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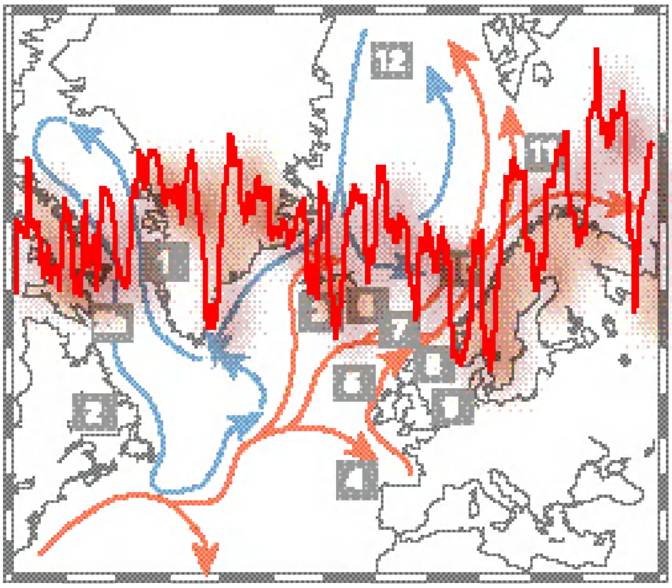
The Annual ICES Ocean Climate Status Summary 2004/2005



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Contents

1 Overview

In almost all areas of the eastern and western North Atlantic during 2004, temperature and salinity in the upper layers remained higher than the long-term average, with new records set in numerous regions. There was isolated cooling off the eastern North American coast. In most areas the trend over the last decade (1994–2004) has been one of warming.

Figure 1 shows annual-mean normalised temperature and salinity anomalies for selected time-series in the upper layers of the ocean around the North Atlantic Region. The trends in these data over the past 10 years are illustrated in Table 1. Table 2 contains additional information about each of the time-series.

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

2 Area summaries

Area 1 – West Greenland

West Greenland experienced warmer than normal air temperatures in 2004. West Greenland shelf waters saw low ice conditions during winter 2003/2004. Mean 0–200 m water temperatures were up to 2°C warmer than normal in autumn 2004.

Area 2 – Northwest Atlantic, Scotian Shelf, Newfoundland and Labrador Shelf

Annual mean air temperatures over the Northwest Atlantic remained above normal during 2004 north of the Scotian Shelf, while values to the south were below normal. Sea-ice coverage during 2004 decreased over conditions in 2003, remaining below normal for the 10th consecutive year on the Newfoundland and Labrador Shelf. Ocean temperatures on the Newfoundland and Labrador Shelf remained above normal, reaching record highs in some areas, continuing the warm trend experienced during the past several years. Further south on the Scotian Shelf, ocean temperatures were below normal (except for the deep basins) and in some areas they decreased to the lowest values since the cold period of the early 1990s. Shelf water salinities which increased to the highest observed in over a decade during 2002 remained above normal in 2004.

Area 2b – Labrador Sea

The upper layers of the Labrador Sea remained warmer and more saline than normal in 2004. Annual mean sea surface temperatures in the west-central Labrador Sea reached record high values.

Area 2c – Mid-Atlantic Bight

Temperatures in the upper layers on the continental slope were close to average in 2004. Further inshore, on the Georges Bank, temperatures were also close to normal, after a period of warming from the mid-1990s until 2003.

Area 3 – Icelandic Waters

Temperature and salinity were, in general, above the long-term mean. Both were well above the mean for the waters south, west and north of Iceland, while conditions were closer to average in the east. The extent of Atlantic water to the north in the northern area was less than the two previous years.

Area 4 – Bay of Biscay and Eastern Atlantic

Meteorological conditions in the north of the Iberian Peninsula indicate that 2004 was an average year resulting from a cold winter and a warm summer. Sea surface temperatures were above the monthly mean value of the time-series from June to October. No substantial changes in temperature and salinity were detected in the water column from below the thermocline down to 300 m due to low advection of warmer and saltier water (winter poleward current) in the southern Bay of Biscay in 2004, which resulted in an average year for temperature and salinity.

Area 5 – Rockall Trough

No update available for 2005.

Area 5b – North Atlantic

No update available for 2005.

Area 6 – Faroe Bank Channel and Faroe Current
No update available for 2005.

Area 7 – Faroe Shetland Channel
Atlantic Waters (NAW and MNAW) flowing through the Faroe Shetland Channel were again much warmer and saltier than normal in 2004, but slightly less than the record high values seen in 2003.

Areas 8 and 9 – Northern and Southern North Sea
In the North Sea, the temperature was above the long-term mean in 2004. The run of positive SST anomalies that started in June 2001 continued through into 2004. The summer SST was the second highest in the record since 1968; the annual maximum heat content has remained above average since 1998. The salinities in most parts of the North Sea were close to the long-term normal, showing increasing influence of the North Atlantic following negative salinity anomalies in recent years.

Area 9b – Baltic, Kattegat and Skagerrak
The hydrographic state of the Baltic Sea, the Kattegat and the Skagerrak were close to average during most of the year. A warm water inflow into the Baltic Sea in the summer had only minor effects on the conditions in the deeper parts of the Baltic.

Area 10 – Norwegian Sea
High values of temperature were observed in Norwegian Sea during 2004. In the southern Norwegian Sea averaged Atlantic water was about 0.5°C above the long-term mean. Along the Norwegian continental slope the core of Atlantic Water was in 2004 0.5–0.8°C warmer than normal with highest anomaly in the south. The salinity was also high in 2004, with values in the southern Norwegian Sea reaching record high values.

Area 11 – Barents Sea
The Barents Sea was warmer than average during 2004. The temperature was 0.3–0.8°C warmer than normal in January–March. For the rest of the year, the temperature was approximately 0.6–1.1°C above the long-term average in the entire southern Barents Sea.

Area 12 – Greenland Sea
In June/July 2004 mean temperature of Atlantic Water west of Spitsbergen coast and in the Fram Strait region was much higher than in 2003. At latitude 76°30', temperature and salinity of the West Spitsbergen Current core in 2004 reached the highest values observed since 1996. In 2004 temperature and salinity in the Greenland Sea and the Fram Strait increased significantly relative to previous year. In the Greenland Sea mean properties were close to the long-term average while in the Fram Strait significantly higher. In the Fram Strait the area of Atlantic Water nearly doubled since 2002. Thus the southward net volume transport due to the stronger East Greenland Current did not prevent the increase of the northward heat transport.

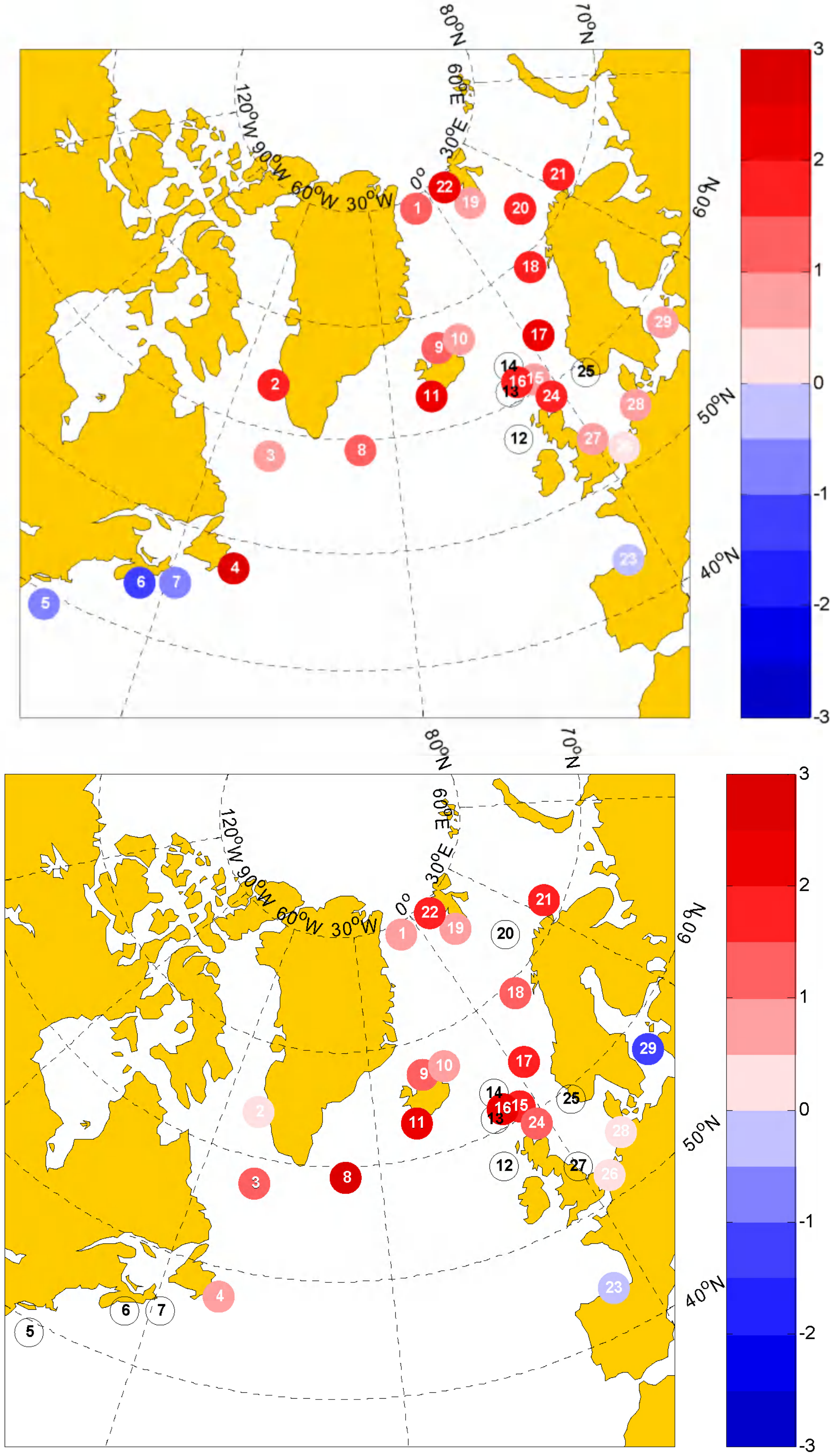


Figure 1: Map of annual anomalies in 2004 of temperature (upper panel) and salinity (lower panel) over the North Atlantic region. The index number can be used to cross reference each point with information in Tables 1 and 2. Unless specified (in Table 2) these are upper layer anomalies. The anomalies are normalised 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 was available for 2004 at the time of publication.

Table 1: Changes in temperature (upper panel) and salinity (lower panel) at selected stations in the North Atlantic region over the last decade. The index number can be used to cross reference each point with information in Figure 1 and Table 2. Unless specified these are upper layer anomalies The anomalies are normalised 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. NaN indicates that no data was available for that particular year at the time of publication.

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
1	NaN	NaN	-0.05	-0.25	0.68	0.06	0.60	-1.52	0.32	1.22
2	0.18	1.61	0.71	1.51	0.95	1.57	1.80	-0.37	2.75	1.54
3	-0.04	-1.08	0.63	0.86	1.07	-0.06	0.20	0.22	1.82	0.73
4	-0.39	2.47	-0.04	-0.04	1.18	1.13	1.24	0.68	1.18	2.94
5	1.74	-1.88	-1.27	-0.80	1.05	1.48	1.11	0.48	-0.17	-0.57
6	0.57	0.98	0.51	-2.64	-0.28	0.28	0.47	0.07	0.07	-1.10
7	-0.80	-0.35	-0.17	0.19	0.84	1.33	-0.16	0.40	-1.43	-0.74
8	-0.43	-0.47	-0.11	0.15	0.75	0.14	0.68	0.54	0.61	1.13
9	-2.73	0.26	0.07	-0.12	0.91	1.10	0.08	-1.28	2.27	1.01
10	-0.90	0.46	-1.13	-0.47	0.12	-0.61	-0.68	-1.44	2.14	0.55
11	-1.51	1.25	1.90	3.07	1.14	0.63	0.84	0.59	2.26	2.20
12	0.40	0.68	2.19	0.67	1.86	0.71	0.07	NaN	1.37	NaN
13	-0.83	0.45	0.76	2.26	-0.13	0.62	1.55	1.62	4.99	NaN
14	-1.92	0.64	0.57	1.80	0.51	0.62	0.57	0.94	3.00	NaN
15	0.19	0.64	1.28	0.90	-0.11	-0.17	0.13	2.41	3.36	2.44
16	-0.48	-0.09	0.28	0.82	0.87	1.21	1.69	3.21	4.37	3.75
17	0.60	-1.11	1.47	1.21	-0.23	1.32	0.41	2.92	1.95	2.19
18	0.92	-2.16	0.55	0.51	1.18	-0.46	0.65	NaN	NaN	1.80
19	1.61	-0.32	-0.03	-0.17	0.31	-0.04	0.54	0.10	NaN	0.78
20	0.82	-0.33	-0.40	0.24	1.32	0.90	0.56	1.09	0.88	1.56
21	0.85	-0.34	-0.75	-0.57	0.65	1.47	1.16	1.04	0.48	1.80
22	NaN	NaN	-0.62	-0.95	1.05	0.32	1.42	0.93	1.01	2.26
23	-1.05	0.20	0.22	0.99	-0.26	-0.60	-0.57	-0.50	-0.15	-0.47
24	-0.18	0.29	1.02	0.96	0.45	0.52	0.69	1.28	1.87	1.56
25	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
26	0.80	-0.34	0.23	0.47	0.53	0.66	0.63	0.90	0.44	0.46
27	0.61	-0.75	0.57	0.19	0.74	0.60	0.49	0.69	0.84	0.68
28	1.52	-1.61	0.18	0.62	1.50	1.11	1.09	1.60	1.29	0.59
29	1.39	-1.28	0.13	-0.68	1.01	NaN	1.20	2.84	0.29	0.98

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
1	NaN	NaN	0.32	-0.04	0.78	-0.95	0.69	-1.40	0.41	0.50
2	0.06	0.27	-0.05	0.15	0.16	0.14	0.51	-0.51	0.49	0.31
3	-0.18	-1.72	0.21	0.61	-0.52	0.39	-0.19	0.58	0.40	1.08
4	-1.73	-0.08	0.33	0.33	-0.44	0.43	-0.88	1.15	0.54	0.93
5	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
6	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
7	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
8	-0.56	-0.59	-1.14	-0.57	2.09	0.12	0.97	2.23	0.73	2.73
9	-1.04	-0.55	-0.52	-0.72	1.42	0.84	0.91	-0.73	1.71	1.21
10	0.58	-0.72	-1.43	-2.24	0.33	1.00	0.57	-0.20	0.48	0.59
11	-1.04	-0.36	1.80	2.50	1.82	1.00	0.84	0.98	2.57	2.40
12	0.38	-0.46	1.03	1.63	1.45	0.76	0.78	NaN	2.45	NaN
13	-0.89	-0.97	0.05	1.62	0.89	1.03	0.78	0.84	3.17	NaN
14	-0.93	-0.36	0.33	1.36	1.18	0.86	0.80	1.05	2.57	NaN
15	0.63	1.01	1.46	2.01	1.38	0.31	1.01	2.46	2.62	2.88
16	0.43	0.43	0.52	1.35	1.63	1.56	1.83	2.62	3.18	2.83
17	0.55	-0.78	0.83	1.19	0.33	0.77	0.35	1.37	1.71	1.91
18	0.30	-1.01	-0.16	-0.03	0.72	-0.09	0.23	NaN	NaN	1.34
19	-0.03	-0.70	-0.49	-0.63	0.16	-0.17	0.55	0.25	NaN	0.95
20	1.17	0.57	0.10	-0.14	-0.50	1.26	1.28	0.58	0.89	NaN
21	-1.05	-0.38	1.45	0.28	-0.05	0.12	-0.72	-0.22	0.95	1.95
22	NaN	NaN	-0.50	-0.50	1.39	0.25	1.76	1.39	1.39	1.76
23	-1.40	0.68	1.01	1.51	0.84	-0.10	-1.37	-0.05	-0.54	-0.29
24	-0.06	0.28	0.35	0.47	0.41	-0.55	-0.68	0.07	0.73	1.04
25	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
26	-1.07	0.24	0.25	0.94	0.49	0.05	-1.06	-1.23	-0.39	0.36
27	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
28	-1.33	0.37	0.52	1.11	0.52	0.08	-0.92	-0.26	0.46	0.47
29	-0.92	-1.25	-1.37	-1.45	-2.00	-1.12	-1.99	-1.50	-1.78	-1.40

Table 2: Details of the datasets included in Figure 1 and Table 1. Grey boxes indicate areas where no measurements are taken. 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	79.00	−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	3.74	0.47	34.69	0.07
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	1971–2000	39.00	−71.50				
6	Emerald Bank - Central Scotian Shelf - Canada	Near Bottom	1971–2000	44.00	−63.00	9.16	0.83		
7	Misaine Bank - North East Scotian Shelf - Canada	Near Bottom	1971–2000	45.00	−59.00	1.57	0.67		
8	Central Irminger Sea	200–400 m	1991–2000	59.00	−36.00	3.99	0.38	34.88	0.38
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 - North East 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 - South West Iceland - Irminger Current	0–200 m	1971–2000	63.00	−22.00	7.58	0.39	35.15	0.03
12	Ellet Line - Rockall Trough - UK (Section Average)	0–800 m	1975–2000	57.00	−10.00	9.27	0.21	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*	1987–2000	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	0.48	35.36	0.05
16	Faroe Shetland Channel - Faroe Shelf (Modified North Atlantic Water)	Upper Layer HSC*	1971–2000	61.50	−6.00	7.85	0.56	35.21	0.04
17	Southern Norwegian Sea - Svinøy Section - Atlantic Water	50–200 m	1978–2000	64.00	2.00	8.07	0.40	35.23	0.05
18	Central Norwegian Sea - Gimsøy Section - Atlantic Water	50–200 m	1978–2000	69.00	10.00	6.66	0.37	35.25	0.03
19	Northern Norwegian Sea – Sørkapp Section - Atlantic Water	50–200 m	1978–2000	76.50	11.00	3.84	0.68	35.06	0.04
20	Fugloya - Bear Island Section - Western Barents Sea - Atlantic Inflow	50–200 m	1971–2000	73.00	20.00	5.22	0.49	35.05	0.04
21	Kola Section - Eastern Barents Sea	0–200 m	1971–2000	71.50	33.50	3.92	0.49	34.76	0.06
22	Fram Strait - West Spitsbergen Current - Section Average 5°E to Shelf edge	50–500 m	1980–2000	79.00	8.00	2.61	0.58	34.99	0.03
23	Santander Station 6 (shelf break) - Bay of Biscay - Spain	5–300 m	1993–2000	43.70	−3.78	12.71	0.17	35.59	0.06
24	Fair Isle Current Water (waters entering North Sea from Atlantic)	0–100 m	1971–2000	59.00	−2.00	9.84	0.53	34.90	0.15
25	Western Edge Norwegian Trench - Atlantic Water Inflow - North Sea	Near Bottom	1971–2000	59.00	5.00				
26	Section Average - Felixstowe – Rotterdam – 52°N	Near Surface	1971–2000	52.00	3.00				
27	UK Coastal Waters - Southern Bight - North Sea	Surface	1971–2000	54.00	0.00				
28	Helogoland Roads - Coastal Waters - German Bight North Sea	Surface	1971–2000	54.19	7.90	9.93	0.67	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*

3 Introduction

Ocean climate data from fifteen areas around the North Atlantic are summarised in this report. Observations in 2004 are compared to the average conditions and to the longer-term trends in each dataset. The key parameters described in the report are seawater temperature and salinity, and less frequently, air temperature. Figure 2 illustrates the general pattern of oceanic circulation in the North Atlantic in relation to the areas described in this report.

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

Where appropriate, data in this report are presented as anomalies in order to show how the values compare to the average or 'normal' conditions. For this report the normal conditions refer to the long-term average of each parameter during the period 1971–2000. For datasets that do not extend as far back as 1971, the average conditions have been calculated from the start of the dataset up to 2000.

Where necessary, the seasonal cycle has been removed from each dataset, either by calculating the average seasonal cycle over the period 1971–2000, or drawing on other sources such as regional climatological datasets.

