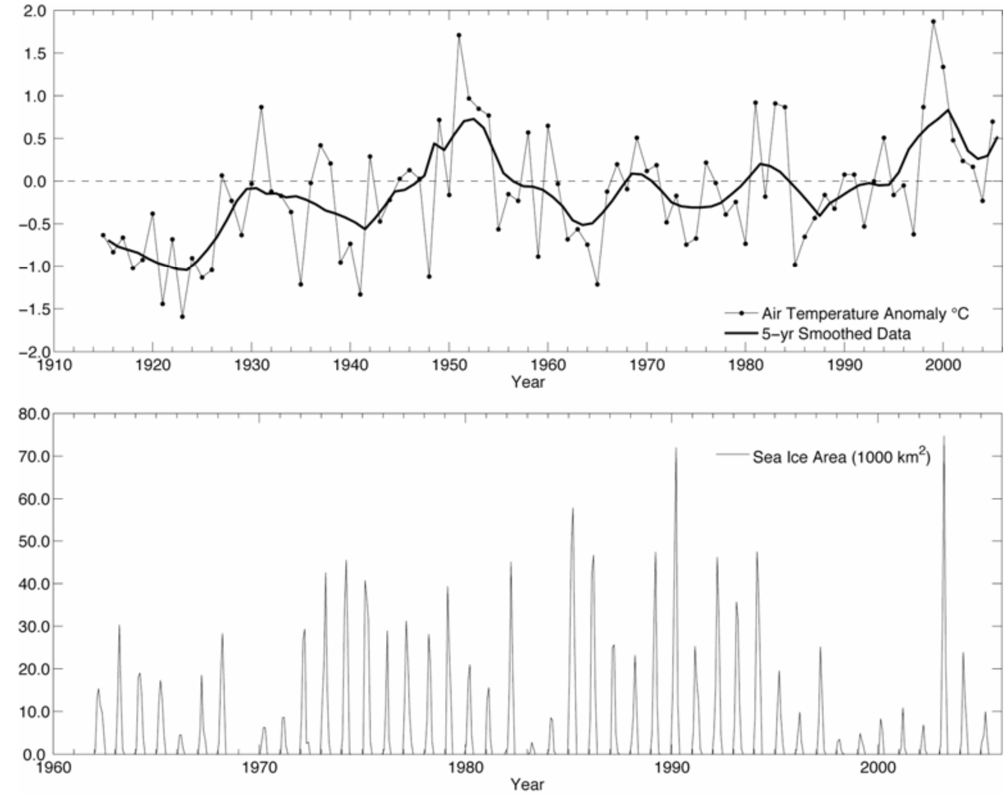


Figure 11: Area 2 – Northwest Atlantic: Scotian Shelf. Upper panel shows annual air temperature anomalies at Sable Island on the Scotian Shelf; lower panel shows monthly mean of ice area seaward of Cabot Strait.

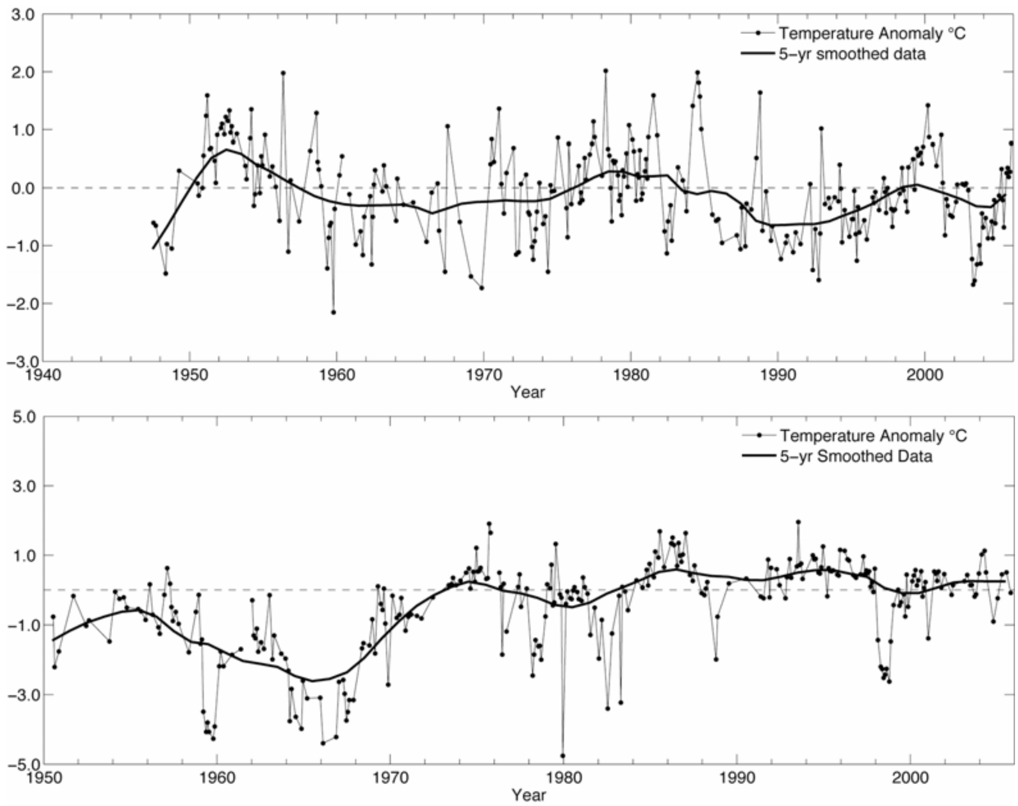


Figure 12: Area 2 – Northwest Atlantic: Scotian Shelf. Near-bottom temperature anomalies in the northeastern Scotian Shelf (Misaine Bank, 100 m, upper panel) and the central Scotian Shelf (Emerald Basin, 250 m, lower panel).

Newfoundland and Labrador Shelf

Arctic outflow to the northwest Atlantic was weaker than normal. Annual air temperatures in 2005 were 1–2°C above normal, sea ice extent was below average, with a shorter ice season than normal.

At the standard monitoring site off eastern Newfoundland (Station 27), the depth-averaged annual water temperature decreased slightly from 2004 to just over 0.5°C above normal. Surface temperatures remained at the record high value of 1°C above normal. Bottom temperatures were above normal by 0.8°C. Annual surface temperatures off southern Labrador were 1°C above normal, and on the Flemish Cap they were 2°C above normal.

A good index of ocean climate conditions in eastern Canadian waters is the extent of the cold intermediate layer (CIL) of <0°C water overlying the continental shelf. This winter-cooled water remains trapped between the seasonally heated upper layer and the warmer shelf-slope water throughout the summer and fall months.

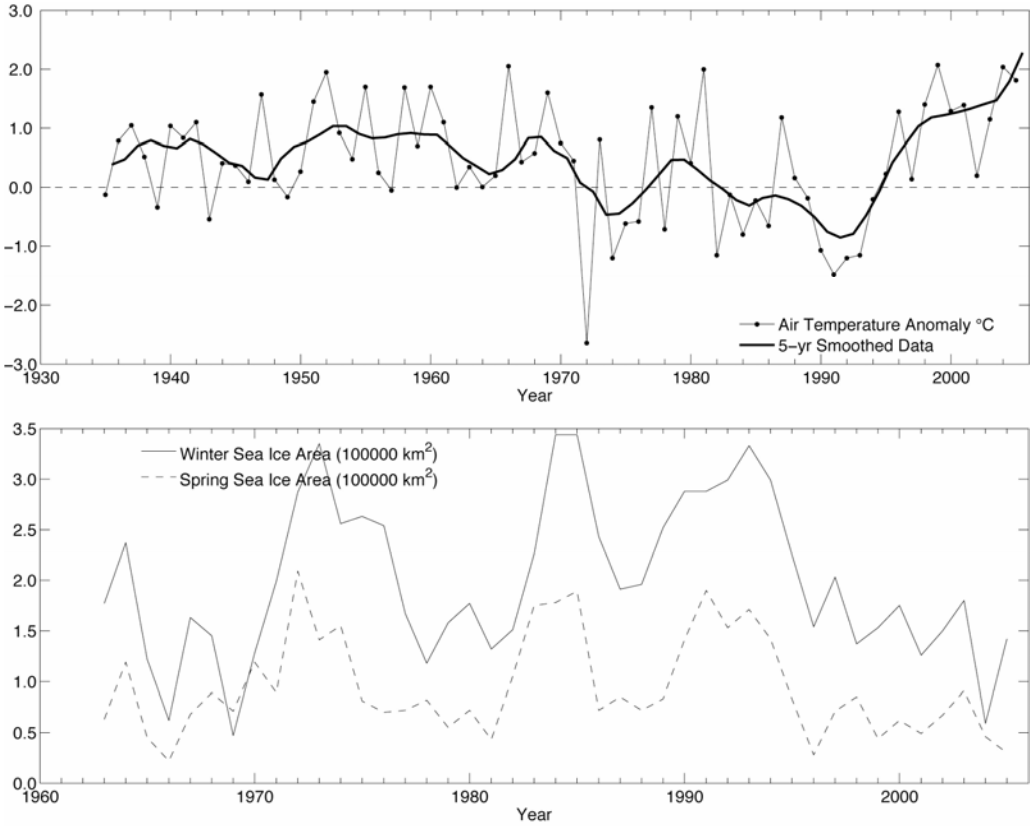


Figure 13: Area 2 – Northwest Atlantic. Upper panel shows annual air temperature anomalies at Cartwright on the Labrador Coast. Lower panel shows sea ice area off Newfoundland and Labrador between 45 N–55 N for the winter and spring.

During the 1960s, when the NAO was well below normal, the volume of CIL water was at a minimum, and during the high NAO years of the early 1990s, the CIL volume reached near record high values. During 2005, the CIL remained below normal.

In 2005, bottom temperatures reached a record 2°C above average on Hamilton Bank off southern Labrador. The area of sea floor on the Grand Banks covered by sub-zero °C water has decreased from >50% during the first half of the 1990s to nearly 15% during 2004/2005.

In general, ocean temperatures on the Newfoundland and Labrador Shelf during 2005 decreased slightly over 2004, but remained well above their long-term means, continuing the warming trend experienced since the mid- to late-1990s. Shelf water salinities, which were lower than normal throughout most of the 1990s, have increased to above normal values during the past four years.

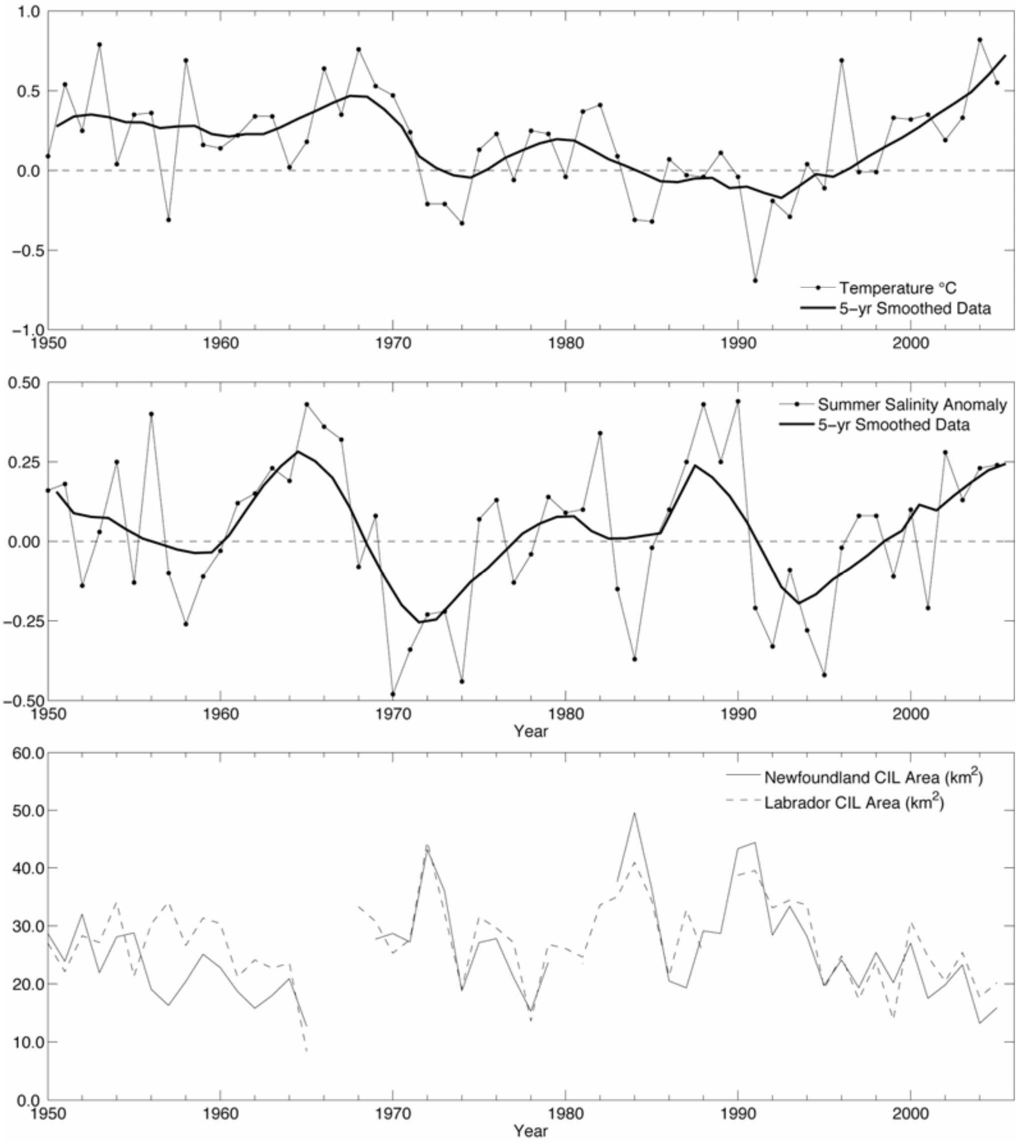


Figure 14: Area 2 – Northwest Atlantic: Newfoundland and Labrador Shelf. Annual depth-averaged Newfoundland Shelf temperature (upper panel), summer salinity anomalies (middle panel), and area of cold intermediate layer (CIL) on the Newfoundland (solid line) and Labrador (dashed line) Shelf (lower panel).

6.4 Area 2b – Labrador Sea

The Labrador Sea is located between Greenland and the Labrador coast of eastern Canada. Cold, low salinity waters of polar origin circle the Labrador Sea in a counterclockwise current system that includes both the north-flowing West Greenland Current on the eastern side and the south-flowing Labrador Current on the western side. Warm and saline waters from more southern latitudes flow northwards into the Labrador Sea on the Greenland side and become colder and fresher as they circulate.

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

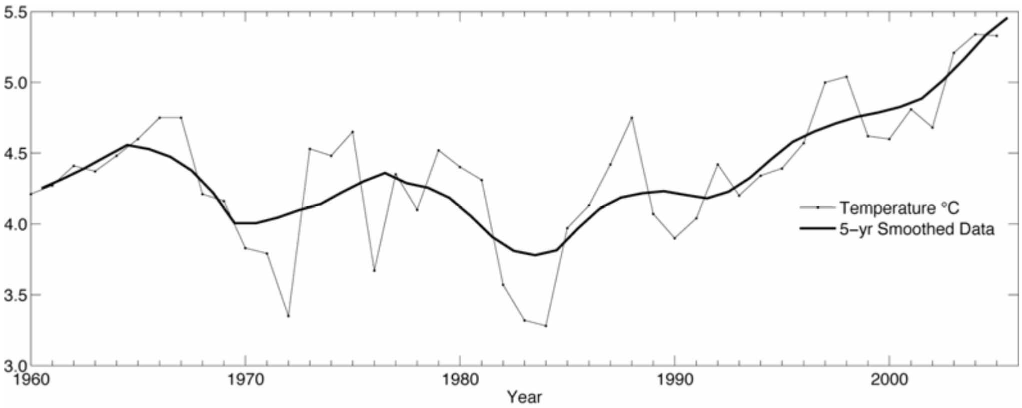


Figure 15: Area 2b – Labrador Sea. Annual mean Sea Surface Temperature data from the west-central Labrador Sea (56.5°N 52.5°W). Data obtained from the HadISST1 Global Sea Surface Temperature data set, UK Meteorological Office, Hadley Centre.

A sequence of severe winters in the early 1990s led to the most recent period of deep convection that peaked in 1993–1994. Subsequent winters have generally been milder than normal, and the upper levels of the Labrador Sea have become steadily warmer and more saline. The upper 150 m of the west-central Labrador Sea have warmed by more than 1°C and increased in salinity by more than 0.1 since the early 1990s. This trend to warmer and more saline conditions persisted in 2005.

The 2005 annual mean sea surface temperatures in the west-central Labrador Sea was warmer than normal for the 12th consecutive year, with values equal to the 45-year record high set in 2004.

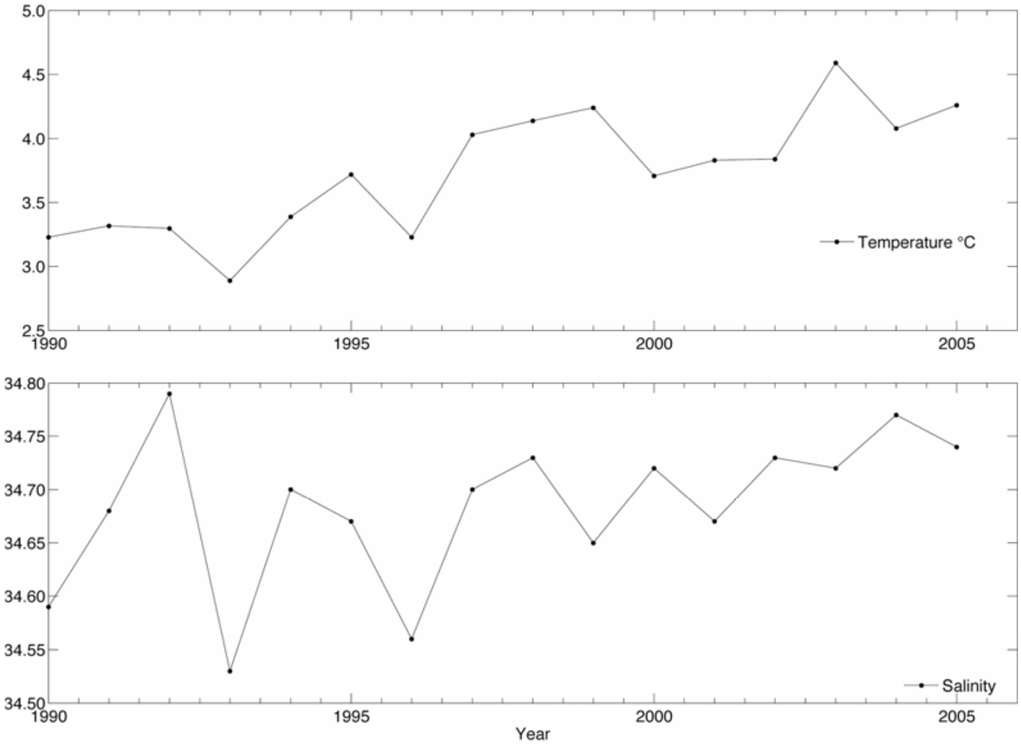


Figure 16: Area 2b – Labrador Sea. Spring/early summer potential temperature (upper panel) and salinity (lower panel) values for 0–150 m depth from four stations in the west-central Labrador Sea (centred at 56.7°N 52.5°W).

6.5 Area 2c – Mid-Atlantic Bight

Hydrographic conditions in the Mid-Atlantic Bight and Western Slope Sea regions depend substantially on the advective inflow of waters from the Labrador Sea, both on the shelf and along the continental slope. Since 1978, a monthly time-series of XBT sections of temperature and surface salinity has been maintained by the National Marine Fisheries Service of NOAA. The section starts just off New York City and ends at the northern edge of the Gulf Stream.

Temperature anomalies across the section show gradual variations in temperature that are coherent across the entire region. The year 2005 was cooler during the first half and warmer during the second half.

A second Voluntary Observing Ship line operates out of Boston. On the longer time scales, this section shows the same trends as the New York line, but evinces a stronger presence of higher frequency variability. The first half of the year was cooler than normal east of Boston, while it was warmer during the latter half.

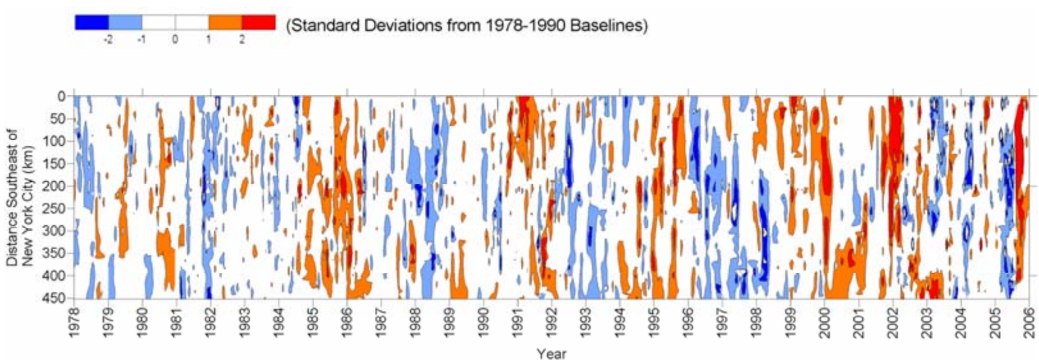


Figure 17: Area 2c – Mid-Atlantic Bight. Sea surface temperature anomalies southeast of New York City.

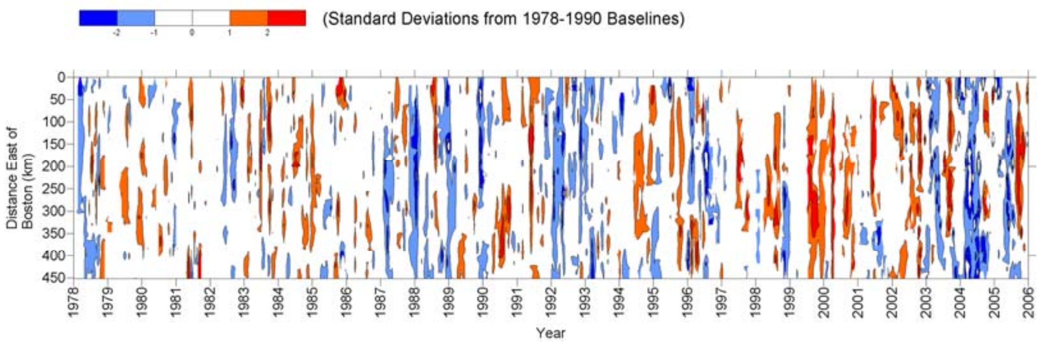


Figure 18: Area 2c – Mid-Atlantic Bight. Sea surface temperature anomaly along a line extending east of Boston.

It is of interest to compare hydrographic conditions of Georges Bank with the offshore conditions. Surface temperature and salinity are extracted from the NOAA National Marine Fisheries Service surveys that take place six times a year. The surface temperature anomaly pattern suggests that the general warming evident from the mid-1990s through approximately 2003 moderated in 2004 and early 2005, followed by warming in the second half of 2005. The surface salinity remained low in 2005.

Sea surface salinities in the Georges Bank region have generally been low since the early 1990s. Salinity anomalies in the Georges Bank decrease as temperature increases. This is the opposite of what occurs on the continental shelf southeast of New York City where temperature increases with salinity. On the shelf (and in the Slope Sea north of the Gulf Stream), a strong correlation exists between temperature, salinity, and mean latitude of the Gulf Stream: as the current shifts to the north, temperature, salinity all increase. The reason for this appears to be a lesser transport along the continental margin of cold fresh waters from the Labrador Sea region. In the Georges Bank area, the opposite correlation between salinity and temperature may reflect an atmospheric origin, i.e. warmer airs bring in more moisture.

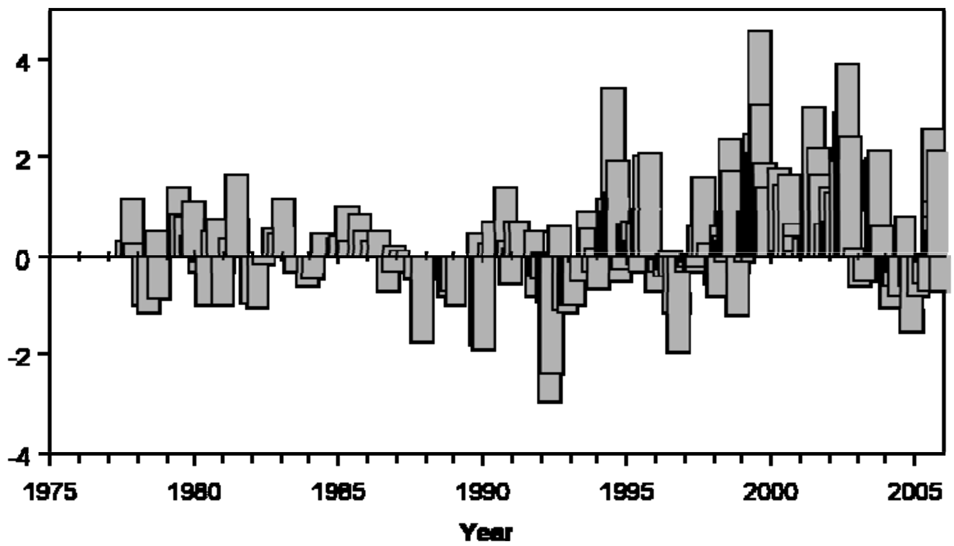


Figure 19: Area 2c – Mid-Atlantic Bight. Time-series of sea surface temperature anomalies over Georges Bank.

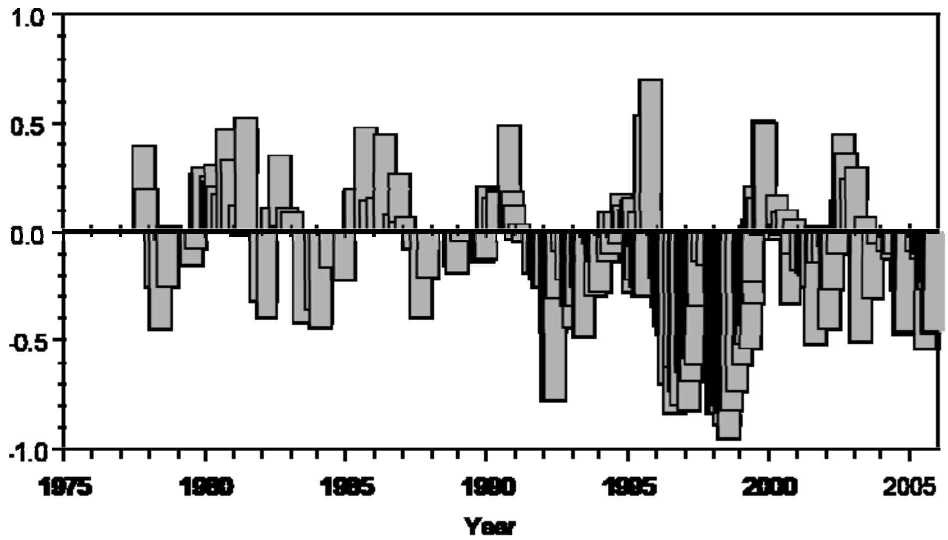


Figure 20: Area 2c – Mid-Atlantic Bight. Time-series of sea surface salinity anomalies over Georges Bank.

6.6 Area 3 – Icelandic waters

Iceland is at a meeting place of warm and cold currents, which meet in an area of submarine ridges (Greenland-Scotland Ridge, Reykjanes Ridge, Kolbeinsey Ridge), forming 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.

Hydrographic conditions in Icelandic waters are generally closely related to 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 2005, mean air temperatures in the south (Reykjavik) and north (Akureyri) were above long-term averages. Sea ice was carried from the East Greenland Current into the waters north of Iceland in late February and early March, and extended eastward to north of Langanes in northeast Iceland. This event was reflected in the temperature and salinity of the surface layers in the north and east for the rest of the year, but conditions seemed to have returned to pre-ice status in February 2006. However, salinity and temperature in the Atlantic water from the south remained at high levels, similar to previous years. The salinity in the East Icelandic Current in spring 2005 was close to average, but the temperature was above the long-term mean.

In the northern area, temperatures in 2005 were down from 2004, but in recent years temperatures have been comparable to the "warm period" of 1920–1960.

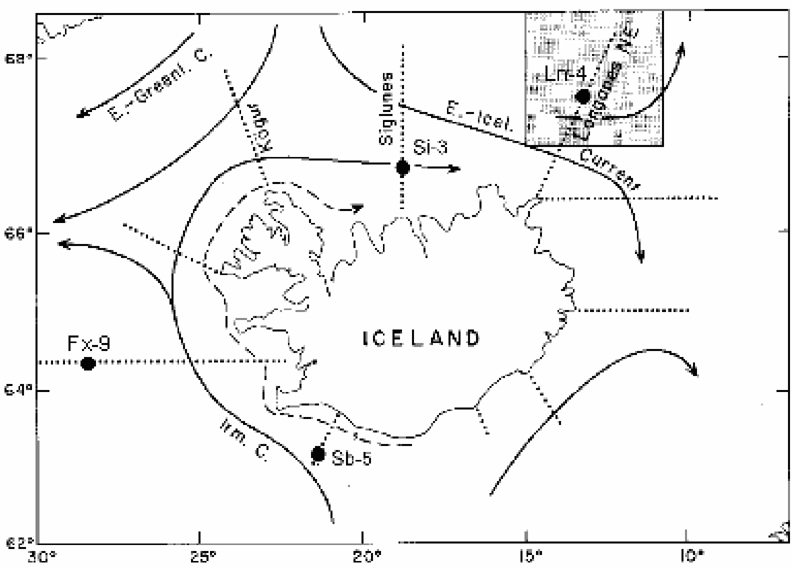


Figure 21: Area 3 – Icelandic waters. Main currents and location of standard hydrobiological sections in Icelandic waters.

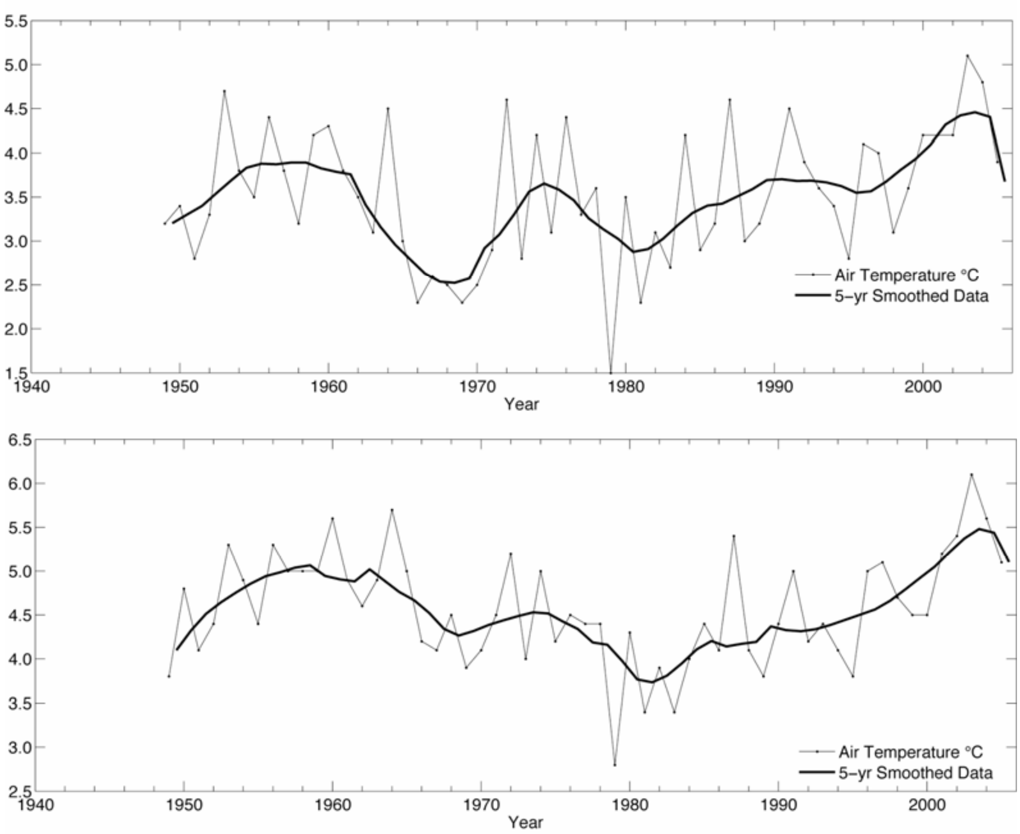


Figure 22: Area 3: Icelandic waters. Mean annual air temperature at Reykjavík (upper panel) and Akureyri (lower panel).