In the summary tables and figures, normalised anomalies have been presented to allow intercomparison of trends in the data from different regions (Figure 1 and Table 1). The anomalies have been normalised by dividing the values by the standard deviation of the data during the period 1971–2000. Thus a value of +2 represents data (temperature or salinity) that was 2 standard deviations higher then normal.

The North Atlantic Oscillation index (NAO) is a measure of the difference in normalised 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 has been useful in the past to describe the climate of the North Atlantic region. Many of the area descriptions in this report refer to the NAO index and relate it to conditions observed in that 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 2004 was calculated from sea level pressure anomalies between December 2003 and March 2004.

Two slightly different versions of the NAO index are referenced in this report. The Rogers Index is more closely correlated with conditions in the western North Atlantic and the Hurrell index is more closely correlated with conditions over the eastern North Atlantic. The instrumental 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 over the last 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, except for the winter preceding 2001 (Figure 3). 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, however it has remained mainly negative since 1996 with the exception of the two positive winters preceeding 1999 and 2000.

The NAO Indices during 2004 and 2005 are described in the textbox on pages 9 and 10 – The Winter NAO Index.

Sea surface temperate across the whole North Atlantic can also be obtained from a gridded sea-surface temperature (SST) dataset. Figure 4 shows the annual and seasonal SST anomaly for 2004 extracted from the Optimum Interpolation SSTv2 dataset, provided by the NOAA-CIRES Climate Diagnostics Center, in the USA. In high latitudes where *in situ* data is sparse and satellite data are hindered by cloud cover the data may be less reliable. The annual pattern of SST anomaly for 2004 matches very closely that from the *in situ* data (Figure 1 – upper panel). There is a large band of positive anomalies stretching across both sides of the North Atlantic Ocean. The area of negative anomalies on the eastern North American coast is also very clear.

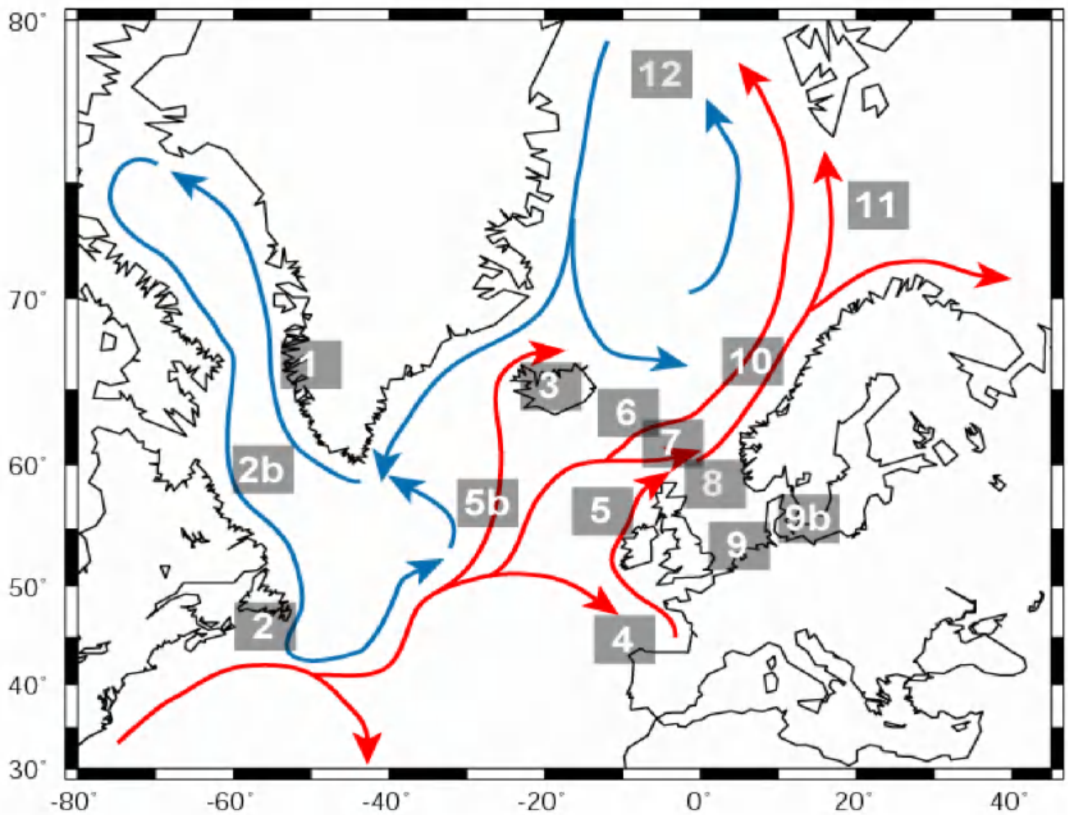


Figure 2: Schematic of the general circulation of the North Atlantic in relation to the numbered areas presented in the Annual ICES Ocean Climate Status Summary. The blue arrows indicate the cooler waters of the sub-polar gyre. The red arrows show the movement of the warmer waters in the sub-tropical gyre.

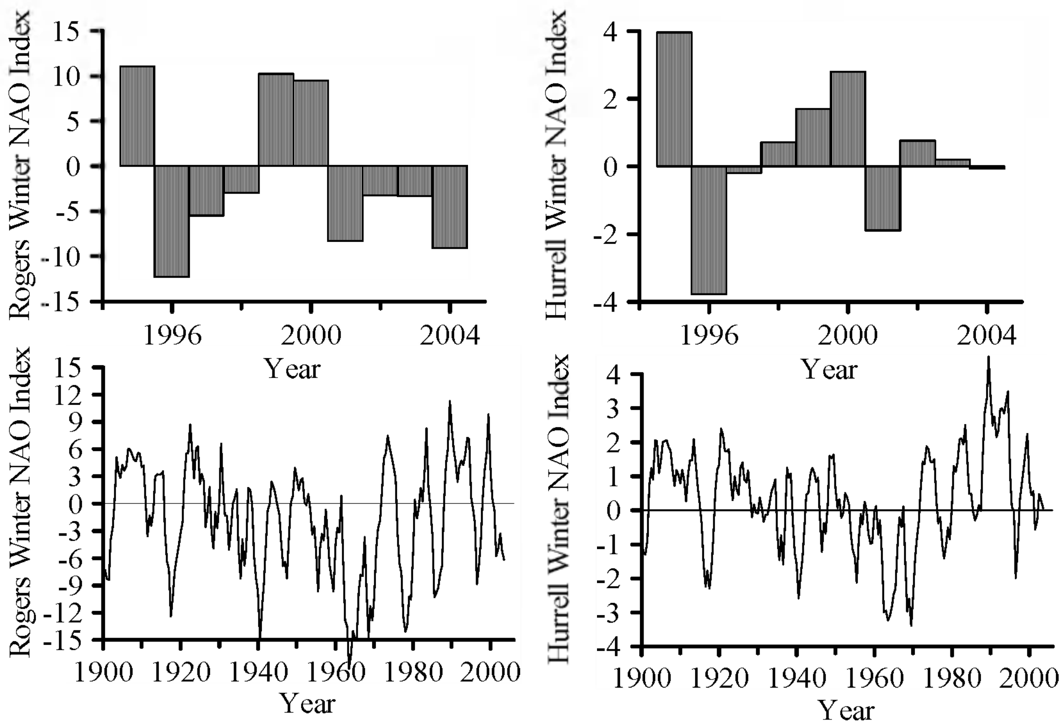


Figure 3: The winter NAO index in terms of the present decade (upper panel) and the last 100 years (lower panel – a two-year running mean has been applied). The Rogers index is presented on the left and the Hurrell index is presented on the right.

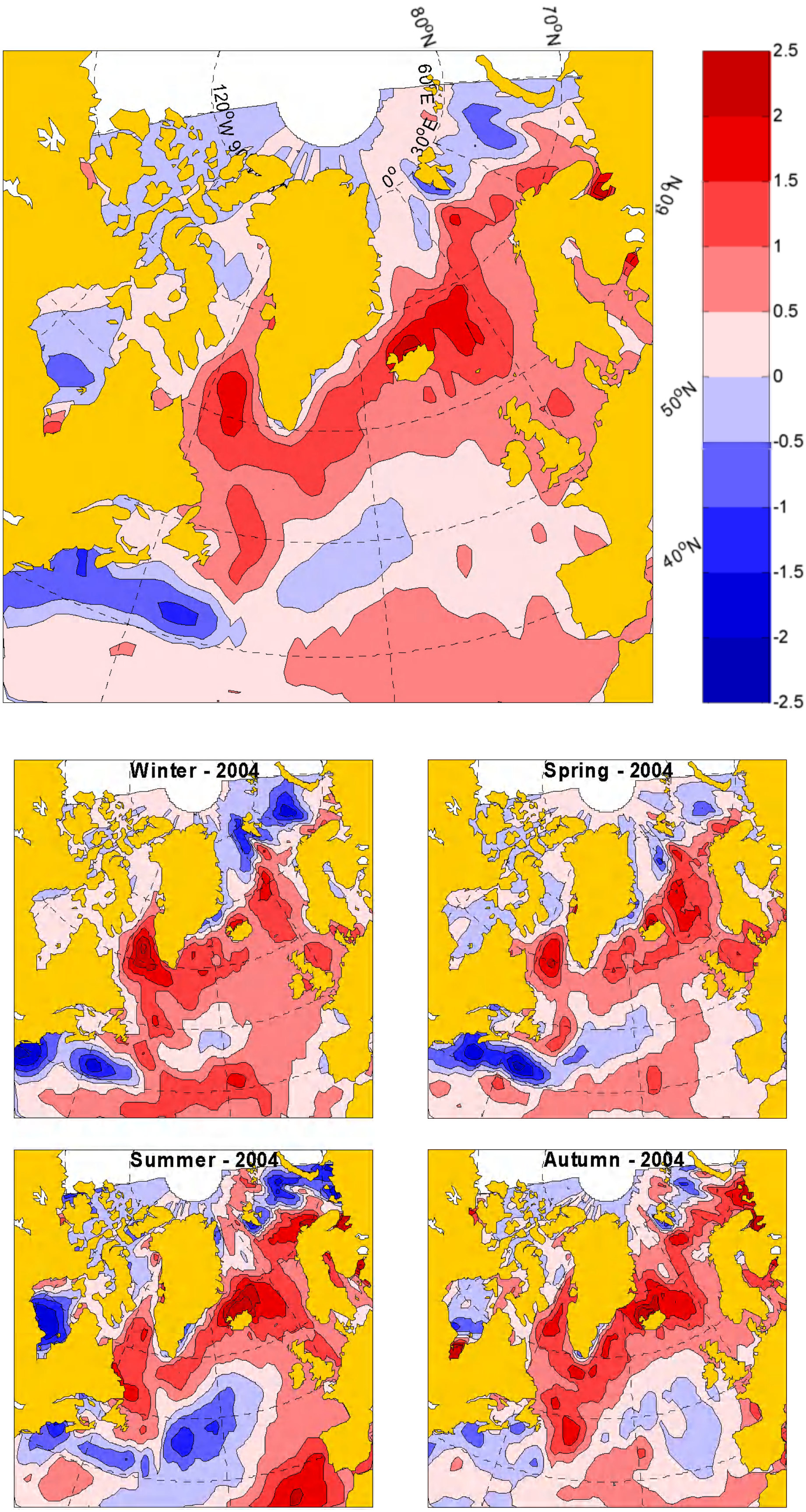


Figure 4: Map of annual (lower panel) and seasonal (lower panel) sea surface temperature anomalies (°C) over the North Atlantic for 2004 from the NOAA Optimum Interpolation SSTv2 dataset, provided by the NOAA-CIRES Climate Diagnostics Center, USA. The colour coded temperature scale is the same in all 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.

Winter North Atlantic Oscillation Index (NAO) in 2003 and 2004

The Hurrell Winter NAO index for 2004 was −0.07, based upon the pressure difference between Iceland and the southern Iberian Peninsula. The Rogers NAO index for 2004, using simple pressure difference between Iceland and the Azores as the southern node, was −7.2 mbar, the strongest negative anomaly for the Rogers version of the index since 1996.

Figure 5a shows the sea pressure anomaly field in the North Atlantic for the composite mean of the four winter months (NCEP/NCAR reanalysis data), the pattern has some of the NAO North south dipole nature. The cause of the very slight negative Hurrell NAO index is the small SLP anomaly between Iceland and Lisbon and the normalisation routine equalizes the effect of greater variance in the Iceland Low compared to the Azores High. Winter-time air temperatures (Figure 5b) reflect these conditions with a warm anomaly over the Labrador Sea and cool conditions south-west of Newfoundland and across the eastern Barents Sea.

Early indications for the winter in 2005 (December 2004–March 2005) are that the index for the winter months will again be negative. Whilst the instrumental NAO indices are likely to be of similar magnitude and signature as in winter 2004, the detailed anomaly in atmospheric forcing across the North Atlantic region appears to have been stronger in 2005. The composite SLP anomaly for the 2005 winter (Figure 6) shows a closed anti-cyclonic anomaly of about 10 mbar centred south of Iceland, with lower than average pressures to the north-east and south-west.

Hurrell NAO index: www.cgd.ucar.edu\~jhurrell\nao.stat.winter.html
Rogers NAO index: http://polarmet.mps.ohio-state.edu/NAO/

Figure 5a

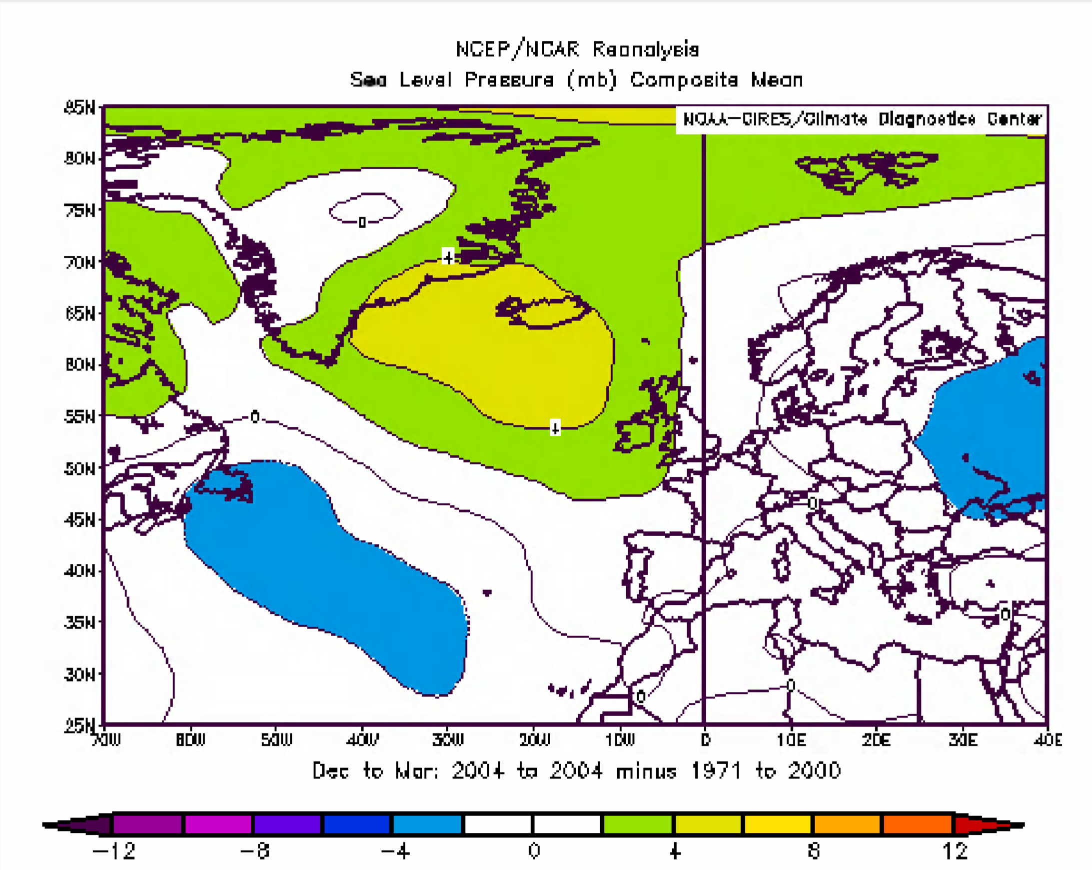
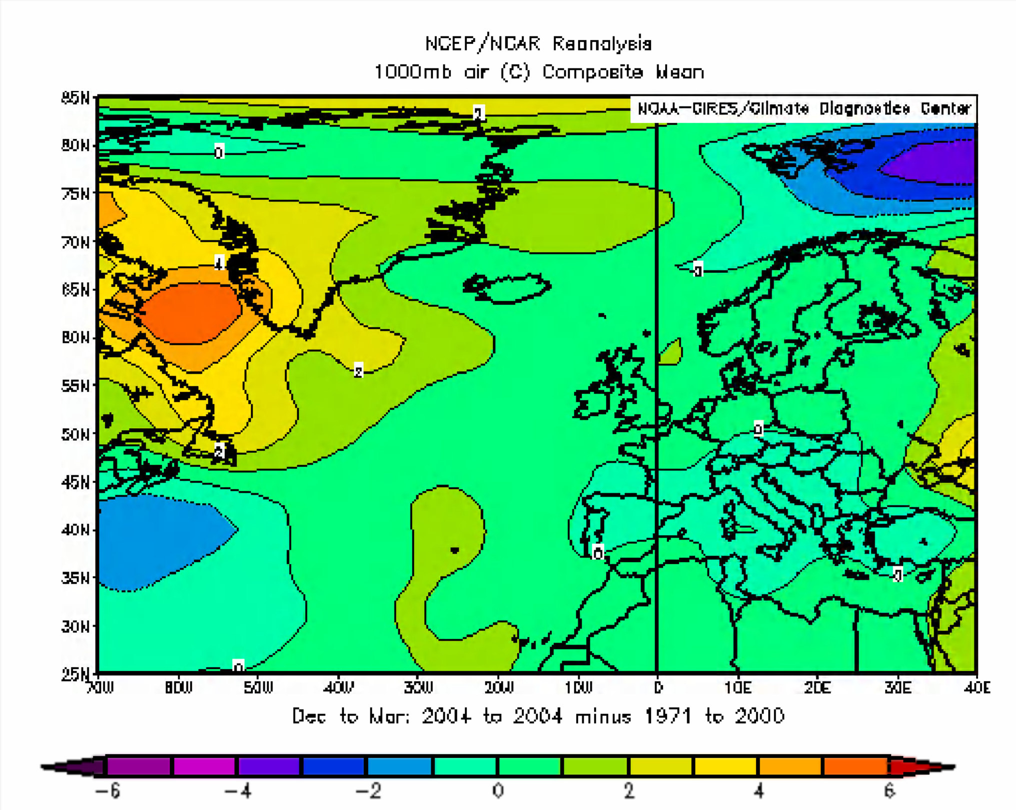


Figure 5: NAO. The North Atlantic distribution of (a) SLP anomaly (b) Air Temperature anomaly for composite period of December 2003 to March 2004, relative to 1971–2000. (NCEP/NCAR Reanalysis data from NOAA-CIRES Climate Diagnostics Center: www.cdc.noaa.gov/Composites).