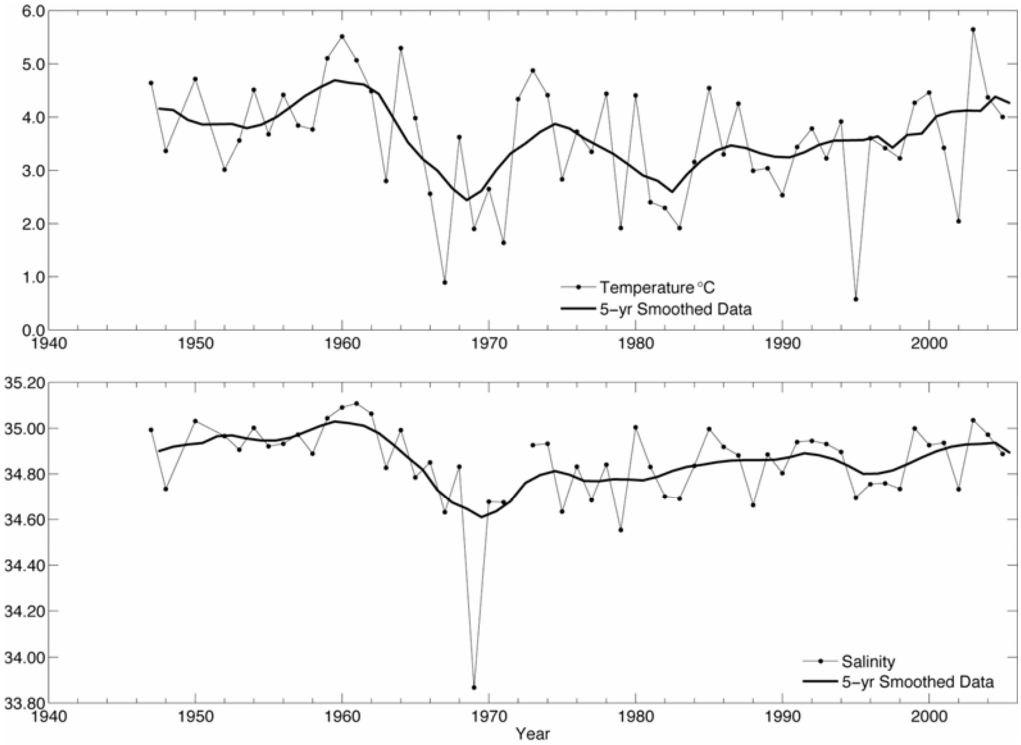


Figure 23: Area 3 – Icelandic waters. Temperature (upper panel) and salinity (lower panel) at 50–150 m depth at Stations Si-2–4 in North Icelandic waters.

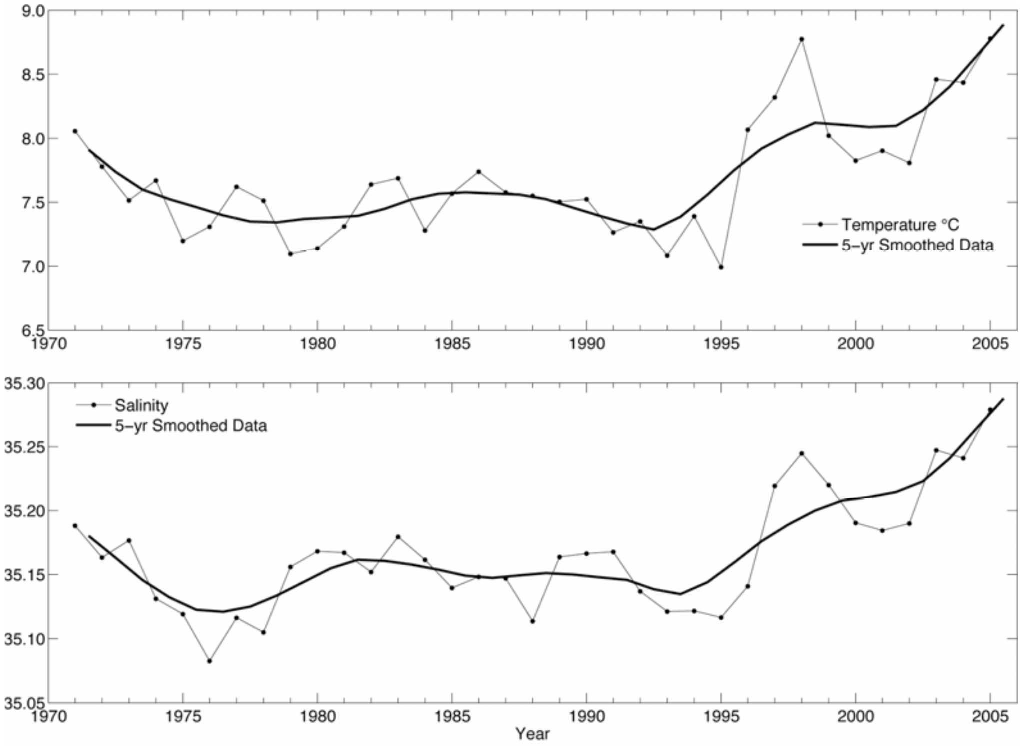


Figure 24: Area 3 – Icelandic waters. Temperature (upper panel) and salinity (lower panel) between 0 and 200-m depth at Station Sb-5 in South Icelandic waters.

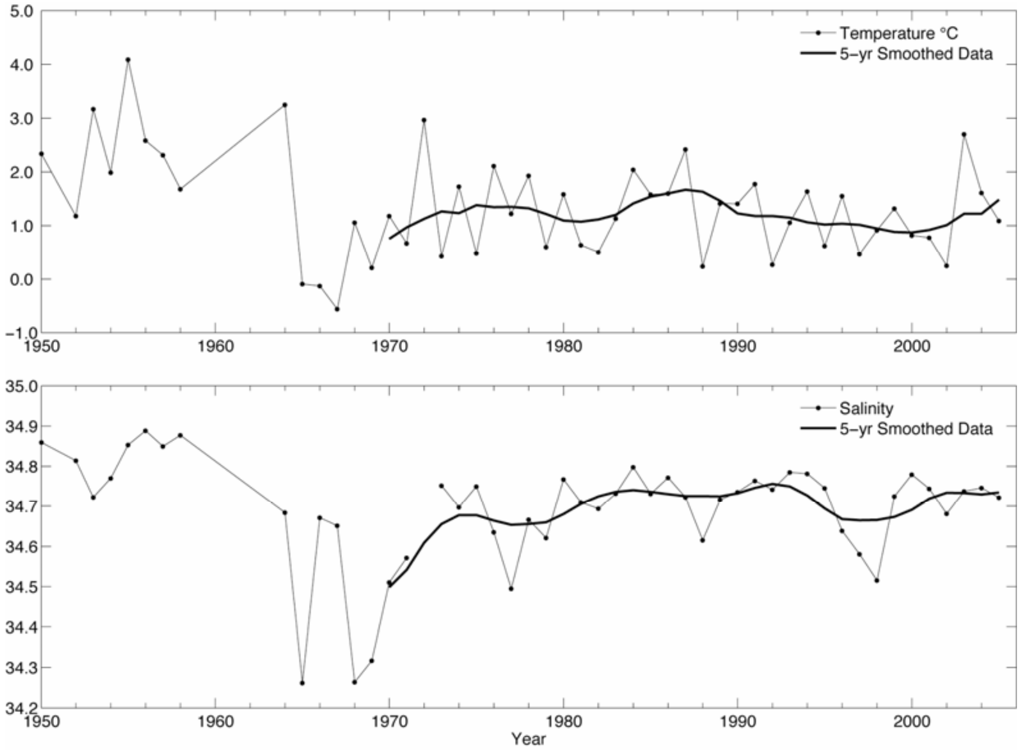


Figure 25: Area 3 – Icelandic waters. Temperature (upper panel) and salinity (lower panel) between 0 and 50-m depth in the East Icelandic Current (Station Lna2–6).

6.7 Area 4 – Bay of Biscay and eastern Atlantic

The Bay of Biscay is located in the eastern part of the North Atlantic. Its general circulation follows the subtropical anticyclonic gyre and is relatively weak (1–2 cm s−1). In the southern part of the Bay of Biscay, east-flowing shelf and slope currents are common in autumn and winter as a result of westerly winds. In spring and summer, easterly winds are dominant, and coastal upwelling events are frequent.

Meteorological conditions in the northern part of the Iberian Peninsula in 2005 were generally close to the long-term average. However, as in recent years, the annual mean disguises unusually cold winters and warm summers. In 2005, late autumn and winter were especially cold; in February the air temperature was 2.8ºC below normal. As a result, the sea surface temperature from February to March 2005 was below the mean value, and in March 2005, was the lowest value of the time-series (11.4ºC). During the rest of the year, sea surface temperature was higher than average, especially in August when 22.5ºC was recorded. The cold winter and warm summer produced a yearly sea surface temperature close to the average, but over the upper water column (0–300 m), the cold deep winter mixed layer led to 2005 being the coldest of the time-series.

Between 1998 and 2001, freshening was observed in 0–300 m. In 2002, this trend was reversed, especially during a period of the episodic Iberian Poleward Current (IPC) at the beginning of the year. During 2005, the salinity increased, and the values became close to the long-term mean. There has been no IPC event at the Santander shelf break since 2002.

The deepening of the mixed layer was the main feature during 2005. The extremely cold sea surface temperature (11.5ºC) and strong winds combined to produce a 300-m depth mixed layer never seen previously at this location. This event effectively reversed the recent warming trend of the upper layers of the eastern North Atlantic Central Water.

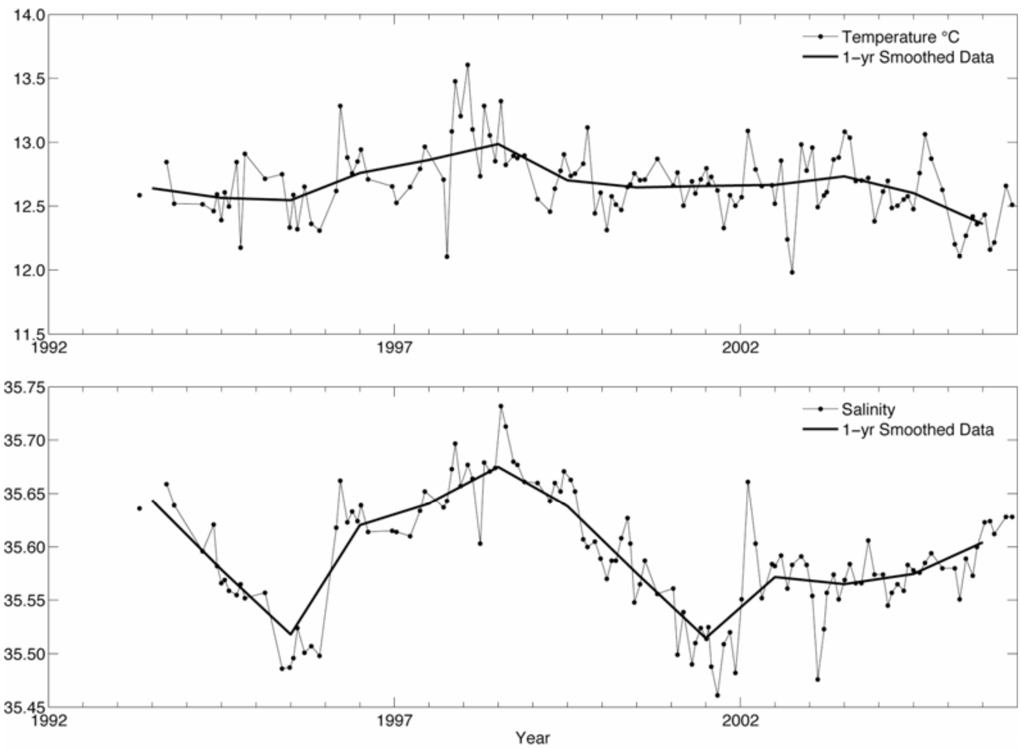


Figure 26: Area 4 – Bay of Biscay and eastern Atlantic. Potential temperature (upper panel) and salinity (lower panel) at Santander station 6 (5–300 m).

6.8 Area 5 – Rockall Trough

The Rockall Trough is situated west of Britain and Ireland, and is separated from the Iceland Basin by the Hatton and Rockall Banks and from the Nordic Seas by the shallow (500 m) Wyville-Thomson Ridge. It is one pathway by which warm North Atlantic upper water reaches the Norwegian Sea, where it is converted into cold dense overflow water as part of the thermohaline overturning in the North Atlantic. The upper water column is characterized by poleward-moving eastern North Atlantic Water, which is warmer and saltier than waters of the Iceland Basin that also contribute to the Nordic Sea inflow.

Below 1200 m, the intermediate water mass, the Labrador Sea Water, is trapped by the shallowing topography to the north, which prevents through-flow but allows recirculation within the basin.

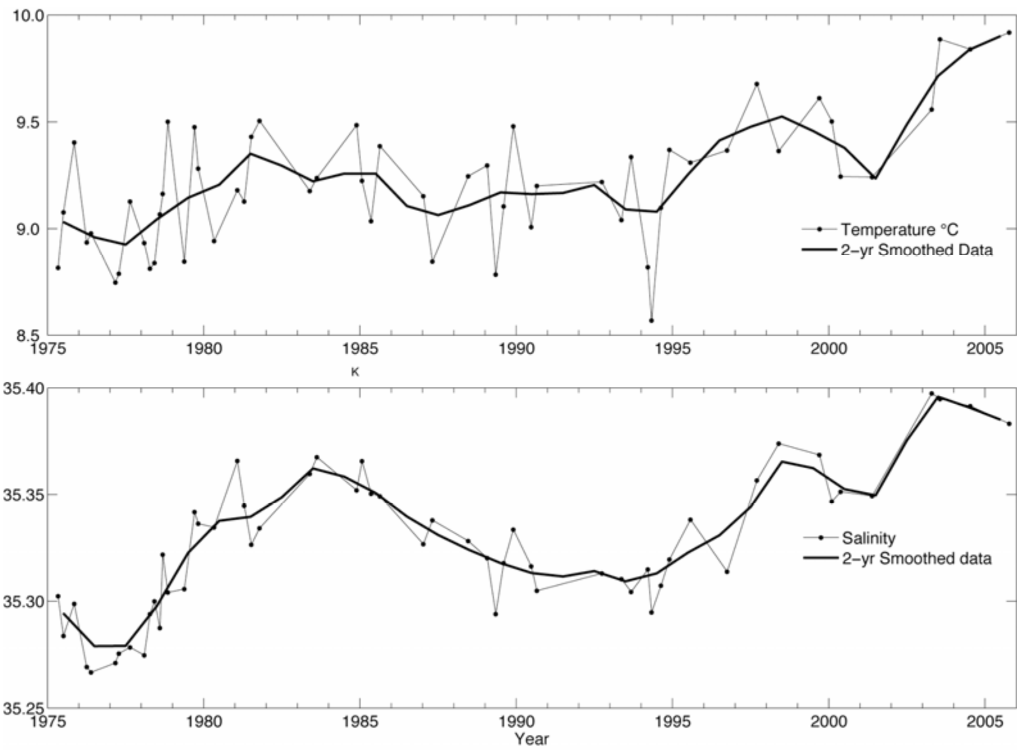


Figure 27: Area 5 – Rockall Trough. Temperature (upper panel) and salinity (lower panel) for the upper ocean (0–800 m).

In 2005, the decade-long trend toward warmer and saltier upper ocean water continued. Temperatures were the highest recorded, though salinity showed a very small decrease from 2004 and 2003. Upper ocean temperatures were 0.6°C and salinity 0.06 above the long-term mean (1975–2000).

Meanwhile, the core of the Labrador Sea Water showed continued cooling, a trend that has dominated the entire time-series, though 2005 showed a substantial increase in salinity from the 2004 value. The depth of the Labrador Sea Water core (defined as a minimum in stratification) had also increased from 2004.

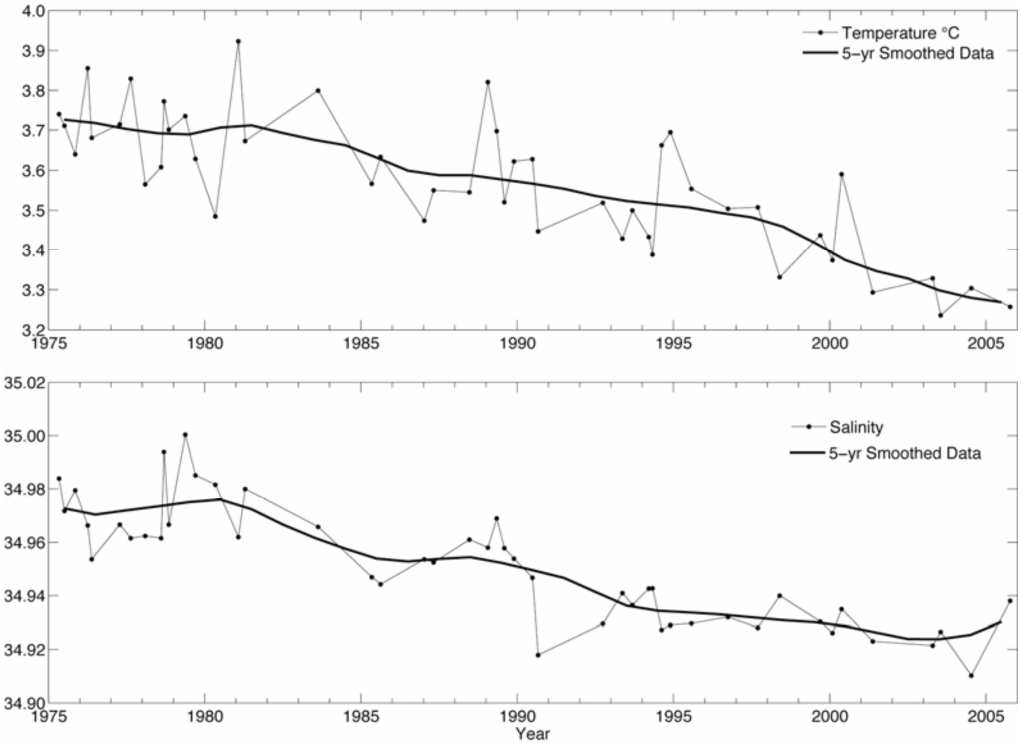


Figure 28: Area 5 – Rockall Trough. Temperature (upper panel) and salinity (lower panel) of Labrador Sea Water (~depth 1800 m).

6.9 Area 5b – Irminger Sea

The Sub-Polar Mode Water (SPMW) in the centre of the Irminger Sea, in the pressure interval 200 to 400 dbar, reached its highest temperature and salinity since 1991 in 2004. Although convection that reached depths of over 600 m in the following winter reduced temperature and salinity slightly, the values of these parameters for the SPMW in the summer of 2005 were still the second highest since 1991. Thus, the increasing trend of temperature and salinity that started in 1995/1996 seems to have continued during 2005.

From 1600 to 2000 dbar, a cold and low-salinity core was observed in the Irminger Sea during the early 1990s. This was the result of the presence of deep Labrador Sea Water (LSW) formed in the period 1988–1995. Since the summer of 1996, this LSW core has been increasing in temperature and salinity as it mixes with surrounding water masses. The salinity increase levelled off in 2002 to 1991 values and remained constant until 2005. Still, the temperature was slightly increasing from 2003 to 2005, and in 2005 recovered to its 1991 value.

The salinity and potential temperature of the Denmark Strait Overflow Water (DSOW) near Cape Farewell show considerable well-correlated interannual variations between 1991 and 2005 (correlation = 0.6). However, while the salinity does not show a trend over time, the potential temperature shows a linear decreasing trend of 0.3ºC from 1991 to 2005 (correlation = 0.78). This implies a long-term increase of the density of the DSOW. The standard deviation of the residual, relative to the linear trend, amounts to less than 0.1ºC.

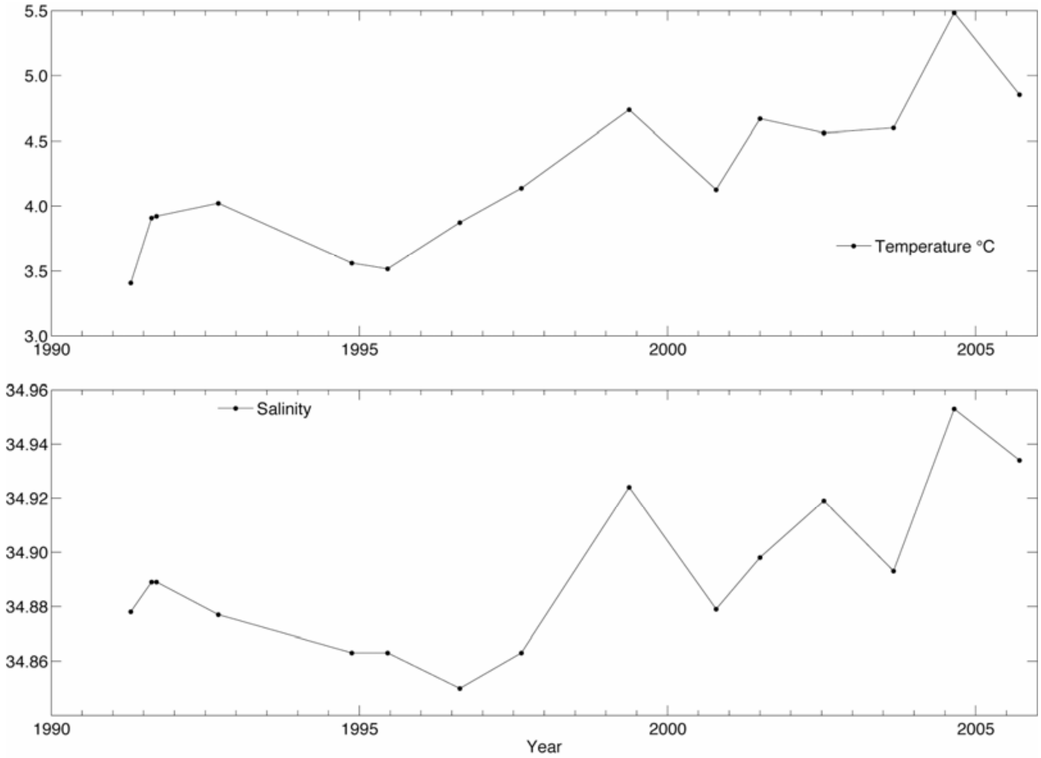


Figure 29: Area 5b – Irminger Sea. Temperature (upper panel) and salinity (lower panel) of Sub-Polar Mode Water (averaged over 200–400 m).

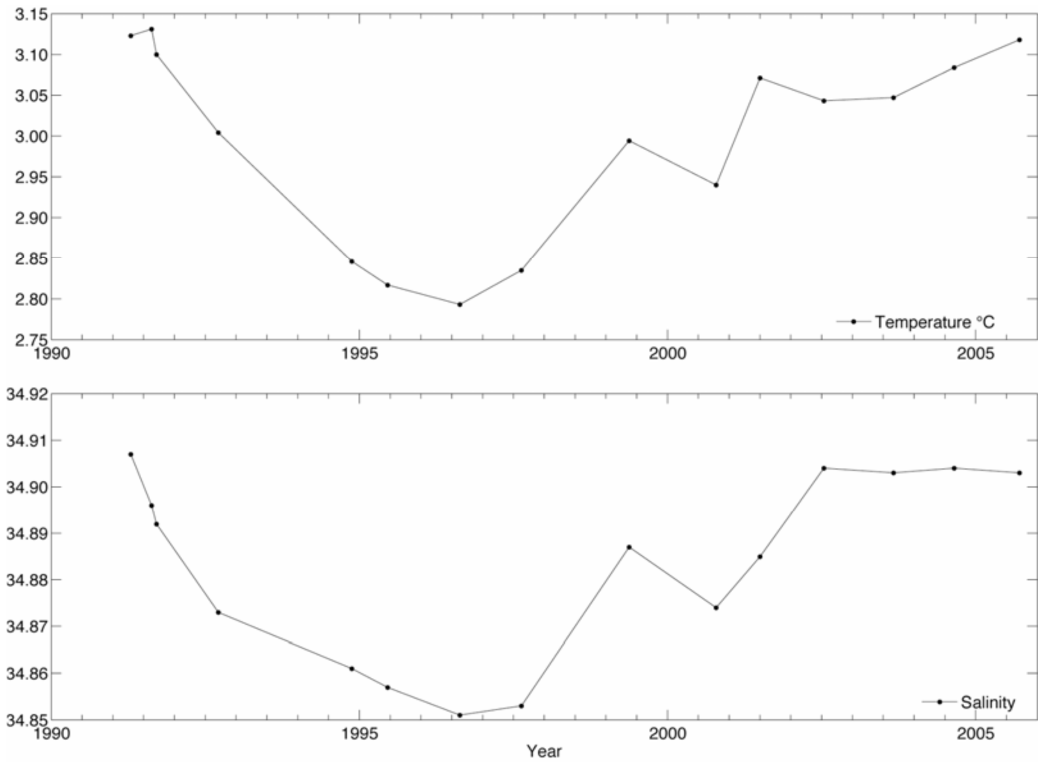


Figure 30: Area 5b – Irminger Sea. Temperature (upper panel) and salinity (lower panel) of Labrador Sea Water (averaged over 1600–2000 m).

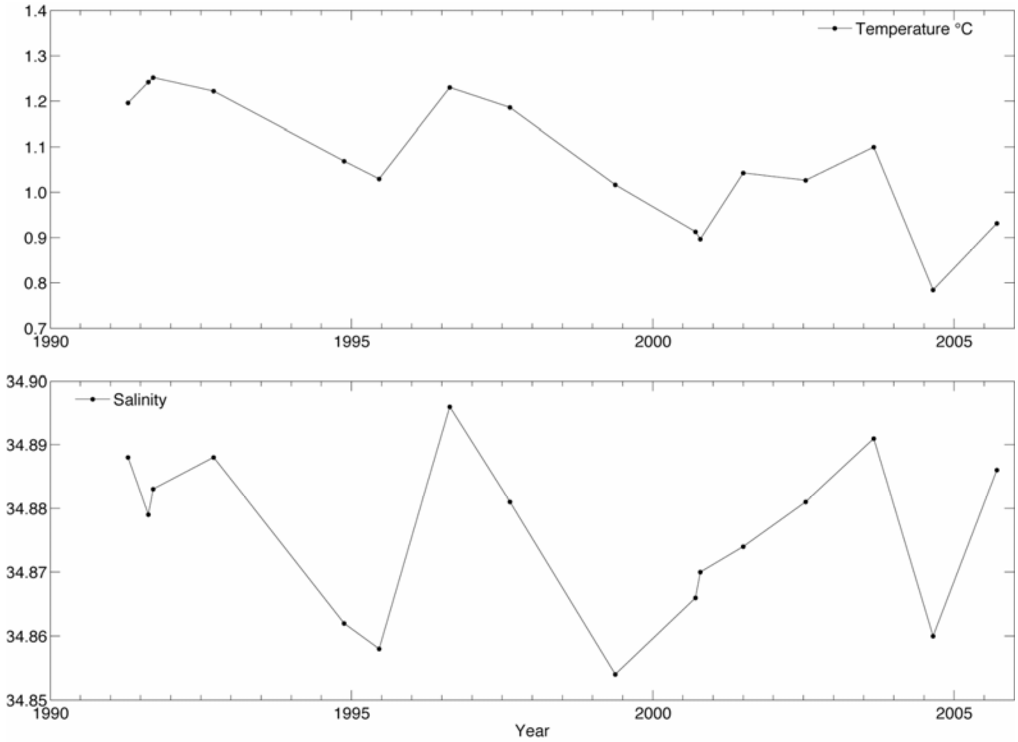


Figure 31: Area 5b – Irminger Sea. Temperature (upper panel) and salinity (lower panel) of Denmark Strait Overflow Water on the East Greenland Slope.

6.10 Area 6 – Faroe Bank Channel and Faroe Current

One branch of the North Atlantic Current crosses the Greenland-Scotland Ridge on both sides of the Faroes (to the south through the Faroe Bank Channel, to the north in the Faroe Current).

Since 1988, temperature and salinity of the upper waters have been steadily increasing. Values were slightly down from 2004, but remained higher than the average value for the time-series.

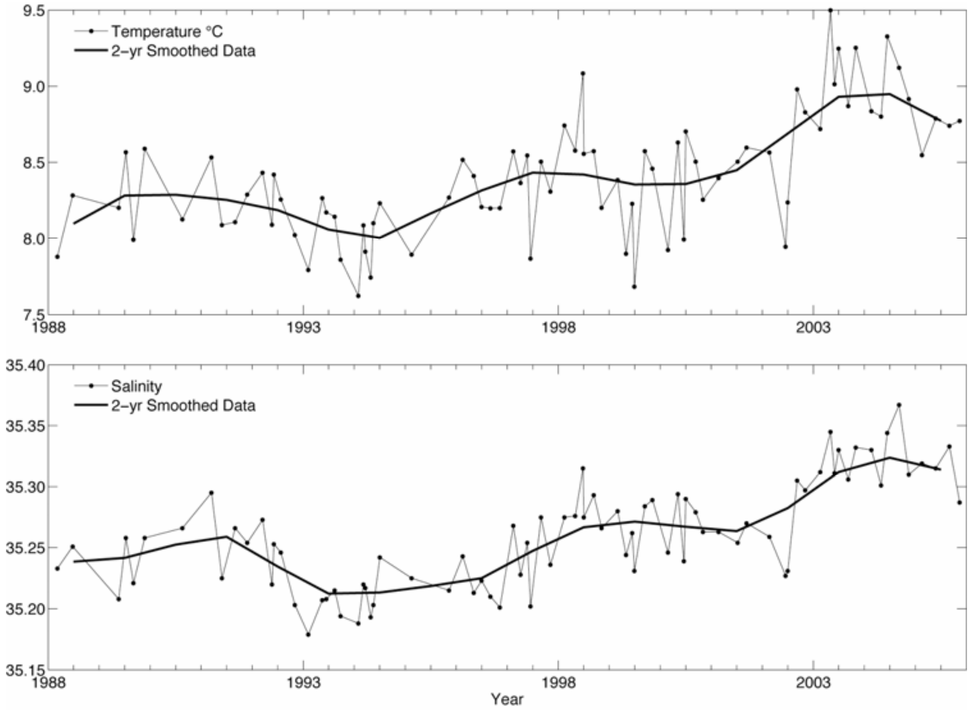


Figure 32: Area 6 – Faroe Bank Channel. Temperature (upper panel) and salinity (lower panel) from the 100–300 m depth layer at two standard stations in the channel.

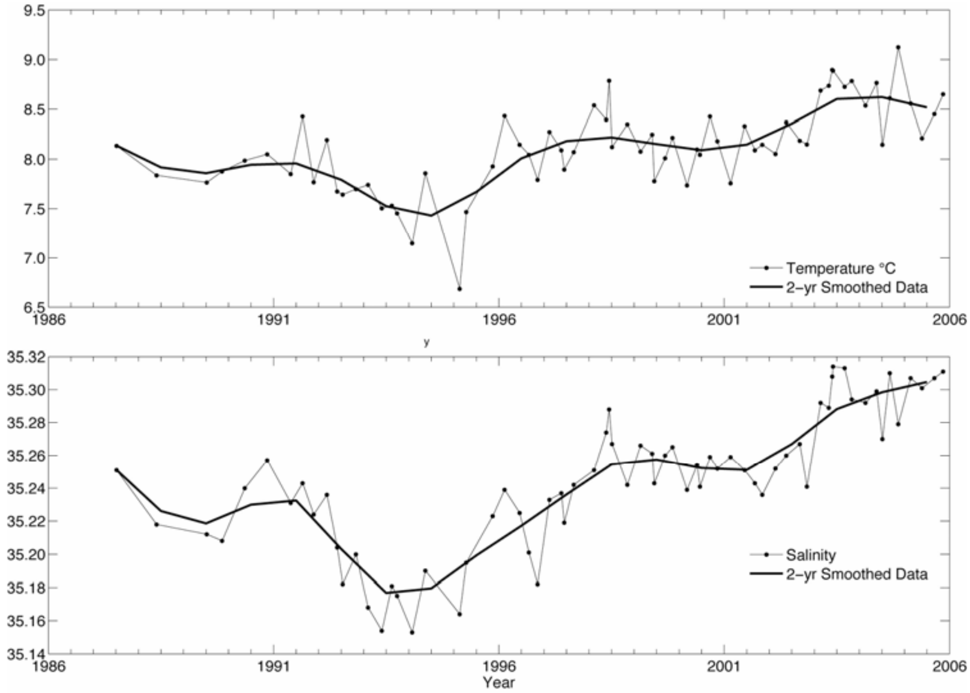


Figure 33: Area 6 – Faroe Bank Channel. Temperature (upper panel) and salinity (lower panel) in the core of the Faroe Current (maximum salinity averaged over a 50-m depth layer).

6.11 Area 7 – Faroe Shetland Channel

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

Although the general trend in the surface waters of the Faroe Shetland Channel since 1990 has shown increasing temperature and salinity, values decreased slightly in 2005, compared with the peaks observed in 2003. In the deeper layers, both the temperature and salinity at 800 m has remained stable since the early 1990s after a period of decreasing salinity values.