Winter North Atlantic Oscillation Index (NAO) in 2003 and 2004 (continued)

Figure 5b



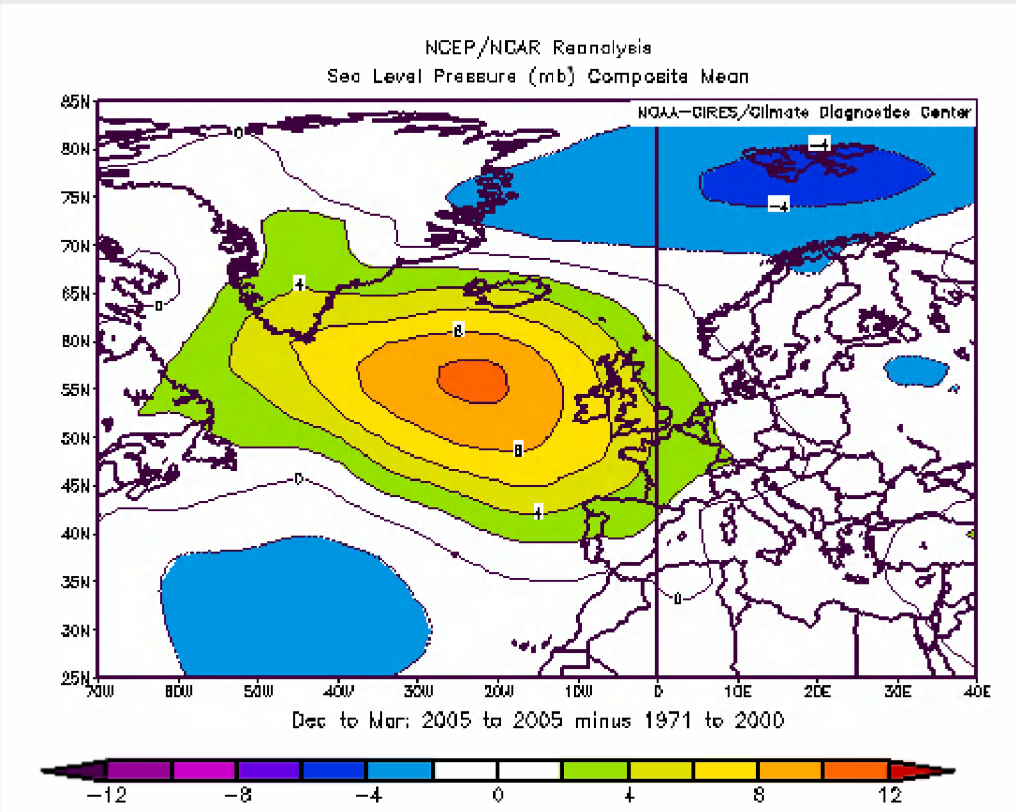


Figure 6: NAO. The Atlantic distribution of SLP anomaly in the North Atlantic for composite December 2004 to March 2005. (NCEP/NCAR Reanalysis data from NOAA-CIRES Climate Diagnostics Center: www.cdc.noaa.gov/Composites).

4 Area descriptions

Area 1 – West Greenland

West Greenland lies within an area that normally experiences warmer conditions when the NAO Index is negative. The pattern of sea level atmospheric pressure over the North Atlantic was anomalous during winter 2003/2004. The pressure anomaly fields during this winter differed considerably from a dipole pattern usually present in the North Atlantic region, with two pressure anomaly cells, one in the Icelandic Low area, the other in the Azores High area. As a consequence of this unusual anomaly pattern, the North Atlantic Oscillation (NAO) index for the winter 2003/2004 was weak and negative.

Air temperature climatic conditions around Greenland continued to be warmer than normal. The climatic conditions at Nuuk are consistent with the NAO index (negative index=mild climate). Annual mean air temperatures at Nuuk in 2004 showed positive anomalies (+1.1°C – Figure 7). Satellite-derived ice charts for 2004 showed reduced ice cover off West Greenland. Autumn 2004 temperatures on the Holsteinsborg section, in the core of the West Greenland Current and on the West Greenland shelf were up to 2°C warmer than normal. At Fylla Bank, subsurface warming during 2004 was in the range of the warm 1960s temperatures, but was less than during autumn 2003 when temperatures were 2.44°C above normal (Figure 8).

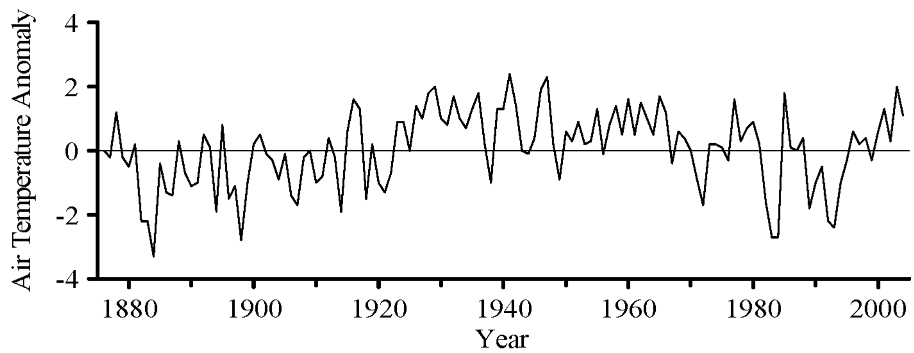


Figure 7: Area 1 – West Greenland. Annual mean air temperature observed at Nuuk for the period 1876–2004.

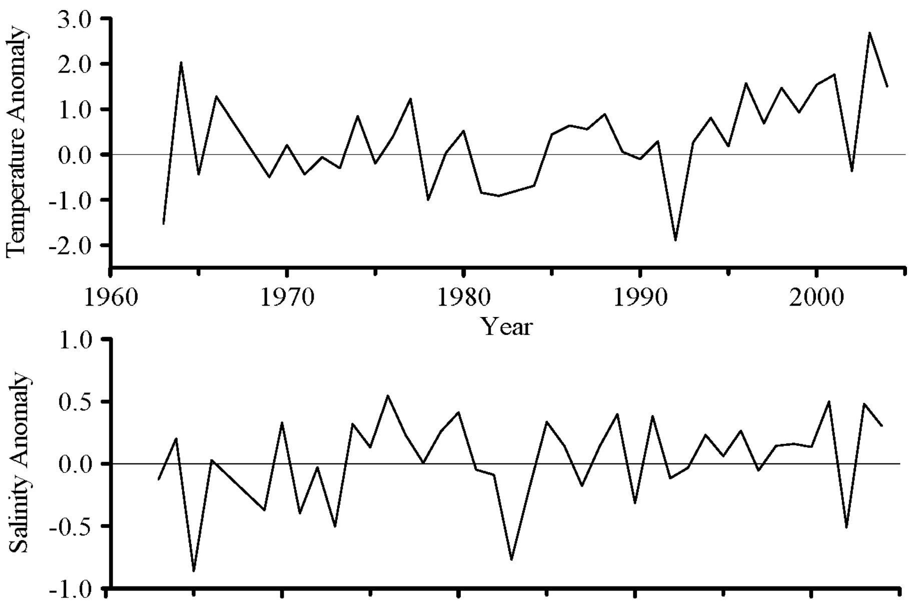


Figure 8: Area 1 – West Greenland. Fylla Bank Station 4 temperature (upper panel) and salinity (lower panel) anomaly autumn, 0–200 m; data from 1963–2004.

Area 2 – North West Atlantic: Scotian Shelf, Newfoundland, and Labrador Shelf

Oceanographic conditions in this region are to a large degree determined 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 numerous 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 southwestward 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 2004, in contrast to the continued warming trend in more northern waters, annual mean air temperatures over the Scotian Shelf, represented by Sable Island observations, were below average by about 0.23°C (based upon 1971–2000), continuing their decline from the record high set in 1999 (Figure 9). Sable Island was just south of the pivot point of large positive temperature anomalies to the north and negative temperature anomalies over the Gulf of Maine.

The amount of sea ice on the Scotian Shelf in 2004, as measured by the area of ice seaward of Cabot Strait between Nova Scotia and Newfoundland, was unexceptional (Figure 9). Overall 2004 ranked 19th in 43 years, ordering from least to greatest cover. This is a major change from 2003 when ice cover was the third highest in the entire record.

Topography separates the northeastern Scotian Shelf from the rest of the Shelf. In the northeast, the bottom tends 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 (Figure 10). They show colder-than-normal conditions in 2004 by about 2°C, the coldest since the early 1990s. In Emerald Basin, temperatures in 2004 were up to 2°C below normal in the upper 175 m and about 0.5°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.

Sea surface waters over the entire Scotian Shelf were about 0.5°C colder than average during 2004. The density difference 0–50 m over the Scotian Shelf decreased on average in 2004 to below normal although there was considerable spatial variability with stratification above normal in some areas.

Newfoundland and Labrador Shelf

The Rogers North Atlantic Oscillation (NAO) index for 2004 was below normal for the third consecutive year, resulting in reduced Arctic outflow to the region. Annual air temperatures throughout the Newfoundland and Labrador Region continued to be above normal during 2004 and in many areas increased over 2003 values. Annual mean air temperatures at Cartwright for example, on the southern Labrador Shelf warmed over 2003 values from 1.2°C above normal to 2°C above normal in 2004, the third highest on record (Figure 11). Winter sea ice coverage on the Newfoundland and Labrador Shelf during 2004 decreased over 2003, remaining below normal for the 10th consecutive year and to the lowest since 1965 (Figure 11).

Off eastern Newfoundland, the depth-averaged ocean temperature ranged from a record low during 1991 (high NAO index), a near record high in 1996 (near record low NAO index), while 1999 through to 2004 was above the long-term average in, with the 2004 value the highest on record (Figure 12). Shelf water salinities increased to saltier-than-normal conditions during 2002 to 2004, ending the decade long fresh anomaly on the Newfoundland Shelf. A robust index of the general oceanic environmental conditions off the eastern Canadian Continental Shelf is the extent of the cold-intermediate-layer (CIL) of <0°C water. This winter cooled water remains trapped between the seasonally heated upper layer and the warmer shelf-slope water throughout the summer and fall months. During the 1960s, when the NAO was well below normal and had the lowest value ever in this century, 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 2004, the CIL remained below normal on the Newfoundland and Labrador Shelf for the 10th consecutive year and the lowest value since 1965 in some areas. In summary, ocean temperatures in the Newfoundland and Labrador region of the Northwest Atlantic remained above normal continuing the warm trend experienced in much of the Northwest Atlantic during the past several years.

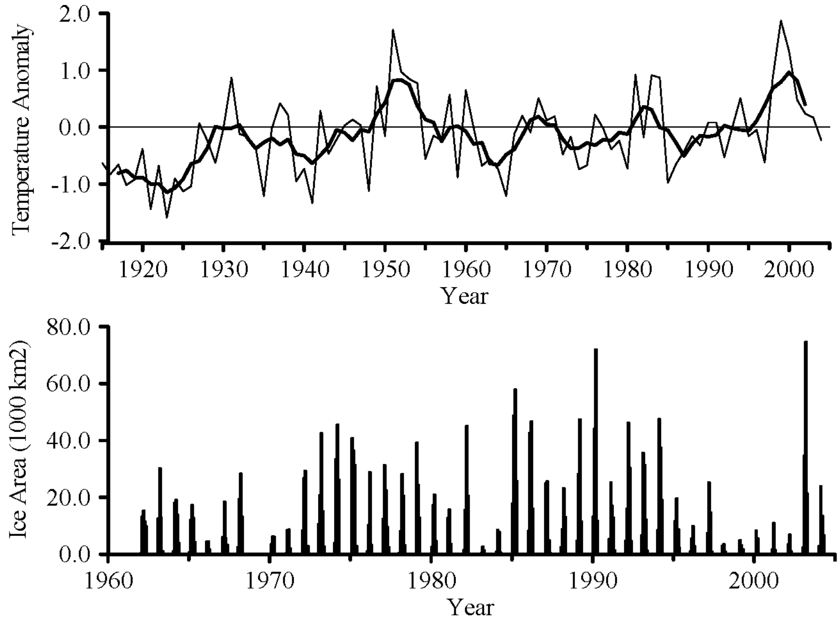


Figure 9: Area 2 – North West Atlantic: Scotian Shelf. Annual air temperatures anomalies at Sable Island on the Scotian Shelf (solid line shows five-year running mean), monthly means of ice area seaward of Cabot Strait.

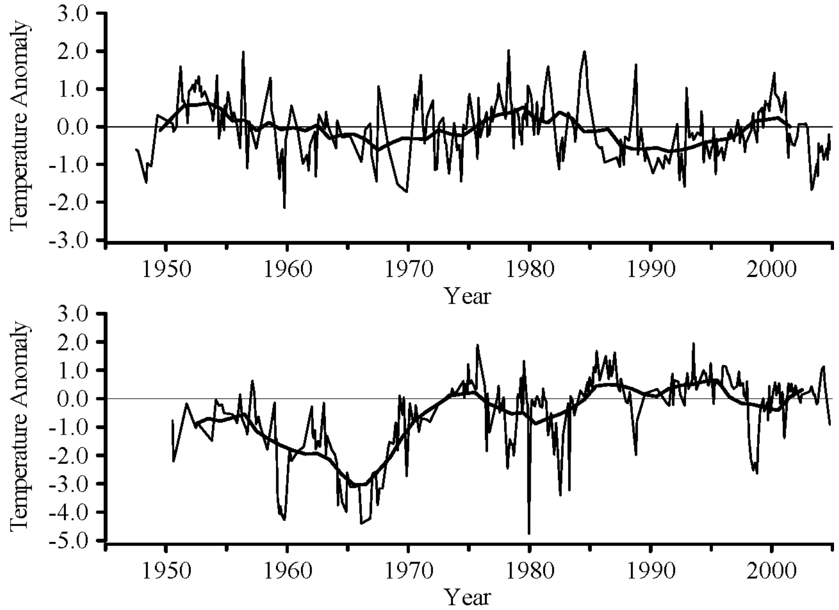


Figure 10: Area 2 – North West Atlantic: Scotian Shelf. Near-bottom temperature anomalies in the northeastern Scotian Shelf (Misaine Bank, 100 m) and central Scotian Shelf (Emerald Basin, 250 m).

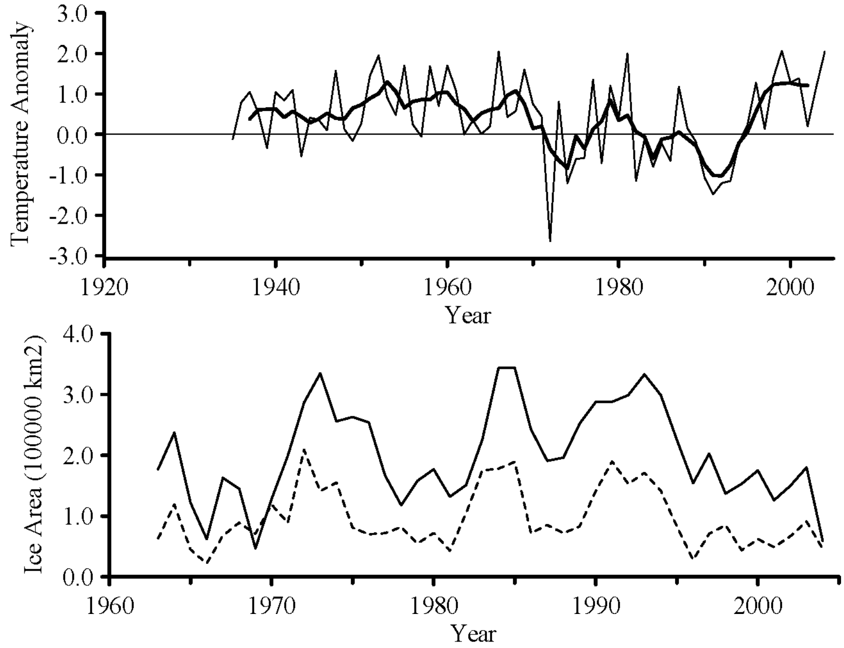


Figure 11: Area 2 – North West Atlantic: Newfoundland and Labrador Shelf. Annual air temperature anomalies at Cartwright on the Labrador Coast (top panel) and sea-ice area off Newfoundland and Labrador between 45°N–55°N for the winter (solid line) and for spring (dashed line).

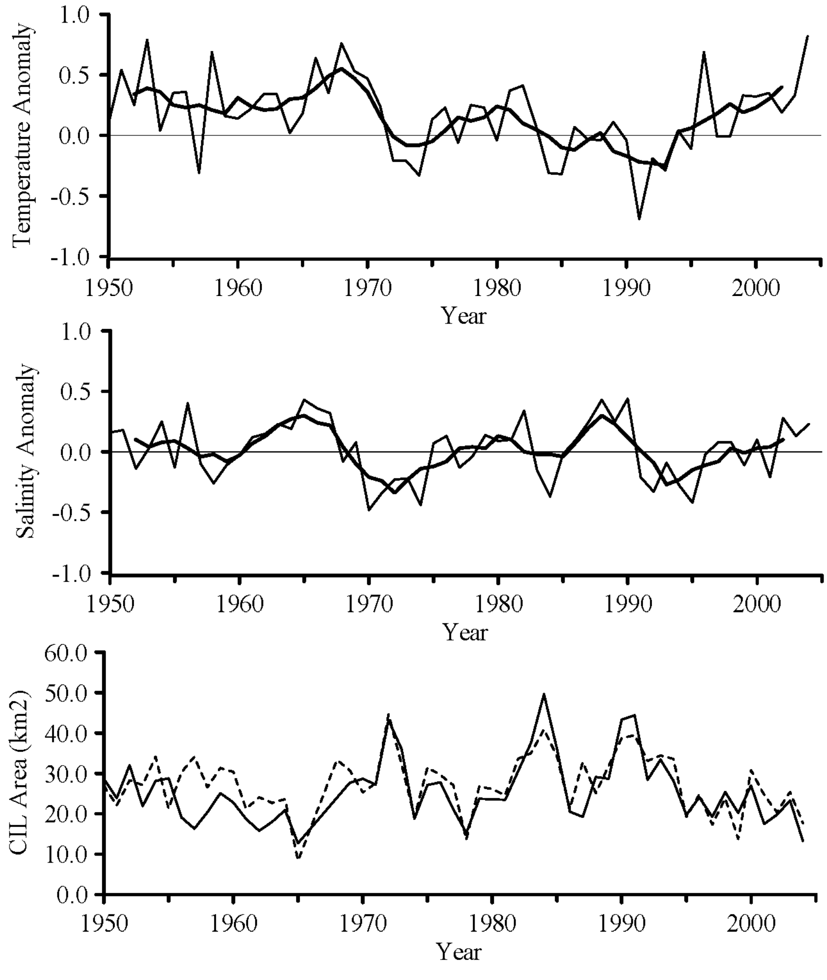


Figure 12: Area 2 – North West Atlantic: Newfoundland and Labrador Shelf. Upper panel: Annual depth-averaged Newfoundland Shelf. Middle panel: Summer salinity anomalies. Lower panel: The cold intermediate layer (CIL) on the Newfoundland (solid line) and Labrador (dashed line) Shelves.

Area 2b – Labrador Sea

Labrador Sea hydrographic conditions depend on a balance between heat lost to the atmosphere and heat gained from warm and saline Atlantic Waters that are carried northwards into the Labrador Sea by the West Greenland current. 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 and saline Atlantic Waters.

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 been generally 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 (Figure 13). This trend to warmer and more saline conditions persisted in 2004 following the winter of 2003–2004, which was even milder than the generally mild winters of recent years. Annual mean sea surface temperatures in the west-central Labrador Sea have been warmer than normal for the past 10 years and in 2004 were the warmest observed in the past 45 years (Figure 14).

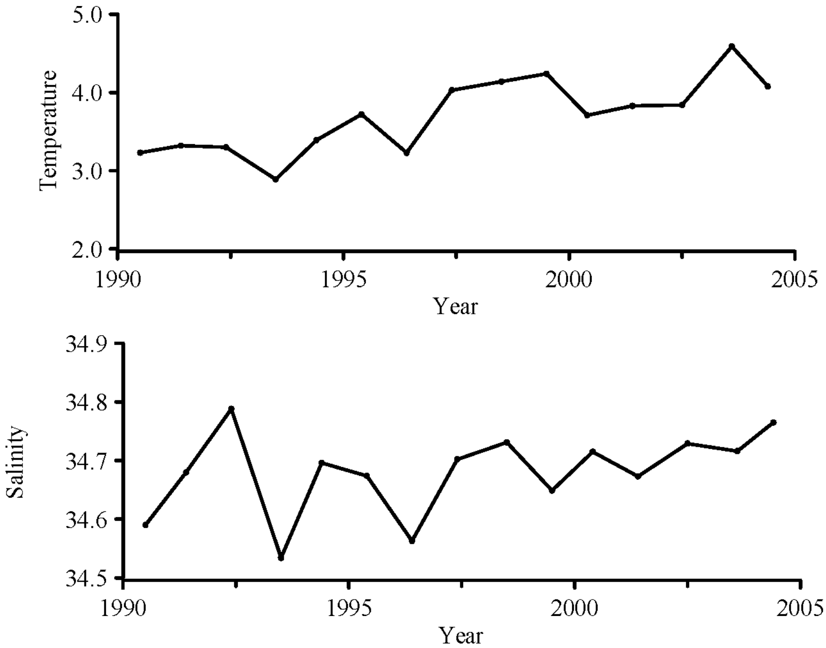


Figure 13: Area 2b – The Labrador Sea. De-seasoned potential temperature and salinity (spring/early summer values) for 0–150 m depth from 4 stations along section AR7, in the central Labrador Sea (320–520 km).