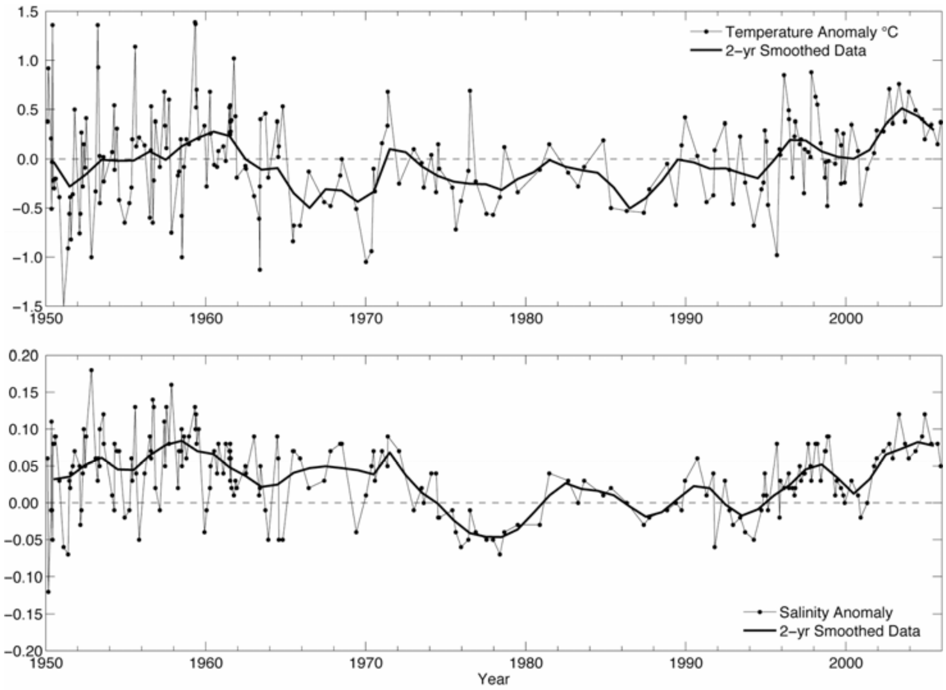


Figure 34: Area 7 – Faroe Shetland Channel. Temperature anomaly (upper panel) and salinity anomaly (lower panel) in the Atlantic Water in the Slope Current.

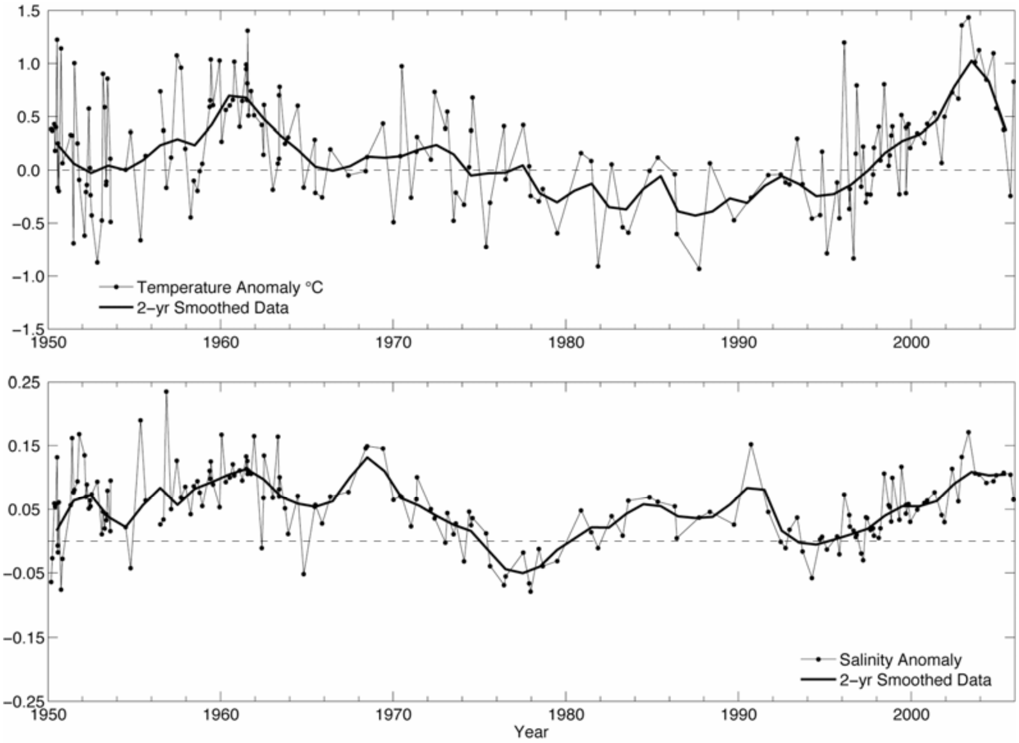


Figure 35: Area 7 – Faroe Shetland Channel. Temperature anomaly (upper panel) and salinity anomaly (lower panel) in the Modified Atlantic Water entering the Faroe Shetland Channel from the north after circulating around Faroe.

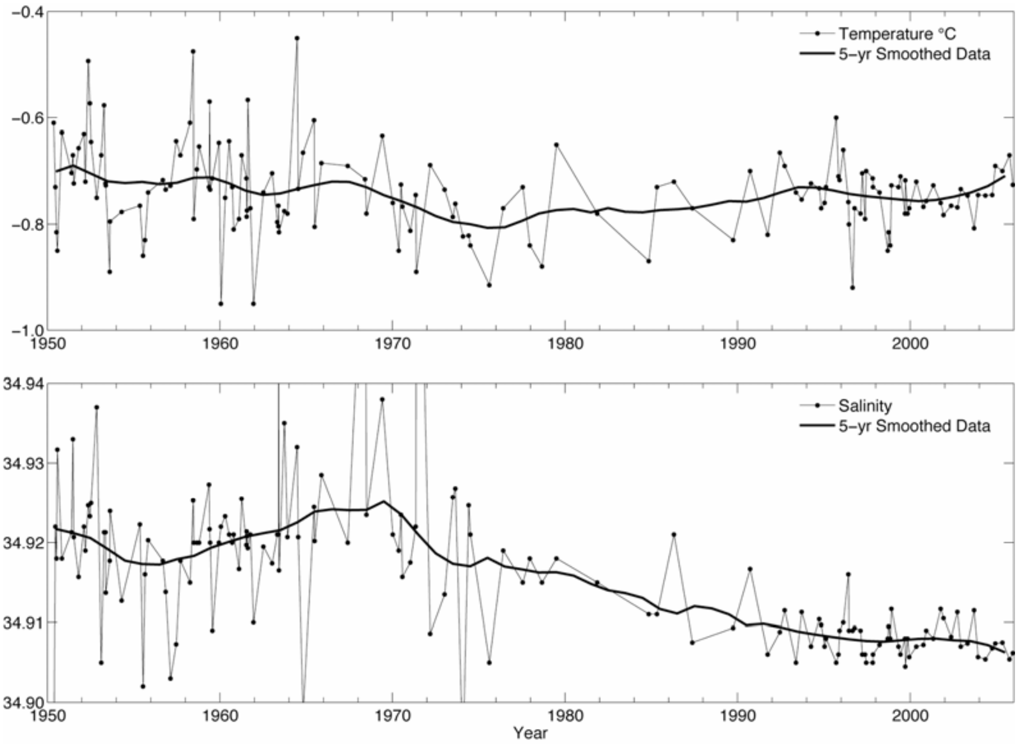


Figure 36: Area 7 – Faroe Shetland Channel. Temperature (upper panel) and salinity (lower panel) at 800 m in the Faroe Shetland Channel.

6.12 Areas 8 and 9 – northern and southern North Sea

North Sea oceanographic conditions are determined by the inflow of saline Atlantic water and the ocean-atmosphere heat exchange. The inflow through the northern entrances (and to a lesser degree, through the English Channel) can be strongly influenced by the NAO. Numerical model simulations also show strong differences in the North Sea circulation, depending on the state of the NAO. The Atlantic water mixes with the river run-off and lower-salinity Baltic outflow along the Norwegian coast. A balance of tidal mixing and local heating force the development of a seasonal stratification from April/May to September in most parts of the North Sea.

Area-averaged Sea Surface Temperature (SST) of the North Sea has been increasing since June 2001. The vegetation period (primary production) was much longer than usual in 2005.

At the beginning of 2005, the upper water masses were about 1–1.5°C warmer than normal all over the North Sea. Mild southerly winds in December 2004 and January 2005 were followed by relatively cold winter winds, which lead to a rapid normalizing of the water temperature. June and August had cooler than average SST, but extremely warm weather in late summer and early autumn led to October and November SST being the highest since 1971. At the end of 2005 and the start of 2006, the temperatures in the upper layer of the North Sea were extremely high, about 2.0°C warmer than normal. The Helgoland standard station shows that, since the cold winter of 1996, SST has been above the 30-year mean, with positive anomalies of 0.5–1.0°C.

In the Skagerrak in addition to overall increased temperature, the length of the warm season has increased significantly during the last years (conditions in the Skagerrak are thought to be representative of conditions throughout the North Sea). This is unlike most of the past 45 years, though similar conditions were observed around 1990. The result is that cold water previously observed during large parts of the year has now been absent for several years. Together with the high temperatures, this will have significant effects on the ecosystem dynamics in the North Sea and the Skagerrak.

In summer 2005, the general North Sea salinity distribution at the sea floor was comparable to 2004, but the 35-isohaline reached farther to the south, and the salinity in the southern North Sea was slightly higher. The 34-isohaline, which marks the boundary between the saline North Sea water and the less saline water modified by the Baltic and river outflows, had the same position as in 2004.

At the surface, the Baltic outflow off the Norwegian coast reached farther west than in preceding years. In the Fair Isle Channel, salinity values greater than 35.25 were observed, and salinity off the British coast was also higher than in preceding years.

In 2005, run-off from the rivers Elbe and Weser was close to the long-term mean after a minimum run-off in 2004. This led to a small decrease in surface salinity at Helgoland in 2005.

Temperature and salinity at two positions in the northern North Sea illustrate conditions in the Atlantic inflow (Figure 40). The first (A) is at the near bottom in the northwestern part of the North Sea, and the second (B) is 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 previous winter's conditions. The average temperature at location (A) was 1–2°C lower than location (B), and the salinity was also slightly lower. In both places, there were high temperatures and salinities in 2005. This was the result of the high salinity of the inflowing Atlantic water and the effect of a mild winter (though the relatively cold winter and spring of 2005 lead to less extreme temperatures in the deep layers than in 2004).

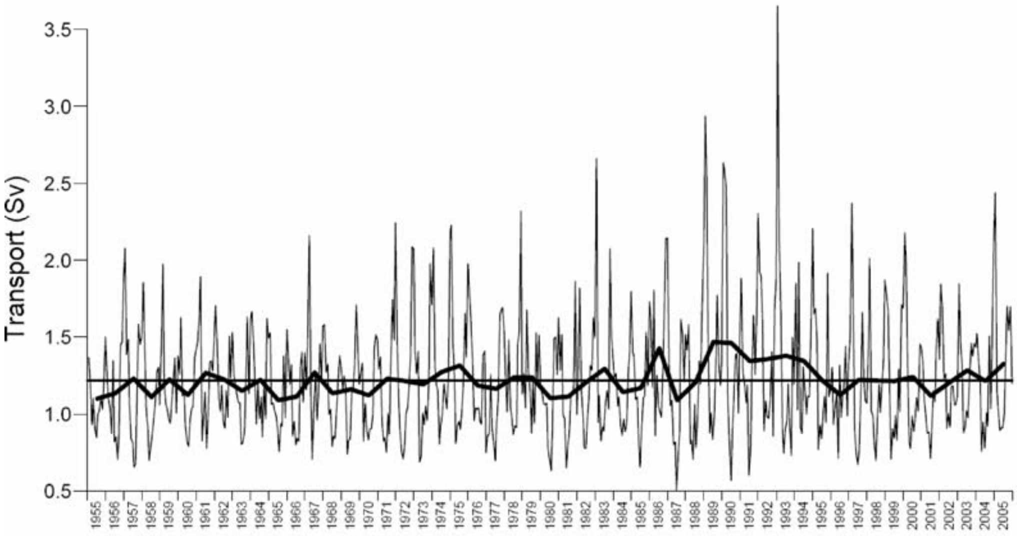


Figure 37: Areas 8 and 9 – Northern and southern North Sea. Modelled annual mean (bold) and monthly mean volume transport of Atlantic water into the northern and central North Sea southward between the Orkney Islands and Utsira, Norway.

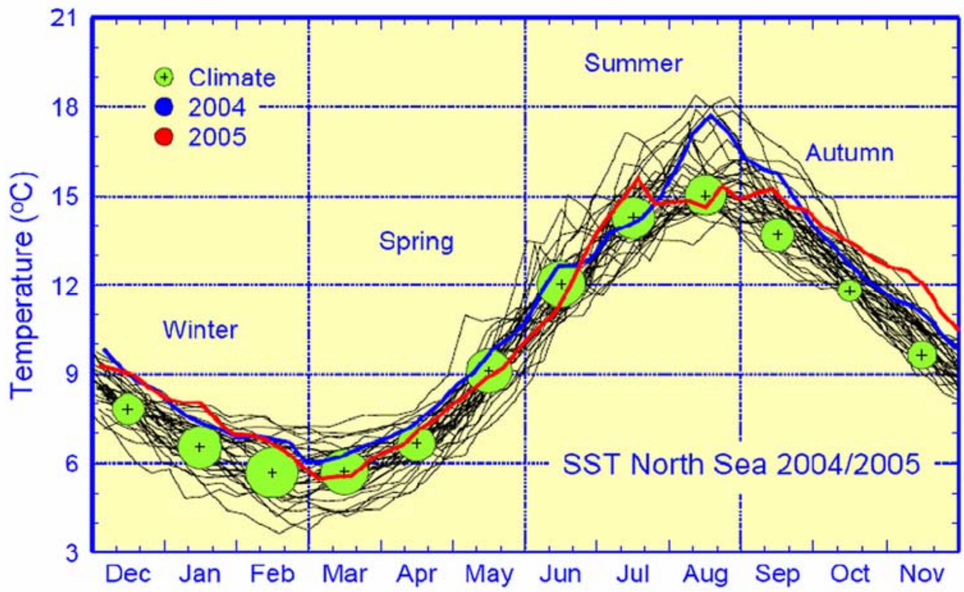


Figure 38: Areas 8 and 9 – Northern and southern North Sea. North Sea area-averaged Sea Surface Temperature (SST) annual cycle; monthly means based on operational weekly North Sea SST maps. Climatology 1971–1993 green dots; blue line 2004, red line 2005; black thin lines individual years.

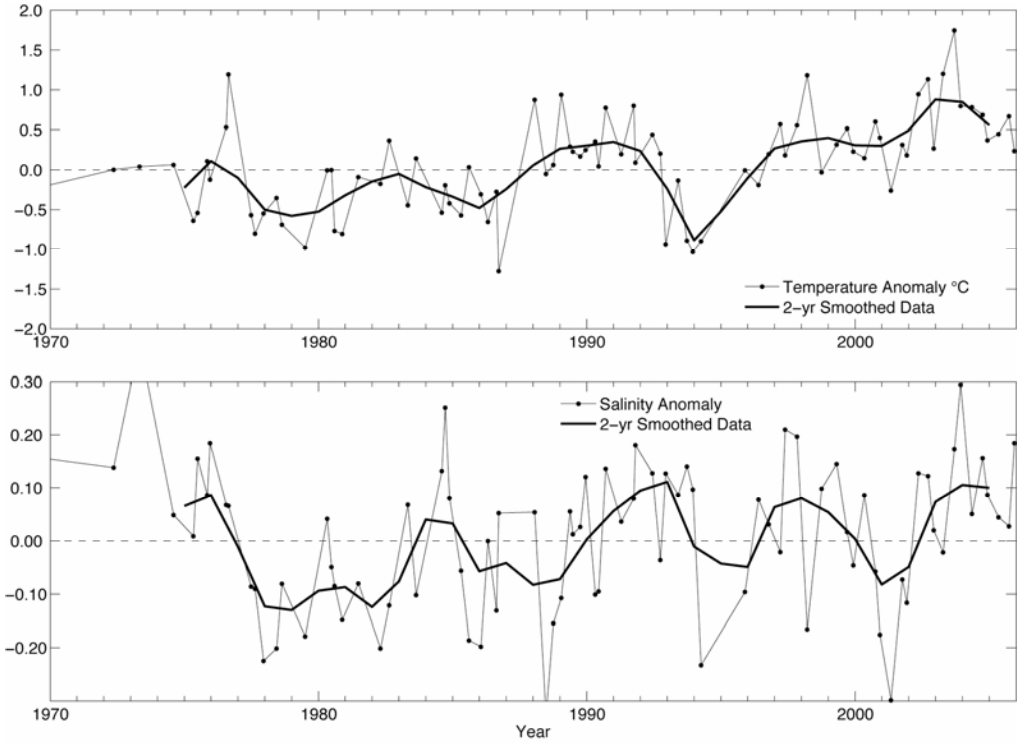


Figure 39: Areas 8 and 9 – Northern and southern North Sea. Temperature anomaly (upper panel) and salinity anomaly (lower panel) in the Fair Isle Current entering the North Sea from the North Atlantic.

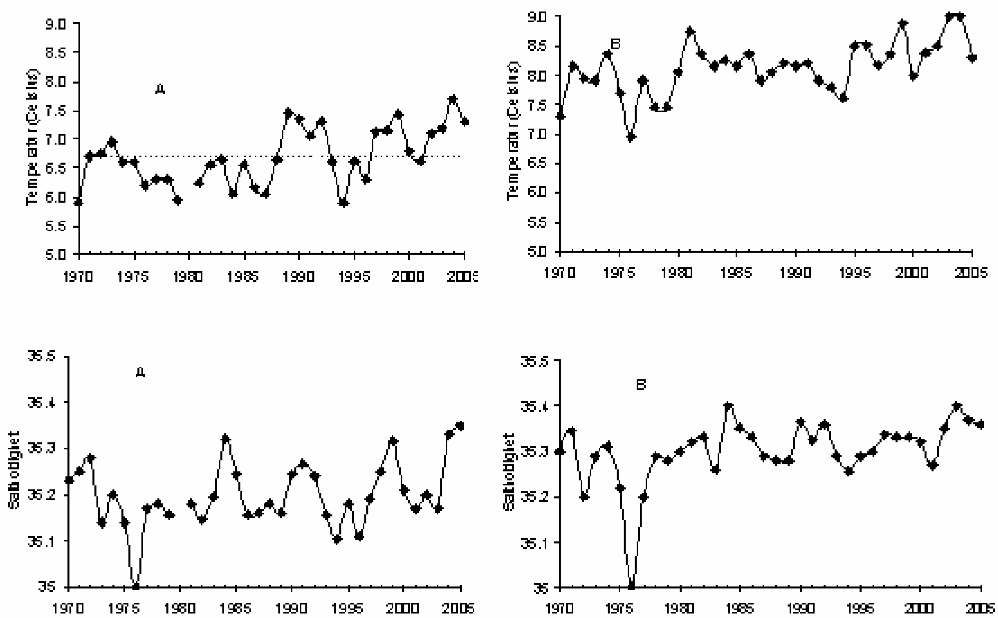


Figure 40: Areas 8 and 9 – Northern and southern North Sea. Temperature (upper panel) and salinity (lower panel) near the sea-floor in the northwestern part of the North Sea (A) and in the core of Atlantic water at the western shelf edge of the Norwegian Trench (B) during the summers of 1970–2005.

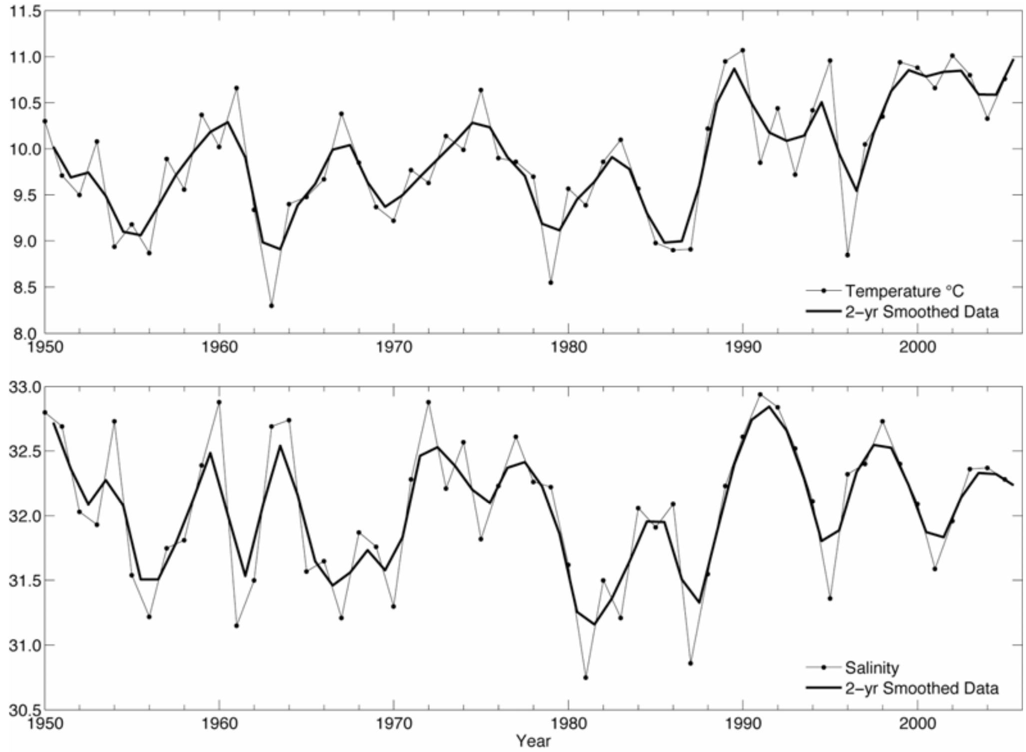


Figure 41: Areas 8 and 9 – Northern and southern North Sea. Annual mean surface temperature (upper panel) and salinity (lower panel) at Station Helgoland Roads.

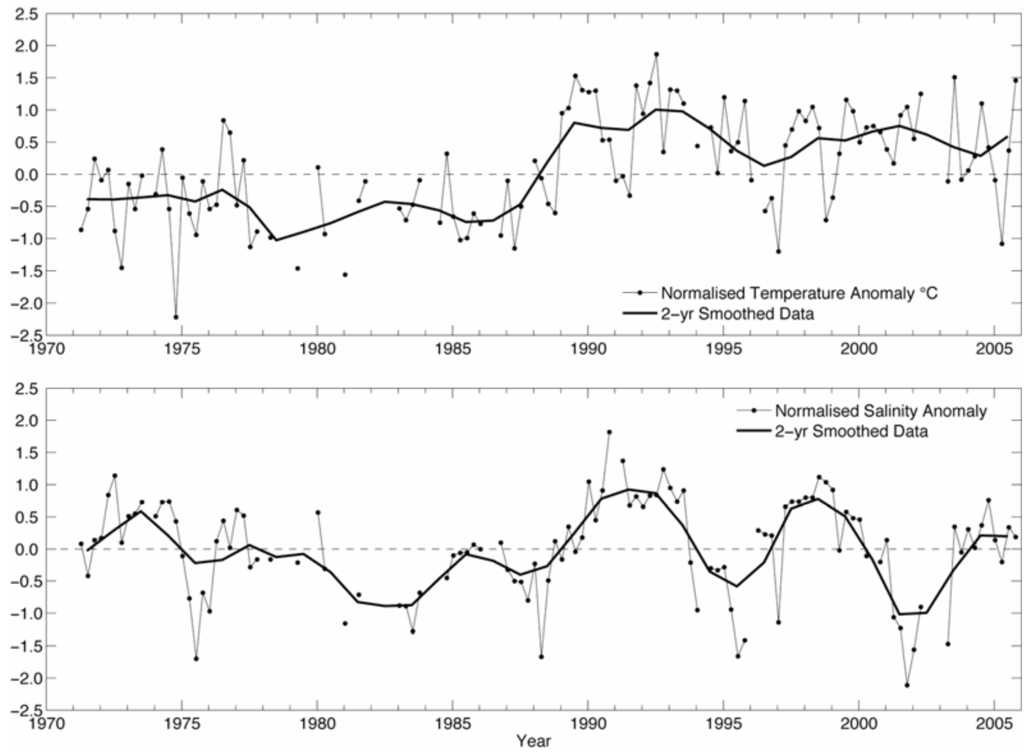


Figure 42: Areas 8 and 9 – Northern and southern North Sea. Time-series of normalized sea surface temperature anomaly (upper panel) and salinity anomaly (lower panel) relative to the period 1971–2000 measured along 52°N, a regular ferry at six standard stations. The time-series in black show the seasonal section average (DJF, MAM, JJA, SON) of the normalized variable.

6.13 Area 9b – Skagerrak, Kattegat, and the Baltic

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

The most dramatic event during 2005 was the storm Gudrun that hit the Nordic region during 8 and 9 January. The total amount of water in the Baltic Sea was already well above mean level in January and this, coupled with the storm, caused sea levels to reach record values in the Gulf of Finland. In St. Petersburg, water levels reached 2.5 m above reference, and on the Swedish west coast, the sea level rose 1 m in six hours.

In general, the hydrographic conditions in 2005 were close to the long-term mean values. Owing to warm weather at the end of June and beginning of July, the highest sea surface temperatures were reached during the first half of July in the Baltic Sea as well as in Kattegat and coastal Skagerrak, which is half-a-month earlier than average. In autumn, the surface temperatures were somewhat higher than the mean values. The surface salinity was slightly above average in the southern part of the Baltic.

Long-term hydrographic time-series are shown for two stations, LL7 in the Gulf of Finland and BY15 in the Baltic Proper. At station LL7, a very weak trend toward warmer summers might be seen. The summer sea surface salinity has decreased slightly in the long run. In the deeper parts of the Gulf of Finland, the salinity is rather variable because of the dynamics and the large horizontal salinity gradients. However, the decrease in salinity from the early 1970s to the early 1990s is evident.

Since 1993, there has been a slight trend toward higher salinity. In May 2005, there was a short period when the salinity at 70-m depth was larger than ever since the early 1980s. The yearly mean surface salinity at station BY15 continued to increase somewhat in 2005, and the downward trend seen from the late 1970s seems to have turned.

During 2005, only two minor deepwater inflows to the Baltic Sea took place, one in January and one in November. On both occasions, the volume was around 35 km3. The November event brought very saline and warm water to the Arcona Basin. The influence of the inflows was restricted to the southwestern parts of the Baltic and lasted only for short periods. The outflow from the Baltic was close to mean values except for January and February, when it was well above average. The net outflow from the Baltic during 2005 was higher than the mean value.

The ice winter 2004/2005 was classified as average, with the maximum ice extent occurring on 16 March 2005.

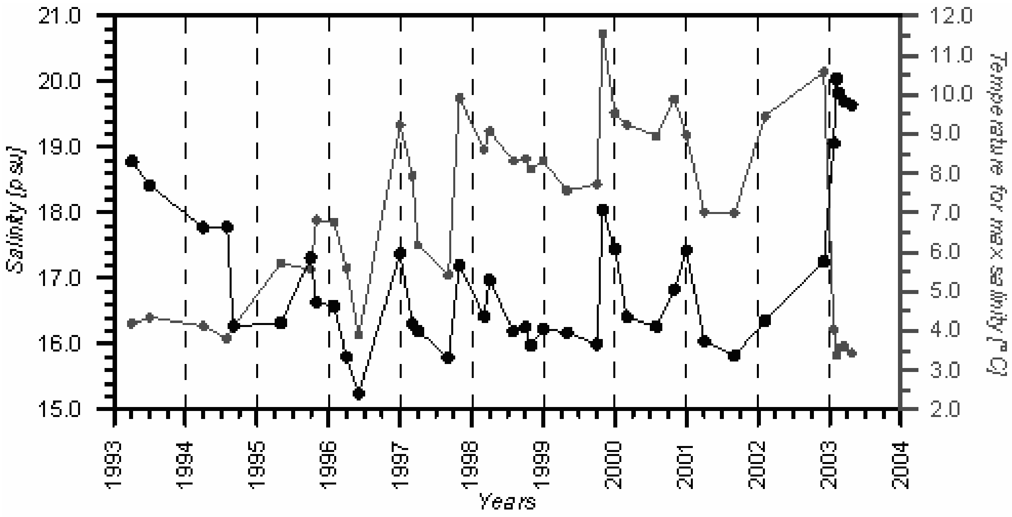


Figure 43: Area 9b – Skagerrak, Kattegat, and the Baltic. Maximum salinity and temperature of the bottom water in the Bornholm Basin (the Baltic Proper).

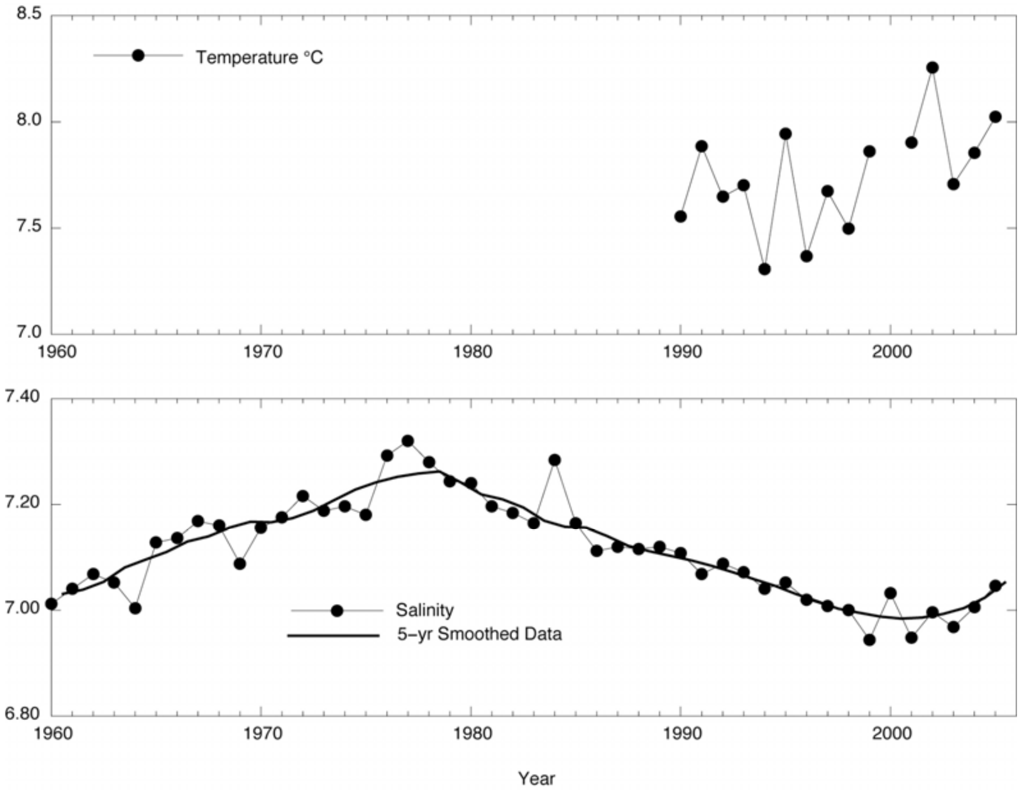


Figure 44: Area 9b – Skagerrak, Kattegat and the Baltic. The surface temperature (upper panel) and surface salinity (lower panel) at station BY15 (east of Gotland) in the Baltic proper.

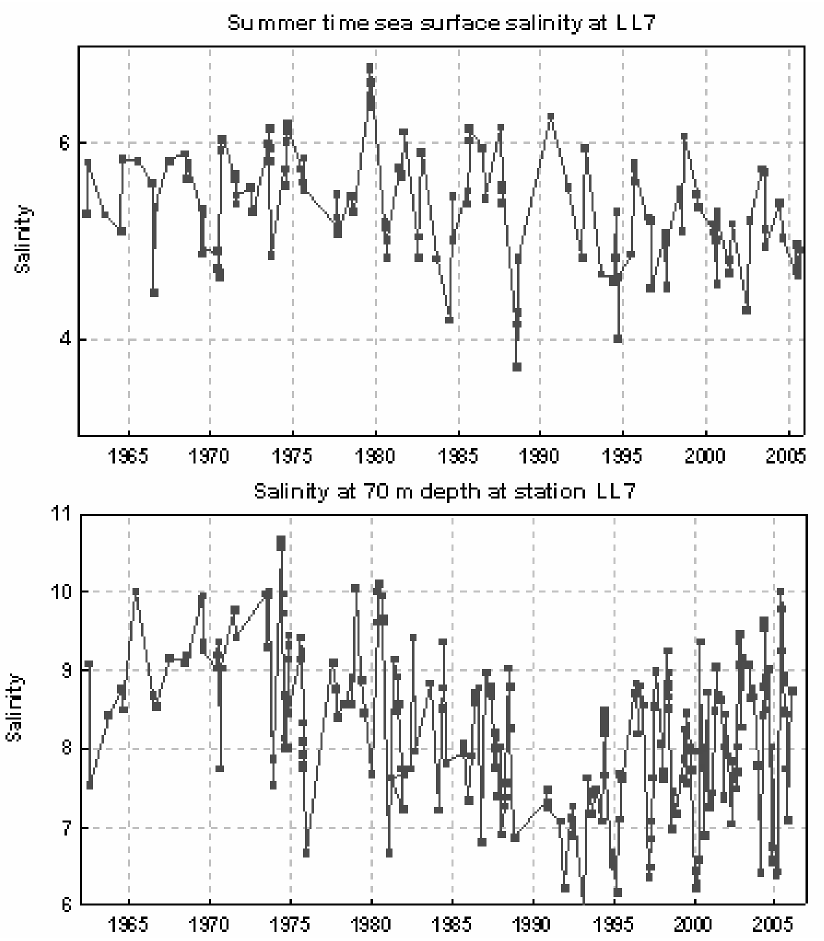


Figure 45: Area 9b – Skagerrak, Kattegat, and the Baltic. Time-series of salinity in the Gulf of Finland.