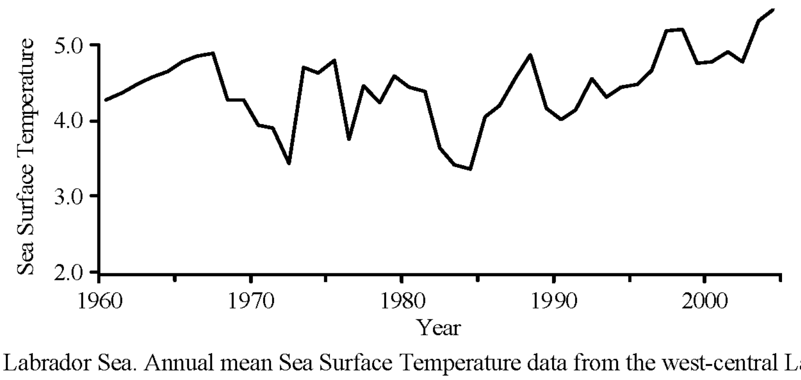


Figure 14: Area 2b – The Labrador Sea. Annual mean Sea Surface Temperature data from the west-central Labrador Sea (55.5–57.5°N, 53.5–51.5°W). Data obtained from the HadISST 1.1 – Global Sea Surface Temperature dataset, UK Meteorological Office, Hadley Centre.

Area 2c – Mid-Atlantic Bight

The hydrographic conditions in Mid-Atlantic Bight and Western Slope Sea regions depend substantially upon 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 and ends at the northern edge of the Gulf Stream. Figure 15 shows a Hovmøller diagram of temperature at 5 m depth and its anomaly after removal of the annual cycle for each 20 km bin.

The anomaly figure clearly shows gradual variations in temperature that are coherent across the entire region. Overall the year 2004 was near average relative to the 27-year average.

Figure 16 shows the corresponding Hovmøller diagrams for surface salinity. The annual cycle shows up most closely near the coast with a conspicuous summer freshening. Close to the Gulf Stream (500 km) salinities variations will be strongly influenced by the advection and leakage from the stream. Once the annual cycle is removed, the interannual anomalies emerge very clearly, and one can clearly see that these are correlated with sea surface temperature anomalies such that saltier than normal waters correspond to periods of warmer than normal waters such as around 1980, 1985, 1995 and year 2000.

To illustrate in more compact form the above figures, one can plot the average of temperature and salinity anomaly as a function of time. Figure 17 shows these for the distance interval 120 km to 400 km, an interval that includes the outer shelf and much of the Slope Sea. More specifically, this central range avoids the impact of local coastal fluctuations on the one hand, and direct contact with the Gulf Stream, on the other. The upper panel shows temperature and the lower salinity. The green line shows the data and the red lines the corresponding one-year low-passed filtered time-series. Again, on the longer time scales a correlation can be observed between the two such that warm periods are generally saltier. In terms of surface density, the linear trend in salinity over the 27-year period is −0.35 PSU and +0.25°C increase in temperature. These both contribute to a decrease of about 0.3 sigma-t units. Interestingly, the salinity decrease is of the same order, 0.1 PSU/decade, as the decreases around the sub-polar North Atlantic reported by Dickson *et al.* (2002), but the trend would be significantly less were it not for the exceptionally fresh period between 1996 and 1999. The year 2004 is somewhat on the cool and fresh side although substantial short-term variability can be observed within the year. Not surprisingly, the temperature record shows more activity month-to-month reflecting its greater sensitivity to local and regional atmospheric forcing. There was, for example, a very cold spell at the start of the year.

It is of interest to compare hydrographic conditions of Georges Bank with the offshore conditions reported above. Figure 18 shows surface temperature and salinity over Georges Bank from the NOAA/NMFS surveys that take place six times a year. The surface temperature anomaly pattern for Georges Bank suggests that the general warming evident from the mid-1990s through about 2003 moderated in 2004 with cooler temperatures. The surface salinity also decreased in 2004 with a return to negative salinity anomalies within a pattern of multi-year oscillations of higher and lower salinity as can be seen also in the offshore records.

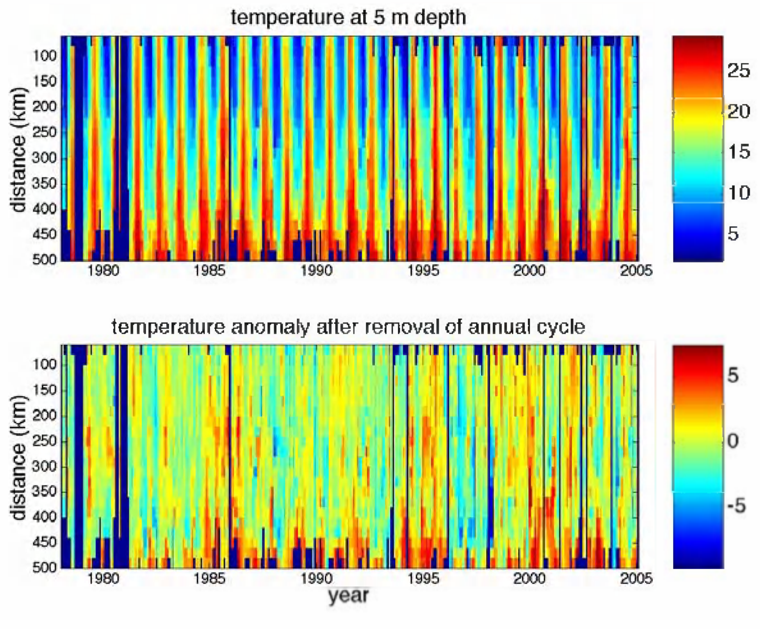


Figure 15: Area 2c – Mid-Atlantic Bight. Hovmøller diagram of temperature at 5 m depth between New York and the northern edge of the Gulf Stream at 500 km.

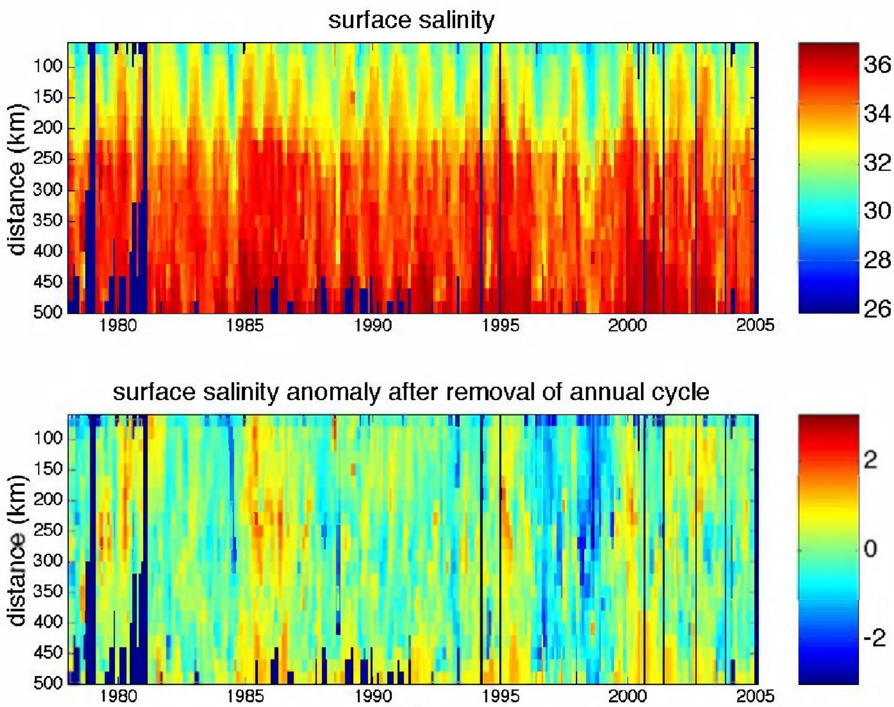


Figure 16: Area 2c – Mid-Atlantic Bight. Hovmøller diagram of sea surface salinity and its anomaly between New York and the northern edge of the Gulf Stream at 500 km.

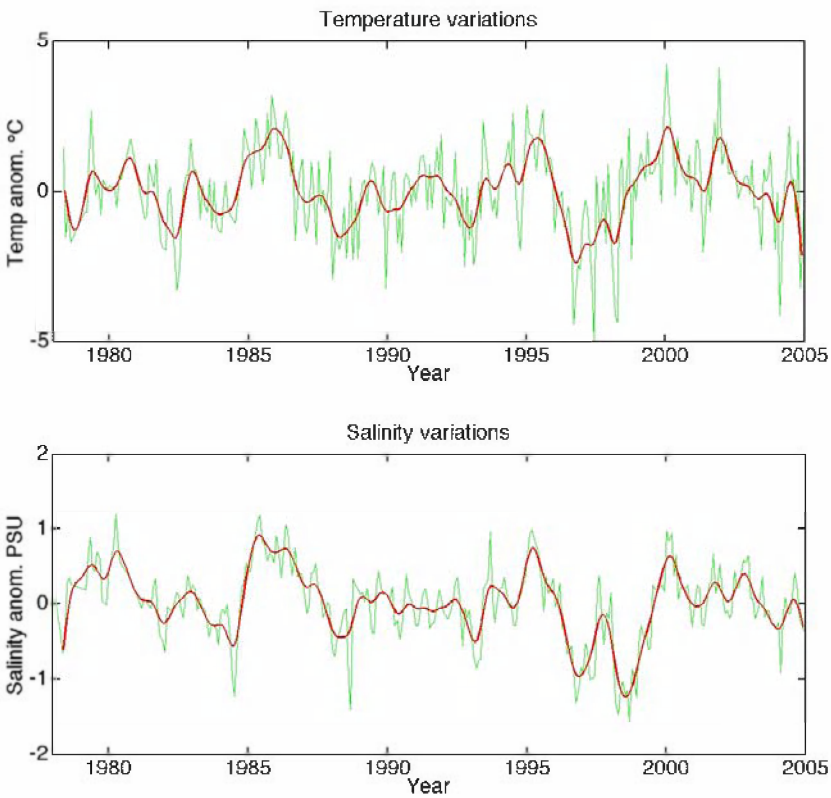


Figure 17: Area 2c – Time-series of temperature and sea surface salinity for the shelf and Slope Sea between 120 and 400 km.

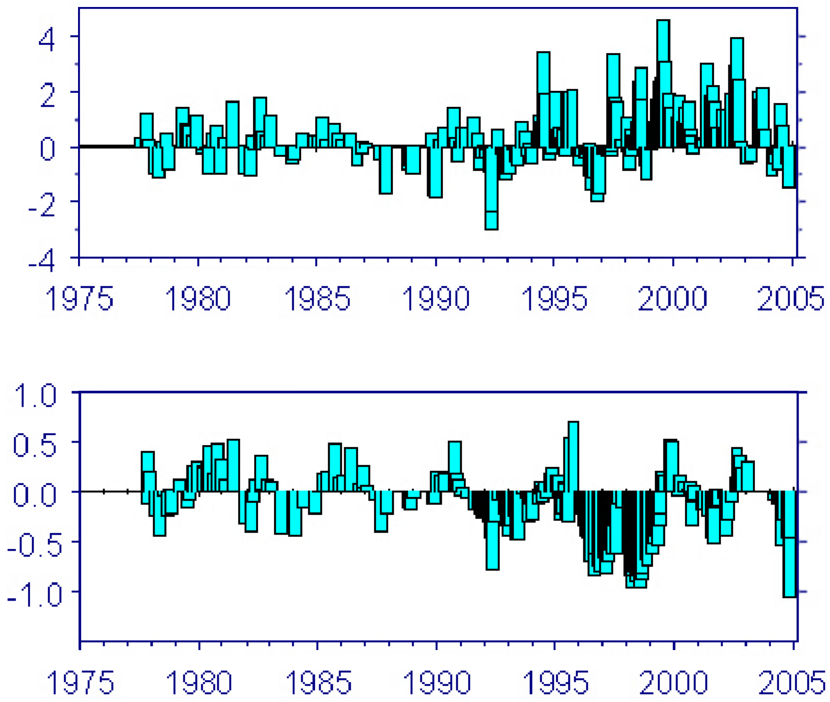


Figure 18: Area 2c – Mid-Atlantic Bight. Time-series of temperature (upper panel) and sea surface salinity (lower panel) anomalies over Georges Bank (courtesy Dr. David Mountain, NOAA/NMFS).

Area 3 – Icelandic Waters

Iceland is situated at a meeting place of warm and cold currents (Figure 19), which meet in an area of submarine ridges (Greenland–Scotland Ridge, Reykjanes Ridge, Kolbeinsey Ridge), which form natural barriers against the main ocean currents. To the south is the warm Irminger Current which is a branch of the North Atlantic Current (6–8°C), and to the north are 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 reflected in the atmospheric or climatic conditions in and over the country and the surrounding seas, mainly through the Icelandic Low and the Greenland High. 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.

Air temperatures in Rekjavik and Akureyri in 2004 were slightly lower than in 2003, but still above the long-term mean (Figure 20). The hydrographic conditions in 2004 revealed winter, spring, summer and autumn values on the shelf (Figure 21) above the long-term mean (1970–2004) for both temperature and salinity. The salinity and temperature in the Atlantic water from the south (Figure 22) remained at high levels similar to previous years and similar to 2003.

Atlantic water extended relatively far to the north in the northern area. The cold water north, north-east and east of Iceland and in the East Icelandic Current was in 2003 far offshore. The extension of Atlantic water was less to the north and closer to average in 2004. Temperature and salinity in the East Icelandic Current in spring 2004 were above long-term mean (Figure 23).

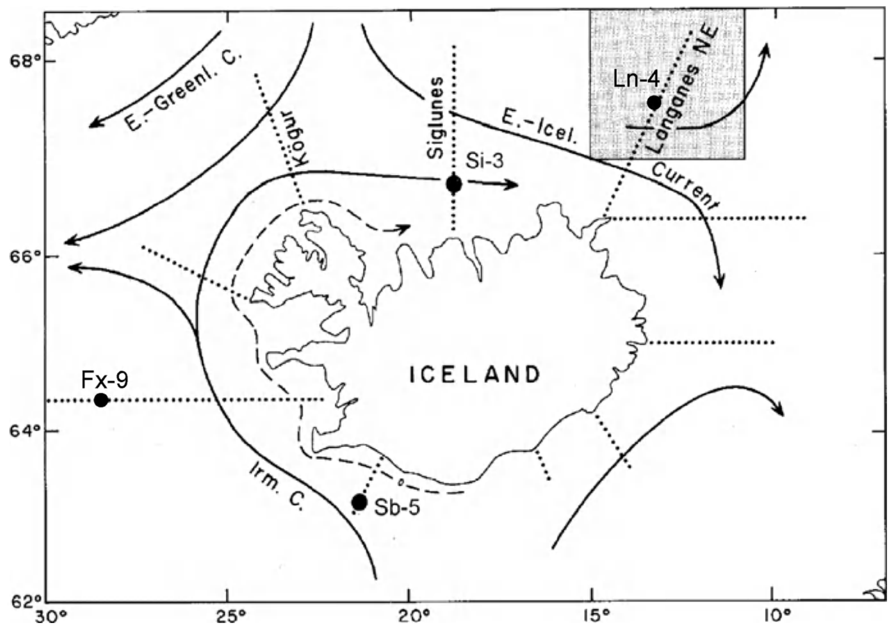


Figure 19: Area 3 – Icelandic Waters. Main currents and location of standard hydro-biological sections in Icelandic Waters. Selected areas and stations dealt with in this report are indicated.

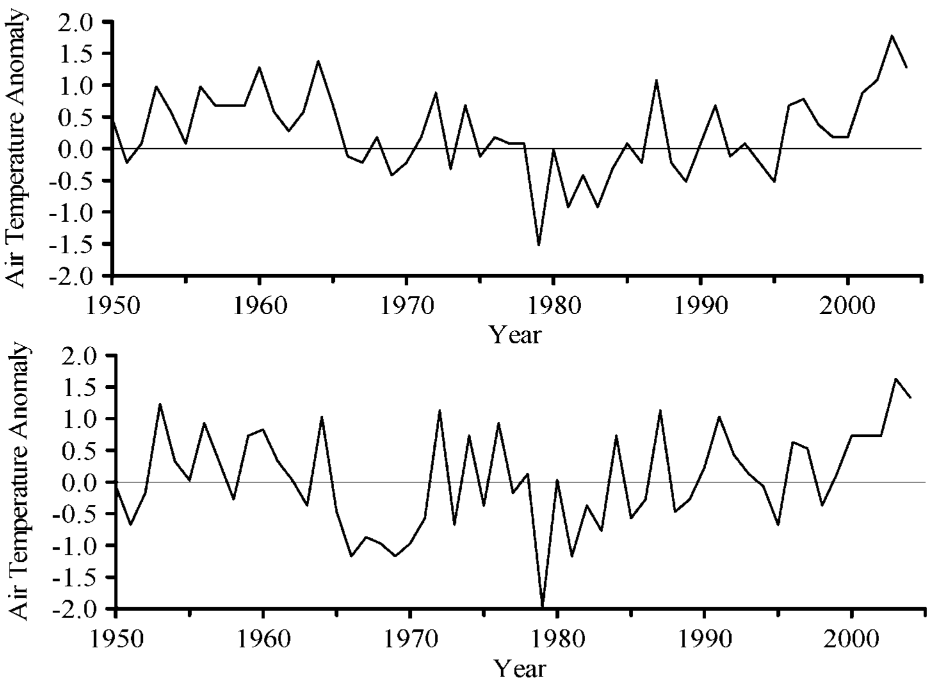


Figure 20: Area 3 – Icelandic Waters. Mean annual air-temperature anomalies at Reykjavík (upper panel) and Akureyri (lower panel) 1950–2004. Anomalies are relative to the 1971–2000 mean.

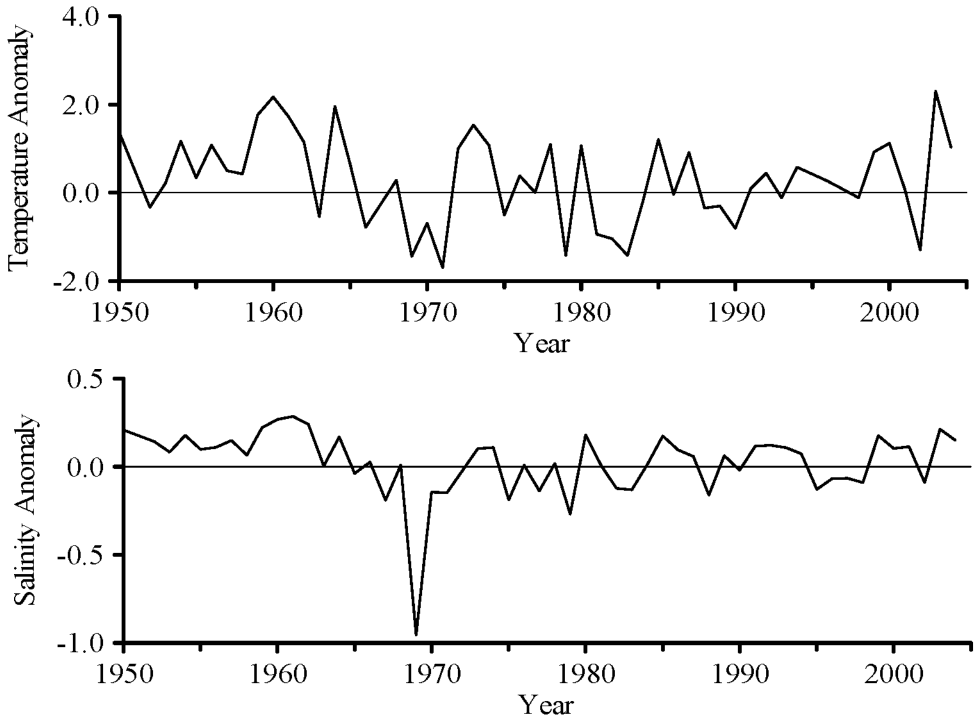


Figure 21: Area 3 – Icelandic Waters. Temperature (upper panel) and salinity (lower panel) anomalies at 50–150 m depth at Stations Si-2-4 in North Icelandic Waters 1950–2004. Anomalies are relative to the 1971–2000 mean.

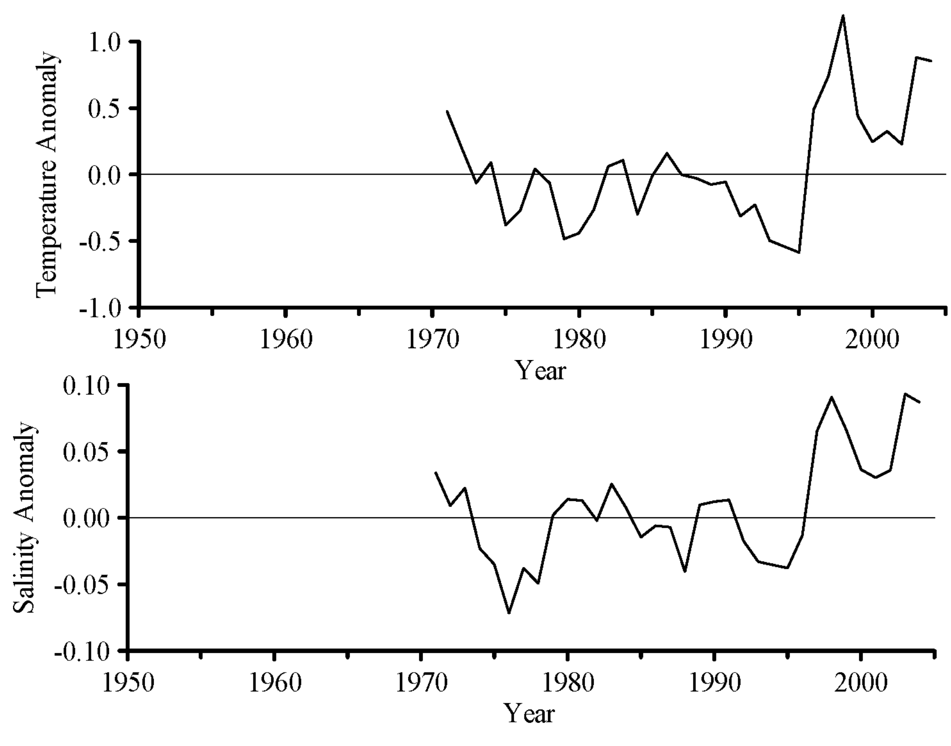


Figure 22: Area 3 – Icelandic Waters. Temperature (upper panel) and salinity (lower panel) anomalies between 0–200 m depth at Station Sb-5 in South Icelandic Waters 1971–2004. Anomalies are relative to the 1971–2000 mean.

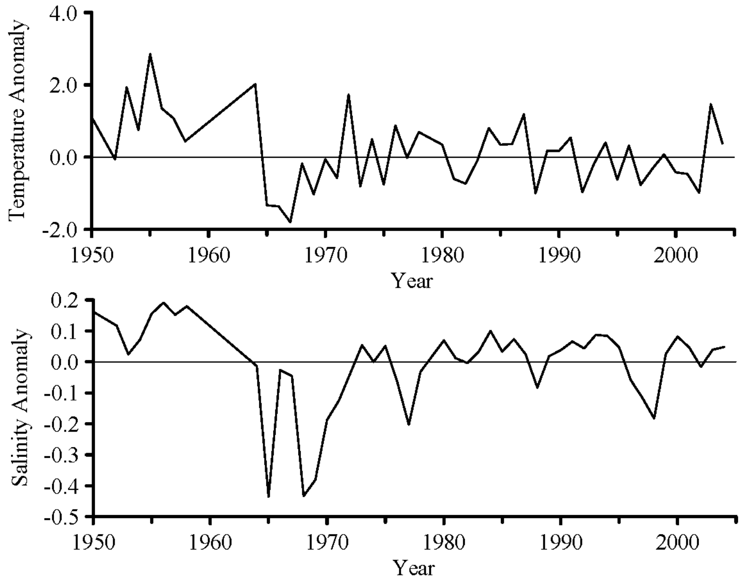


Figure 23: Area 3 – Icelandic Waters. Temperature (upper panel) and salinity (lower panel) anomalies between 0–50 m depth in the East Icelandic Current (Station Lna2-6) 1950–2004. Anomalies are relative to the 1971–2000 mean.

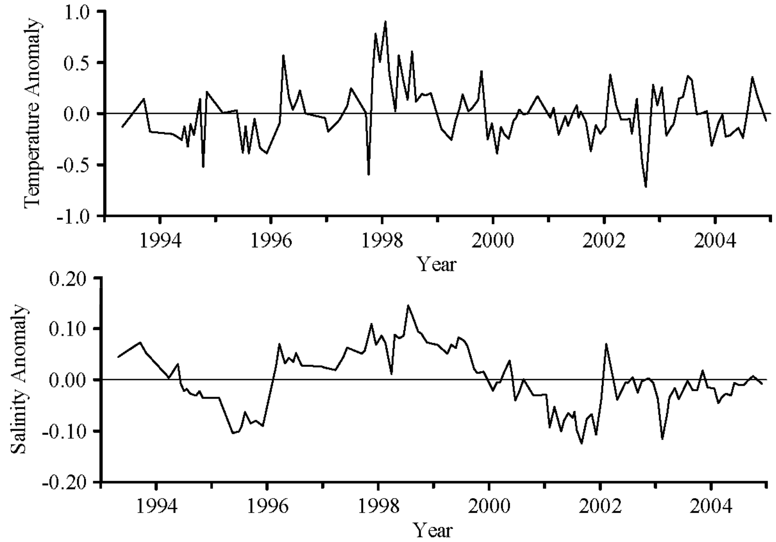


Figure 24: Area 4 – Bay of Biscay and Eastern Atlantic. Upper panel: Temperature anomaly (5–300 m) at Santander station 6 (shelf-break). Lower panel: Salinity anomaly (5–300 m) at Santander station 6. Seasonal cycle has been removed from the data. Data are related to the mean time-series (1993–2004).

Area 4 – Bay of Biscay and Eastern Atlantic

Meteorological conditions in the north of the Iberian Peninsula indicate that 2004 was an average year resulting from a cold winter and a warm summer. The annual mean air temperature over the southern Bay of Biscay during 2004 was close to normal, at 14°C, it was only 0.1°C over the 1961–2004 average. The seasonal cycle amplitude was 10.7°C from February to August. Precipitation was low with respect to the mean for the period 1986–2004.

Sea surface temperature was above the mean from June to October but below the mean between January and May. In the Santander shelf-break section summer 2004 was the warmest in the time-series (1993–2004) reaching 22.7°C in August. Heat content during 2004 seems to have a strong seasonal cycle reflecting the cold winter and warm summer. In the upper layers (5–300 m) the heat content seasonal cycle is one of the strongest in the time-series, but the mean temperature after removal of the seasonal cycle is close to the time-series average. (Figure 24 – upper panel).

Salinity contours in the southern Bay of Biscay show high salinity at the beginning of winter due to the poleward current and in spring and autumn due to seasonal upwelling, but in 2004 neither of these features were evident and advection and river runoff were low. Between 1998 and 2001, evidence of a decline in salinity was found up to a depth of 300 m. In 2002 this trend was reversed, particularly during the poleward episode at the beginning of the year. The lack of poleward current, upwelling events and strong precipitations have kept salinity values close to the time-series average (Figure 24 – lower panel).

Area 5 – Rockall Trough

In 2004, the Ellett Line with extension to Iceland was carried out by UK scientists on the RV Poseidon. However, calibration problems were not resolved in time to present the data at the annual ICES WGOH meeting. The figures below present data to 2003. Data for 2004 will be included in next year's report. The 2005 occupation is scheduled for October on RRS Charles Darwin.

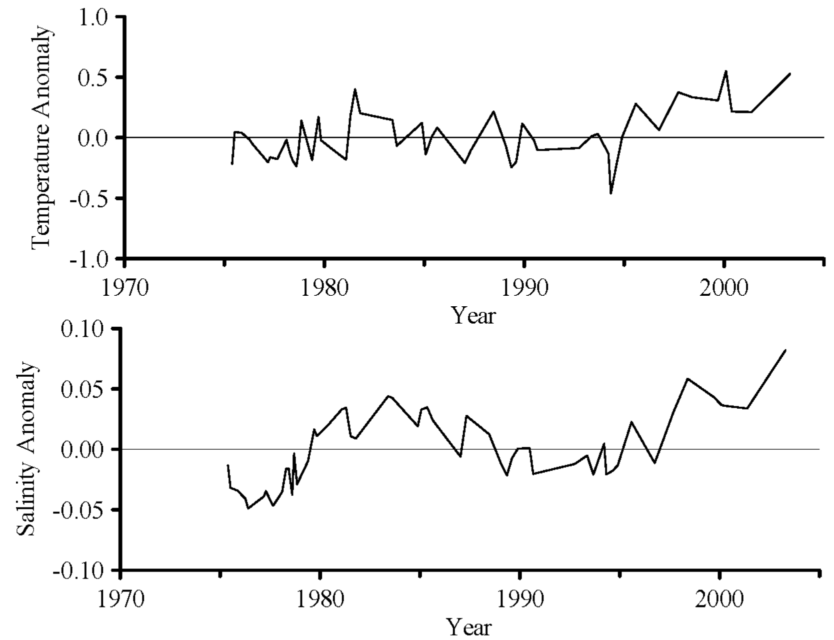


Figure 25: Area 5 – Rockall Trough. (Data to 2003 only). Temperature and salinity anomalies for the upper ocean (0–800 m) of the northern Rockall Trough. Average across section, seasonal cycle removed.

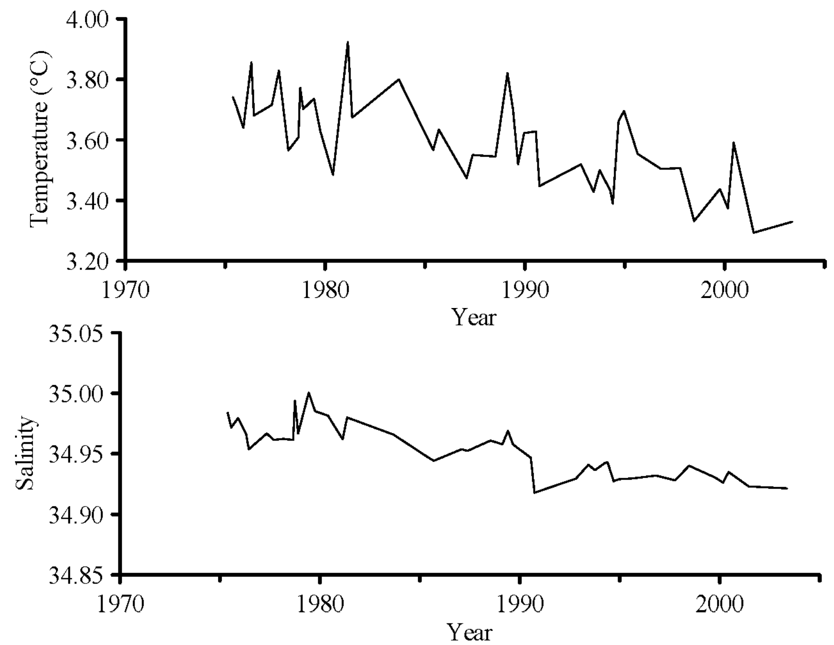


Figure 26: Area 5 – Rockall Trough. (Data to 2003 only). Temperature and salinity of Labrador Sea Water in the Rockall Trough (~depth 1800 m).

Area 5b – North Atlantic

The figures below present data to 2003. No data were available in 2004.

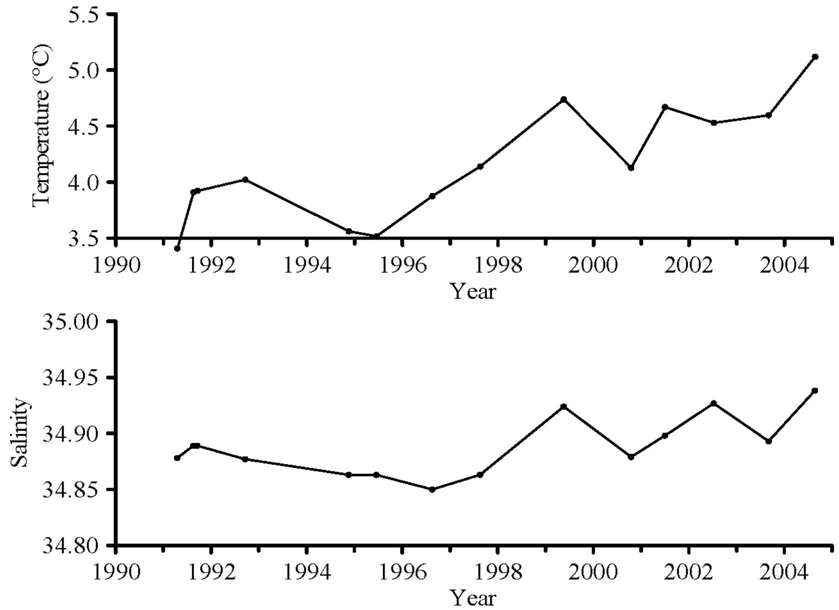


Figure 27: Area 5b – Northern North Atlantic. Temperature (upper panel) and salinity (lower panel) of sub-polar mode water (averaged over 200–400 m) in the central Irminger Sea.

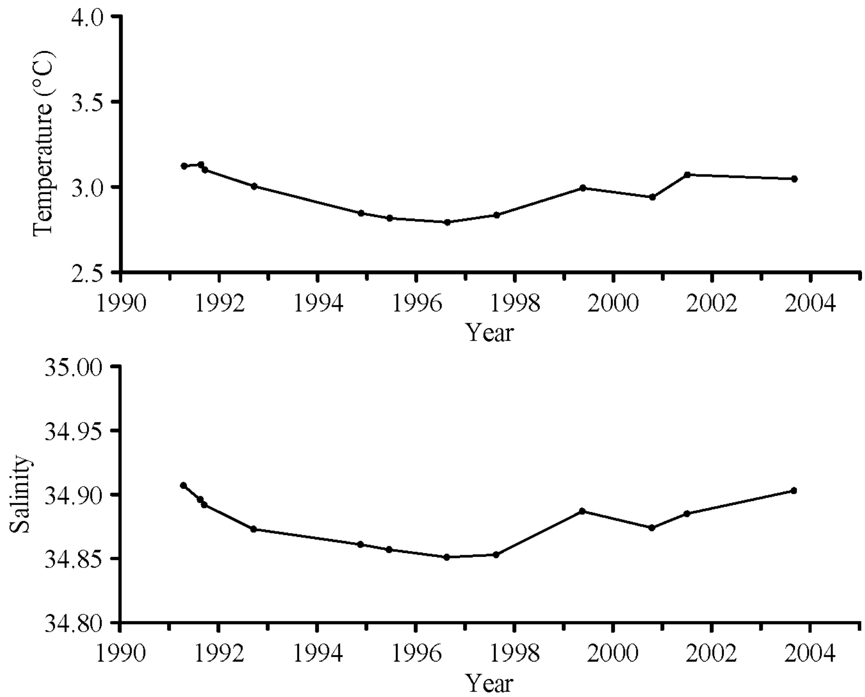


Figure 28: Area 5b – Northern North Atlantic. (Data to 2003 only). Temperature (upper panel) and salinity (lower panel) of Labrador Sea Water (averaged over 1600–2000 m) in the central Irminger Sea.

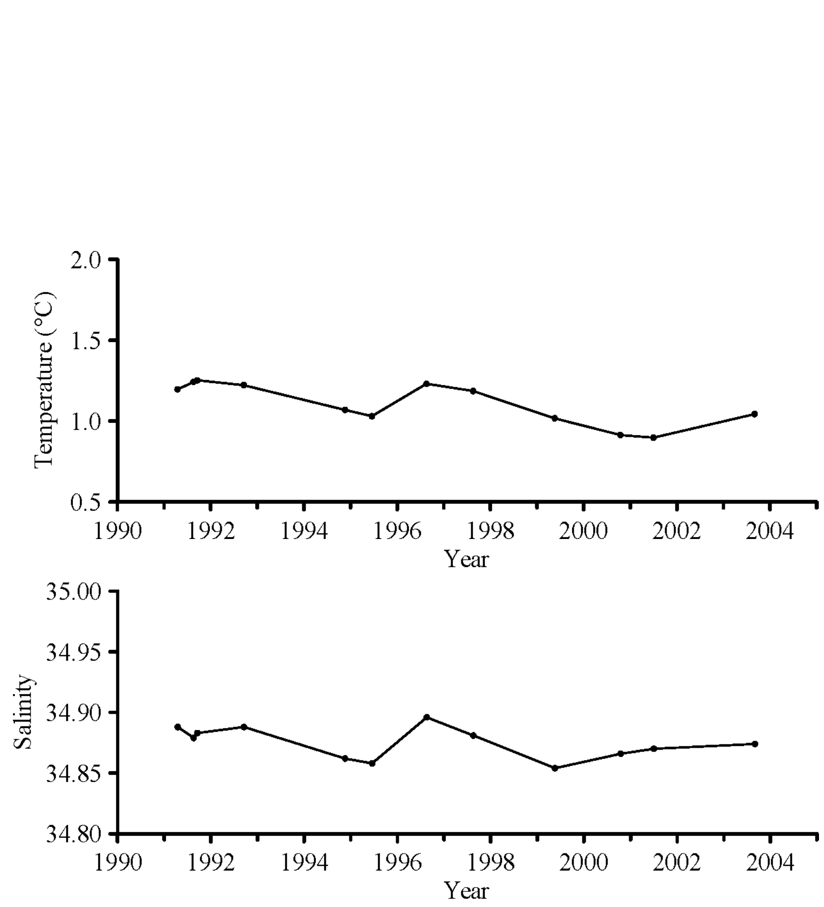


Figure 29: Area 5b – Northern North Atlantic. (Data to 2003 only). Temperature (upper panel) and salinity (lower panel) of Denmark Strait overflow water on the East Greenland Slope.

Area 6 – Faroe Bank Channel and Faroe Current

The figures below present data to 2003. No data were available in 2004.

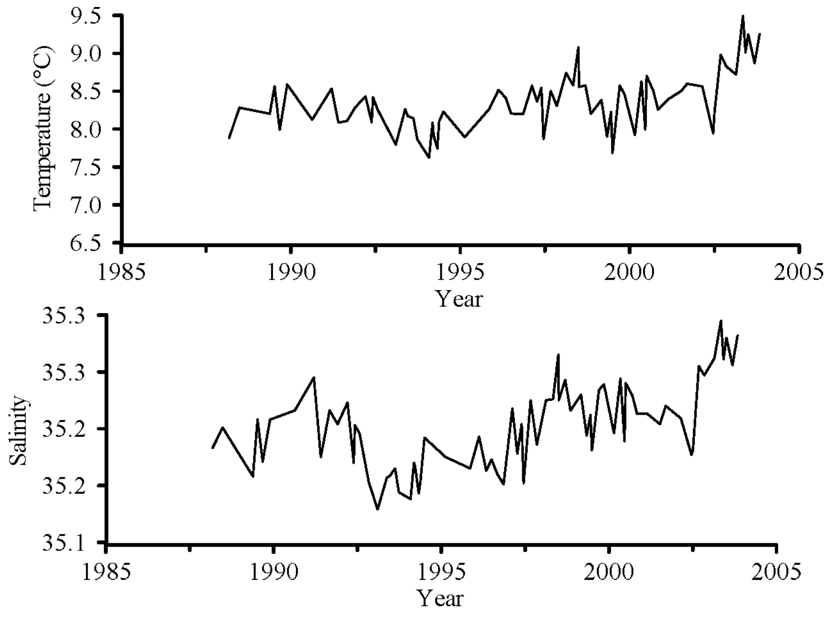


Figure 30: Area 6 – Faroe Bank Channel. (Data to 2003 only). Temperature and salinity from CTD profiles in the Faroe Bank Channel. The curves show averages over the 100–300 m depth layer at two standard stations in the channel. The typical seasonal variation has been removed from the curves.