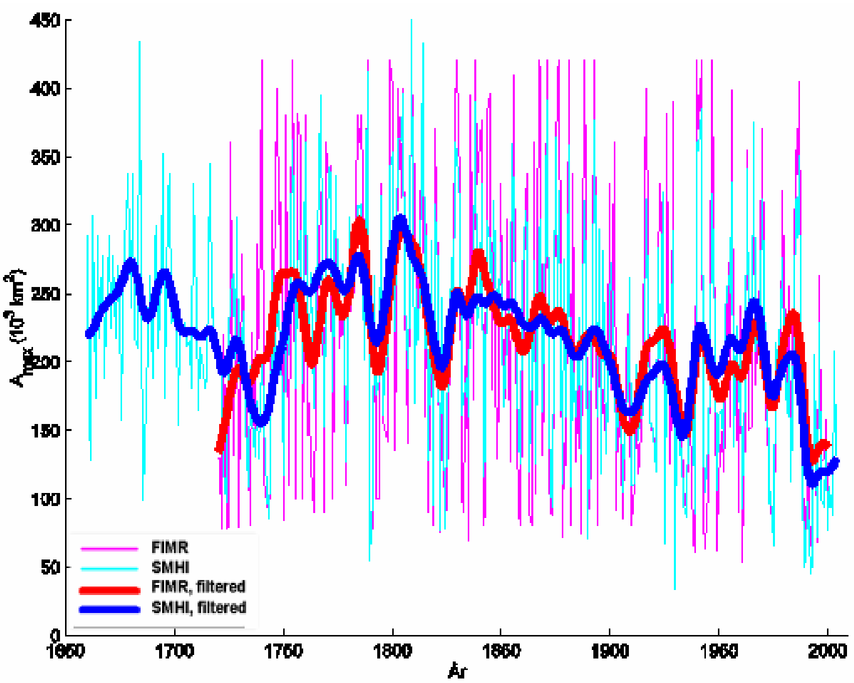


Figure 46: Area 9b – Skagerrak, Kattegat, and the Baltic. Yearly maximum ice extent in the Baltic Sea (thin lines) and low pass filtered data (thick lines). Data to 2004 only.

6.14 Area 10 – Norwegian Sea

The Norwegian Sea is characterized by warm Atlantic Water on the eastern side and cold Arctic water on the western side, separated by the Arctic Front. Atlantic water enters the Norwegian Sea through the Faroe Shetland Channel and between the Faroes and Iceland via the Faroe Front. A smaller branch, the North Icelandic Irminger Current, enters the Nordic Seas on the western side of Iceland. The Atlantic water flows northwards as the Norwegian Atlantic Current splits when it reaches northern Norway; some enters the Barents Sea, while the rest continues northwards into the Arctic Ocean as the West Spitsbergen Current. Arctic waters are transported into the Norwegian Sea from the south-flowing East Greenland Current mainly via the East Icelandic and Jan Mayen Currents.

Three sections from south to north in the eastern Norwegian Sea show the development in temperature and salinity in the core of Atlantic Water (Svinøy, Gimsøy, and Sørkapp). In general, there has been an increase in temperature and salinity in all three sections from the mid-1990s to the present. In 2002–2004, the temperature in the Svinøy section had the largest values in the time-series. Now, the temperature increase can also be observed in the Sørkapp section. In 2005, the temperature and salinities were 0.4°C, 0.5°C, and 1.0°C and 0.09, 0.08, and 0.07 above the long-term-mean for the time-series in the Svinøy, Gimsøy, and Sørkapp sections, respectively. The high salinity values reflect saltier Atlantic Water in the Faroe Shetland Channel.

Ocean Weather Station "Mike" located at 66°N 2°E showed the 2005 temperature and salinity at 50 m to be above the long-term mean, though there was a slight decrease in both from 2004 values. At 2000 m, the temperatures continued the upward trend begun in the mid-1980s, though salinity was lower in 2005 than in recent years.

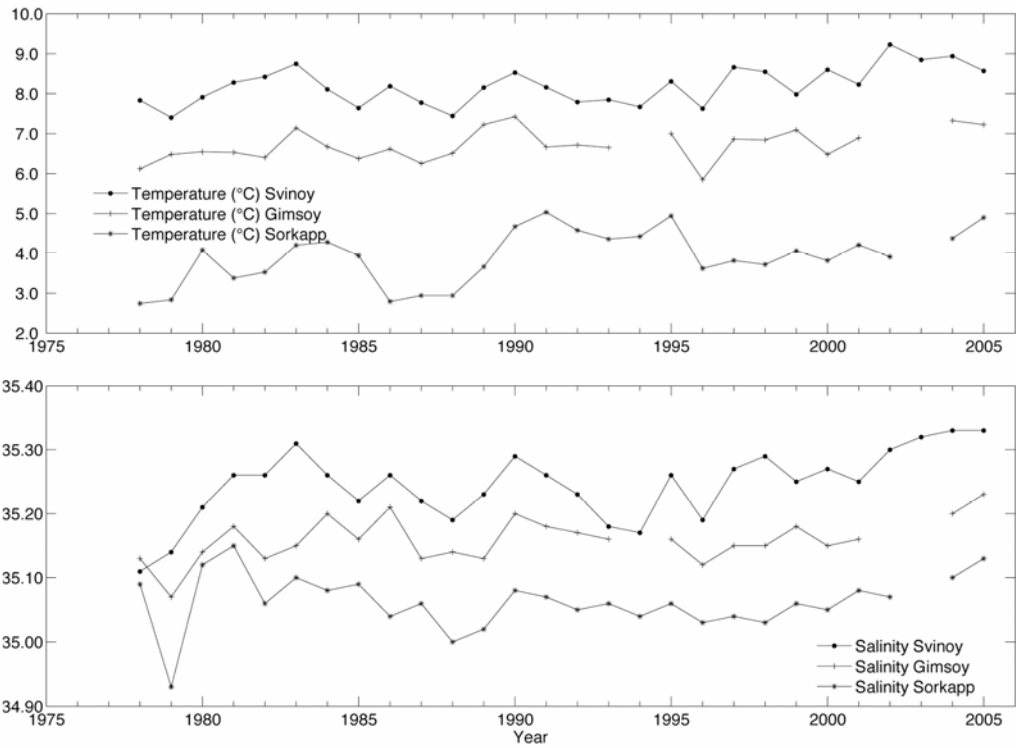


Figure 47: Area 10 – Norwegian Sea. Average temperature (upper panel) and salinity (lower panel) above the slope at three sections, Svinøy (63°N), Gimsøy (69°N), and Sørkapp (76°N).

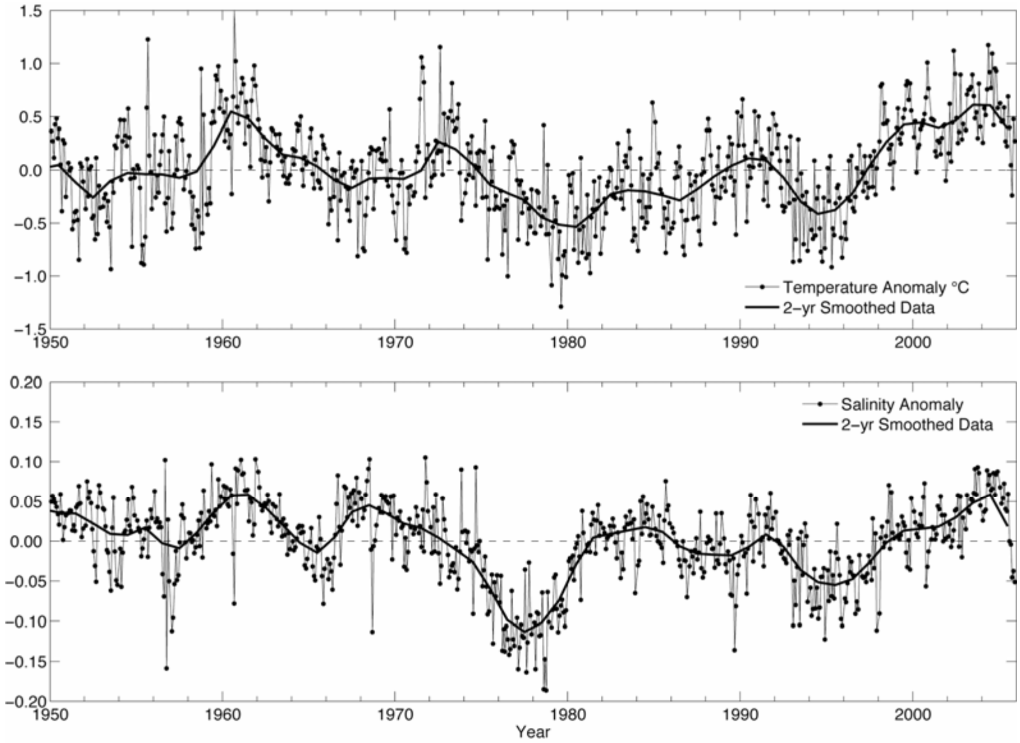


Figure 48: Area 10 – Norwegian Sea. Temperature anomaly (upper panel) and salinity anomaly (lower panel) at 50-m depth at Ocean Weather Station "Mike" (66°N 2°E).

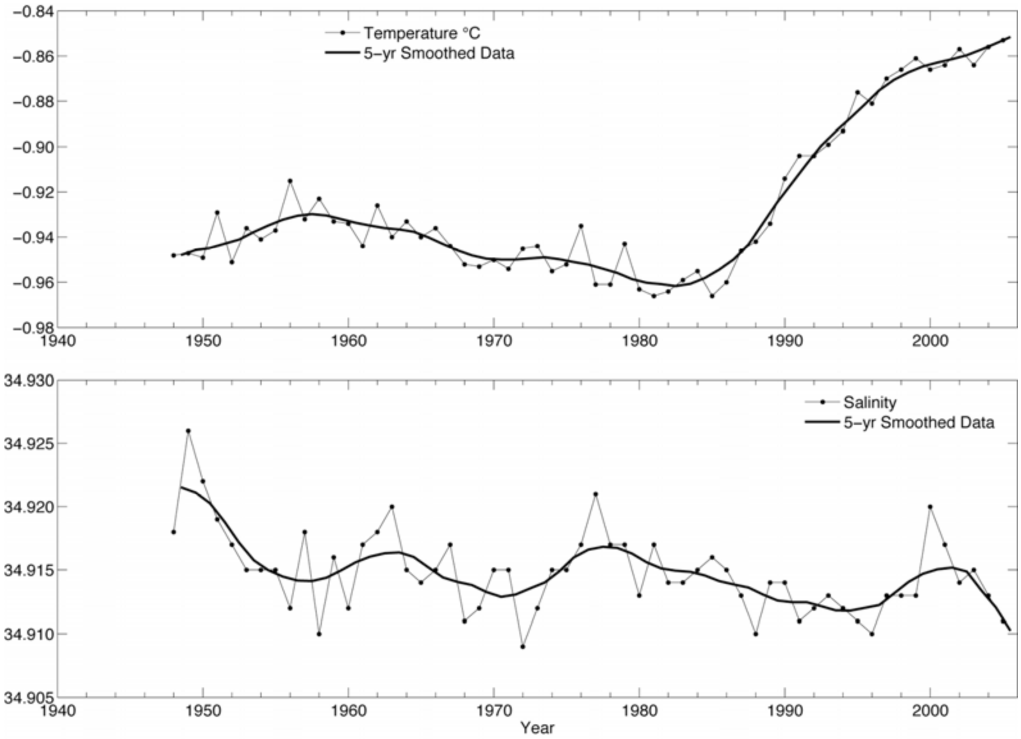


Figure 49: Area 10 – Norwegian Sea. Temperature (upper panel) and salinity (lower panel) at 2000-m depth at Ocean Weather Station "Mike" (66°N 2°E).

6.15 Area 11 – Barents Sea

The Barents Sea is a shelf sea, receiving an inflow of warm Atlantic water from the west. The inflow shows considerable seasonal and interannual fluctuations in volume and water mass properties, particularly in heat content and, consequently, ice coverage.

After a period with high temperatures in the first half of the 1990s, the temperatures in the Barents Sea dropped to values slightly below the long-term average over the whole area in 1996 and 1997. From March 1998, the temperature in the western area increased to just above the average, while the temperature in the eastern areas stayed below the average during 1998. From the beginning of 1999, there was a rapid temperature increase in the western Barents Sea that also spread to the eastern part of the Barents Sea. Since then, the temperature has stayed above average.

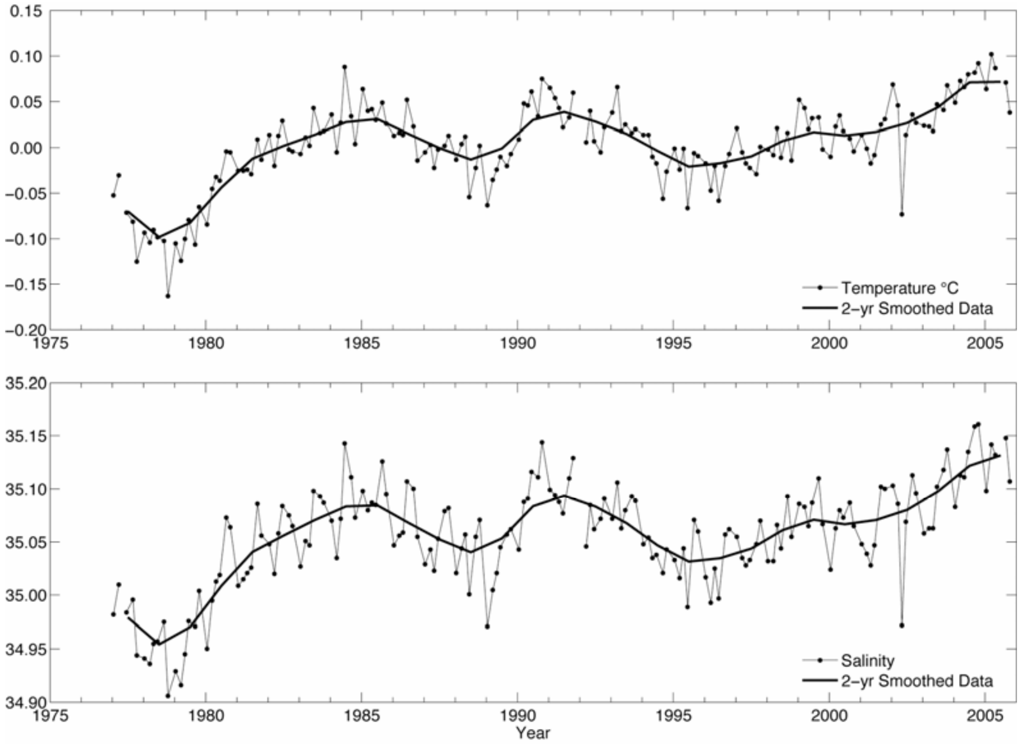


Figure 50: Area 11 – Barents Sea. Temperature (upper panel) and salinity (lower panel) in the Fugløya–Bear Island section.

The year 2005 began with temperature anomalies about 1ºC above the average in most of the southern Barents Sea. During spring and summer, the temperature decreased relative to the long-term mean, and the positive anomalies were approximately 0.5ºC. During late autumn, the temperature increased rapidly in the southern Barents Sea and reached a new all-time high during the end of 2005 and beginning of 2006. In the western Barents Sea, the temperature was almost 1.5ºC above the long-term average, while further east, the positive temperature anomaly was 1.1ºC. Generally, the ice coverage in the Barents Sea during the year was less than normal.

Current measurements showed a strong inflow of Atlantic water in January and February 2005, and after a short period with low inflow, the inflow during summer and early fall of 2005 was above average.

The water temperature in the southern Barents Sea in 2006 is expected to be higher than the long-term mean. The positive anomaly will decrease during spring and summer compared with the winter anomaly.