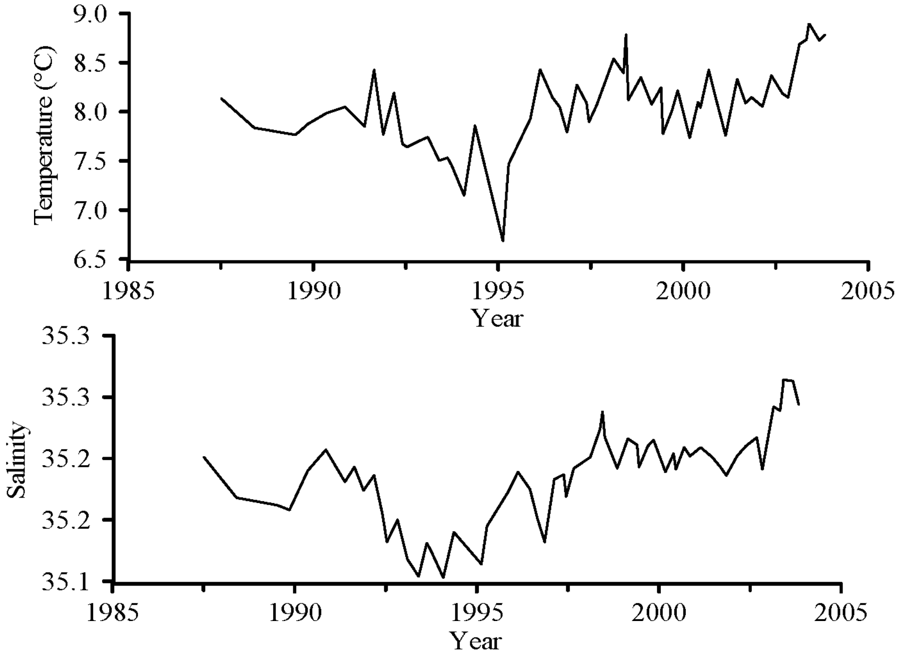


Figure 31: Area 6 – Faroe Current. (Data to 2003 only). Temperature and salinity in the core of the Faroe Current (defined as having maximum salinity averaged over a 50 m depth layer). The typical seasonal variation has been removed from the curves.

Area 7 – Faroe Shetland Channel

The continental Slope Current flows along the edge of the north-west 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.

Surface waters in the Faroe Shetland Channel continued the general warming trend observed over the last 20 years. Modified Atlantic Waters in the Faroe Shetland Channel were warmer and saltier in 2003 than at any period during the last 50 years, the values decreased a little in 2004 (Figures 32 and 33).

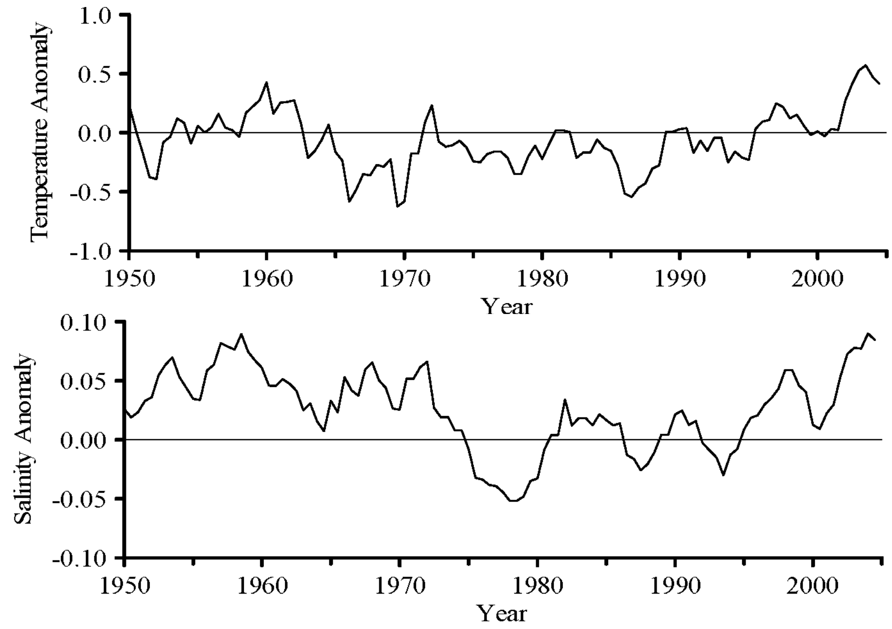


Figure 32: Area 7 – Faroe Shetland Channel. Temperature and salinity anomalies in the North Atlantic Water (NAW) in the Slope Current.

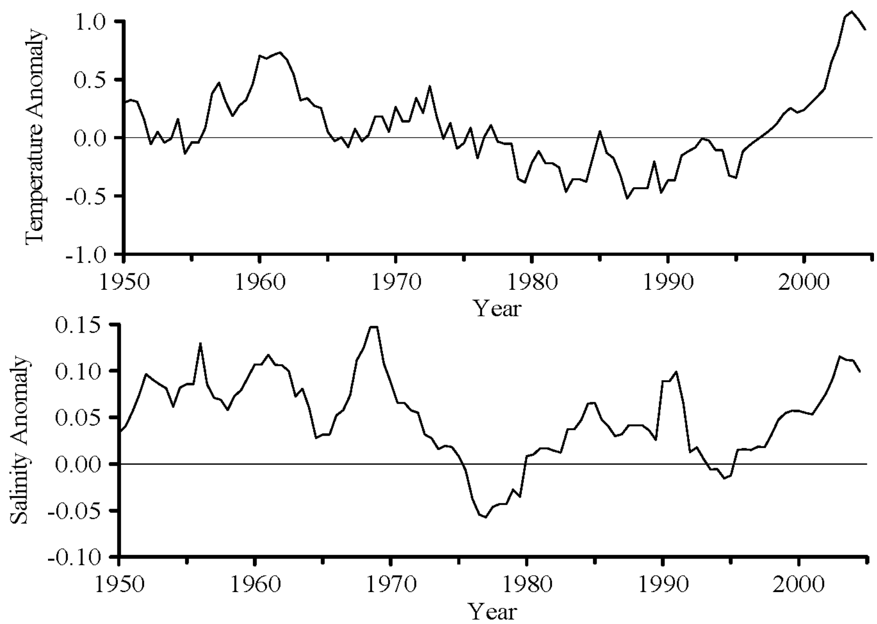


Figure 33: Area 7 – Faroe Shetland Channel. Temperature and salinity anomalies in the Modified Atlantic Water (MNA) entering the Faroe Shetland Channel from the north after circulating around Faroe.

Areas 8 and 9 – Northern and Southern North Sea

North Sea oceanographic conditions are determined by the inflow of saline Atlantic water through the northern entrances and to a lesser degree through the English Channel. The Atlantic water mixes with the river run-off mainly and with lower-salinity Baltic outflow along the Norwegian coast. The temperature of the North Sea is controlled by local solar heating and heat exchange with the atmosphere.

The salinity and the temperature of the North Sea generally reflect the influence of the NAO on the movement of Atlantic water into the North Sea and the ocean-atmosphere heat exchange. 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. Numerical model simulations show strong differences in the North Sea circulation depending on the state of the NAO.

Estimates from a numerical ocean circulation model showed that the circulation in the North Sea was quite normal throughout 2004. Also the inflow of Atlantic water to the northern and central North Sea was at a normal level, with somewhat higher values at the end of the year due to heavy south and westerly winds (Figure 34). The inflow through the English Channel was also at a normal level. In October and December 2003 and August, September and December 2004 relatively warm and high salinity Atlantic water masses (>35.3) was observed along the slope of the Danish side in the Skagerrak. Such high values have not been observed since autumn 1991 and relates well with observations in the northern North Sea and the Faroe-Shetland channel.

The North Sea SST shows a very long run of positive anomalies starting June 2001. This positive anomaly probably ended in March 2005. Figure 35 shows the weekly area averaged North Sea SST. The green circles denote the monthly climate data; the size is a measure for the standard deviation. All weeks in 2004 are above the climatology and in August 2004 the temperature was close to the record of 2003. The strong positive anomaly continued during the autumn. The temperature of the upper layer of most of the North Sea was between 0.5 to 1.5°C warmer than normal, with the exception of the western Norwegian coastal water which was close to normal during the first half year. Intense and mild weather from the south and west during the last part of the year and the beginning of 2005 has resulted in water more than one degree warmer than normal in December and January (2005) and about two degrees warmer in the Skagerrak.

The Atlantic water transports large amounts of nutrients to the North Sea. A coupled numerical model (NORWECOM) shows as expected relatively normal annual primary production due to normal inflows of Atlantic water and relatively normal wind conditions. The production after the spring bloom was unusually low in the Skagerrak, related to the somewhat lower than normal modelled production in the south and south eastern North Sea. The vegetation period (primary production) in the North Sea was much longer than normal due to the mild winter 2003/2004 and a postponed start of autumn. The time-series of the of the temperature and salinity anomalies (Figure 36) in the Fair Isle Current (FIC) entering the North Sea from the North Atlantic confirm the warm and salty inflow which continued in 2004.

Figure 37 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. Also the salinity is slightly lower at the plateau. In both places there was extremely high temperature and salinities in 2004. This is a result of very high salinity in the inflowing Atlantic water and the effect of a mild winter.

Figure 38 displays the long time-series from the Helgoland station (data provided by Biologische Anstalt Helgoland/Alfred-Wegner-Institut). Since the cold winter 1996 the Helgoland SST has been above the 30-year mean, with decreasing positive anomalies of about 0.5°C. The salinity in the German Bight has recovered after the strong run-off event in 2002. The very low run-off from the rivers Elbe and Weser continued in 2004 resulting in an increase of the surface salinity at Helgoland, which is strongly influenced by the Elbe run-off and the position of the Elbe river plume.

The time-series of normalised sea surface temperature and salinity anomaly relative to the period 1971–2000 measured along 6 stations of a regular ferry route at 52°N, is presented in Figure 39. The data confirm the model results regarding the inflow of Atlantic water into the North Sea via the English Channel and the other temperature time-series from the North Sea.

For the North Sea two surface salinity distributions for the year 2004 are available, one for January–March (IYBT survey and RV Gauss data) and a second survey (Delphin data Gauss 425) from summer. The winter data show a pronounced inflow of Atlantic water east of Shetland extending to the Norwegian Trench. The summer survey 2004 showed a northern inflow with salinities above 35 extending to the Dogger Bank. The continental coastal strip, the German Bight and also the eastern part of the North Sea show higher salinities due to the reduced run-off of the continental rivers. The Baltic outflow was strong and therefore the salinities above the Norwegian Trench lower than normal. The inflow of Atlantic water through the English Channel has increased; the IBTS data show salinities above 35 in the Southern Bight. The Skagerrak coastal water is defined with salinity between 25.0–32.0. Water with lower salinity is defined as brackish water. Along the coast of southern Norway, the thickness of the Skagerrak coastal water was most of the year about 10–30 m. The temperature in the deeper Skagerrak water (150 m) was 1–1.5°C above normal most of the year, and the salinity was most of the year more than one standard deviation above long-term mean. As predicted in 2003 there was renewal of the deep oxygen-rich water in February to April, without significant higher density.

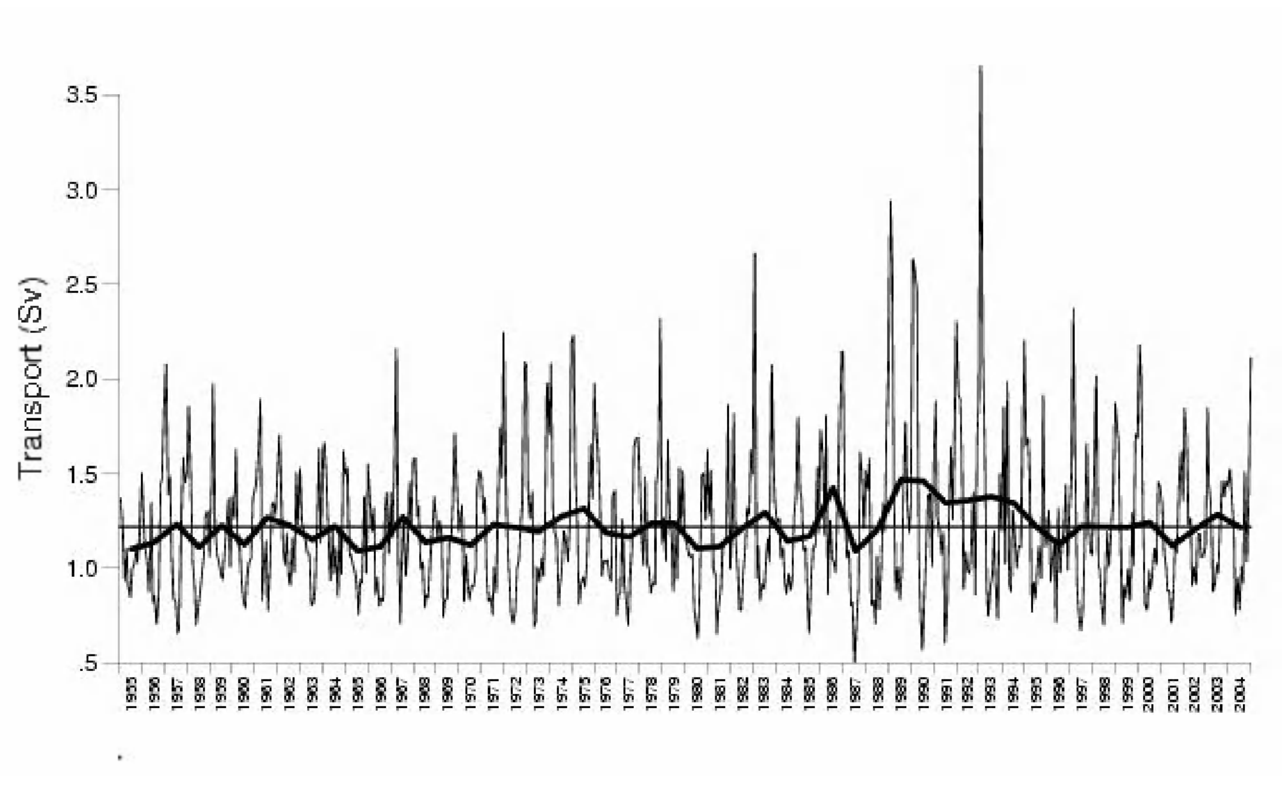


Figure 34. Areas 8 and 9 – Northern and Southern North Sea. Time-series (1955–2004) of modelled annual mean (bold) and monthly mean volume transport of Atlantic water into the northern and central North Sea southward between the Orkney Islands and Utsira Norway. 1 Sv = 106 $m^3 s^{-1}$. (Anon., 2005).

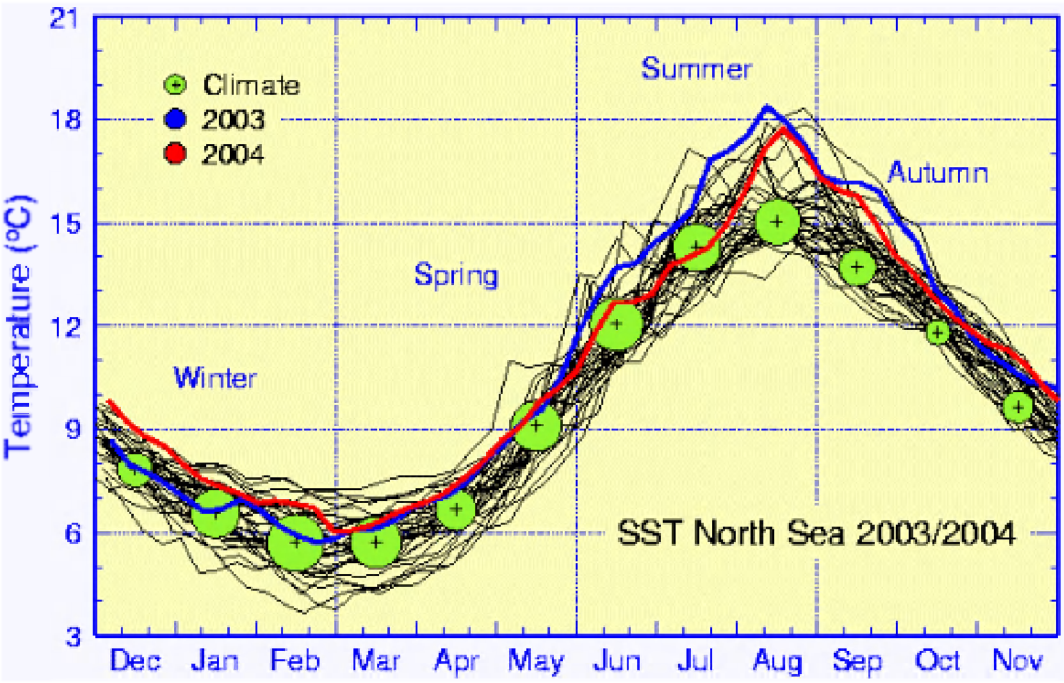


Figure 35: Areas 8 and 9 – Northern and Southern North Sea. North Sea area averaged SST annual cycle, monthly means based on operational weekly North Sea SST maps. Climatology 1971–1993 green dots; blue line 2003, red line 2004; black thin lines individual years.

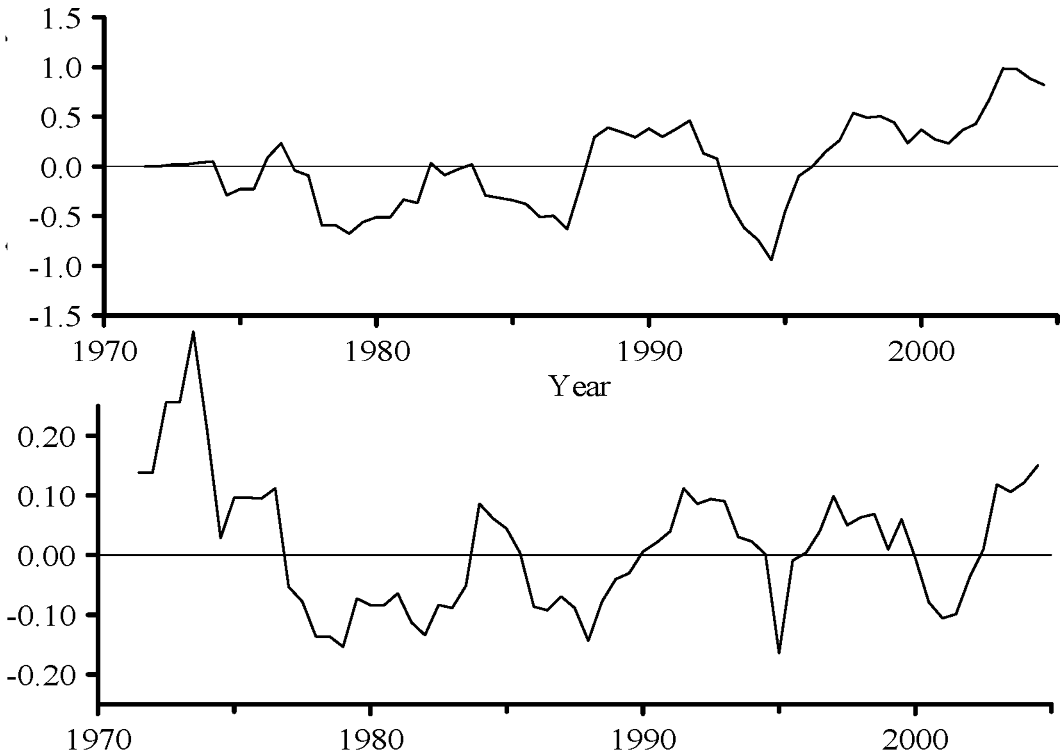


Figure 36: Areas 8 and 9 – Northern and Southern North Sea. Temperature and salinity anomalies in the Fair Isle Current (FIC) entering the North Sea from the North Atlantic.

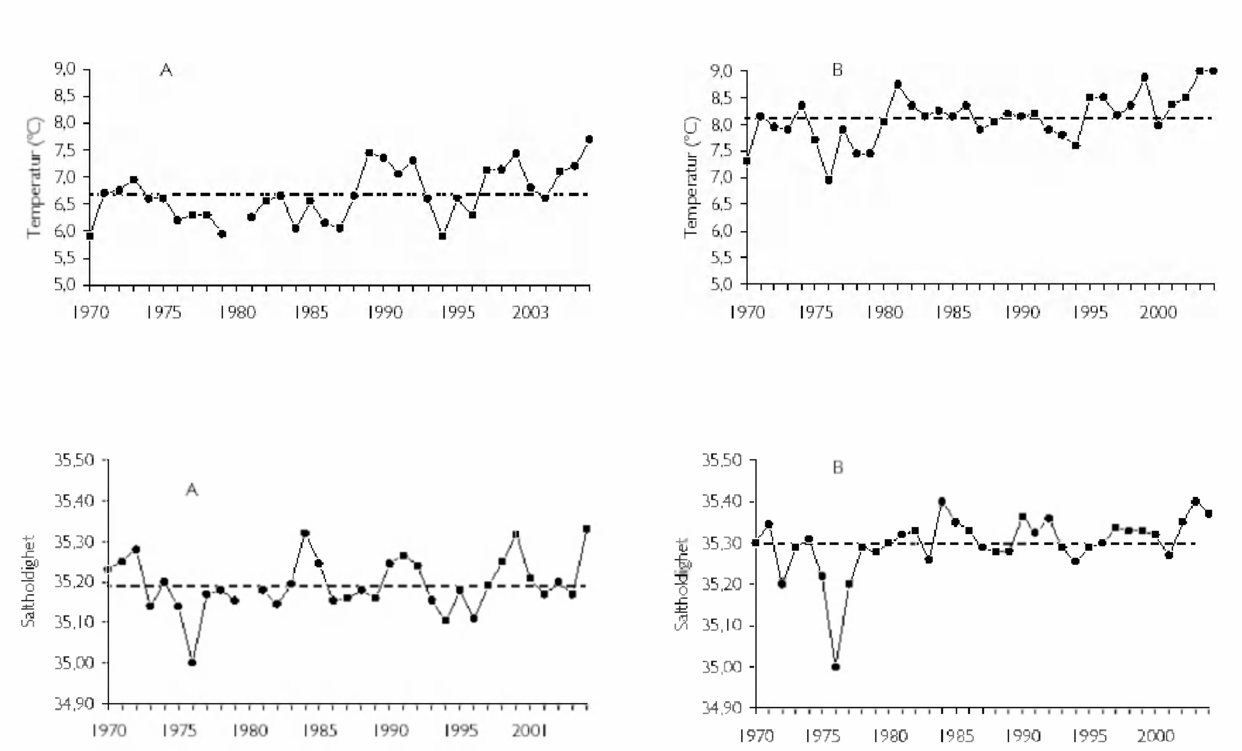


Figure 37: Areas 8 and 9 – Northern and Southern North Sea. Temperature and salinity near bottom in the north-western part of the North Sea (A) and in the core of Atlantic water at the western shelf edge of the Norwegian Trench (B) during the summers of 1970–2004.

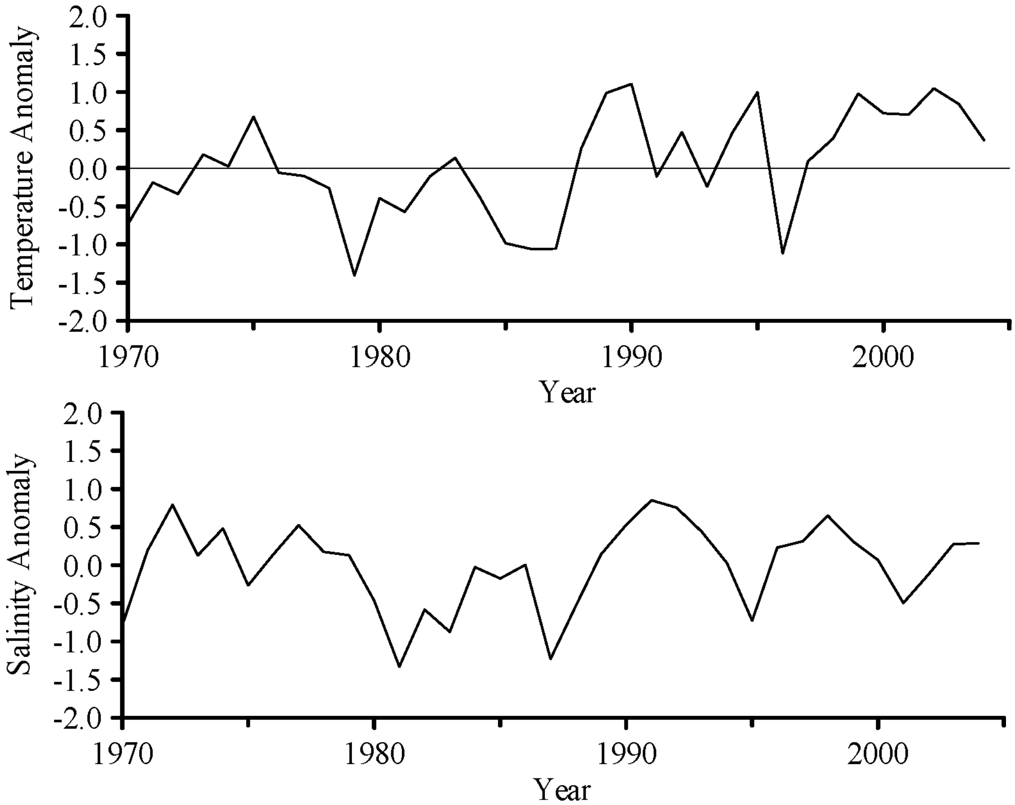


Figure 38: Areas 8 and 9 – Northern and Southern North Sea. Annual mean surface temperature and salinity at Station Helgoland Roads.

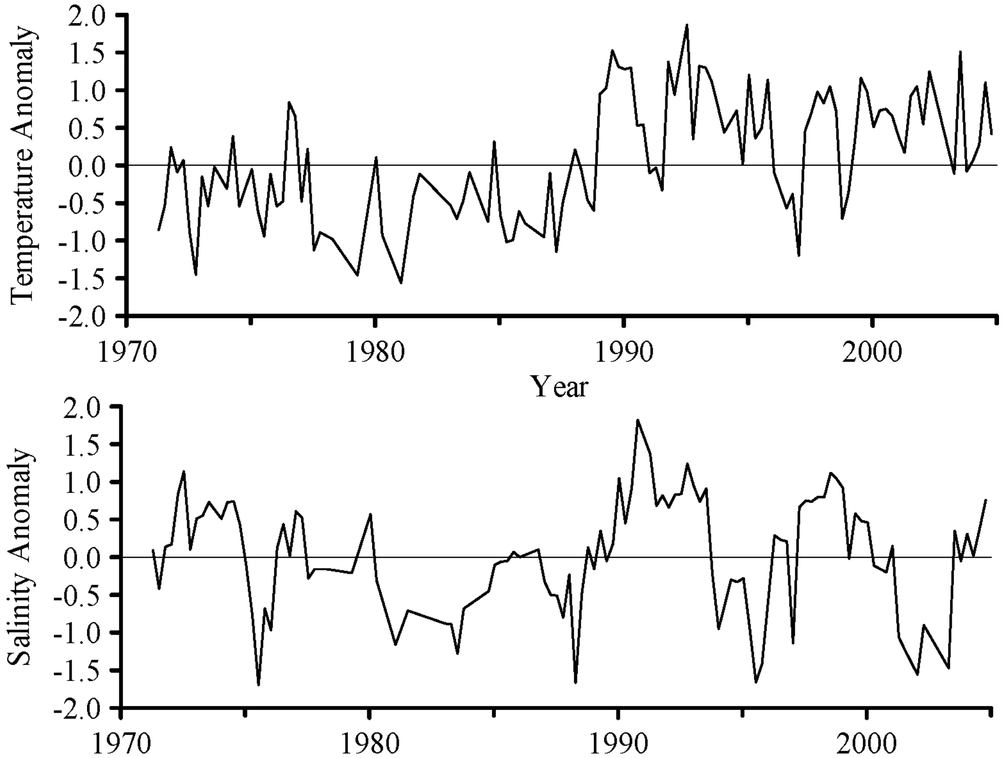


Figure 39: Areas 8 and 9 – Northern and Southern North Sea. Time-series of normalised sea surface temperature and salinity anomaly relative to the period 1971–2000 measured along 52°N a regular ferry at 6 standard stations. The time-series show the seasonal section average (DJF, MAM, JJA, SON) of the normalised variable.

Area 9b – Skagerrak, Kattegat, and the Baltic

The seas around Sweden are distinguished by large salinity variations. In Skagerrak water masses from different parts of the North Sea are found. The Kattegat is a transition area between the Baltic Sea and Skagerrak. The water is strongly stratified with a permanent halocline. The deep water 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 small inflows pass fairly quickly causing large variations and the conditions in the deeper parts are here 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 hydrographic conditions in the Baltic Sea, the Kattegat and the Skagerrak were close to average during most of the year although some slightly anomalous periods could be noted. During the spring and early autumn warmer than average surface temperatures were found in some areas in the Baltic, with the largest deviation in the beginning of August, which was unusually warm. The most striking event in Skagerrak was exceptionally low values of the surface salinity found in April and it was deduced that the Baltic current had formed a bight returning southwards west of 10°40'E.

The exceptional warm water inflow into the Baltic Sea in summer 2002 (Figure 40), which preceded the major Baltic inflow of January 2003, was surprisingly repeated in modified form in summer 2003 and again in summer 2004 (Feistel *et al.*, 2004). Since the inflow was warm it only had minor effects on the conditions in the deeper parts of the Baltic. It is possible that the repetition of these warm, baroclinic inflows could be regarded as a possible regional indicator for climate change.

Long-term changes of the salinity are shown for some stations in the Baltic. For station BY15 in the Baltic Proper surface salinity data from 1965 to 2004 have been plotted in Figure 41. No further decrease in salinity was noted in the area. In Figure 42 the surface and deep-water salinity is displayed for station LL7 in the Gulf of Finland and SR5 in the Bothnian Sea. These time-series cover the period 1991–2004.

The ice winter 2003/2004 was classified as average with the maximum ice extent occurring on 11 March 2004. A time-series of the maximal ice extent for the period 1660–2004 has been constructed at SMHI (Axell, 2004) using data from ice charts and historical reconstructions, see Figure 43. The diagram also shows the corresponding series obtained by FIMR. Statistical methods have been used to calculate trends for various parts of the time-series. For the period 1960–2004 the trend is statistically significant and negative.

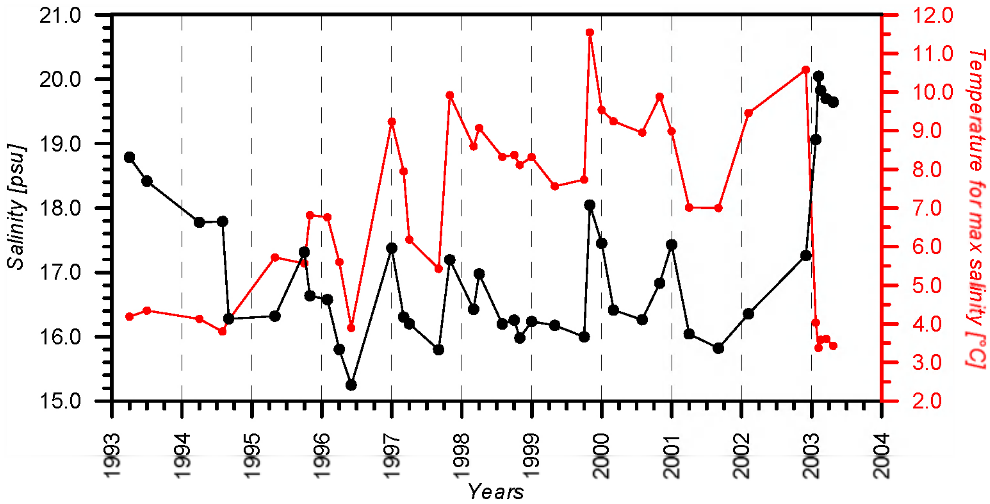


Figure 40: Area 9b – Skagerrak, Kattegat and the Baltic. (Data to 2003 only). Maximum salinity and temperature of the bottom water in the Bornholm Basin (the Proper Baltic).

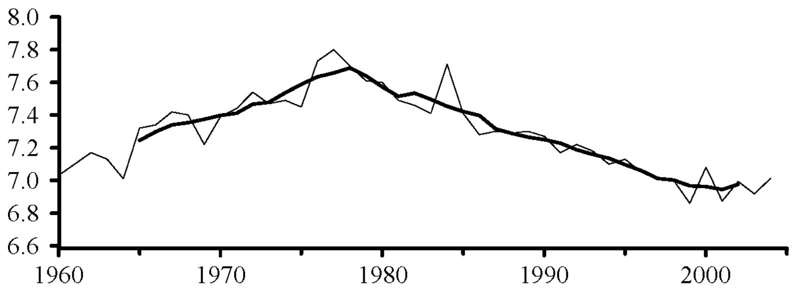


Figure 41: Area 9b – Skagerrak, Kattegat and the Baltic. The surface salinity at station BY15 (east of Gotland) in the Baltic Proper (bold line is a five-year running mean).

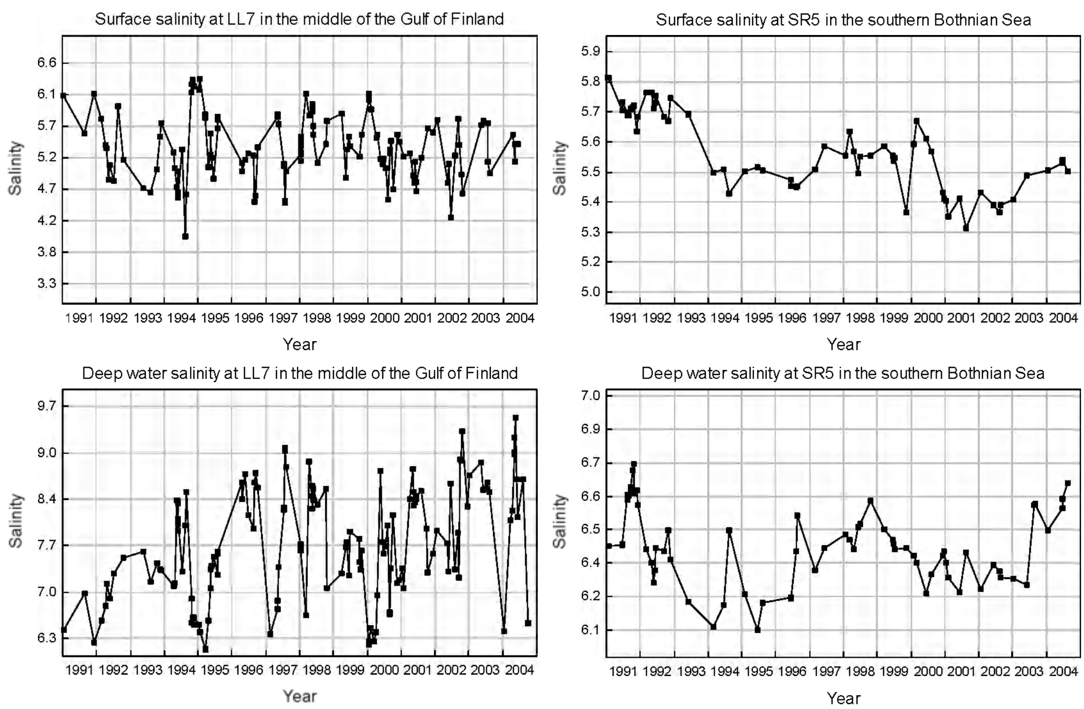


Figure 42: Area 9b – Skagerrak, Kattegat and the Baltic. Time-series of salinity in the Gulf of Finland and the Bothnian Sea.

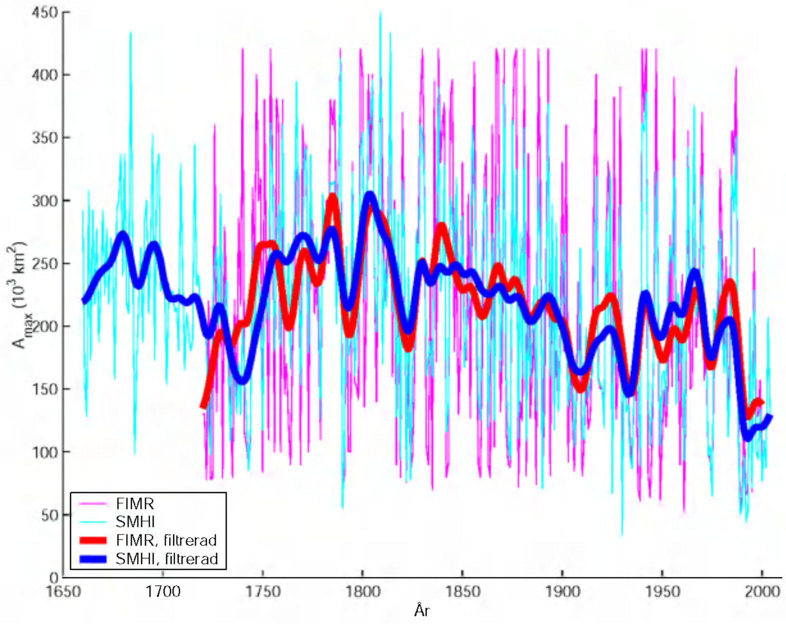


Figure 43: Area 9b – Skagerrak, Kattegat and the Baltic. Yearly maximal ice extent in the Baltic Sea (thin lines) and low pass filtered data (thick lines). (From Axell (2004). Reconstruction of maximal ice extent in the Baltic for the period 1660–2004, manuscript).

Area 10 – Norwegian Sea

Figure 44 shows the development in temperature and salinity in three different sections from south to north in the Norwegian Sea. Since the beginning of the 1990s the temperature and salinity in the Svinøy section has increased. In the last three years the temperature had the largest values in the time-series. The salinity had also large values the last three years. In 2004 it was the highest ever (about 0.09 above normal) in the time-series. The temperature was in 2004 the next largest in the time-series, about 0.8°C above normal. The Gimsøy and Sørkapp sections had also large values of temperature and salinity for 2004. It was then about 0.6°C and 0.5°C higher than normal for temperature and 0.05 and 0.04 higher than normal for salinity, for Gimsøy and Sørkapp section, respectively.

The area of Atlantic water (defined with S>35.0) in the Svinøy-section has been calculated. The mean temperature within the limited area has also been calculated, and the results for summer are shown in Figure 45. There are considerable variations both in the area of Atlantic water distribution and its temperature. The distribution area of Atlantic water decreased since the beginning of 1980s to mid-1990s and increased from there to present. The temperature has shown a steady increase. Since 1978 the Atlantic water has been about 0.6°C warmer. In 2002 the temperature increased considerable and had in 2003 the largest value in the time-series. The temperature the last three years has been the largest values in the time-series and in 2004 the temperature was about 0.5°C higher than the long-term-mean. The area of Atlantic water in 2004 was close to the long-term mean.