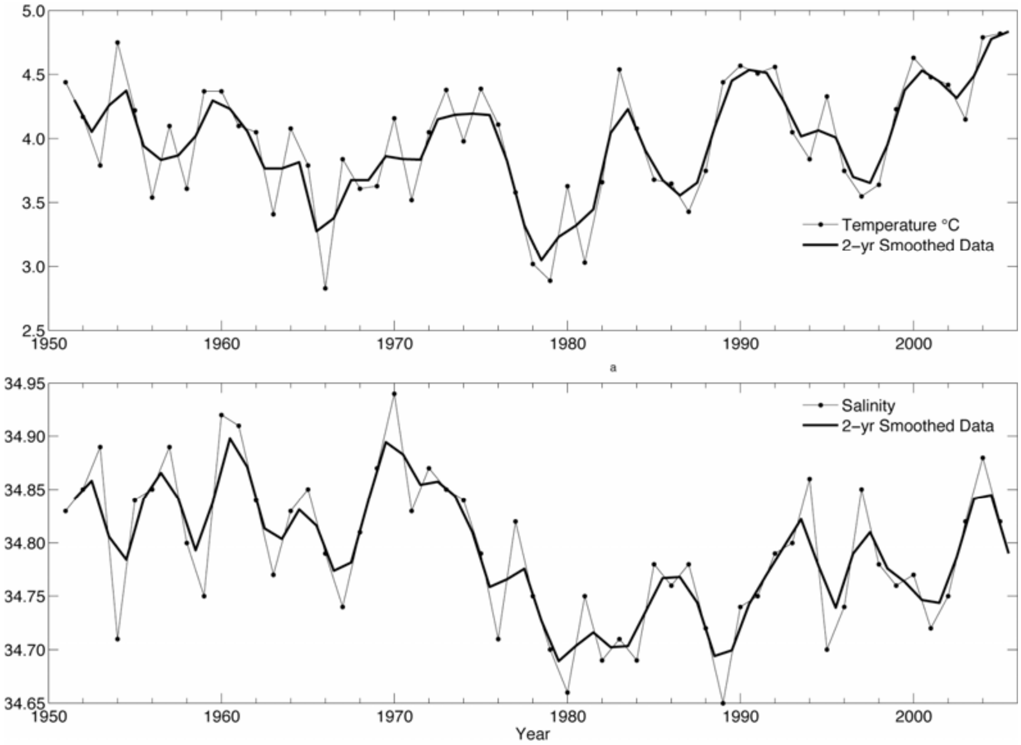


Figure 51: Area 11 – Barents Sea. Temperature (upper panel) and salinity (lower panel) in the Kola section (0–200 m).

6.16 Area 12 – Greenland Sea and Fram Strait

The Greenland Sea and its northern border, Fram Strait, form the main pathway taken by the Atlantic water before entering the Arctic Ocean. The Atlantic water is carried northwards by the West Spitsbergen Current, and volume and heat fluxes show strong seasonal and interannual variations. A significant part of the Atlantic water also recirculates within Fram Strait and returns southward. Polar water from the Arctic Ocean flows southwards in the East Greenland Current and affects water masses in the Nordic Seas.

Besides advection, the bottom-water renewal by the deep convection determines the hydrographic conditions in the Greenland Sea. Since the late 1980s, no bottom-water renewal has taken place. At the standard section at 75°N, the deepwater properties have changed toward higher temperatures and salinities. A doming structure in the Greenland Gyre was replaced by the two-layered water mass arrangement with a density step, currently located at approximately 1800 m. The winter convection seems to have reached only approximately 1000 m, except in small-scale convective eddies, where it has been significantly deeper.

In 2005, a very strong increase of mean temperature and salinity was observed in the Atlantic Water and Return Atlantic Water, continuing the change found in 2004. Temperatures and salinity of Atlantic Water have reached maximum values since the beginning of observations (Tmax = 5.61°C and Smax = 35.16). After a long period of colder and less saline conditions in previous years, the temperature and salinity of Return Atlantic Water in 2005 recovered to the high values from the mid-1990s, resulting in positive anomalies from the long-term mean.

From the series of hydrographic sections between Norway and Svalbard, temperature and salinity values of the Atlantic Water in June/July 2005 were higher than those observed in summer 2004 and higher than the mean properties for the summers of 2000–2005. Large areas (up to 150 km radius) of strong temperature, salinity, and heat content anomalies (calculated in reference to June/July 2000–2005 mean) were observed in the western part of the West

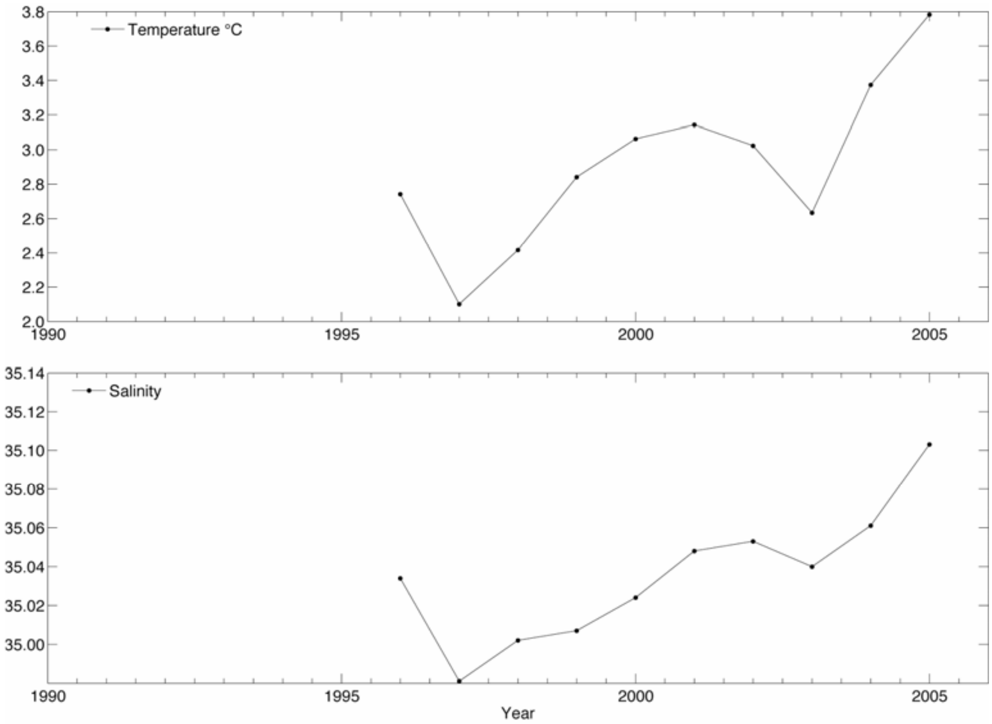


Figure 52: Area 12 – Greenland Sea and Fram Strait. Temperature (upper panel) and salinity (lower panel) at 200 m in the Spitsbergen section (76°30'N).

Spitsbergen Current, over the Mohns and Knipovitch Ridges, at 73° and 76°N. For the standard section at 76°30'N, temperature and salinity at 200 dbar, averaged between 9–12E, was 3.78°C and 35.10, respectively in 2005, compared to 3.37°C and 35.06 in 2004. West of the Spitsbergen slope, temperature and salinity of Atlantic Water reached the highest values observed since 1996 (4.90°C and 35.13 at 200 dbar). In the entire Fram Strait region, the warm signal was broad and shifted westward. Based on upstream observations, it is expected that heat transport through the Fram Strait will increase in 2006.

In the Fram Strait at 78°50'N, three characteristic areas can be distinguished in relation to the main flows: the West Spitsbergen Current between the shelf edge and 5°E, the Return Atlantic Current between 3°W and 5°E, and Polar Water in the East Greenland Current between 3°W and the Greenland Shelf. In 2005, temperatures in the West Spitsbergen Current were still high, as observed in 2004, while salinity increased further, reaching the maximum for the whole time-series (Smax = 35.08). Strong warming and salinification were observed in the Return Atlantic Current and East Greenland Current domains. The strongest increase of temperature and salinity found in the East Greenland Current domain resulted from continued westward shift of the boundary between the recirculating Atlantic Water and Polar waters. The intermediate layer with temperature over 2.5°C has been observed farthest west since the beginning of observations, reaching the edge of the east Greenland shelf, where its thickness was doubled. In the recirculation area (Return Atlantic Current), the thickness of the Atlantic Water layer (T >2°C, S >34.92) was nearly the same as in the West Spitsbergen Current. Mean temperature and salinity in the layer 50–500 m in three domains were all higher than the long period average and have continued to increase as observed already in 2003 and 2004. The intensification of the northward flow was observed in winter in the West Spitsbergen Current from mooring data, but the annual average of the northward heat flux in 2004/2005 was comparable to the 2003/2004 value.

Hydrographic properties of the Atlantic Water (defined as water mass with T >2°C and S >34.92) reveal the clear trend for the past seven years. Although the area of the cross section occupied by Atlantic Water varied strongly between years, the mean temperature and salinity have been increasing since 1997. A fraction of warm Atlantic Water (T >2°C) in the total Atlantic Water (T >0°C) at the section has been continuously increasing since 2002.

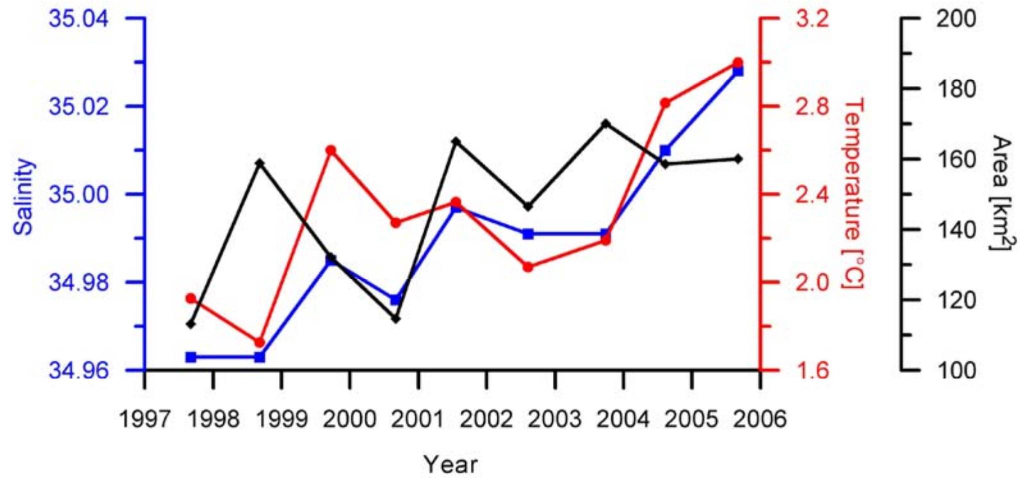


Figure 53: Area 12 – Greenland Sea and Fram Strait. Mean properties of Atlantic Water (T>2°C, S>34.92) in the Fram Strait (78°50'N).

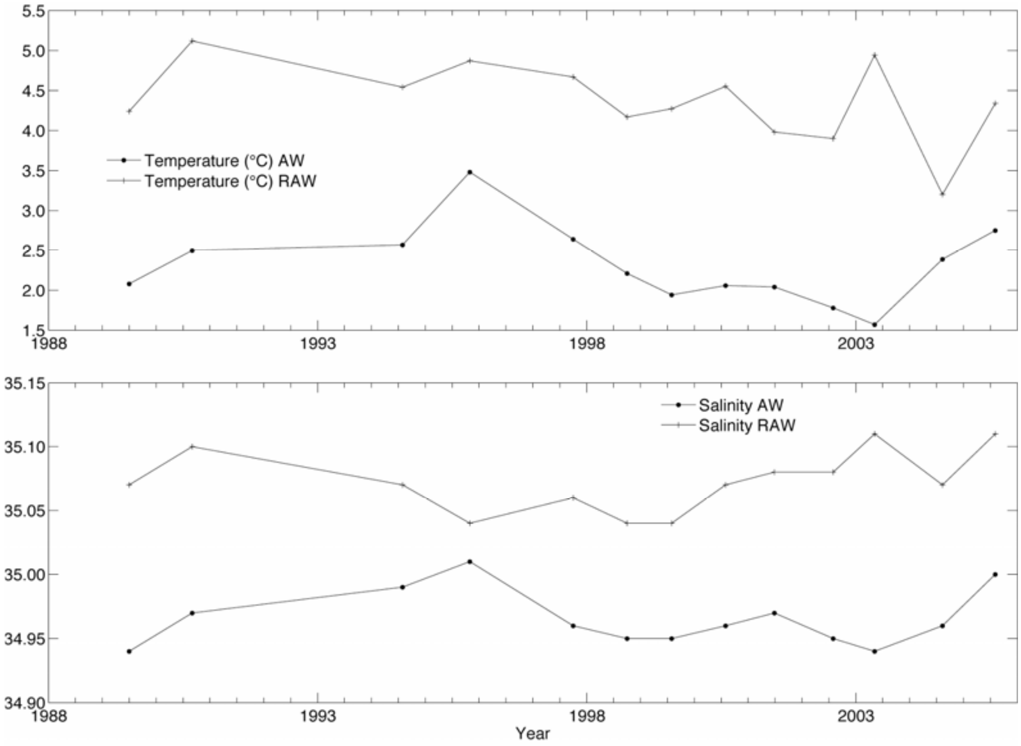


Figure 54: Area 12 – Greenland Sea and Fram Strait. Temperature (upper panel) and salinity (lower panel) anomalies of the Atlantic Water (AW) and Return Atlantic Water (RAW) in the Greenland Sea section at 75°N. Atlantic Water properties are 50–150 m averages at 10°–13°E. The Return Atlantic Water is characterized by the temperature and salinity maximum below 50 m averaged over three stations west of 11.5°W.

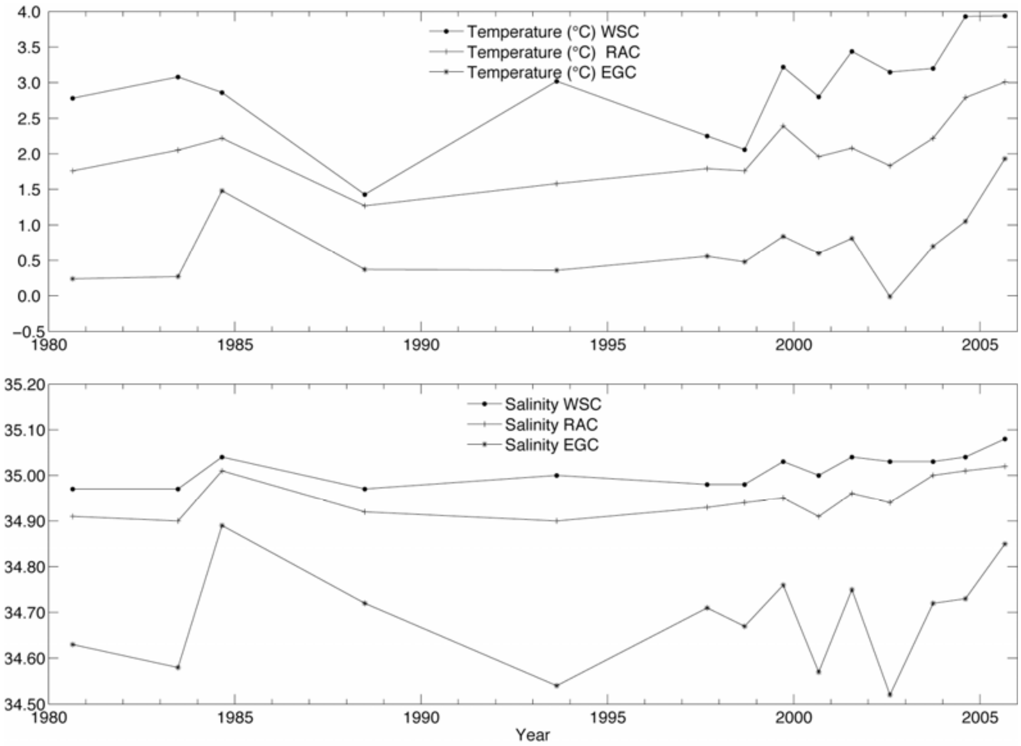


Figure 55: Area 12 – Greenland Sea and Fram Strait. Temperature (upper panel) and salinity (lower panel) anomalies in Fram Strait (78°50'N), in the West Spitsbergen Current (WSC) between the shelf edge and 5°E, Return Atlantic Current (RAC) between 3°W and 5°E, and Polar Water in the East Greenland Current (EGC) between 3°W and the Greenland Shelf for the layer 50–500 m.

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NOAA National Marine Fisheries Service, USA

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Natural Environment Research Council, UK

Polar Research Institute of Marine Fisheries and Oceanography, Murmansk, Russia

Scottish Association of Marine Science, UK

Scottish Executive, UK

Swedish Meteorological and Hydrological Institute, Sweden

Hurrell NAO index: www.cgd.ucar.edu\~jhurrell\nao.stat.winter.html

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