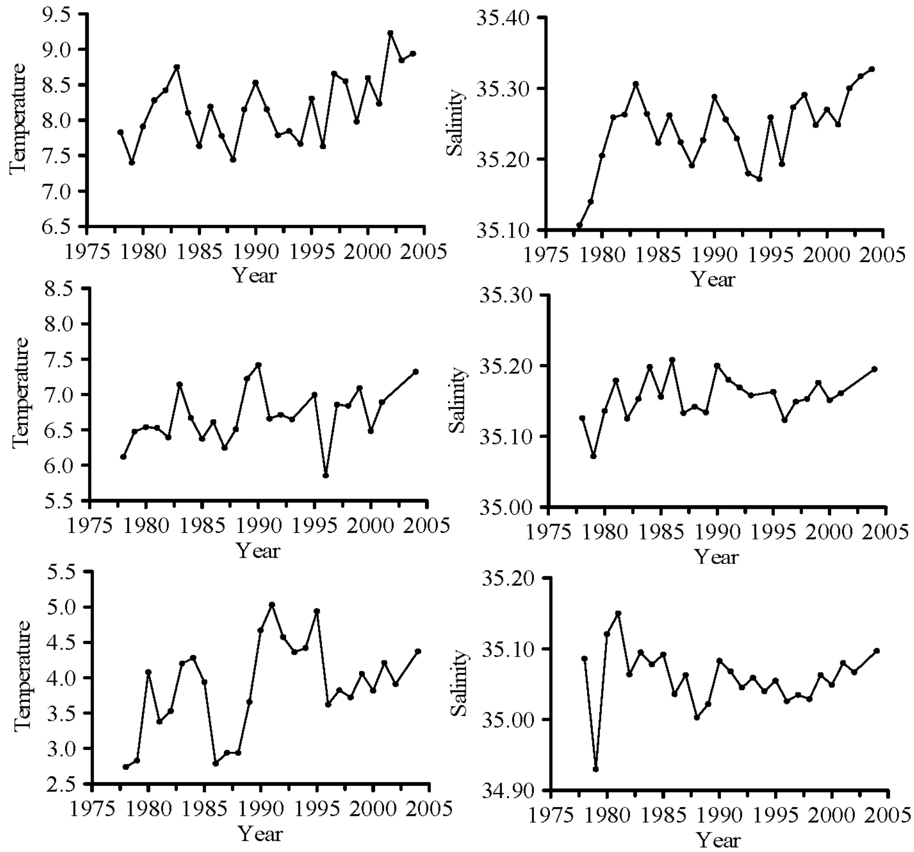


Figure 44: Area 10 – Norwegian Sea. Average temperature and salinity above the slope at three sections, Svinøy (approx. 63°N – upper panel), Gimsøy (approx. 69°N – middle panel), and Sørkapp (approx. 76°N – lower panel), representing the southern, central and northern Norwegian Sea.

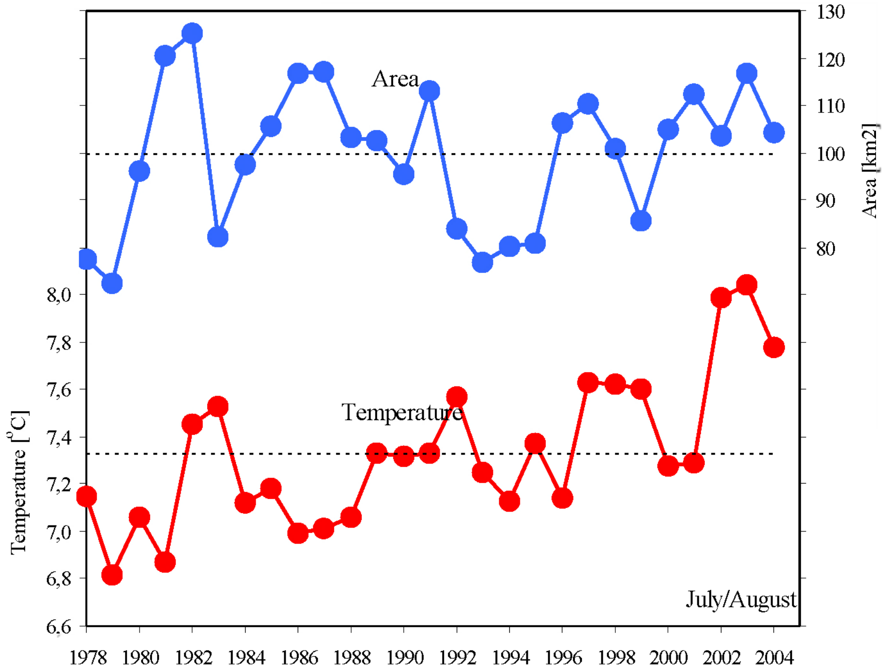


Figure 45: Area 10 – Norwegian Sea. Time-series of area (in km^2) and averaged temperature (red) of Atlantic water in the Svinøy section, observed in July/August, 1978–2004.

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. Regular measurements of the Atlantic inflow to the Barents Sea started in 1997.

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 (Figure 46), while the temperature in the eastern areas stayed below the average during 1998 (Figure 47). 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.

During the whole year of 2004 the temperature in the Atlantic water masses was higher than in 2003 and the long-term average. In January–March the temperature in the southern Barents Sea was 0.3–0.8°C warmer than the long-term mean. In August–September the temperature of the Atlantic water was highest observed since the early 1950s (1.0–1.1°C above normal), and the temperature continued to stay high also in the beginning of 2005 (1.1–1.2°C higher than average). However, near bottom, negative temperature anomalies were observed in the eastern and extreme south-eastern part of the sea. Generally, the ice coverage in the Barents Sea during the year was less than normal.

At the same time as temperature increased, the volume flux of Atlantic water decreased. This is the result from current measurements in the western opening of the Barents Sea, and it is surprising that temperature increased while the flow decreases.

The mean annual water temperature in the southern Barents Sea is expected to be higher than the long-term average in 2005.

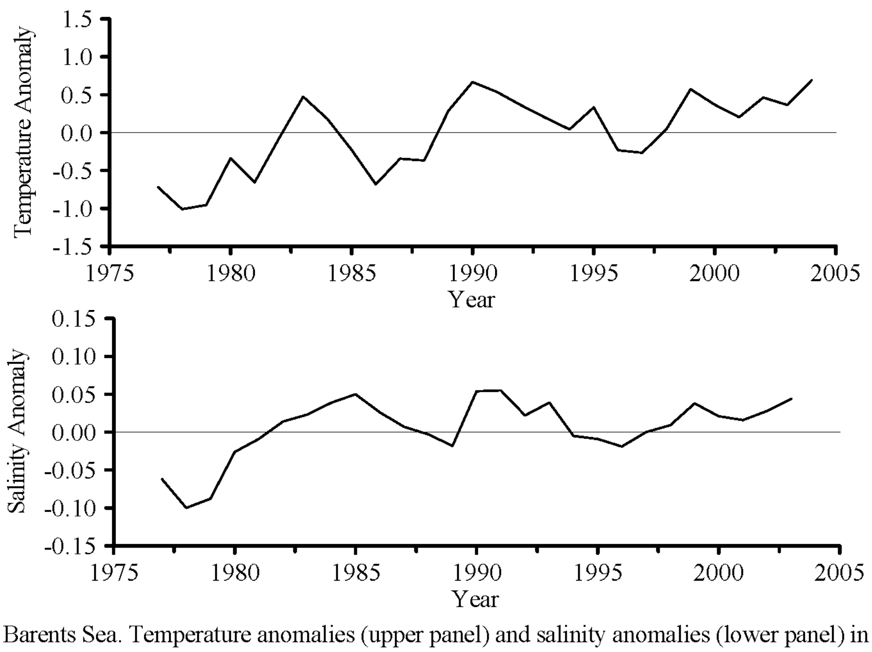


Figure 46: Area 11 – Barents Sea. Temperature anomalies (upper panel) and salinity anomalies (lower panel) in the Fugløya – Bear Island section. ** Note salinity data not updated for 2004.

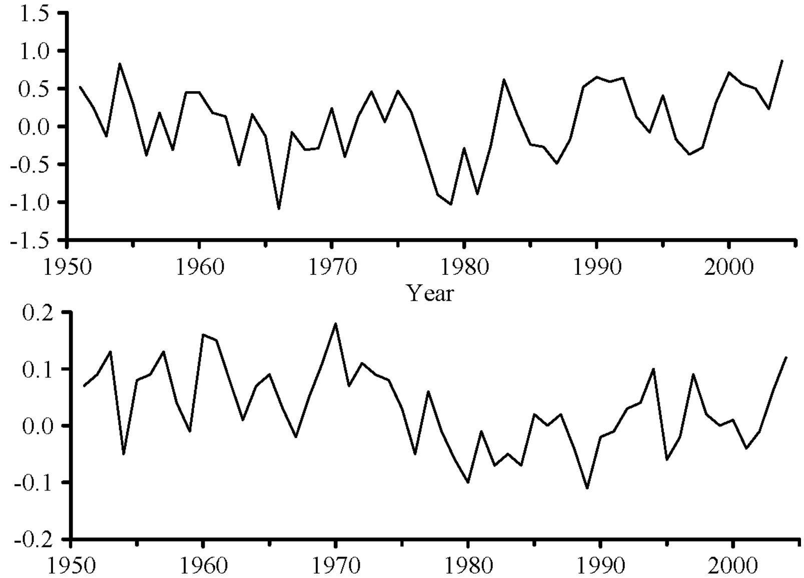


Figure 47: Area 11 – Barents Sea. Temperature and salinity anomalies in the Kola section (0–200 m).

Area 12 – Greenland Sea and Fram Strait

The Greenland Sea and its northern border, Fram Strait, form the main pathway that the Atlantic water takes before entering the Arctic Ocean. The warm and salty Atlantic water is carried northward by the West Spitsbergen Current and both volume and heat fluxes are characterised by the strong seasonal and interannual variations. A significant part of the Atlantic water also recirculates within Fram Strait and returns southward. The Polar water outflow from the Arctic Ocean is transferred south by the East Greenland Current and affects the water mass modification in the Nordic Seas. Besides advection, the bottom water renewal by the deep convection determines the hydrographic condition in the Greenland Sea.

Since the late 1980s no bottom water renewal by winter convection took place. At the standard section at 75°N the deep water properties changed towards higher temperatures and salinities. A doming structure in the Greenland Gyre was replaced by the two-layered water mass arrangement with a density step located presently at about 1800 m. In 2004 the depth of a temperature maximum in the intermediate layer increased by about 100 m as compared to 2003. This descent was in contrast to the previous year but in agreement with the long-term trend. The bottom water temperature increase continued in the Greenland Sea with a difference between spring 2003 and summer 2004 of about 0.01°C, observed through the whole layer below the temperature maximum.

The winter convection seems to have reached only about 1000 m except for the small-scale convective eddies where it was significantly deeper (up to 1500 m). The properties of the Atlantic Water (AW) are given as temperature and salinity averages over the depth range from 50 to 150 m of the stations between 10° and 13°E. The Return Atlantic Water (RAW) is characterized by the temperature and salinity maximum below 50 m averaged over 3 stations west of 11.5°W. In 2004 in both AW and RAW domains, the mean temperature and salinity recovered from the strong decrease observed in 2003. Temperatures came back to the high values from 2002 and the increase of salinity was the strongest one in last eight years. Mean temperature and salinity of the Return Atlantic water were close to the long-term mean after the long period of colder and less saline conditions in previous years (Figure 48).

At 76°30'N in June/July 2004 water temperature and salinity in the upper layer of Greenland Sea was higher than observed in the same period of 2003 and higher than mean properties for summers 2000–2004. Measurements at the standard section averaged between latitudes 004°E and 015°E gave, at the 200 dbar level, the mean temperature of 3.30°C and salinity of 35.047 in comparison to 2.18°C and 35.00 in 2003. Between latitudes 009–011°E of the section, mean temperature and salinity at 200 dbar were in 2004 respectively 3.37°C and 35.06 in comparison to 2.63°C and 35.04 in 2003. The Atlantic Water core salinity and temperature reached at 76°30'N the highest values within the observation period of last 9 years. The intensive inflow of warm water resulted in shifting the ice edge located north-west of Spitsbergen by 65 Nm to the north-east as compared to 2003.

In Fram Strait at 78°50'N three characteristic areas can be distinguished in relation to the main flows: the West Spitsbergen Current (WSC) between the shelf edge and 5°E, the Return Atlantic Current (RAC) between 3°W and 5°E, and Polar Water in the East Greenland Current (EGC) between 3°W and the Greenland Shelf. In 2004 the outstanding warming and salinification were observed in the entire Fram Strait and especially in the RAC domain (Figure 49). The Atlantic layer in the core of the WSC was warmer by more than 1° and up to

200 m deeper than in 2003. The intermediate layer with temperature over 1.5°C was observed the farthest west in last years, reaching the edge of the east Greenland shelf. In the eastern part of the recirculation area (RAC) the amount of the AW (T>2°, S>34.92) nearly doubled as compared to 2003 and its temperature strongly increased. Mean temperature and salinity in the layer 50–500 m in three domains (WSC, RAC, EGC) were all higher than the long period average and continued the increase observed already in 2003. The strong intensification of the southward flow in the EGC was observed from mooring data together with only slightly stronger northward flow in the WSC what resulted in the southward net volume transport through the strait.

Hydrographic properties of the Atlantic water (defined as water mass with T>2°C and S>34.92) reveal the clear trend for last seven years (Figure 50). While the area of the cross-section occupied by AW varied strongly between years, the mean temperature and salinity of Atlantic Water have been increasing since 1997. In 2004 the mean temperature and salinity of the AW recovered from the slight decrease in 2003 and returned to the high values from 2002. In addition to high temperature and salinity, the AW occupied an exceptionally big area of the section which resulted in the largest heat content since the beginning of time-series.

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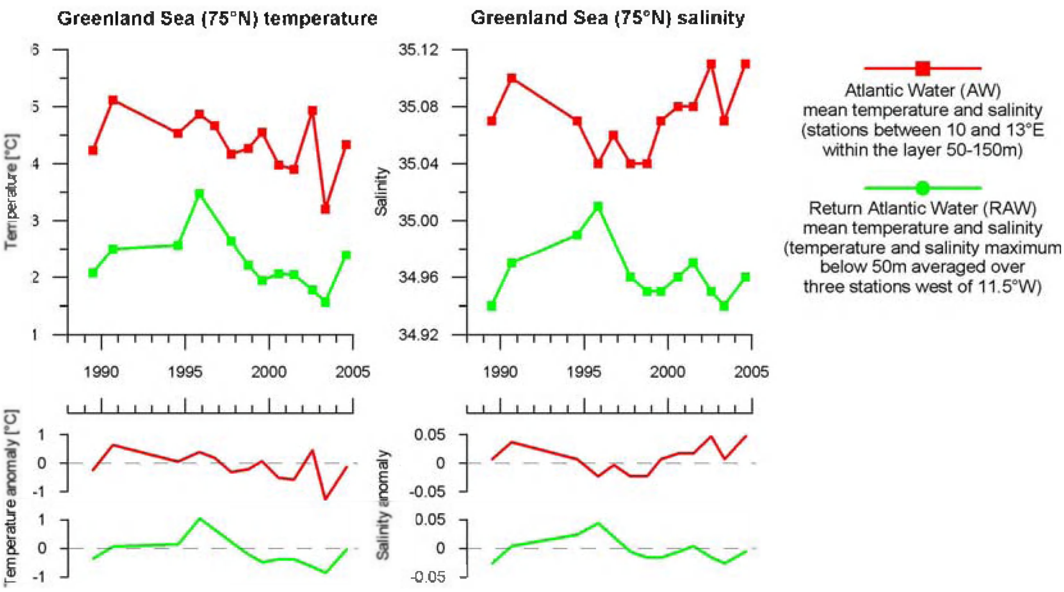

Figure 48: Area 12 – Greenland Sea. Properties of the Atlantic Water (AW) and Return Atlantic Water (RAW) in the Greenland Sea, section at 75°N. Anomalies from the long-term averages shown at the bottom plots. The properties of the Atlantic Water (AW) are given as temperature and salinity averages over 50 to 150 m for stations between 10° and 13°E. The Return Atlantic Water (RAW) is characterised by the temperature and salinity maximum below 50 m averaged over 3 stations west of 11.5°W.

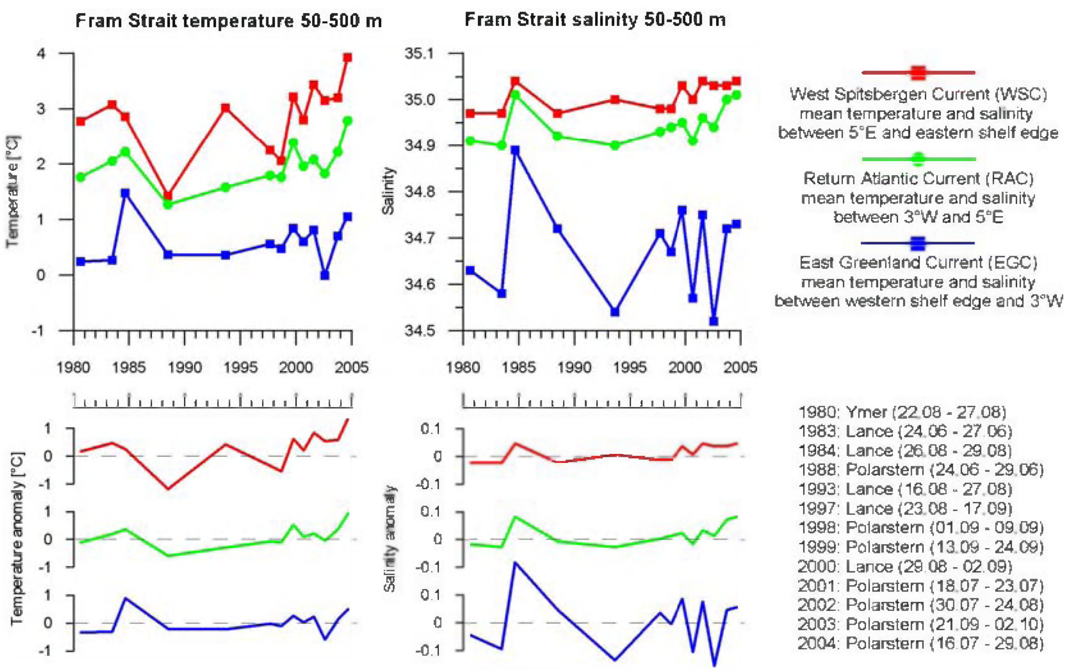

Figure 49: Area 12 – Greenland Sea. The variations of the mean temperatures and salinities in Fram Strait (section at 78°50'N), in the West Spitsbergen Current (WSC), Return Atlantic Current (RAC), and East Greenland Current (EGC) for the layer 50–500 m. Anomalies from the long-term averages shown at the bottom plots.

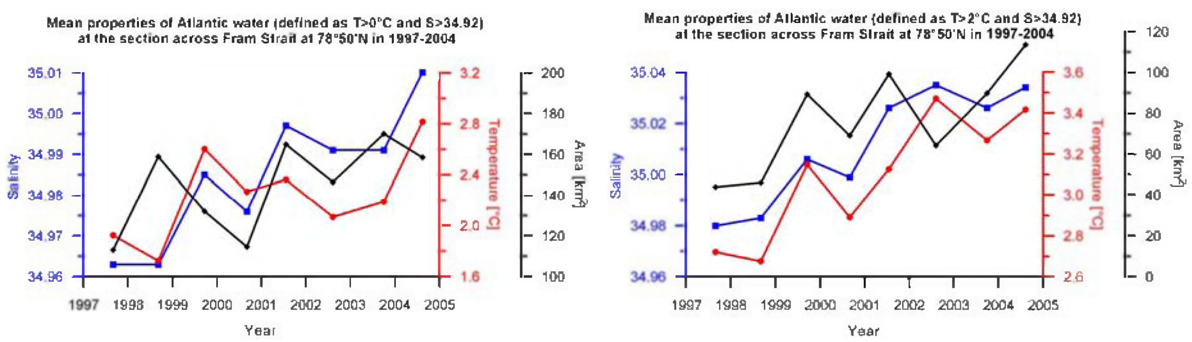

Figure 50: Area 12 – Greenland Sea. Mean properties of Atlantic Water defined as water mass with T>0°C (left figure) and T>2°C (right figure), and S>34.92 in both cases at the section through Fram Strait at 78°50'N in 1997–2003.

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